ULTRAFILTRATION SYSTEM FOR TREATMENT OF THE WASTEWATER FROM URANIUM PROCESSING PLANT IN FELDIOARA

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Summary: This paper presents the ultrafiltration plant, as part of the wastewater treatment plant resulting from the uranium ore preparation plant in Feldioara. Is presented the overall constructive solution of the plant, construction and operation of ultrafiltration membranes as actuators providing superior operating parameters for the entire plant, and practical methods of washing and backwashing the membranes, while ensuring the maintenance of functional parameters of the installation.

Key words: uranium, wastewater, contaminant, ultrafiltration, membrane, washing, backwash, clearing, rinsing, air, solution, parameter, operating

1. GENERAL OVERVIEW [8]

Ultrafiltration plant is part of the treatment plant of the wastewater resulting from the preparation of uranium ore, being located in the technological flow between classical filtering system and ion exchanger.

The necessity for this station results from complying with international law transposed into our country by the Norm on pollutant load limits of the industrial and municipal wastewater at the discharge into natural receivers, NTPA-001/2002.

It is worth noting that, compared to existing legislation in the country in this field; the Norm came into force in 2002 and requires very stringent conditions on the quality of water discharged into the environment, which largely explains scientific endeavour, especially the material effort necessary for achieving the station.

The main role of the ultrafiltration plant is to remove the pathogens, the particles and impurities from the water, which because of their scale cannot be removed by conventional filtration.

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2. THE DESIGN AND FUNCTIONING SOLUTION OF THE ULTRAFILTRATION PLANT [1], [2], [3], [4], [5], [7]

The ultrafiltration system is based on pressurized membranes that filter from outside to inside and are very tolerant to high turbidity waters.

Ultrafiltration system consists of three batteries of ultrafiltration membranes, mounted in parallel, each battery forming a module of 8 × 2 identical membranes, resulting in the end 48 active membranes.

Figure 1 shows the constructive and functional diagram of the ultrafiltration assembly system that contains, in addition to the three membranes batteries, as actuators, the ultrafiltered water storage tanks and of those used for washing, compressed air circuit for membrane cleaning, as well as tanks and associated circuits with chemical reagents used for membranes backwashing.

Figure 2 shows a constructive and functional diagram of a membranes battery with its 16 membranes, inlet and outlet circuits, as well as backwashing circuits and cleaning with air.

Batteries are supplied from the tanks associated with centrifugal pumps.

Membranes basically retain all the particles in suspension, respectively the organic materials. Ultrafiltered water is sent to storage tanks.

The filter medium being the membranes, is required their washing in counter-current. Membranes washing is performed by circuits supplied with water filtered through centrifugal pumps.

On the pump discharge pipes are provided connections which dose the chemical reagents that improve the quality of backwash.

The chemical reagents added to washing water are:

- sodium hypochlorite solution with a concentration of 15%, circulated from the storage tank with two dosing pumps, one with low flow rate and the other one with high flow rate;
- hydrochloric acid solution with a concentration of 33%;
- sodium hydroxide solution with a concentration of 50%.

Ultrafiltration membranes, Figure 3, consist of PVDF fibres with holes of 1.3 × 0.7 mm. They consist of double walls with minimum of macropores. Membrane pore size is 0.03 μm, which is an excellent combination of high rejection and high permeability and long-term stable filtration.

These membranes have high strength, are robust, have very good chemical and thermal resistance and they are treated to increase the hydrophilic characteristics.

During filtration process, the inflow equals the permeate flow.

Concentrate (the rejection) occurs during backwashing and rinsing.

Filtration phase lasts 20…60 min, depending on incoming water quality.

Figure 4 presents an overview of a filtering element, where the membrane is mounted in a metal tube. Primary water is allowed inside the tube, at the exterior of the membrane and filtered water is discharged through the outlet, the contaminant being retained on the membrane.

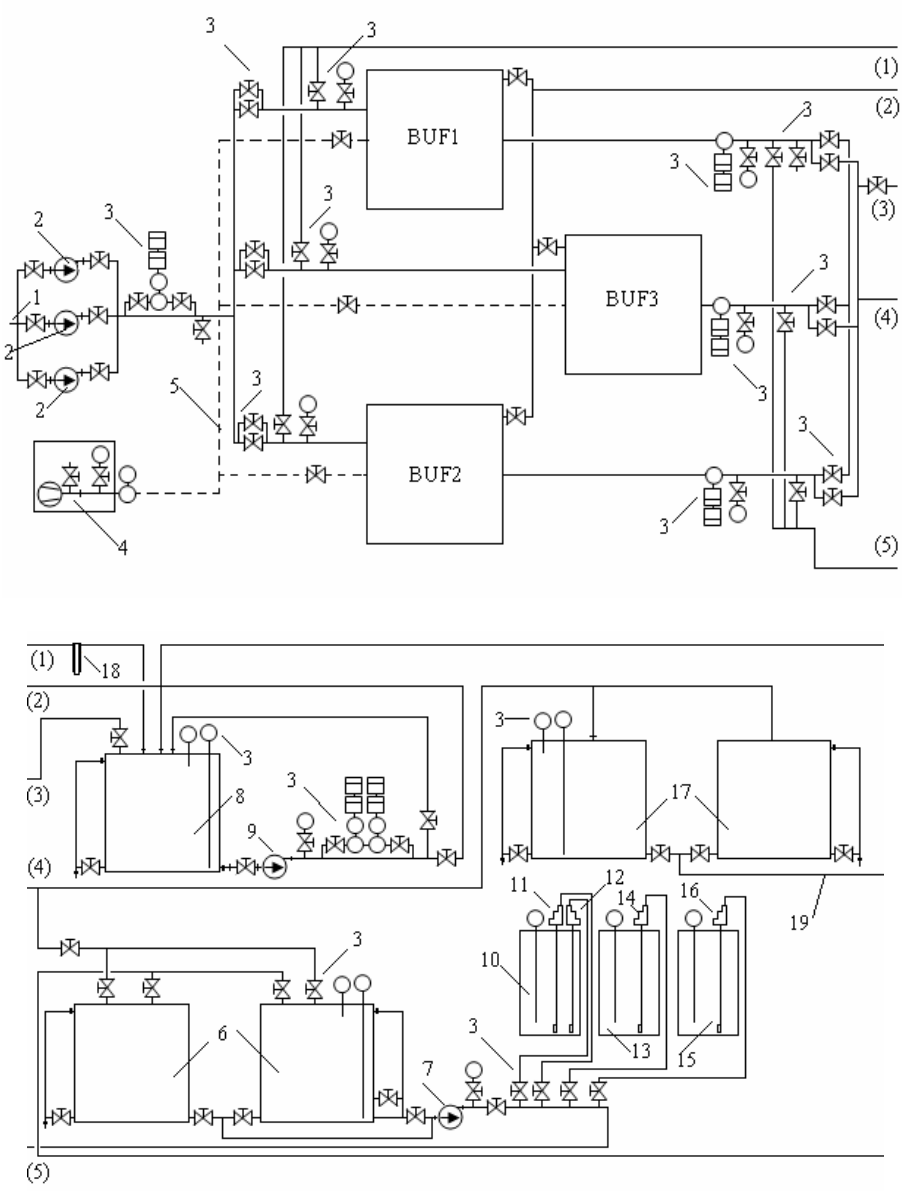

Fig. 1. Constructive and functioning diagram of the ultrafiltration plant

BUF1, BUF2, BUF3 – ultrafiltration batteries identical in construction; 1 – raw water supply pipeline from the microfiltering plant; 2 – centrifugal pumps connected in parallel; 3 – command equipment, distribution, command and control; 4 – compressor; 5- compressed air pipe for cleaning with air; 6 – ultrafiltered water tank for backwashing; 7 – centrifugal pump for backwashing circuits; 8 – ultrafiltered water tank for intensive rinsing; 9 – centrifugal pump for intensive rinsing circuit; 10 – sodium hypochlorite tank; 11 – low flow dosing pump; 12 – high flow dosing pump; 13 – hydrochloric acid tank; 14 – hydrochloric acid dosing pump; 15 – sodium hydroxide tank; 16 – sodium hydroxide dosing pump; 17 – ultrafiltered water tanks; 18 – control filter; 19 – connection pipe with ion exchange system.

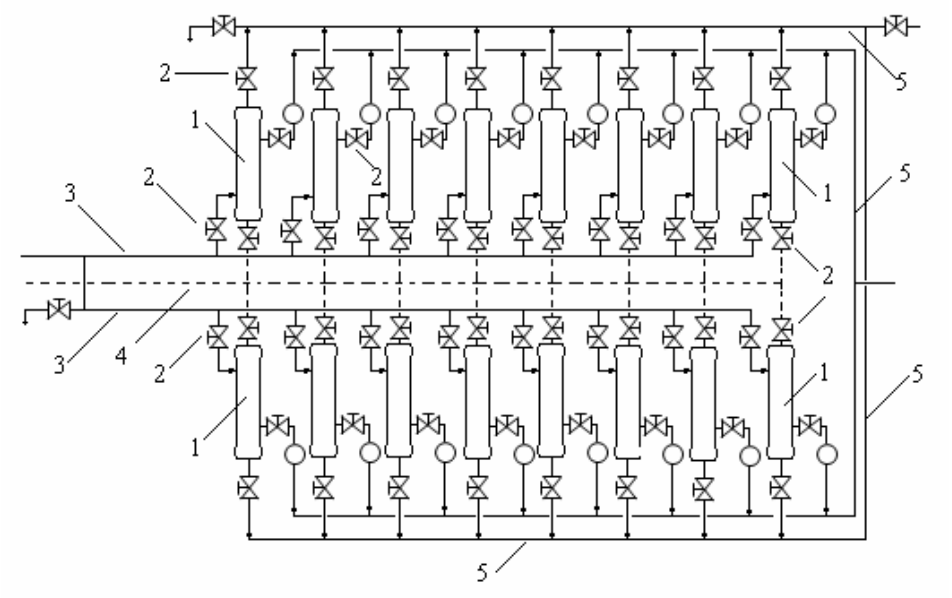

Fig. 2. Constructive and functional diagram of the membranes battery
1 – membrane for ultrafiltration; 2 – command and control equipment of ultrafiltration, purification and backwash; 3- raw water supply pipe of the battery; 4 – compressed air supply pipe for cleaning the membranes; 5 – drain pipe for the ultrafiltered water.

Fig. 3. Working principle of the membranes

A backwash is performed periodically with water in order to remove particles in suspension accumulated on the surface of the membranes. At these backwashes is added disinfectant to help control the microbial activity on the surface of the membrane.

Also on frequent backwashes, is provided periodically the following maintenance cleaning operations: cleaning with air, which produces a jet of air on the membranes, which helps to detach the particles; acid backwash to remove colloids and inorganic salts that are deposited on the inside and outside of the membrane; alkaline backwash to remove organic and biological contaminants from the membranes; rinsing the membranes, which is conducted after every chemical backwash; intensive rinsing, when it's performed an acid and an alkaline rinse, the frequency of its occurrence being 1 ... 3 months.

During the operation of the ultrafiltration plant, is carried out the following activities, both production and maintenance and operations: filtering itself, as direct activity, productive, codified UF; rinsing or displacement through forward flow, recognized in the specialized literature, generalized for this type of plant as Forward-

Flush, backwash BW1 (backwash) backwash BW2, cleaning with air, chemical backwash CEB (chemically Enhanced backwash); intensive rinsing CIP (Cleaning In Place).

UF Filtering, figure 5. During the process of filtering, the water crosses the membrane from outside to inside, the particles contained in water being retained outside the membrane. During the filtration, the pressure on the membrane should be controlled, that is the difference between inlet and outlet pressure.

The ultrafiltered water is sent to backwash deposit, as well as at the ultrafiltered water tanks, until their fill, from where it is pumped to the ion exchange system.

When both backwash deposits and ultrafiltered water, are full, the ultra-filtration plant is stopped. During this phase is not not distributed any chemical reagent in the ultrafiltration plant.

Rinse or displacement by forward flow, Forward-Flush, figure 6. During Forward-Flush it's produced a water displacement along the membrane, this serving as a rinse. Before the filtration phase and after backwash will be performed a Forward-flush to clear the membranes of chemical products.

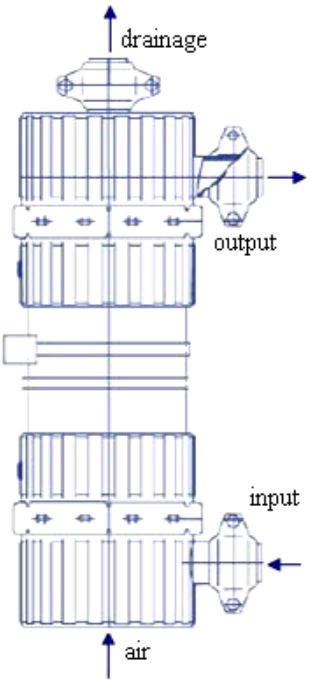

Fig. 4. Overview of a filtering tube

Backwash, BW1 and BW2, figures 7 and 8. During filtration, particles in suspension contained in the water are retained by the ultrafiltration membrane, the particles adhering to the outside of the membrane. At backwashes, ultrafiltered water is introduced in the opposite direction, penetrating through the membrane from the inside to outside, detaching and engaging the retained particles. At these backwashes is dosed a hypochlorite solution to disinfect and prevent biological growth in the membrane.

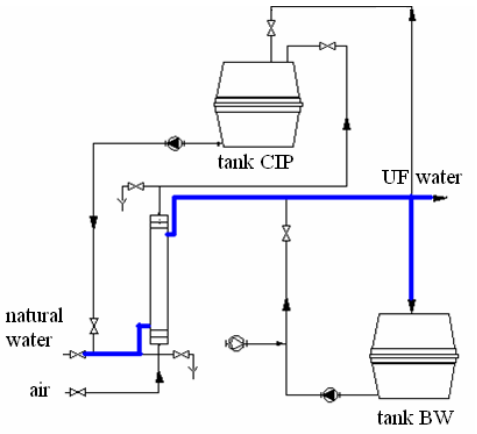

Fig. 5. The schematic diagram of UF Ultrafiltration

Cleaning with air, figure 9. Before each backwash, it's performed a cleaning with air, followed by drainage. Cleaning with air consists of passing a current of air to the outside of the membrane. By bubbling air on the membrane is produced a better separation of adhered particles than by backwash. After each cleaning with air is performed a drainage.

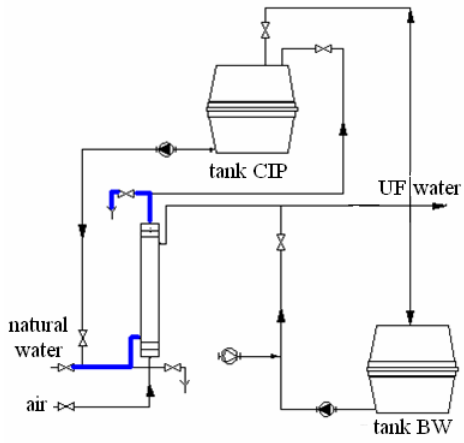

Fig. 6. The schematic diagram of rinsing, Forward-Flush

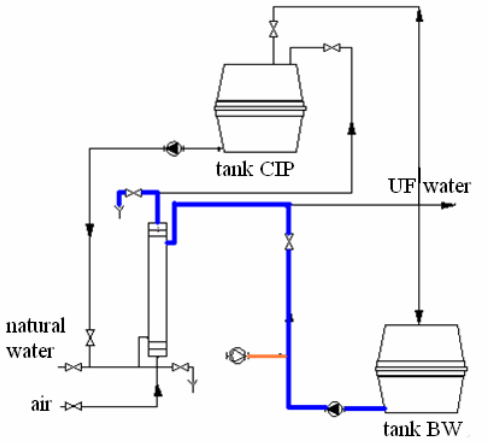

Fig. 7. The schematic diagram of backwash BW1

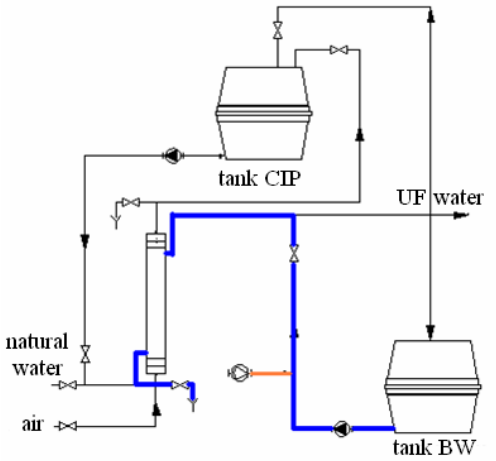

Fig. 8. The schematic diagram of backwash BW2

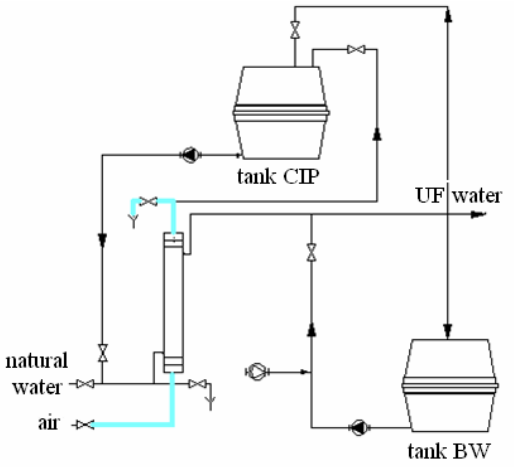

Fig. 9. The schematic diagram of cleaning with air

Chemical backwash CEB, figure 10. Chemical backwashes are performed periodically, named CEB (Chemically Enhanced Backwash). It accomplishes two types of backwashes, an alkaline one which doses sodium hypochlorite solution and sodium hydroxide solution, and an acid one which doses hydrochloric acid. The objective of the chemical backwashes is to eliminate the crusts that may occur during the filtration phase and cannot be removed by backwashes. The flow and the sense is the same as a backwash, but with dosage of chemical reagents.

After a CEB procedure is important to remove the chemical residue that may remain in the system, particularly those that may pose a risk to equipment or subsequent processes. For this it is recommended to complete the CEB with a short

water backwash, a displacement or drainage with a water volume so that the system is ready again on the filtering mode. Won't be dosed in the circuit a solution of sodium hydroxide with hydrochloric acid, nor sodium hypochlorite solution with hydrochloric acid, they beeing incompatible products.

Intensive rinsing CIP, figure 11. When there occurs an increase in pressure passing through the membrane, must be performed an intensive rinsing (in depth) of the system, called CIP (Cleaning In Place). To achieve CIP it's charged the deposit with ultrafiltered water and is prepared the chemicals. The manual valves are operated, the pump is started so that it's performed a recirculation of deposit water until the chemical homogeneity is achieved. After it's made the necessary switching of the valves and it's started the CIP, hence the process is automatic. During CIP is performed a recirculation on membranes, including a pause stage.

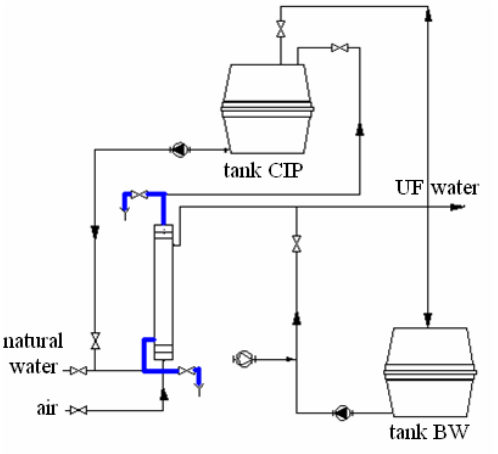

Fig. 10. The schematic diagram of chemical backwash CEB

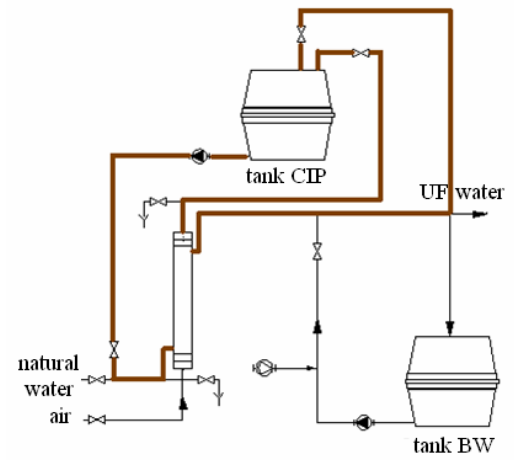

Fig. 11. The schematic diagram of intensive rinsing CIP

Before executing the CIP rinsing is recommended to perform a full sequence of backwash, including aeration, system drainage, backwash on the bottom and repeating these steps three to eight times to completely remove the contaminates that does not require chemical action. Subsequently, the system is drained to remove the water excess and avoiding diluting the chemical solutions. The chemical solution drains back on the outside of the membrane, typically for 30 to 60 minutes, then opens the permeate valve after a few minutes of recirculation, which is also returned to the tank.

An increase of the solution temperature to 40 °C helps to effectiveness of the clarification. After the recirculation stage, the system is soaked with cleaning solution for a period which may vary depending on the degree and nature of the deposit (usually 60 to 90 minutes), for finishing it is performed a new stage of recirculation (20-30 min).

The recirculation phase once completed, begins a stage of aeration, followed

by drainage, backwash and final displacement (rinsing) for the complete elimination of chemical solution in the system. When operating CIP is normally used the same chemical reactive used in previous CEB at higher concentrations. If it's wanted to perform various CIP operations with different chemical reagents, must be followed all the steps described above for each chemical rinse solution. It's recommended the performance of a CIP each 1 ... 3 months, depending on the scaling from water and backwashing efficiency. Connection pipes are made of PVC-U resistant to chemical corrosion and mechanical shock. Valves and related parts are made of materials with high corrosion strength.

3. FUNCTIONING PARAMETERS OF ULTRAFILTERING PLANT [3], [7]

In table 1 are presented the working parameters at the input of the ultrafiltering membranes.

Table 1. **Working parameters at the input of the ultrafiltering membranes**

No.	Parameter	MU	Parameter value
1	Maximum operating temperature	ºC	35
2	Maximum turbidity	NTU	300
3	Solids quantity in suspension	mg/l	100
4	Maximum particle size	μm	300
5	Maximum pressure	bar	6

Table 2 presents the normal operating parameters of ultrafiltration plant, noting that these parameters correspond to the simultaneous operation of the three modules.

*Table 2***. Normal operating parameters of UF plant**

No.	Parameter	MU	Parameter value
Normal operating parameters			
1	Input pressure	bar	1.0...2.0
2	Maximum input pressure	bar	6.0
3	Average production flow	m^3/h	140
4	Maximum forward-flush flow	m^3/h	32
5	Maximum backwash flow	m^3/h	97.9
6	Backwash pressure	bar	1.5
7	Air pressure	bar	1.0
8	Maximum air pressure	bar	2.0
9	Maximum recommended load loss	bar	1.8
10	Maximum CIP flow	m^3/h	24
11	CIP pressure	bar	2.9
Chemical reactive dosage			
12	NaClO, BW	ppm	15
13	NaClO, CEB	ppm	1000

No.	Parameter	MU	Parameter value
14	NaOH, CEB	ppm	500
15	HCl, CEB	ppm	1000
16	NaClO, CIP	ppm	2000
17	NaOH, CIP	ppm	1000
18	HCl, CIP	ppm	2000

4. OPERATING CONDITIONS OF ULTRAFILTRATION PLANT [3], [7]

UF systems are designed for continuous operation and therefore they behave better if are ran continuously. However, in practice there are frequent stops and starts. Before each stop is recommended a rinsing of the system with and then perform a backwash to avoid a biological growth in membranes. The water used at backwashing the system before shutting down must be free of chemicals. Dosing the chemical reagents, in the supply line as well in the backwash line must be interrupted before stopping. After the described backwash, the system is isolated by closing all the valves. To avoid losses in membranes during stoppages, a special attention should be paid to counter pressure, especially when performing an emergency stop or when there is a power failure. The system can be turned off for up to 48 hours, without the need for addition of preservative solution. When the system is out of service for more than 48 hours, must be taken into account: to avoid the drying of membranes, because dry membranes irreversibly lose their permeability; the system must be protected against biological growth, through rinsing for 30 to 60 minutes per day or adding preservative solution and isolating the system; protect the system from extreme temperatures.

In Table 3 are given recommendations on measures to be taken depending on the length of the plant stoppage.

Table 3. **Recommendations on protecting the plant during stoppages**

No.	Stoppage time	Recommendations
1	<48 hours	Clearing with air, backwashing with water, system isolation
2	2…7 days	Rinsing with air, backwashing with air, isolating the system and operating from 30 to 60 minutes per day, or better, rinsing with air, backwashing with air, add preservation solution and isolating the system
3	7…90 days	Clearing with air, backwashing with water, add preservation solution and isolating the system
4	>90 days	Clearing with air, backwashing with water, replacing the preservation solution and isolating the system

Operations of production, insufflations, backwash and clarification are provided automatically by the PLC of the overall command system, i.e. automatic pneumatically operated valves, instrumental air being provided by a compressor.

Ultrafiltration plant is so designed that requires minimal attention from the

user. Like any mechanical system, regular and appropriate maintenance ensures a correct operation. Maintenance operations on behalf of the user are limited to: adjusting and recording operating parameters; checking the pretreatment; verification of chemical dosing equipment; preparation of chemical reagents to be dosed; rinse the inside and outside of storage of chemicals; periodically check the accuracy of the measuring instruments indications; cleaning/protecting the membranes, if necessary; reviewing and checking the automatic valves operation.

5. CONCLUSIONS

Ultrafiltration plant is part of the treatment plant of the wastewater resulting from the preparation of uranium ore. The main role of the installation is removing pathogens, particles and impurities from wastewater which due to their size cannot be removed by conventional filtration. The achieved filter fineness is up to 3 μm.

Ultrafiltration system consists of three membrane batteries mounted in parallel, each battery constituting a module of 8 × 2 identical membranes, resulting in the end 48 active membranes. Pressurized membranes are the main elements of the system, which ensures the required smoothness of filtering and that filter from outside and inside, being very tolerant to high turbidity waters. The main parameters that are characterizing the ultrafiltration system are working inlet pressure of the wastewater of 1.0 ... 2.0 bar (maximum 6 bar) and filtered flow of 140 m^3/h.

The operation of pressurized membranes implies the compulsory cleaning, backwash, clearance and rinsing them, inclusive through the use of chemical reagents in order to ensure the optimum use parameters.

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