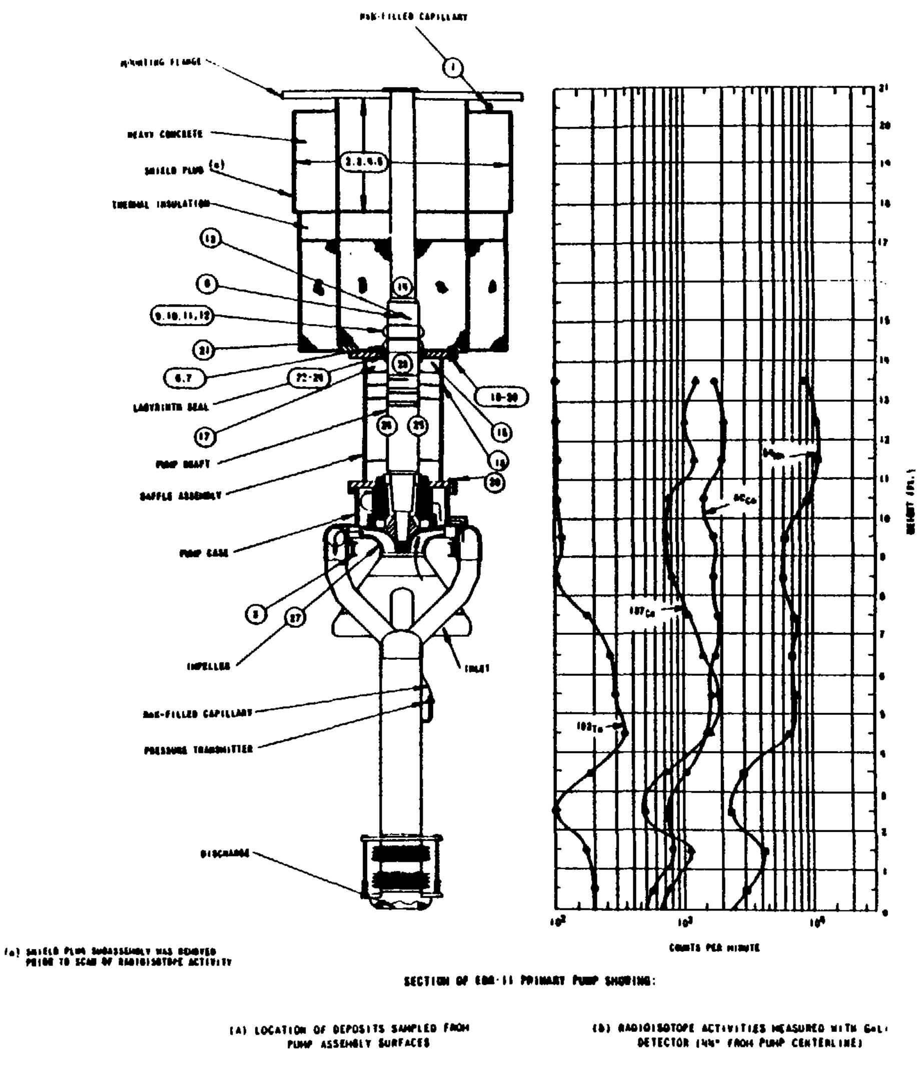

Fig. 4 Radioactivity Scan of EBR II Primary Pump No. 1



# AN EXPERIENCE OF CLEANING AND DECONTAMINATION OF THE BN-350 REACTOR COMPONENTS*

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## Abstract

In the course of start-up, adjustment and operation of the BN-350 reactor there arose a need for cleaning from sodium and decomntamination of primary and secondary equipment components. Design schemes of the systems provided for this purpose as well as those specially designed for cleaning of steam generator evaporators are considered. Technological processes of cleaning and decontamination for some reactor components (removable parts of circulating pumps, evaporators, valves) are descrѝbed, the results are presented.

## I. Introduction.

The sodium-cooled fast reactor BN-350 was put into operation on June 16, 1973. In the course of start-up and adjustment work and initial power operation a need for cleaning of components from sodium residues has repeatedly arisen. Some-

* The report was distributed at the meeting and was not presented and discussed.

times such a problem was connected with a normal technological process (cleaning of transfer tanks, of sodium preparation system filters, mock-up subassemblies), in other cases - with a necessity for repair work. Especially complicated were operations of cleaning for those steam generators where water-sodium reaction took place as a result of loss of tube tightness. In some cases (large leaks) there arose a need for purification of the total sodium circuit of the loop from sodium-water interaction products. Prior to bringing the plant into power operation the primary and secondary circuit equipment was basically cleaned from sodium residues by the same technology. After bringing the plant on power the technology of cleaning primary circuit equipment became more complicated.

During reactor operation the primary coolant is contaminated by radioactive fission products: $Cs^{137}$, $Ba^{140}$, $La^{140}$, by products of structural materials corrosion and by fission products. Fig.1 shows the relative rate of fission product activity caused by surface contamination of fuel elements and of corrosion product activity in the primary circuit during 1973-1976.

The quantity of radioactive deposits on equipment surfaces increases as a function of the quantity of radioactive impurities in the primary coolant; therefore, in addition to cleaning from sodium a necessity for equipment decontamination from radioactive impurities can arise depending on its further purpose (repair, preservation, storage). On the BN-350 reactor from the beginging of its operation various components both large - and small-size ones were cleaned from sodium. The radioactive impurity content in the primary coolant being up to now not very high, only experimental fuel elements were decontaminated before their dismantling and cutting in the hot cell. The list of the BN-350 reactor components cleaned from sodium is presented in Table I.



Table I.

| N | Components | Number of cleaned equipment units |
|---|---|---|
| 1. | Evaporator | 12 |
| 2. | Removable part of the primary circuit pump | 2 |
| 3. | Removable part of the secondary pump | 2 |
| 4. | Removable part of the primary circuit check value | 1 |
| 5. | Secondary pipes (D=360mm) adjoining the evaporator | Separate sections up to 20m long |
| 6. | Transfer tanks for coolant $V=1\ m^3$ | 1000 |
| 7. | Coolant preparation system pipes | |

## 2. Design Cleaning and Decontamination Facilities and Systems.

To clean from sodium the BN-350 components operating in sodium medium before their repair there is a special system at the reactor plant consisting of three washer-pits intended for cleaning specific components: a rotating washer pit for rinsingand decontamination of intermediate heat exchanger tube bundle, a washer pit for cleaning the removable parts of primary and secondary pumps, of check valves and gate valves, control system mechanisms, etc., sockets for cleaning spent fuel subassemblies.

2.1. The rotating washer pit serves for cleaning from sodium and decontamination of the intermediate heat-exchanger tube bundle. It is provided with electric heating for melting residual sodium in secondary-circuit tube bundle with the aim of its subsequent draining into a special tank. Besides, for better secondary sodium draining the pit can be rotated in a vertical plane through 96° with a pitch of 15° by an electric drive. The heat-exchanger tube bundle is transferred to the washer pit in a special airtight flexible container. After placing the tube bundle in the washer pit it is heated up, secondary sodium is drained and then the tube bundle is cleaned and decontaminated. The processes of cleaning and decontamination are controlled remotely.

Technical Characteristics of the Rotating Cleaning Pit.

| | |
|---|---|
| Geometrical volume | -5 $m^3$ |
| Operating pressure | - 0.06 MPa |
| Operating vacuum | -100 mm of water column. |

2.2. The stationary cleaning pit is used for cleaning and decontamination of the removable parts of primary and secondary pumps, of the removable parts of valves and check valves. The pit is equipped with a mounting flange on which the removable part of the pumps is fastened for cleaning. The valve and check valve removable parts are mounted with the use of transitional shells. The cleaning and decontamination processe are also remotely controlled.



2.3. The washer-pit for cleaning elevators, recharging mechanism and control rod mechanisms.

Technical characteristics of the pit:

| | |
|---|---|
| 1. Geometrical volume | - 2.17 $m^3$ |
| 2. Operating pressure | - 0.15 M Pa |
| 3. Operating vacuum | - 0.01 MPa |

2.4. Spent fuel subassemblies are cleaned from sodium in special cells. All washer-pits are fed with washing media from one collector. To the pits are fed steam, distillate, inert gas and decontaminating solutions. Decontamination solutions are prepared in two tanks of 7.5 $m^3$ volume each and are supplied by the pump into the washer pits. To clean from sodium small parts and components as well as to remòve residiual sodium there is a sodium destruction rig at the plant(for non-radioactive sodium). The system for cleaning from sodium steam generator section at the reactor was not assumed by the design. Therefore, when there arose a necessity for cleaning steam generator sections a provisional system was mounted for cleaning steam generators without their disassembling from their installation sites.

3. Process Flow Diagrams of Cleaning and Decontamination Systems.

A diagram of the system for BN-350 components cleaning is presented in Fig.2. It is a complex of 3 washer-pits each of which being intended for cleaning particular equipment.

Washing media (steam, distillate, inert gas) are fed to a collector. From the collector the washing media are distributed to each separate pit. The steam used for components cleaning has the following conditions: temperature of 140°C, pressure of 0.4 ÷ 0.6 MPa. Steam-sodium reaction products out of washer-pits are supplied to the liquid-waste reprocessing facility. An approximate list of decontamination solutions and the time of one decontamination cycle are given below:

1. 0.5% $KMnO_4$ - 24 hours, T=70°C
2. 5% $HNO_3$ solution + 1% oxalicacid - 3÷4 hr., T=70°C
3. Distillate - 1hr., T=60 ÷ 80°C
4. Desorption solution (5% $HNO_3$ + 1% $H_2C_2O_4$)

After decontamination the solutions are fed into the liquid radioactive waste reprocessing facility.

The diagram of cleaning BN-350 evaporators is shown in Fig.3.

The system for BN-350 evaporators cleaning from sodium and sodium-water interaction products was installed without disassembling evaporators from their operating site. Washing media (steam and inert gas ) are fed to the evaporator both from the secondary and third circuits. Interaction products from the bottom part of the evaporator are fed through the heated pipe (D=100 mm), to a separation tank of V=1 $m^3$ provided with electric heating. The separation tank serves for interaction product liquid and gas phase separation. Then the gas phase is supplied to the condenser and then to the hydroseal which simultaneously serves as a dilution tank. In this tank a constant water level of H=300 mm is maintained. The liquid phase of sodium-water interaction products which is a concentrated alkaline solution is removed from the separation tank by means of water supply into the tank. Sampling lines are used to control hydrogen and oxygen content in primary and secondary circuit volumes of the evaporator. On the discharge line of the dilution hydroseal the discharged water is sampled for alkali content. A rupture disk designed for a pressure of P=0.2±0.7 MPa is mounted at one of the evaporator secondary pipes to ensure safety at cleaning. A heater on the pipe connecting the evaporator to the separation tank serves to maintain sodium-water interaction products in the liquid state. The heater is designed to keep the pipe temperature up to 400°C.

## 4. Cleaning and Decontamination Technology. Cleaning and Decontamination Processes Control.

At the BN-350 reactor a steam-and-gas method is adopted for cleaning the equipment operating in sodium. The technological procedure of cleaning is as follows:

4.1. The component to be cleaned is transported in a sealed protection cask with the inert gas medium to the washer pit. The washer-pit is previously blown through with the inert gas up to oxygen content in the washer-pit volume not more than 0.1 vol.%.

4.2. To the washer pit an inert gas (nitrogen) - superheated steam mixture is fed. In the process the flowrates of steam and inert gas are monitored by the instruments mounted on the lines of steam-gas supply. The hydrogen concentration within the washer-pit volume is monitored either by sampling for the chromatograph or continuously by an analyzer with the palladium probe. The permissible hydrogen content is not higher than 10 %(vol.)

4.3. When, at the continuous steam supply, the release of hydrogen ceases, the sodium is considered to have completely reacted with the steam. The steam is still supplied for some time and then the equipment being wahsed is rinsed with water to remove the unreacted sodium and alkali residues from the surfaces being cleaned. For this purpose the pit is filled with water. The temperature of the water supplied is kept near the temperature of the equipment being cleaned to eliminate thermal stresses in equipment joints . The alkalinity of the media discharged after rinsing is controlled during the rinsing process by means of sampling at specified intervals.

So a number of water filling and draining cycles are carried out until the neutral reaction of the rinsing water is obtained. Depending on contamination of the discharged water it is fed to the appropriate reprocessing complex. If required, the cleaned equipment is decontaminated by means of filling up the washer pits with decontamination solutions.

Evaporator Cleaning Technology.

To carry out repair work on a tube bundle of evaporators the need arose to clean tubes and sodium voids of evaporators from sodium. For this aim the technology of cleaning with the use of steam-nitrogen mixture was adopted. The quantity of sodium remaing on the surfaces working in sodium was preliminary estimated assuming the surface sodium film thickness of about 0.15 mm. This evaluation was necessary for calculating the quantity of steam, gas and water required for cleaning. The cleaning process included four main operations:

1. Cleaning with the 1:1 superheated steam-nitrogen mixture.
2. Cleaning with wet steam in nitrogen medium.
3. Rinsing with water filling.
4. Drying of evaporators by means of nitrogen blowing and evacuation with heating.

Before the superheated steam supply into the evaporator volume it was blown with nitrogen both through the sodium and water chambers up to oxygen content less than 2 vol.% in the discharged mixture. Then the evaporator was heated by standard electric heaters up to 100-120°C. Through the water and sodium chambers of the evaporator nitrogen was supplied at a flowrate of 5 $m^3$/hr. The trend of the steam cleaning procedure is presented in Fig.4.

From the moment of cessation of steam-water reaction that was determined from the absence of hydrogen within the volumes being cleaned the evaporator temperature was gradually decreased to to 80 ÷ 90°C by switching off the elctric heating, and the supplied steam condensing upon the inner evaporator surfaces washed off sodium-to-steam interaction products and the alkali solution flew down into the draining tank. On completion of steam rinsing the evaporators were filled with water at a rate of level rise of 200 mm/hr, hydrogen concentration not exceeding

0.001vol.%. Alkalinity of water was 1.0 g/l. The temperature of water supplied into the evaporator was kept within 80°C ± ± 10°C at an evaporator temperature of 80°C. Immediately after rinsing with water the evaporator heated up to a temperature of 80°C for moisture elimination was blown by dry nitrogen at a flowrate of 30 $m^3$/hr and then was evacuated by the vacuum pump for 20 hours. Vacuum depth of 0.01 at was achieved very quickly. From the moisture separator about 150 $cm^3$ of water was usually drained.

The quantity of sodium removed at cleaning from each evaporator was evaluated from the quantity of the hydrogen evolved and the alkali removed and was about 20 kg of sodium. The calculation of this amount of sodium uniformly distributed over the evaporator surface gives the film thickness of about 0.034 mm.

## Cleaning of the Removable Part of the Secondary Pump.

The removable part of the secondary pump was withdrawn due to the end of its service life. Before disassembling the pump was shut down with switching off of all external systems and was subjected to outer inspection. Sodium was drained from the loop. The removable part of the pump was withdrawn with the use of a soft pressurized case. The inspection of the removable part revealed satisfactory drainability of sodium from the pump volume. Sodium residues in form of local spots of a small thickness were observed on the face plane of the guide apparatus. On the surfaces of the pump removable part being in contact with coolant during pump operation there was a thin deposit of sodium.



After inspection the removable part was placed into the washer pit and disassembled in it.In the washer pit the removable part was blown through with nitrogen and then it was cleaned with the steam-gas mixture of P =0.1MPa, T=150°C during 48 hours. Then the washer pit was filled with water with a hold time of 4 hours afetr which water was drained, the removable part of the pump was dryed with nitrogen during 1.5 hr and kept in nitrogen medium of P=0.02 ÷ 0.03 MPa for 36 hours. Disassembling of the removable part of the pump showed that in the gaps with conjugated details there remained sodium unreacted with steam and water in the washer pit.

The removable part of another secondary pump was cleaned in the same way. At disassembling of the removable part, along with the places of unreacted sodium noted in the first case, corrosion assumed to be connected with the cleaning process was observed in the area of loose fitting of the operating wheel blades to the cover disk. The blades were welded to the cover disk not along the entire length of the blades but locally, and because of loose fitting of the blades to the cover disk a gap of about 0.3 mm and along the length of 280 mm was formed between the blades and the cover disk.

## 5. Radiation Situation during Radioactive Equipment Cleaning.

In connection with the BN-350 primary coolant being slightly contaminated by radioactive products, no complications arose when cleaning the withdrawn primary equipment. So, the maximum dose rate for radioactive products deposited over the removable part of the main circulating part (1974) and over the removable part of the check value (1975) was 3÷4 μr/sec. The radioactivity was caused by $Na^{22}$, $Co^{58}$, $Mn^{54}$, $Zn^{65}$. After cleaning with steam and gas mixture the dose rate decreased to 0.1÷0.2 μr/sec. that didn't call for any additional decontamination of the equipment.

## 6. Cleaning Results.

The Experience of Cleaning the BN-350 components from sodium has shown, that:

1. The steam-water cleaning process has no marked corrosion effect on equipment materials when following the adopted technology. It is confirmed by results obtained from inspection of joints and components of the washed-off equipment as well as by experience of cleaned equipment operation. So after repair the evaporators of the reactor worked, as of 1.03.77, on the average for about 20000 hours. The inspection of the pump removable parts showed that components and joints of the pump removable parts were in satisfactory condition, except for seals. After assembling, the removable parts of the pumps were considered to be suitable for further operation.

2. Due to its simplicity, low cost and good results of cleaning of the BN-350 equipment, the steam-and-gas method of cleaning for austenitic stainless steels is acceptable for cleaning both large and small-size components of sodium-cooled nuclear power plants.



## REFERENCES

1. Arkhipov V.M. et al. Some problems of cleaning fast reactor circuit components from sodium and radioactivity. Paper presented to the IAEA Meeting of Specialists, England, Dounrey, April 1973.

2. Karpov A.V. et al. USSR Experience in fast reactor sodium technology. Paper at the COMECON Meeting of Specialists, DDR, 1977.

3. I.Higson and I.Mathinson. REML experience of cleaning large plant components contaminated with sodium.

4. P.Ponne. Removal of residual sodium from loop components. Proceedings of the IAEA Specialists Meeting on cleaning from Sodium and Decontamination of Fast Reactor Components, England, Dounrey, 1973.

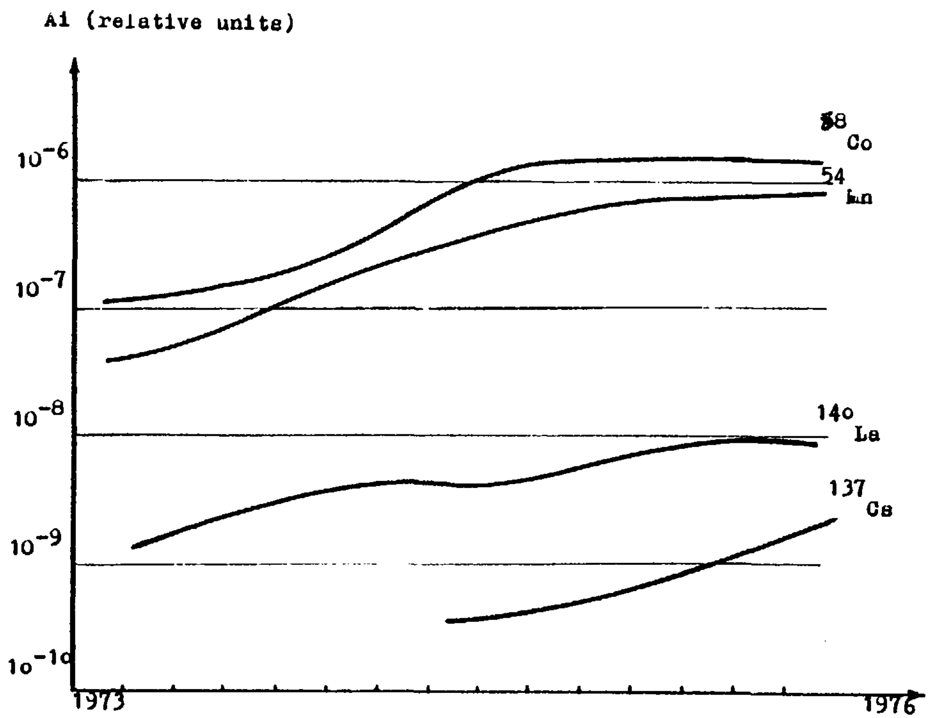


Fig.1. Relative growth of activity of fission products in sodium caused by surface fuel element contamination and of corrosion products activity in the primary coolant during 1973 - 1976.

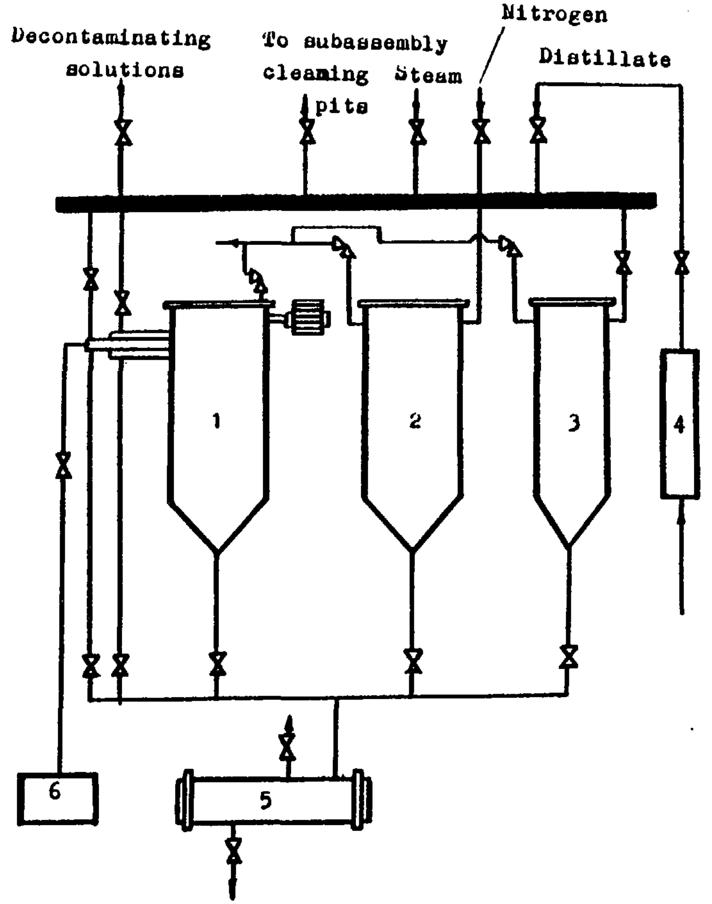


Fig.2. Scheme of a standard system for cleaning the BN-350 equipment.

1. Rotating washer pit. 2. Steady washer pit.
3. Washer pit for elewators and control rods.
4. Distillate heater. 5. Condenser.
6. Sodium dump tank of $V=3m^3$.

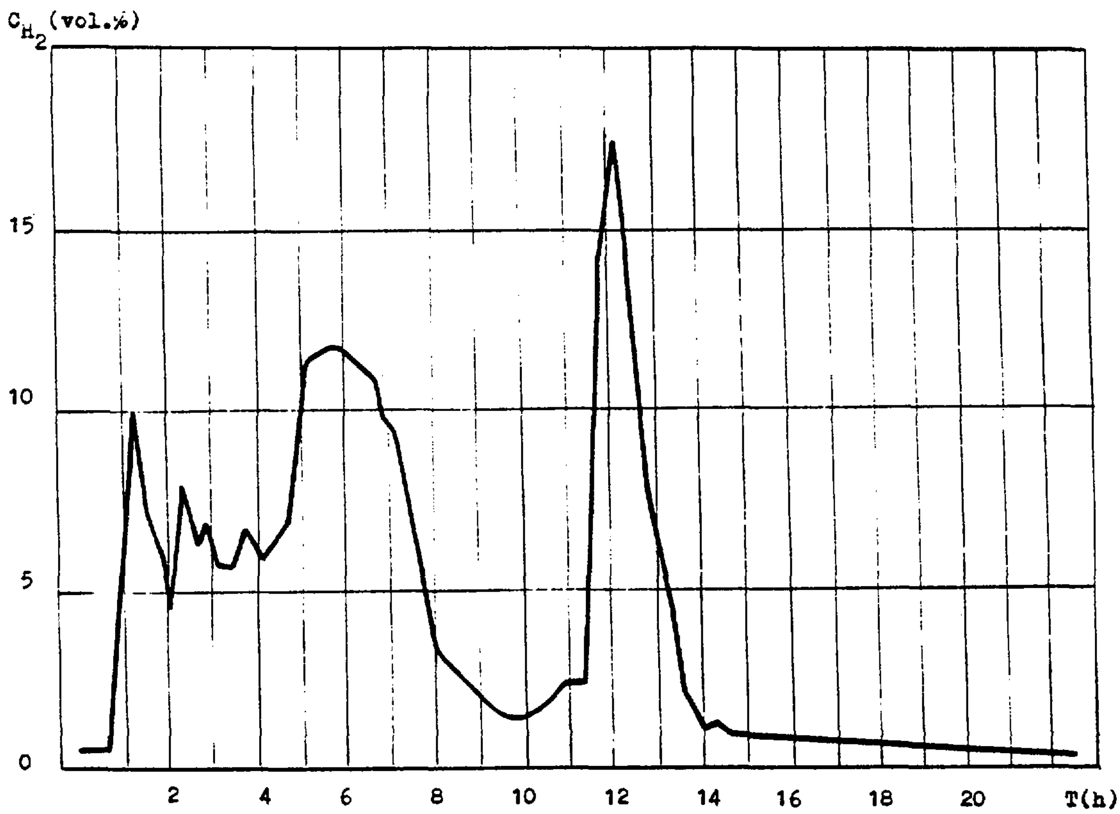


Fig. 4. Hydrogen concentration variation in the process of cleaning the second evaporator

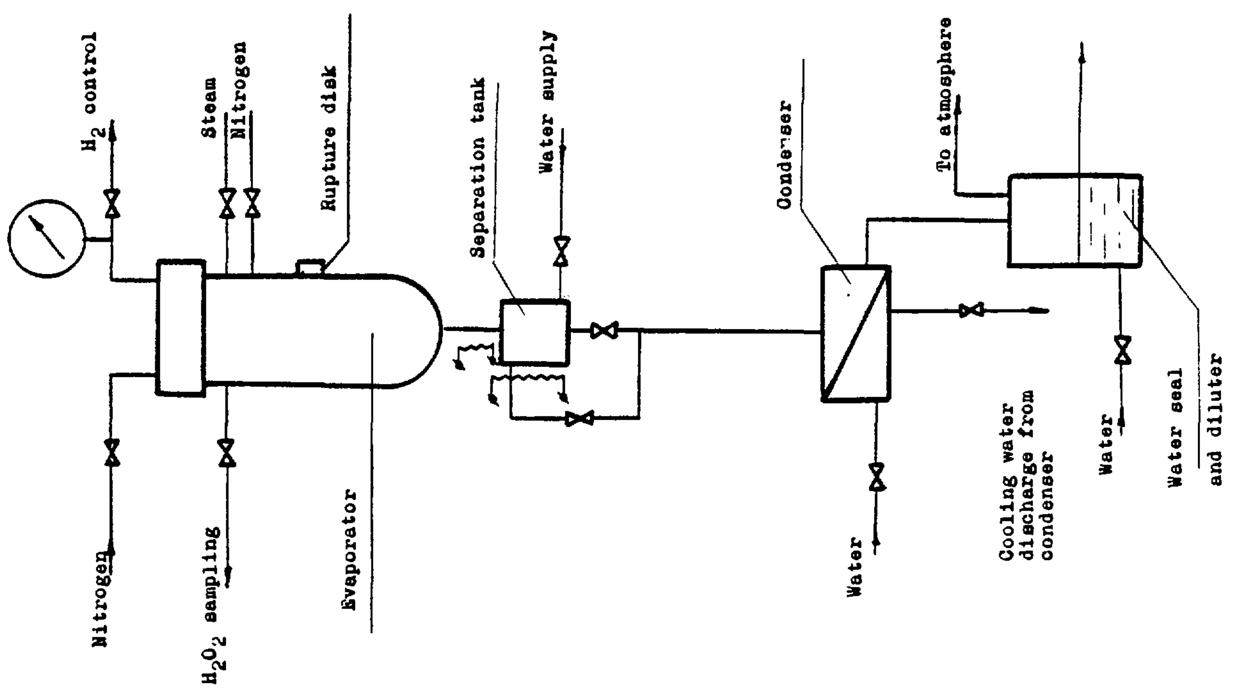


Fig. 3.