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USE OF REACTOR PLANTS OF ENHANCED SAFETY FOR SEA WATER DESALINATION, INDUSTRIAL AND DISTRICT HEATING

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Abstract

Russian designers have developed and can deliver nuclear complexes to provide sea water desalination, industrial and district heating. This paper provides an overview of these designs utilizing the ABV, KLT-40 and ATETS-80 reactor plants of enhanced safety.

The most advanced nuclear powered water desalination project is the APVS-80. This design consists of a special ship equipped with the distillation desalination plant powered at a level of 160 MW(th) utilizing the type KLT-40 reactor plant. More than 20 years of experience with water desalination and reactor plants has been achieved in Aktau and Russian nuclear ships without radioactive contamination of desalinated water.

Design is also proceeding on a two structure complex consisting of a floating nuclear power station and a reverse osmosis desalination plant. This new technology for sea water desalination provides the opportunity to considerably reduce the specific consumption of power for the desalination of sea water.

The ABV reactor is utilized in the "Volnolom" type floating nuclear power station. This design also features a desalinator ship which provides sea water desalination by the reverse osmosis process. The ATETS-80 is a nuclear two-reactor cogeneration complex which incorporates the integral vessel-type PWR which can be used in the production of electricity, steam, hot and desalinated water.

As variants of non-electric use of nuclear energy, Russia design organizations and enterprises have developed and can deliver to the Customer nuclear complexes with reactor plants (RPs) of enhanced safety of ABV, KLT-40 and ATETS-80 type of 38, 160 and 250 MW(th) respectively for sea water desalination, industrial and district heating. The ratio between the amount of heat delivered and desalinated water production is determined by the Customer proceeding from maintaining the thermal power of RPs. As desalinators, distillation and reverse osmosis plants can be used. The stations can be floating and land- based.

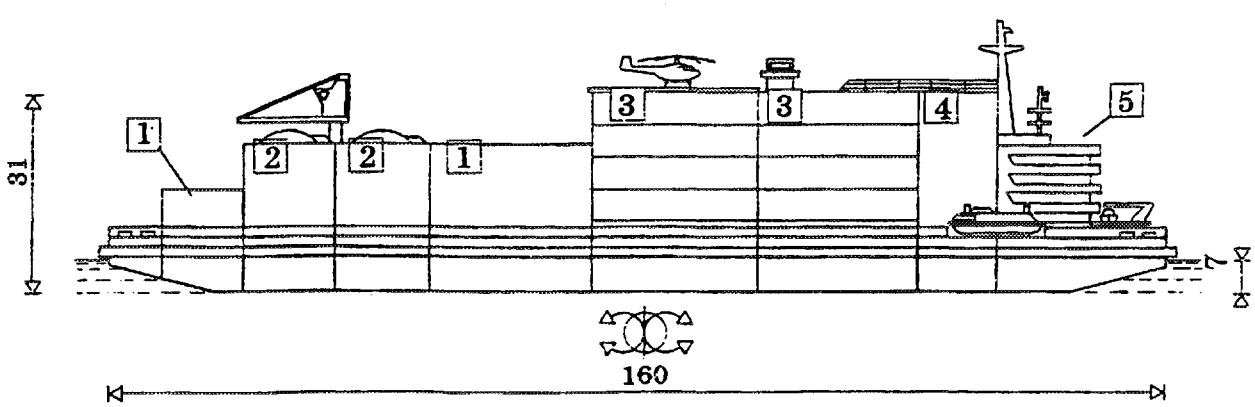
NUCLEAR WATER DESALINATION STATIONS INCORPORATING KLT-40-TYPE REACTOR PLANT

As to the level of perfection the most advanced today is the project of APVS-80 nuclear power station incorporating KLT-40-type reactor plant with distillation desalinator.

APVS-80 is a special non-self-propelled ship with two-reactor power plant destined for sea water desalination in conditions of protected water area together with a complex of external servicing structures (Fig. 1).

APVS-80 Main Technical Data

Length, m	- 160
Width, m	- 44
Draught, m	- 7
Output of desalinated water, m3/day	- 80000



1 - engine compartment

2 - central power compartment

3 - desalination plant

4 - potable water preparating plant

5 - living compartment

FIG. 1. Ship layout.

KLT-40-type RP meets international requirements for safety of ship power plants, home normative documents for NPPs, accounts for IAEA recommendations. This type of modular RP (Fig. 2a, 2b) has been successfully operating during decades in Russia nuclear ships going through successive evolutionary improvement for each subsequent generation on the basis of experience obtained. Now this plant is serially produced in Russia enterprises. At the Customer's request the water desalination plant can be fabricated as one reactor unit. For two-reactor unit the unit power of the reactor amounts to appr. 80 MW(th), for one-reactor unit it is appr. 160 MW(th).

Besides the RP the station includes desalination plant, drinkable water production plant, and ship general systems.

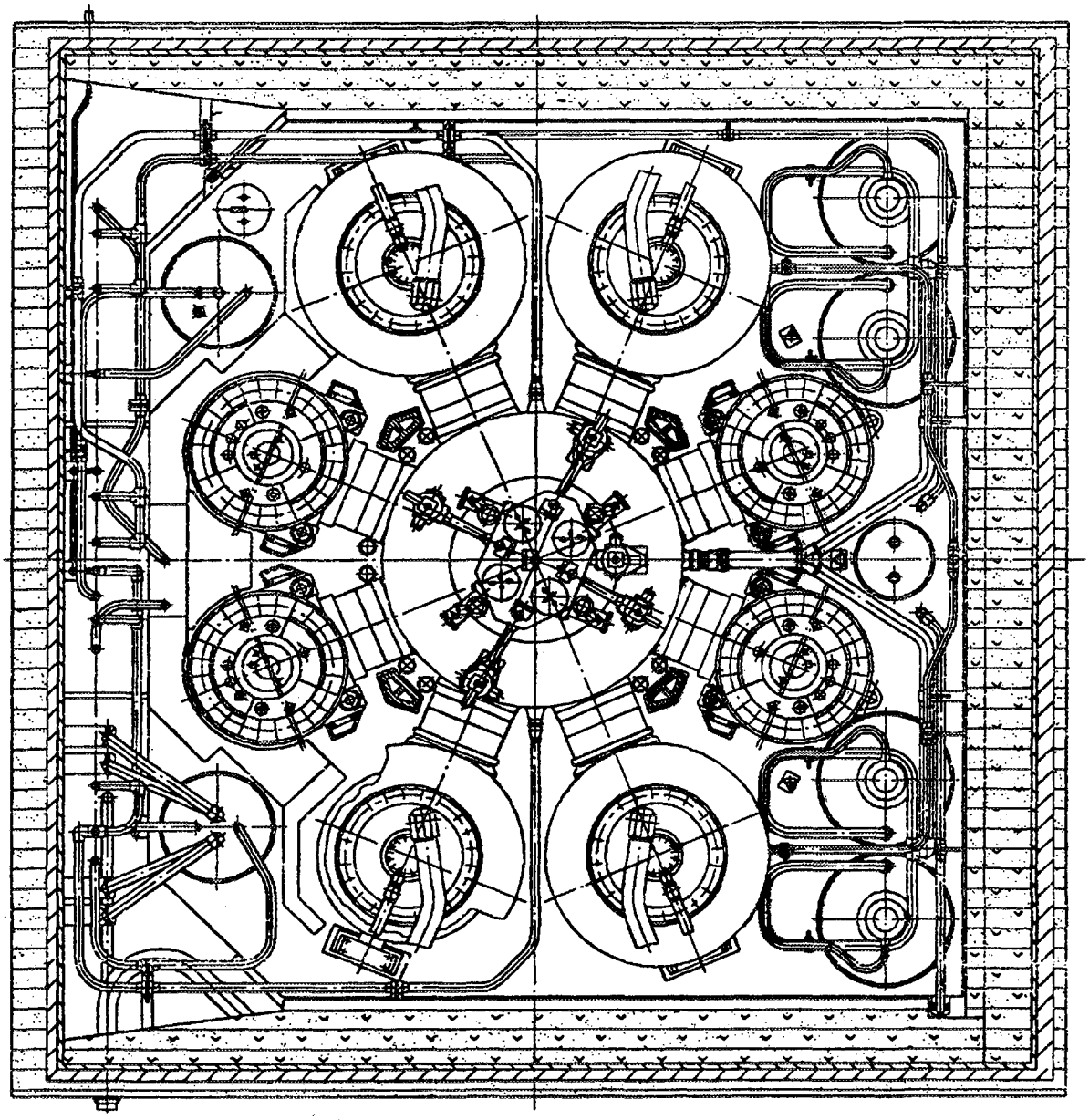


FIG. 2a.

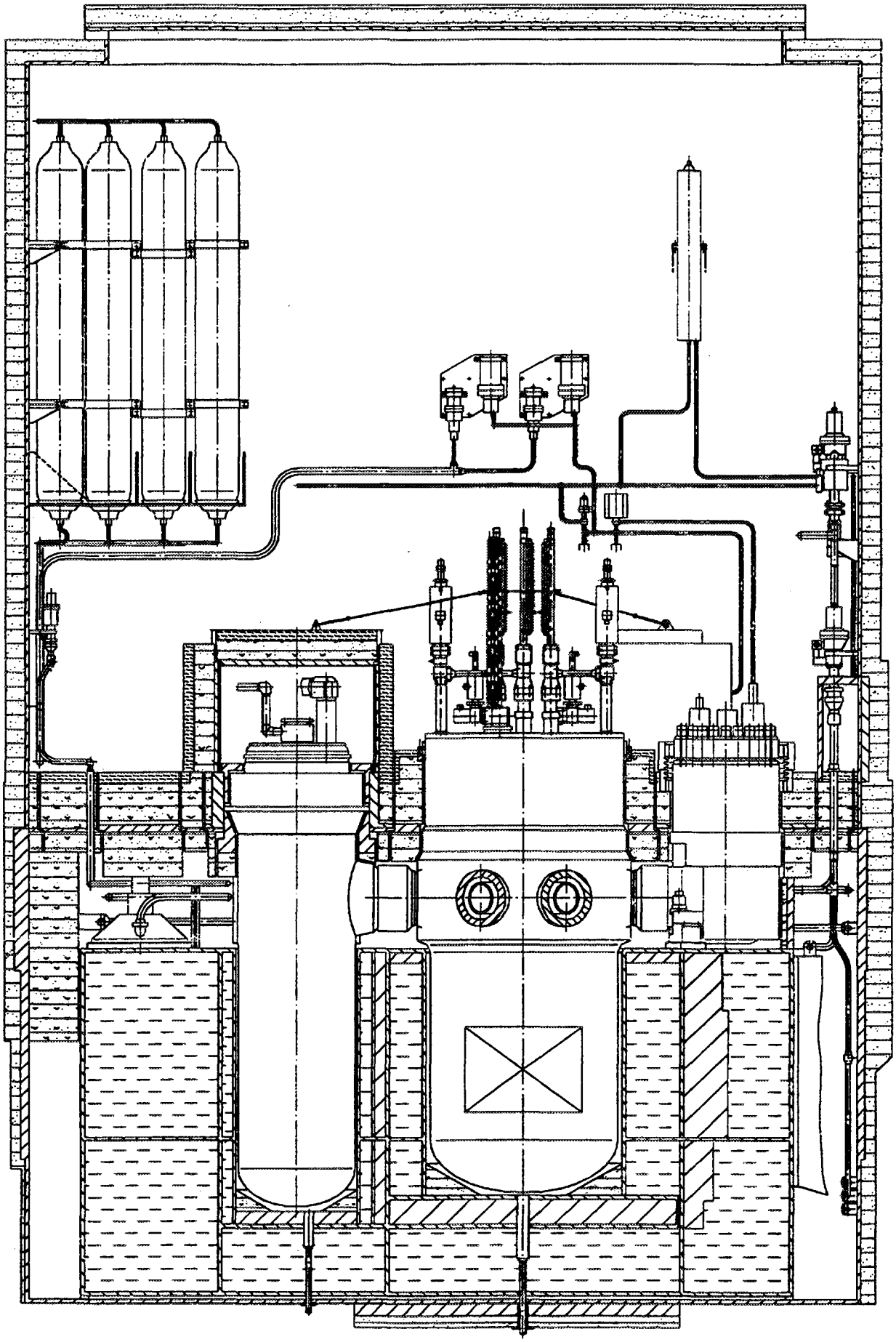


FIG. 2b.

Distillation desalination plants (DDP) equipped with horizontal-tube film evaporators are developed by Sverdlovsk Scientific-Research Institute of Chemical Engineering which is leading Designer of stationary DDPs (Fig.3). These are the most up-to-date, compact, economic evaporators respective consumption of thermal and electric power. There is many-years experience of using analogous plants in industrial complex in Aktau (Kazakhstan), Novocherkask, Urengoy. Machinebuilding enterprises are capable to provide for fabrication and delivery of desalination plants for APVS-80.

The principal diagram of combining the reactor and desalination plants is given in Fig. 4.

More than 20 year experience of joint operation of water desalination and RPs in Aktau and in Russia nuclear ships has shown the absence of radioactive contamination of desalinated water.

To preliminary estimate (variant of desalination complex using KLT-40-type RPs and reverse osmosis desalination plant) is more economic but less developed by Russia enterprises in respect to desalinators. In this variant the complex includes two structures: floating nuclear power station (FNPS)(Fig. 5) and reverse osmosis desalination plant. The desalination plant in this case can be both floating one and land-based.

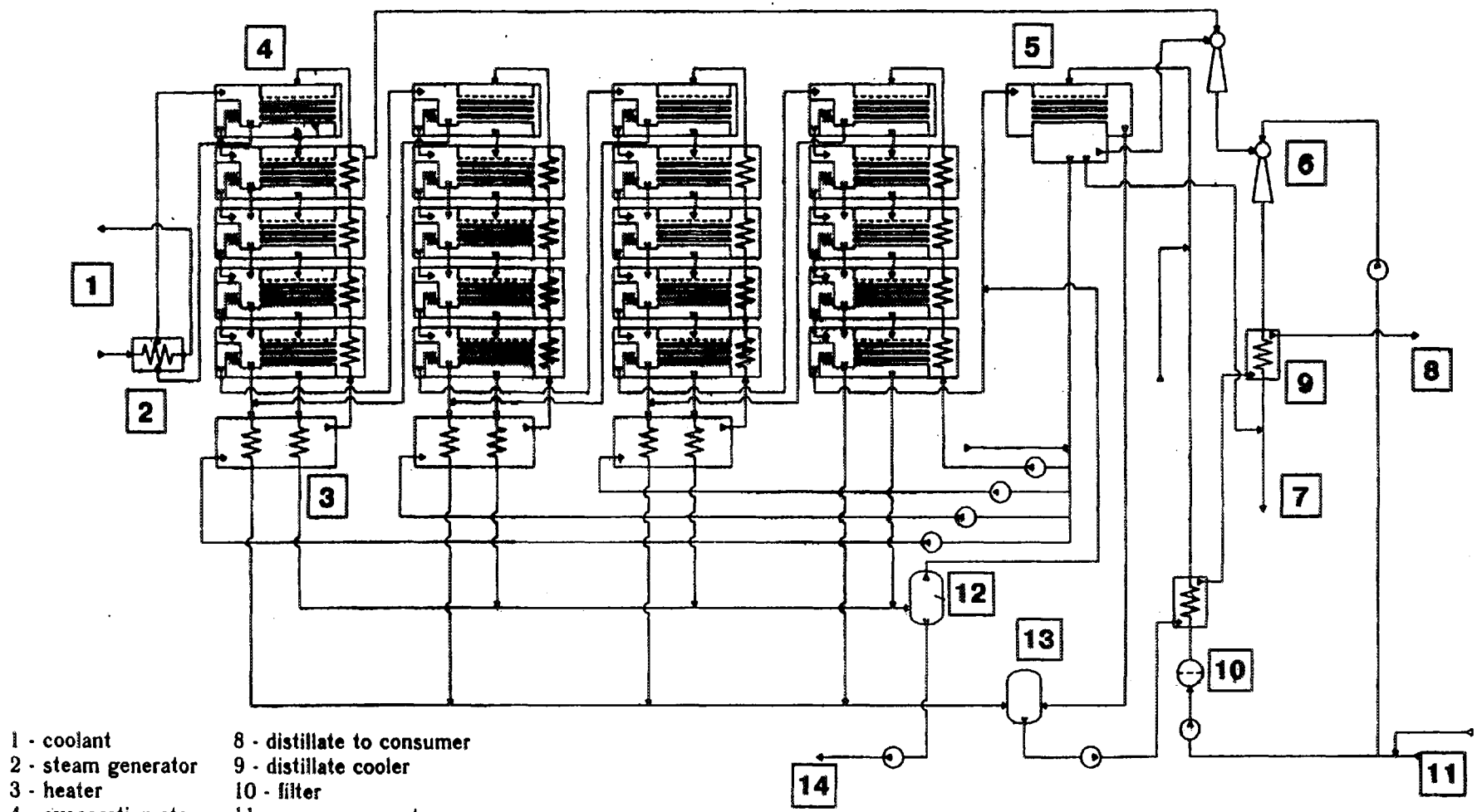
FNPS Main Characteristics

Length, m	- 120
Width, m	- 28
Draught, m	- 3.5 - 4.5
Number of reactor plants	- 2
Power of one-reactor plant, MW(th)	- up to 150
Electric power (gross), MW	- up to 70
Electric power consumed by FNPS, MW	- appr. 5
Heat delivered, Gcal/h	- 50

Now design and industrial enterprises of Russia are working at the creating of floating nuclear co-generation plant for north regions of the country which can be a prototype for FNPS for desalination complex.

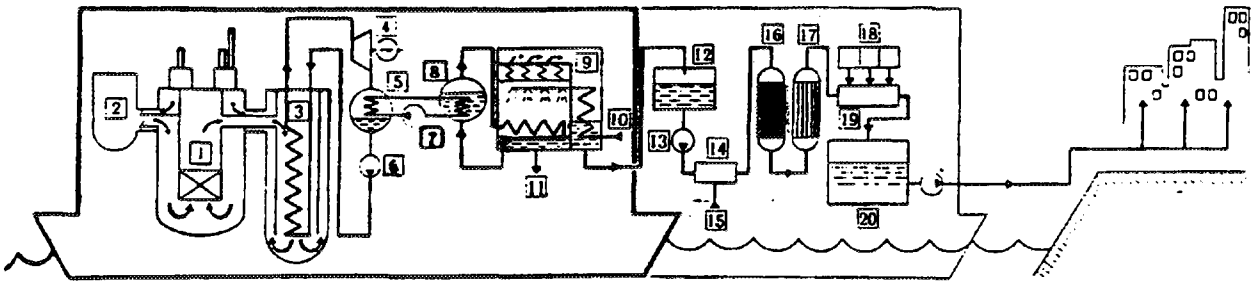
As for reverse osmosis desalination plant Canadian firm "CANDESAL" has reached certain success in their development.

The program of this firm foresees the use of new technologies for sea water desalination using reverse osmosis allowing to considerably reduce the specific consumption of power for desalination and cost of desalinated water. In this connection



1 - coolant
2 - steam generator
3 - heater
4 - evaporation stage
5 - deaerator
6 - water-jet ejector
7 - sea water
8 - distillate to consumer
9 - distillate cooler
10 - filter
11 - source sea water
12 - salf water concentration tank
13 - distillate tank
14 - sea water with high salf concentration

FIG. 3. Distillation desalination plant.



1 - reactor
2 - primary circuit circulator
3 - steam generator
4 - turbo-generator
5 - condenser
6 - secondary circuit electric pump
7 - intermediate circuit electric pump
8 - steam generator
9 - distillation desalinaton plant
10 - sea water
11 - evaporated sea water
12 - intake tank for distillation
13 - electric pump of potable water preparation plant
14 - mixer
15 - H_2CO_3 solution
16 - water enrichment facility
17 - running water ssorbent containing filter
18 - plant for fluorine, chlorine water treatment and stabilization
19 - mixer
20 - potable water tank

FIG. 4. Principal flow diagram of the station.

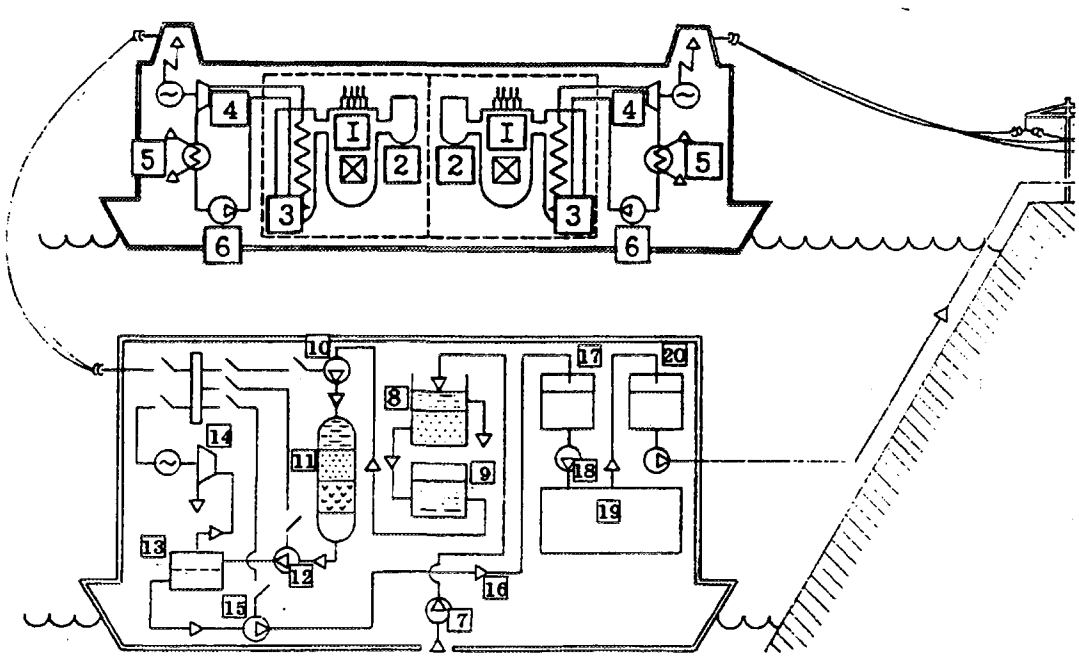
the development of joint Russian-Canadian Project of desalination complex using FNPS on the basis of new technologies of sea water desalination by reverse osmosis seems to be expedient. At specific electric power consumption of appr. 5 KW/m3 the output of such complex for desalinated water can be appr. 300 thousand m3/day.

At present, Russian MINATOM and firm "CANDESAL" have signed Memorandum of Intents on design, marketing and fabrication of APVS using power plant on KLT-40 basis

WATER DESALINATION COMPLEX ON THE BASIS OF ABV REACTOR PLANT

The complex comprises two barges:

- "Volnolom"-type floating nuclear power station with ABV reactor plant (Fig.6)
- desalinator for sea water desalination by reverse osmosis(Fig.7).



1 - reactor
2 - primary circuit circulating pump
3 - steam generator
4 - turbogenerator
5 - condenser
6 - secondary circuit electric pump
7 - sea water
8 - gravity filter
9 - clarified water tank
10 - booster pump
11 - twin-layer pressure filter
12 - high pressure filter
13 - reverse osmosis module
14 - hydroturbine
15 - fresh water pump
16 - filtrate
17 - filtrate intake tank
18 - electric pump of potable water preparation system
19 - potable water preparation unit
20 - potable water storage tank

FIG. 5. Principal flow diagram of the complex.

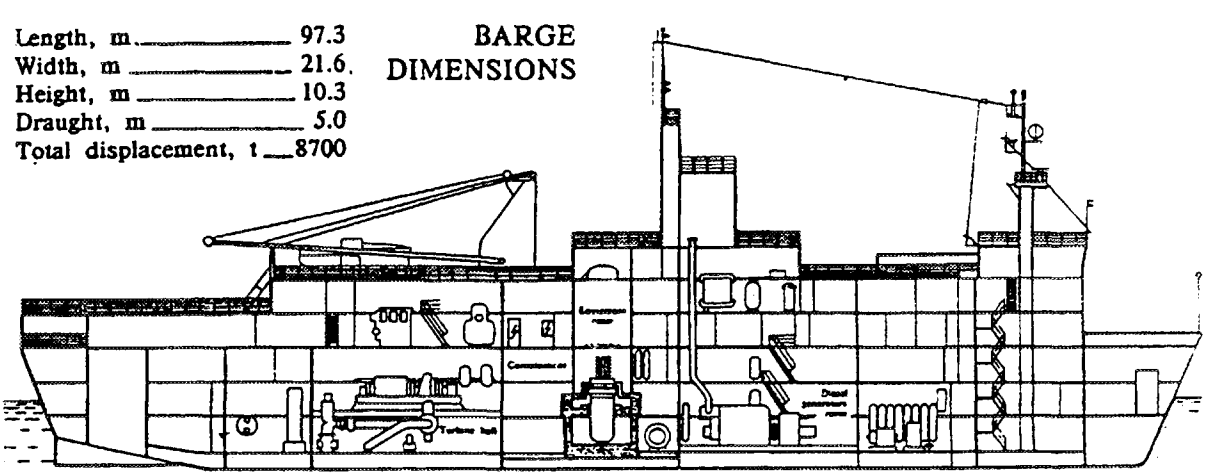
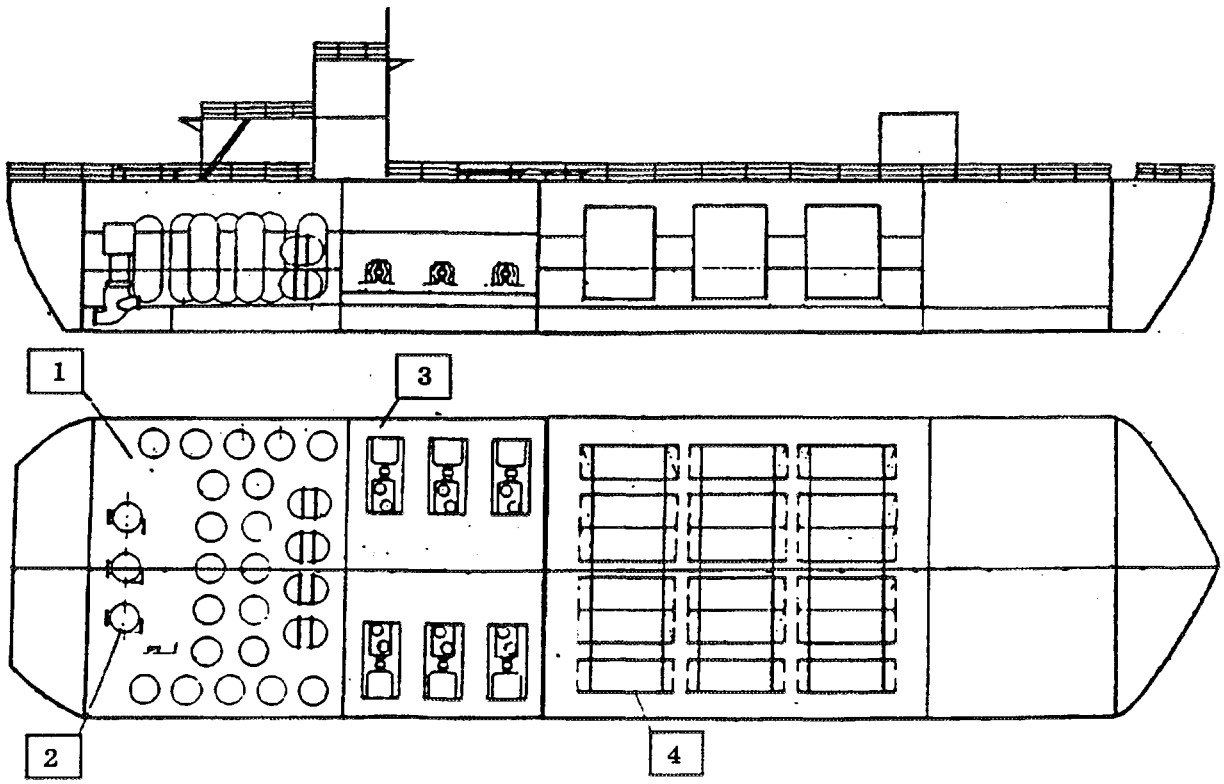


FIG. 6.



1 - room for sea water pre-treatment system

2 - booster pump

3 - desalinating system pump room

4 - desalinating modules

FIG. 7. Desalinating complex layout.

FNPS "Volnolom" Main Technical Data

Length, m	- 97.3
Width, m	- 21.6
Draught, m	- 4.5 - 5
Number of reactor units	- 2
Thermal power of one RP, MW	- 38
Electric power of unit (gross), MW	- 12
Amount of heat delivered, Gcal/h	- 12

The reactor plant is designed using two-circuit scheme with integral type reactor having natural circulation in primary circuit (Fig.8).

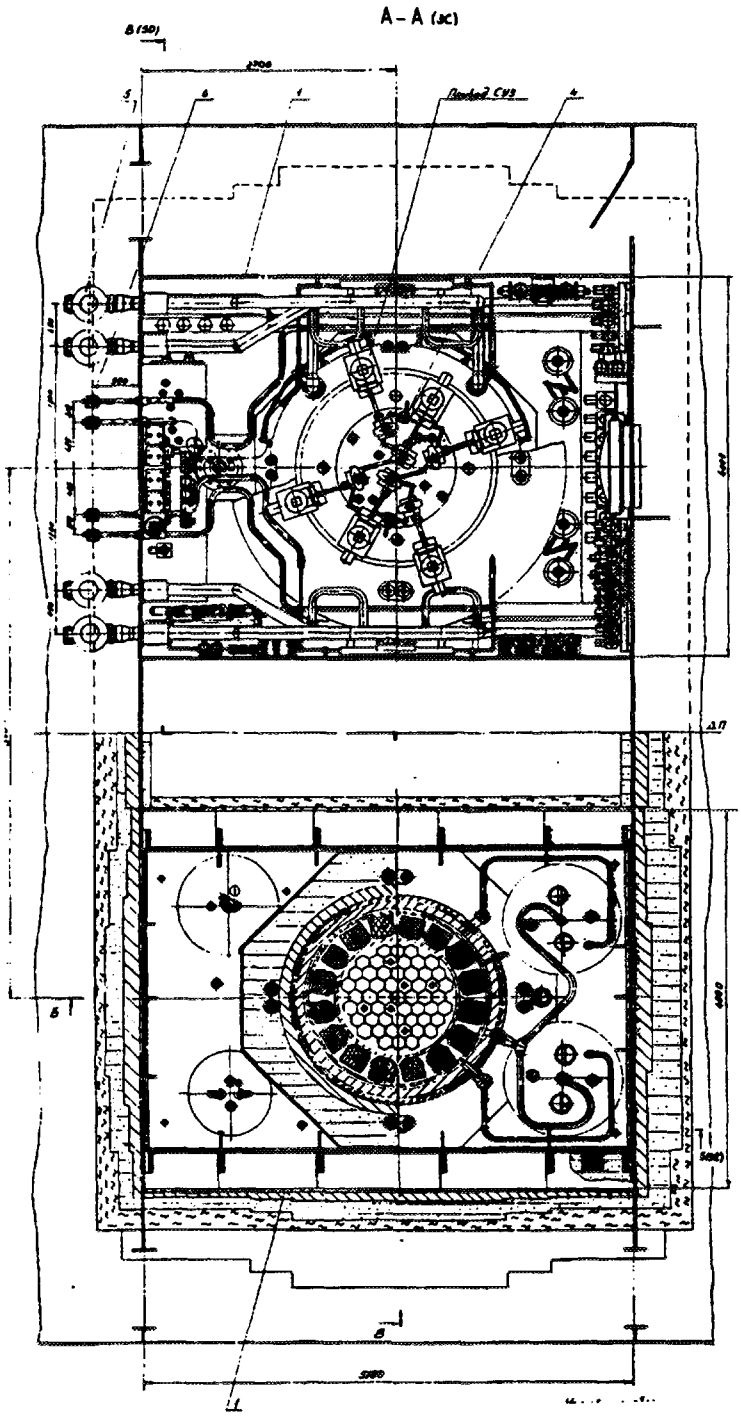


FIG. 8. ABV reactor plant.

The reactor plant was designed in accordance with modern home requirements, IAEA recommendations and with account of advanced NPPs design experience.

KLT-40 and ABV RPs were the winners among the plants of the same power at a competition "Small Nuclear Power Stations-91" held by RF Nuclear Society.

Main Characteristics of Desalinator-Ship

Length, m - 72
Width, m - 24
Draught, m - 3.9
Output of desalinated water, m3/day - 40000

When designing the desalinator-ship the use of fibre modules of "Permasep B-10"-type (Dupont firm) was foreseen.

NUCLEAR CO-GENERATION COMPLEX ATETS-80

ATETS-80 is nuclear two-reactor co-generation complex incorporating integral vessel-type PWR which can be used for production of electricity, steam, hot and desalinated water (Fig.9).

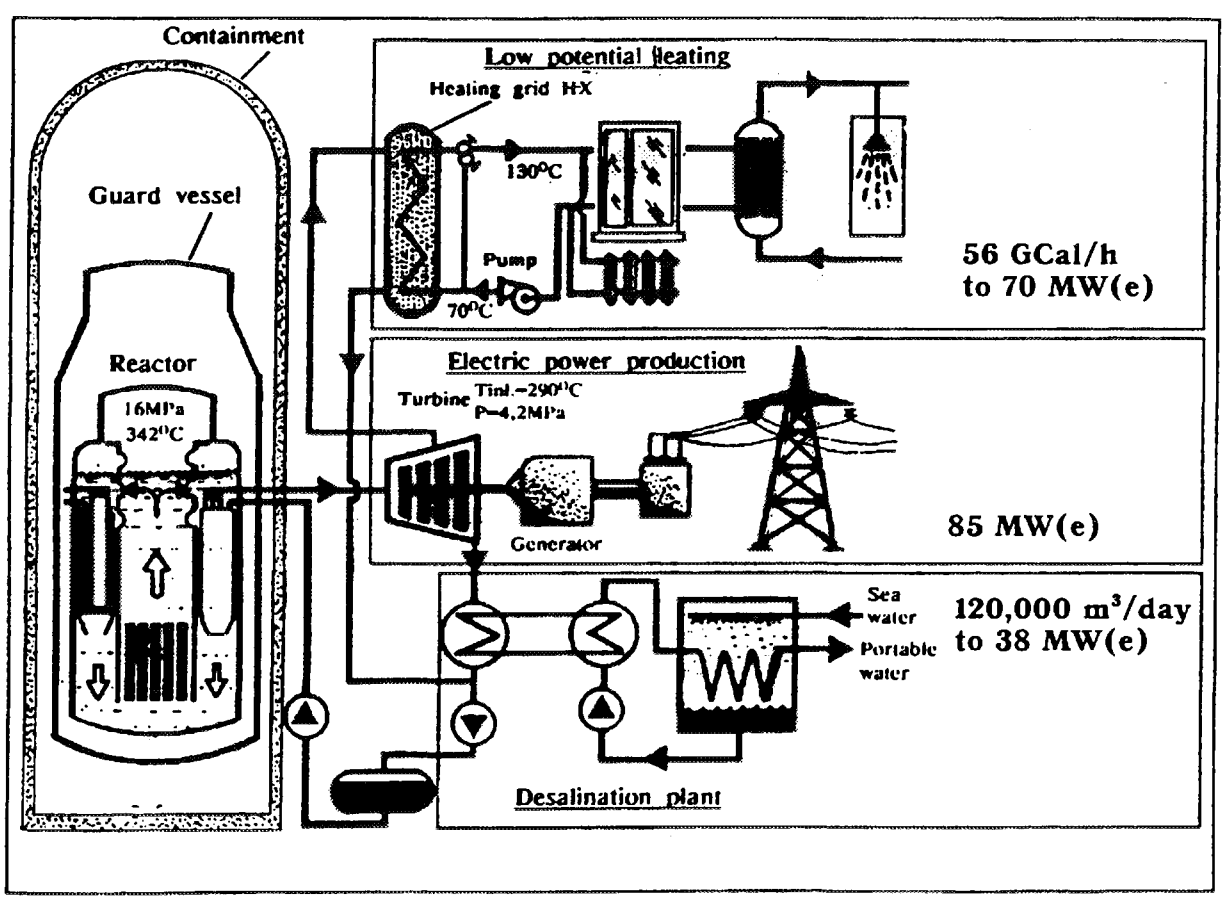


FIG. 9.

ATETS-80 Main Technical Data

Number of RPs	- 2
Reactor thermal power, MW	- 250
Maximum electric power, MW	- 85
Heat capacity (at 70 MW(e)), Gcal/h	- 56

In addition, on the Customer's request ATETS-80 can be used in the following variants:

1) Combined production of electricity, hot water and industrial steam (layout with back-pressure turbine)

Electric power, MW	- 20
Steam (1.2 MPa), Gcal/h	- 40
hot water (150°C), MW	- 160

2) Sea water desalination with the use of distillation plants and autonomous energy supply

Electric power, MW	- 60
Output for desalinated water, m3/day	-70000

3) Sea water desalination with generation of electric power for desalination complex auxiliary needs

Electric power, MW	- 38 (9 MW of desalination complex auxiliary power)
Output for desalinated water, m3/day	- 120000

When erecting ATETS-80 in shore zone of seas and rivers an effective method of their transportation and construction is floating one.. The floating module (reactor compartment, machine hall) is brought to the Site by water. The scope and cost of construction works is reduced.

CONCLUSION

1. Russia design organizations and enterprises had been developed and can supply to the Customer multi-purpose nuclear floating (or land-based) complexes of various power for sea water desalination, industrial and district heating.

2. Concerning the level of safety and ecological cleanness the floating nuclear complexes meet modern international regulations and can be recommended for sea water desalination, industrial and district heat supply (cryosupply) for North Africa, Near East, several regions of Indian Ocean including Insular Indonesia.

3. Perfection of main technical solutions for the complex on the basis of KLT-40 plant and their validation during many-year operation allow to have minimal time for its creation (4-5 years) and acceptable cost of desalinated water.

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