P a r t 2

WATER PROTECTION FROM DISCHARGES

2.3. Treatment of industrial and surface waste water from power companies

2.3.2. Treatment of industrial waste water at power plants

2.3.2.1. Flotation treatment of industrial waste water

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For industrial waste water treatment, in particular, containing oil pollutions the domestic market generally offers technological schemes that operate on the principle of flotation - filtering or settling - filtering.

Let's consider as an example a technology for oily waste water treatment, which is rather commonly offered on the domestic market. The technology is based on a principle of settling, organized as follows: at first a special sedimentation tank to separate sand, then oil separator with establishing of appropriate conditions for extraction of dispersed oil products and the advanced treatment of dissolved and colloidal oil products by means of filling or pressure filters with coal load.

According to the feedback of the majority of customers implemented such treatment system, almost nowhere normative quality of treated waste water on oil (standard - 0.05 mg/l) was achieved. Moreover, this system is designed to clean waste water from oil products only with an oil density of not more than 0.95 kg/dm^3. This system is not efficient, for example, for cleaning of waste water from fuel oil of brand 100, due to blockage of small (10 ... 12 mm) inter-shelf space in an oil separator by dense oil products.

In general, analyzing approaches of domestic and foreign companies, it should be noted that some well-known European companies, such as "Degremon" (France) offer expensive multi-stage schemes for oily waste water treatment, which are almost unacceptable in our practice and domestic companies are trying to apply cheap materials that, ultimately, reduces the technical level of the implemented decisions.

Nevertheless, a number of promising plants for power plant industrial waste water treatment were developed in Russia. This primarily relates to purification of turbine condensate from oil products.

A problem of turbine oil getting into the main condensate line exists at a number of power plant with cogeneration and condensing turbines. This occurs due to oil leakage along a shaft through a seal camera and steam jet ejectors to an ejector cooler and further into the main condensate line.

The above oil leakages go up under transient modes, such as turbine start-ups and shutdowns. Oil content in condensate of seal ejectors under steady load does not exceed 5 mg/liter. When starting up and shutting down a turbine oil concentration may increase up to 50 mg/l or more, leading to a significant reduction of working life of ionic-exchange resins of ionic- exchangers at a unit desalting plant.

In this regard the most effective solution of this problem is local cleaning of seal ejector condensate from oil products. There at the treatment system must be free from pressure filtering elements, since it significantly complicates turbine operation. It is of a particular importance to provide treatment from peak discharges of oil products. In order to solve the above problem oil separators of a settling type were implemented at power units of Yuzhnaya heating thermal power plant (HTPP) of JSC "Lenenergo", equipped with turbines T-250. Experience of operation of these oil separators revealed that they fail solving a condensate treatment problem. There are two reasons for that: the high temperature of condensate (55 ... 70 ° C) and high flow rate. To ensure seal condensate cleaning flotation machine of a pneumatic type was offered and a pilot unit installed at the power unit № 2. Pneumatic flotation machine was included into the advanced scheme of technological condensate treatment following the existing oil separator (Fig. 2.22).

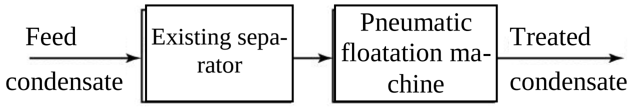

Рис. 2.22. Principal block-diagram of industrial condensate treatment at Yuzhnaya HPPP of JSC "Lenenergo"

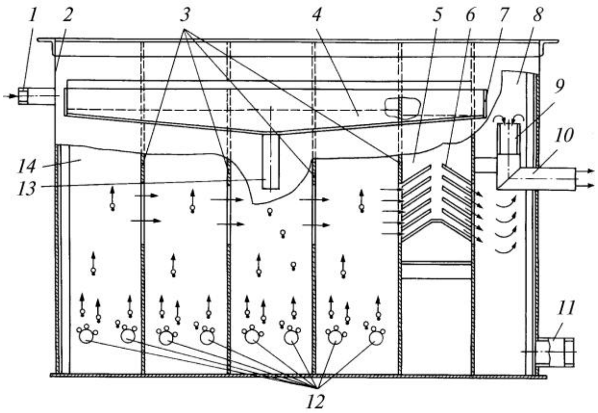

Fig. 2.23. Scheme of a pneumatic flotation machine of a PMF-0,5 type

Pneumatic flotation machine (Fig. 2.23) includes casing *2* divided into four chambers *4* with porous aerators installed at the bottom *12*. Aerators can be produced from flexible (eg, rubber or polyethylene) or rigid (eg, ceramic or metal) materials. At a pilot flotation machine installed at a power unit No2 oil-resistant rubber with size of special holes (pores) of 0.5 mm. was used.

A special unit for thin-layer clarification *6* together with the liquid level control device *9* are installed in the additional chamber *5*. At the outer side of a flotation machine casing inlet *1* and output *10* fittings are installed, respectively, for inlet and output of waste water and also foam channel *7* with an output pipe *13* for withdrawal of trapped impurities in the form of emulsion.

The principle of operation of a pneumatic flotation machine is the following. The original (dirty) water is supplied through the inlet *1*, and then it flows horizontally through the chambers *4* divided by screens *3*, with porous aerators *12* and an additional chamber *5* with a thin layer clarification unit and leaves the machine through the level control device *9* and the output pipe *10*. While water moving through the first four chambers it is aerated (bubbled) by air bubbles appeared due to air venting through porous diffusers.

There at, air bubbles adhere with hydrophobic contaminants and in the form a floated complex oil drops- air bubbles float up. Collected pollutions in the form of foam (emulsion with oil concentration of 10 ... 20%) are removed under gravity through the foam channel *7* and outlet *13*. Connector *11* is designed to drain the fluid when repair of a flotation machine is needed.

It is known that the efficiency of a flotation machine depends on the type and design of aerators. Therefore it is expedients to examine the design and the performance of aerators installed in such machines.

In pneumatic flotation machines pipe type aerators are mainly used. These are welded constructions from pipes, consisting of a casing with a central collector, where feed and dead-end pipes are installed. At the same time fittings are evenly located at a casing. Dispersing elements consisting of perforated rubber pipes are installed on fittings and fixed by loops.

The aerator operates as follows. When compressed air is supplied to the central collector it is equally distributed to all the dispersing elements. The holes in the rubber pipes are expanded, and thus air gets into the water as bubbles. Air flow through such aerators is determined by the inlet pressure, size of the dispersing elements, their quantity and also size of pores of the disperser. Gas permeability of a rubber pipe with the size of 25 × 5 mm (GOST 5496-78) under different perforation modes is shown in Fig. 2.24.

Pores in the dispersing element close when air supply to the aerator is stopped, thus preventing flow of water containing pollution to the aerator casing. Such pipe type diffusers provide uniform aeration, sufficient dispersion of air bubbles and reliability. Operating pressure at the aerator inlet is 0.15 ... 0.25 MPa, depending on the depth of its immersion to the flotation machine.

One of the main characteristics that influence the efficiency of air flotation is aerator resistance under air blowing through the pores. In this regard, the following requirements are stated to all pipe type aerators: minimum and uniform pore sizes and possibly lower resistance under air blowing through them. Increasing of the pore diameter yields decrease of their resistance, but bubble sizes increase. Pore size of pipe type aerators is 0.5 ... 2.5 mm depending on the elasticity of rubber and the hydrostatic pressure of water.

The dependence of air flow in the aerator from pressure is shown in Fig. 2.25. The data presented in Fig. 2.25 show that air flow rate through the pores of the dispersant dramatically increases when pressure increases. Moreover, with the pressure increase an average equivalent diameter of bubbles changes (Figure 2.26): initially increases and reaches its maximum and then decreases to a minimum. When using flexible tubes, this maximum corresponds to a pressure of about 80 kPa, and for rigid tubes - 100 kPa. It should be noted that bubble sizes decrease when foaming agent is added and its concentration is increased.

The test results show that perforated rubber pipes operate stably even in large pneumatic type flotation machines. There at, production of bubbles with a diameter of 0.3 ... 1.5 mm is provided. With consideration of a mechanical reliability and maximum aerating capability of the aerator it was found that optimum number of pores for tubes with an inner diameter of 8 mm to 12 mm makes 35 ... 40 at 1 cm^2 of aerator surface. For large sizes of pipes a number of pores increases to 70 per 1 sm^2 of an aerator. With the increase of a pipe diameter and wall thickness (5 ... 8 mm), pressure increases from 140 to 160 kPa to ensure uniform aeration on the length of the aerator.

Perforation of flexible pipes installed in pipe type aerators is performed on a perforating machine MP-1. End of a tube to be perforated is cut at an angle of 10 ... 45 ° and inserted between the guide and broaching rollers. Then electric motor turns on and drives through a reducer a

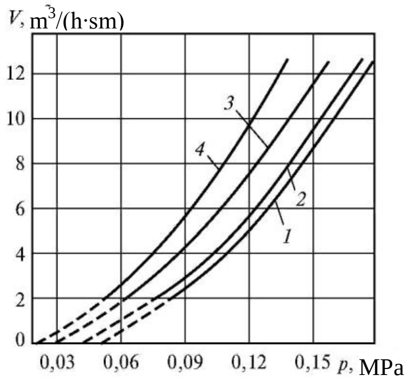

Fig. 2.24. Gas permeability of perforated rubber pipe of size 25×5 mm depending on pressure at the aerator inlet *p* и perforated mode:*1* — needle № 12, 60 holes/sm^2; *2* — needle № 10, holes./sm^2; *3* — needle № 12, 58 holes/sm^2; *4* — needle № 10, 70 holes/sm^2

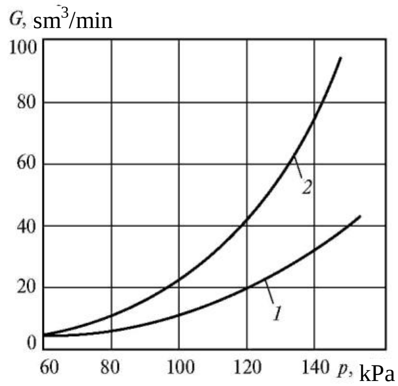

Fig. 2.25. Dependence of air flow from pressure *p* in rubber aerator through one hole:
1 — for flexible tubes; *2* — for rigid tubes

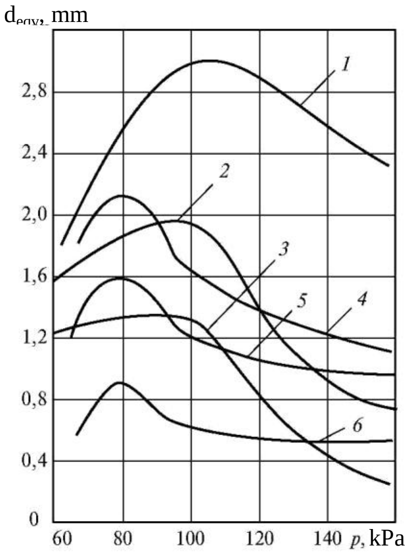

Fig. 2.26. Dependence of average equivalent diameter of a bubble $d_{эк}$ form air pressure *p* inside a pipe type aerator under various foam agent concentrations (0; 4,6; 8,2 mg/l):
1—3 — for rigid tubes; *4—6* — for flexible tubes

carriage with the needle holders and then pipe perforation is performed. The required spacing between the holes in the perforated rubber pipes is determined by the change in a diameter of the broaching drum and the installation of broaching needle in a needle holder with the appropriate step.

MP-1 machine provides perforation of a pipe using round needles with the diameter of 0.5 ... 3.0 mm and flat needles with the hole size of 0.25 mm or more. The length of the hole depends on the width of the needle used and makes up to 6 mm. Porosity of the aerator depends on a number and size of holes in the tube. Holes in the tubes are arranged chequerwise. Typically, the distance between the centers of the holes along a circle makes 2 ... 4 mm depending on the pipe diameter

Perforated tubes are tested for gas permeability, which should be 0.2 ... 0.05 ... 0.45 and 0.15 m^3/min for the pipes 25 and 16 × 5 × 5 mm respectively under pressure of 0.1 MPa for a sample of 1.7 m long. Perforated pipes are tested to rupture during 10 ... 15 min under pressure exceeding operation pressure by 2.0 ... 2.5 times (Fig. 2.27).

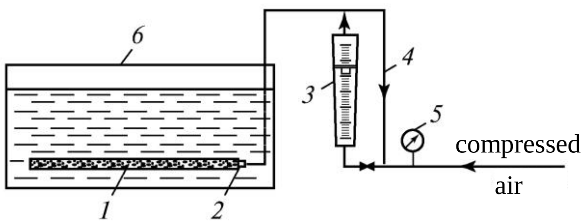

Fig. 2.27. A scheme of testing the perforated pipes to gas permeability and rupture:
1 — perforated tube; *2* — fitting; *3* — rotameter; *4* — air pipeline; *5* — pressure gauge; *6* — tank

Pipe type diffusers are equipped with pipes of the same size and gas permeability. Allowed deviation of gas permeability of perforated tubes must be less than 10%. The final sorting of pipes was carried out in boiler-turbine shop at Yuzhnaya HTPP of JSC "Lenenergo". Assembly and testing of aerators included installation of perforated rubber pipes, hydraulic pressure tests, reliability tests, check of aeration uniformity and determining flow characteristics. For this purpose a test stand was applied shown in Fig. 2.28.

Test stand consists of a cylindrical tank *5* with a diameter 1500 mm and height 1,200 mm. Next to the tank the rotametr *1* is installed, the receiver *2* (oil and moisture trap) with a pressure gauge *3*, flow meter *4* and shut off valves *6, 9, 10, 11*. The inter connection of units and connection with the aerator *7* is provided by means of flexible pipes *8*. The receiver provides independent supply of air to the aerator and rotametr and also trapping of moisture and dust from the compressed air, which are periodically disposed though the valve *6*. Drain valve *12* provides water discharge for the water change.

The described above preparation of the aerators was partly performed at a stage of manufacture of flexible aerators from pipes ∅ 25x5 mm and 900 mm length and partly at an adjustment-commissioning stage. Such preparation provided further efficient operation of the flotation machine that was proved by the results of long-terms tests.

Testing of a pneumatic flotation was carried out within two stages. During the first stage aeration mode, which has a considerable effect on efficiency of condensate flotation cleaning was investigated. The results of a condensate treatment depending on the intensity of aeration under the water level in the a flotation unit of 0.9 m are presented in table 2.5.

Analysis of the data presented in Table. 2.5 shows that the best effect of condensate treatment by means of flotation is achieved when aeration intensity is 0.8 m^3 per 1 m^2 of condensation surface in 1 min.

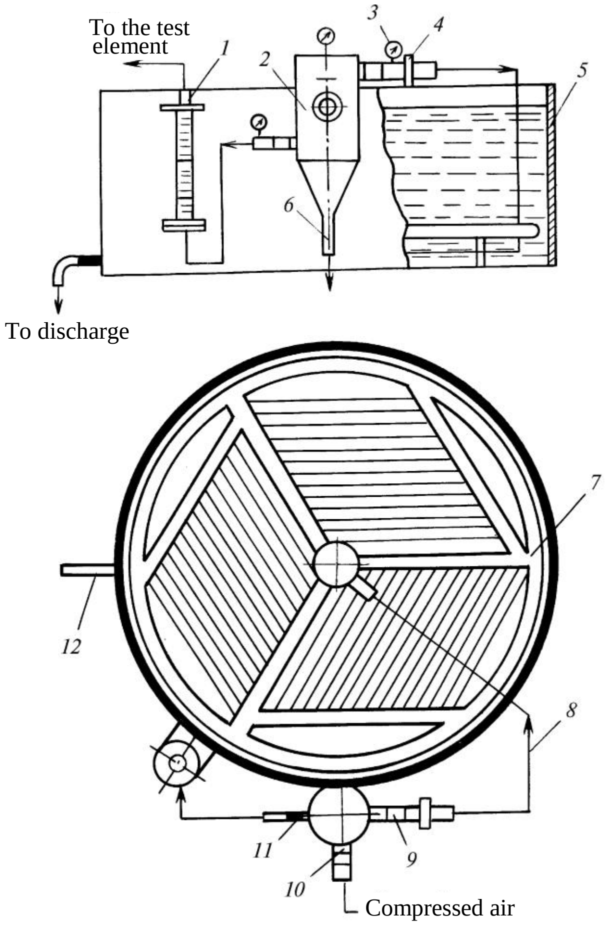

Fig. 2.28. View and cross section of aerator test stand

Table 2.5. **Dependence of effect of a condensate treatment with flotation from aeration efficiency**

Sample	Aeration efficiency, $m^3/(m^2 \cdot min)$	Oil concentration, mg/l		Treatment effect, %
		Before treatment	After treatment	
1	0,3	7,2	4,1	43
2	0,4	7,2	3,9	46
3	0,5	7,2	2,3	68
4	0,6	7,2	1,8	75
5	0,7	7,2	1,1	84
6	0,8	7,2	0,7	90
7	0,9	7,2	1,3	82
8	1,0	7,2	1,9	74
9	1,1	7,2	2,7	63
10	1,2	7,2	3,8	47

Final tests carried out under the same conditions determined that oil product concentration in the treated water after flotation, was 0.3 ... 2.0 mg /l (in separate cases 4 ... 5 mg / l).

Table 2.6. **Final results of industrial tests of pneumatic flotation machines PMF-0,5 at a power unit No 2 of Yuzhnaya HPPP of JSC “Lenenergo”**

Sample	Oil product concentration in the main condensate, mg/l	
	Before treatment	After treatment
1	2,34	0,36
2	41,0	3,7
3	37,0	3,2
4	51,3	4,2
5	28,6	2,0
6	10,1	0,4
7	4,7	0,7
8	8,4	1,0
9	2,6	0,3
10	4,1	0,5

The specified quality of main condensate treatment was confirmed during long-term tests of a pilot unit of a pneumatic flotation machine at a boiler-turbine plant of power unit No 2 at Yuzhnaya HTPP. Final test results are presented in Table. 2.6.

Test results of a pneumatic flotation machine presented in Table. 2.6, show that the oil content in water after treatment against oil products does not exceed 4 ... 5 mg/l, even at high initial concentrations of oil products in the dirty condensate. The above guarantees the determined treatment quality under operation of similar units at the stage of main condensate treatment against oil products.

Guaranteed quality of treated water will largely be determined by the correct operation of local treatment facilities. During the operation of treatment facilities constant monitoring should be provided. Methods to control the operation of treatment facilities include:

- visual inspection of the work process equipment;
- conducting tests using special instruments.