

*International Conference on Non-Electric Applications of Nuclear  
Power: Seawater Desalination, Hydrogen Production and other  
Industrial Applications  
16 – 19 April 2007, Oarai, Japan*

**FEASIBILITY STUDY ON DEPLOYMENT OF  
THE FIRST UNIT OF RUTA-70 REACTOR IN  
OBNINSK: DISTRICT HEATING,  
TECHNOLOGICAL, AND MEDICAL  
APPLICATIONS**

**Yu.S. Cherepnin, A.A. Romenkov, F.Ye. Yermoshin**

Research and Development Institute of Power Engineering, Moscow, Russia

**V.M. Poplavskiy, Yu.D. Baranaev, V.A. Sozonyuk**

State Scientific Center of the Russian Federation – Institute of Physics and Power  
Engineering, Obninsk, Russia

# Contents

**The paper presents a feasibility study on deployment of the first-of-kind RUTA-70 heat supply facility in Obninsk and prospects of various nuclear medical and technological applications of the reactor:**

## **Introduction**

**I. Major technical data and design features of the reactor**

**II. Using low-grade thermal energy generated by the reactor for district heating**

**III. Using the reactor as a neutron source to implement various nuclear technologies**

**IV. Using the reactor for desalination of seawater**

**Conclusions**

# Introduction (1)

---

**The current experience shows that there are no technical obstacles for the use of nuclear reactor heat both in domestic district heating systems and in industrial processes**

**Domestic district heating has a long history and proven experience in practical operation of nuclear facilities of various types**

**Nowadays, nuclear reactors in the world generate less than 1% of the heat used for district heating and in industrial processes while the share of nuclear power plants in electricity production worldwide being  $\square$  15%**

## **Introduction (2)**

---

**Increasing Interest in utilization of nuclear energy for district heating in recent years in Russia:**

- continuous increasing of domestic gas price**
- difficulties and/or very high cost of fossil fuel supply to some remotely isolated areas of the country**
- country-wide reform in the municipal sector**

**Dedicated nuclear heating plant with pool-type reactor producing low potential heat**

**RUTA – Thermal Reactor Unit with Atmospheric pressure**

## Introduction (3)

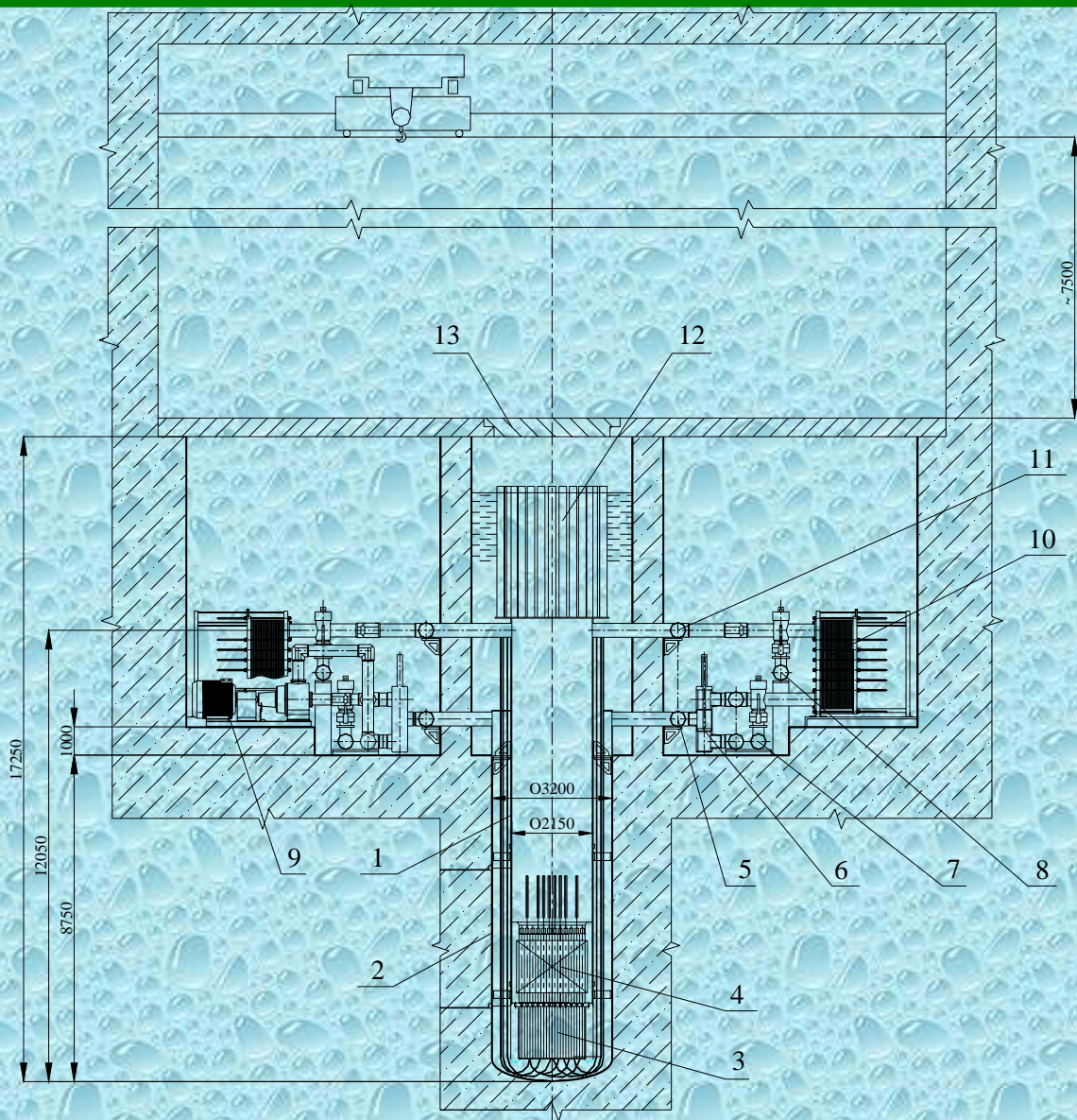
---

**R&D at various design stages are carried out for RUTA reactors with thermal power ranged from 10 to 70 MWt**

**Practical implementation plan -  
construction of the first demonstration  
nuclear heating plant with RUTA-70 in  
Obninsk on the site of the IPPE**

**The FS was prepared by Rosatom Institutes  
NIKIET (General and Reactor Designer)  
AEP (Architect-Engineering)  
IPPE (Research Supervisor)**

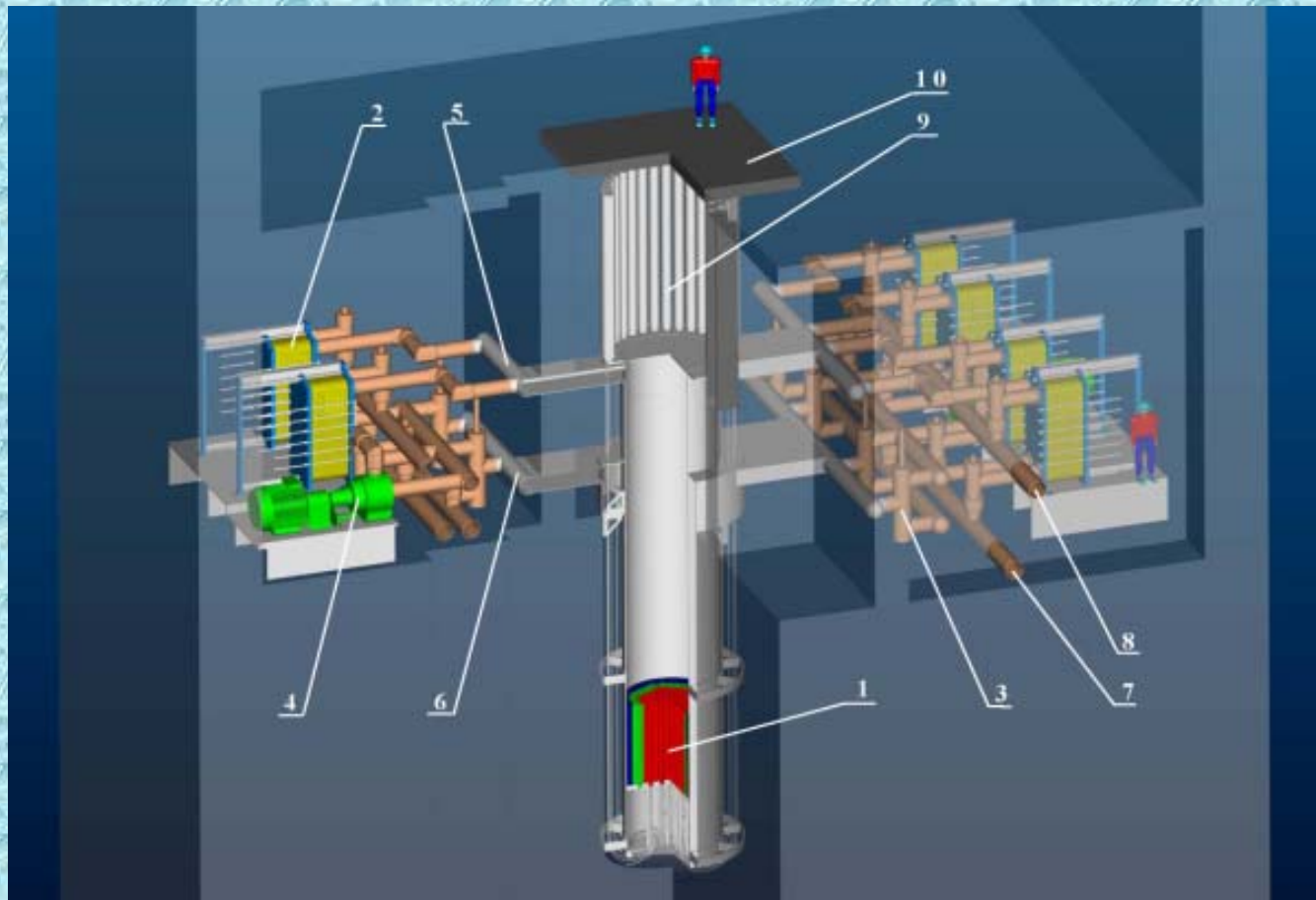
# I. RUTA-70 reactor design



## RUTA-70

- 1 – riser shroud,
- 2 – poll metallic liner
- 3 – core supporting plate with control rod lead tubes,
- 4 – reactor core
- 5 – plenum
- 6 – check valve
- 7 – secondary water inlet
- 8 – secondary water outlet,
- 9 – primary pump
- 10 – primary HX
- 11 – upper header
- 12 – control rod drives
- 13 – isolation plate

# I. RUTA-70 reactor design



## RUTA-70 reactor facility

- 1 – Core 2 – Primary heat exchanger 3 – Check valve 4 – Pump  
5 – Primary circuit distributing header 6 – Primary circuit collecting header  
7 – Secondary circuit supply pipeline 8 – Secondary circuit discharge pipeline  
9 – SCS drives 10 – Upper plate

# I. RUTA-70 reactor design

## Basic technical characteristics of RUTA-70

|  |                                       |
|--|---------------------------------------|
| Maximum reactor thermal power ( $N_{nom}$ ), MWt   | 70                                    |
| Core dimensions (diameter/height), m   | 1,42/1,4                              |
| Nuclear fuel type  | cermet<br>(0.6 $UO_2$ + 0.4 Al alloy) |
| Fuel enrichment, % of $^{235}U$  | 4.2                                   |
| Fuel campaign, eff. days   | 2 332                                 |
| Refueling interval at CF=0.7, years  | 3                                     |
| Portion of refueled assemblies   | 1/3                                   |
| Pool water volume, $m^3$   | 250                                   |
| Primary coolant circulation mode<br>- at (30 – 100)% $N_{nom}$<br>- at (0 – 30)% $N_{nom}$ | forced<br>natural                     |
| Primary coolant<br>- temperature (core inlet/outlet), °C<br>- pressure in core inlet, MPa  | 75 / 101<br>0,27                      |
| Intermediate HX temperature (inlet/outlet), °C<br>Pressure, MPa                            | 68 / 95<br>0,39                       |
| Main HX temperature (inlet/outlet), °C<br>Pressure, MPa                                    | 60 / 90<br>0,95                       |



# I. RUTA-70 reactor design

## Generic advantages of the technology important for heating reactor:

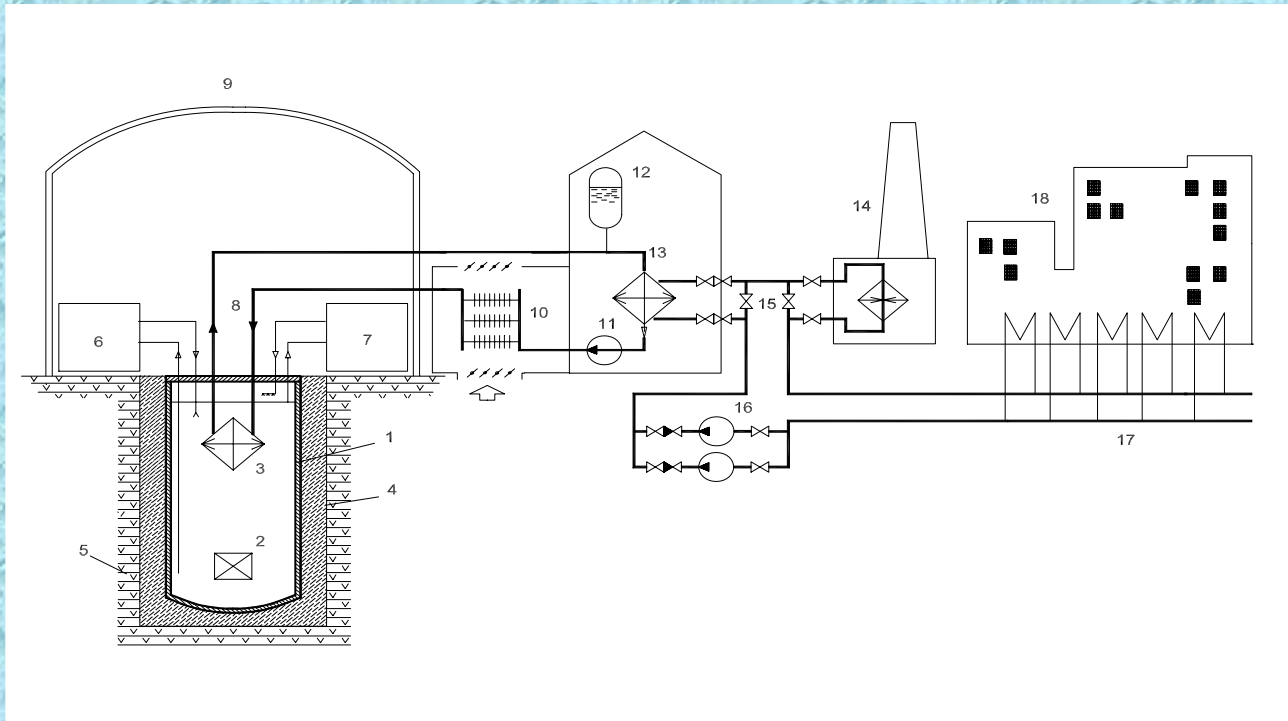
- Principal design simplicity resulting in low construction and operation cost
- High level of safety based on design features, inherent safety characteristics, and reliance on natural laws and forces to provide reactor protection:
  - Atmospheric pressure of primary circuit (no pressurization)
  - High heat capacity of reactor pool water
  - Negative reactivity feedback
  - Low fuel temperature and low value of core power density (30-40 MWt/m<sup>3</sup>)
  - Core cooling in coolant natural circulation mode at normal operation (up to  $\approx 30\%N_{nom}$ ) and under emergency conditions
- Three circuit heat transmission arrangement with two pressure barriers (double pressure reversal):  $p_1 < p_2 < p_3$

## II. RUTA-70 use for district heating

The key feature of pool-type reactors is low temperature of the system water

It defines the following operation approach:

- RUTA covers the base segment of the heat load
- Non-nuclear heat source is used for peak load and as a backup



## **II. RUTA-70 use for district heating**

- In a district heating systems with the maximum required temperature exceeding the available level temperature, system water should be heated by peak water heaters. In this case the capacity factor of the nuclear power source can be 0.6 - 0.8**
- In some cases RUTA can ensure full heat supply over the year. But capacity factor is very low (0.3 - 0.4). So, in these cases it is also preferable to use the RUTA facilities in the base segment of the heat load jointly with peak non-nuclear heat generators**

### **III. RUTA - neutron source**

---

**Taking into account interests of various scientific institutes located in Obninsk-city, important factor favouring the implementation of the RUTA project is provision for multi-purpose application of reactor:**

- production of a broad range of radioisotopes for medical and industrial purposes**
- neutron and transmutation doping of silicon monocrystals for the needs of microelectronics**
- creation of neutron beams for neutron therapy**
- irradiation of thin polymer films for production of track membranes**
- neutron activation analysis**

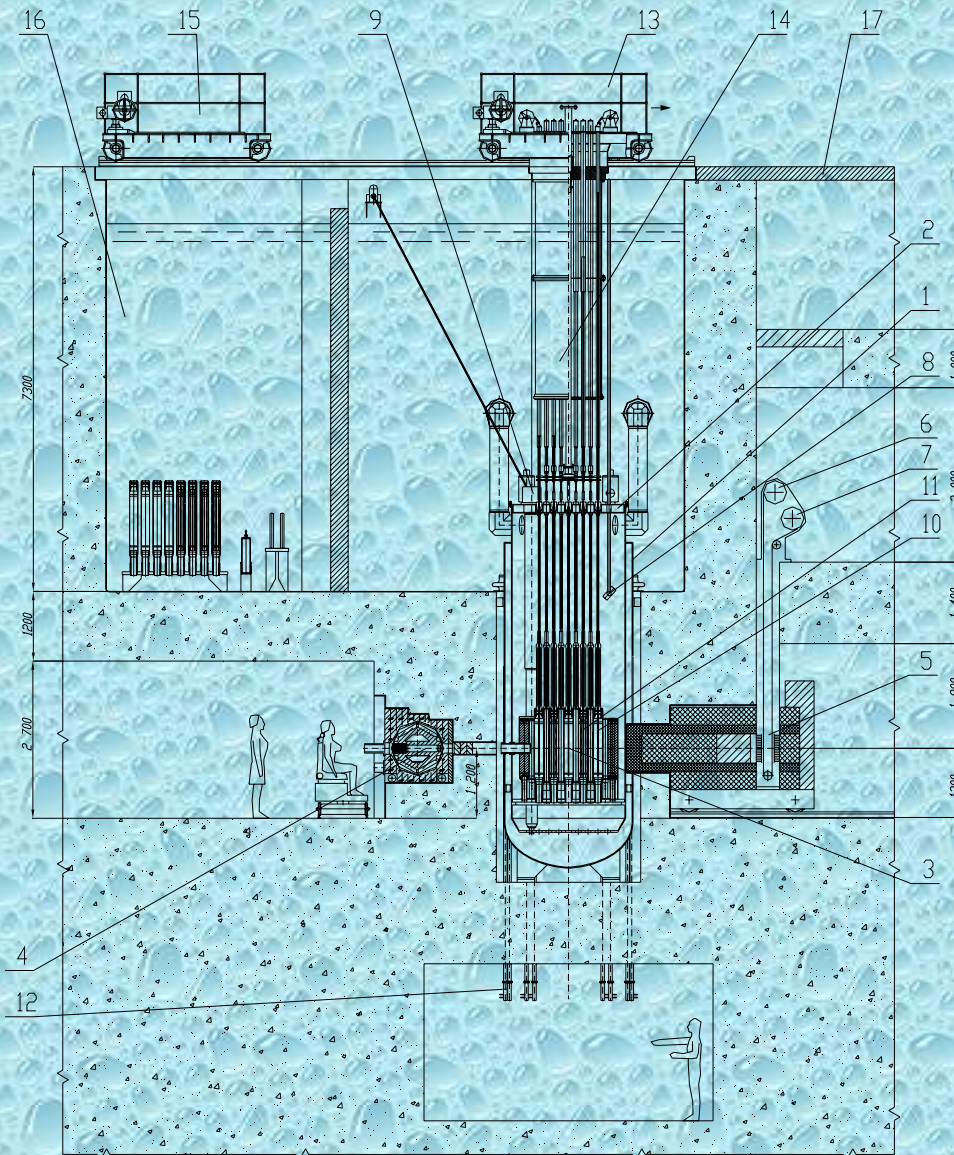
### **III. RUTA - neutron source**

---

**The following irradiation devices are feasible:**

- **irradiation channels in the reflector:**
  - **8 channels for production of radioisotopes**
  - **2 channels for neutron and transmutation doping of silicon**
  - **2 pneumatic rabbit system channels for neutron activation analysis**
- **medical irradiation neutron beams:**
  - **1 for fast-neutron therapy (FNT)**
  - **1 for neutron-capture therapy (NCT)**
- **channel for irradiation of the polymer film used to produce track membranes**

# III. RUTA - neutron source



- 1 - reactor vessel; 2 – cover;
- 3 – core; 4 – FNT channel; 5 – film irradiation devices;
- 6 – fresh film cartridge; 7 – irradiated film cartridge 8 – TV camera; 9 – silicon nuclear doping channel; 10 – power density monitoring sensor; 11– SCS cluster; 12 – IC channel; 13 – SCS drive area; 14 – drive area trunk; 15 – handling trolley; 16 – cooling pool; 17 – upper ceiling.

**Irradiation devices at the RUTA reactor**

# III. RUTA - neutron source

Neutron fluxes at the core center and at locations of irradiation channels and devices for the beginning (b) and the end (e) of the RI,  $10^{13} /(\text{cm}^2 \cdot \text{s})$

| Energy of neutrons in group                 | Central FA |     | First row of the reflector (radioisotope production channel) |         | Silicon doping channel |      | FNT channel |     | NCT channel |      | Graphite column for TM (layer in the water downcomer region) |       |
|---|------------|-----|--|---------|------------------------|------|-------------|-----|-------------|------|--|-------|
|   | b          | e   | b  | e       | b                      | e    | b           | e   | b           | e    | b  | e     |
| $\phi_f(0.1-10 \text{ MeV})$                | 12.1       | 7.6 | 1.0?2.6  | 1.4?2.1 | 0.13                   | 0.16 | 1.3         | 1.5 | 0.83        | 1.0  | 0,012  | 0,011 |
| $\phi_{at}(1 \text{ eV} - 100 \text{ keV})$ | 5.8        | 3.7 | 1.1?2.4  | 1.3?1.9 | 0.11                   | 0.13 | 1.2         | 1.4 | 0.76        | 0.89 | 0,036  | 0,037 |
| $\phi_t(\text{less than } 1 \text{ eV})$    | 3.8        | 2.6 | 7.0?9.6  | 6.0?6.5 | 1.8                    | 2.3  | 4.6         | 5.4 | 2.8         | 2.9  | 1,28   | 1,38  |

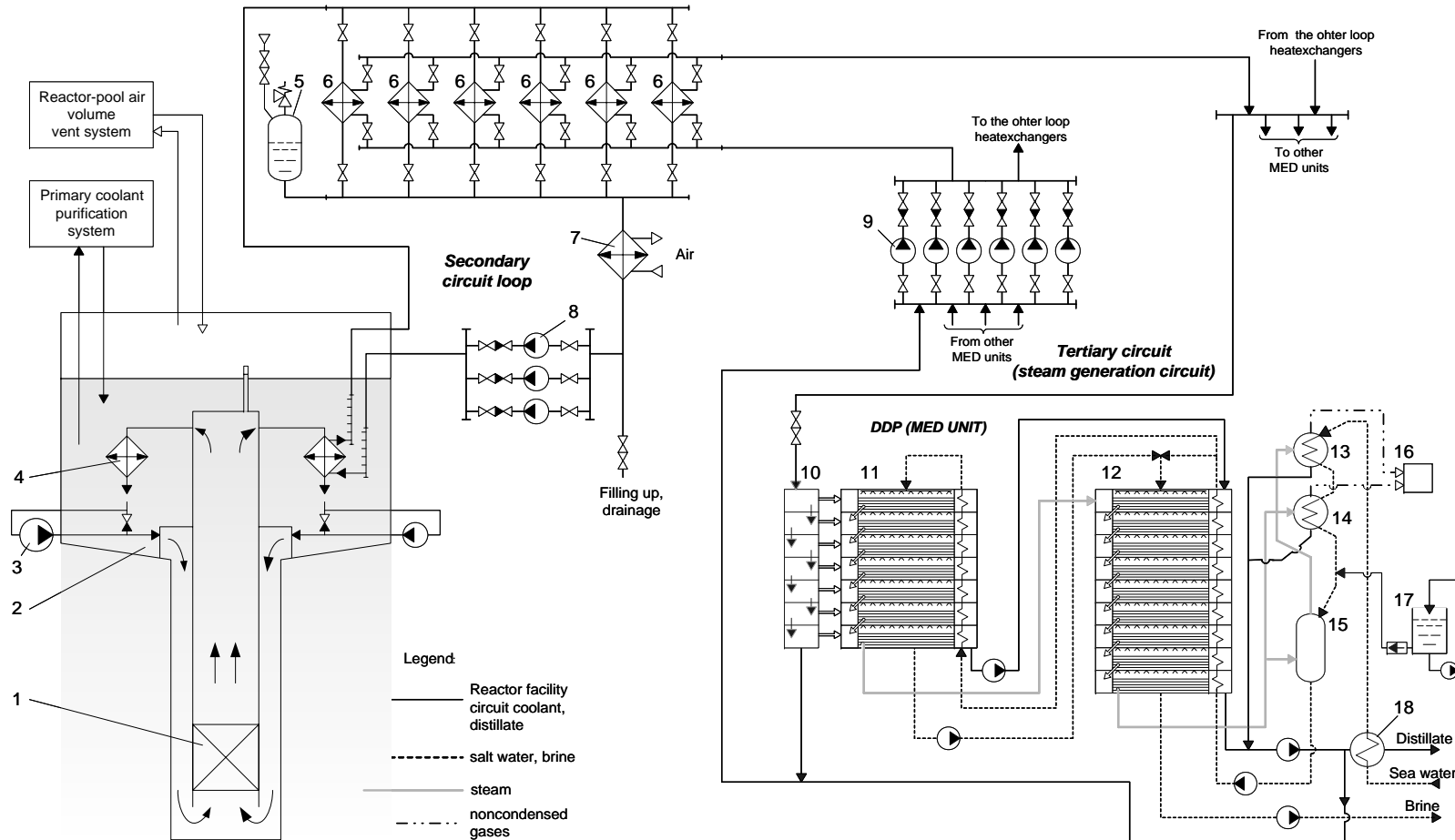
## VI. Evaluation of technical and economic characteristics of NEDC

**Sensitivity analysis for technical and economic characteristics of NEDC on RUTA-70 were carried out using DEEP-3**

**For coupling to MED:** variables “*maximum brine temperature*” and site specific parameter “*required water plant capacity*”

**Objects of analysis:** “*maximal achievable water plant capacity*” and “*product water cost*”





## Flow Diagram of Desalination Complex with RUTA Reactor:

1 – core; 2 – reactor pool; 3 – primary circulation pump; 4 – primary heat exchanger; 5 – secondary pressurizer; 6 – 2/3 circuits heat exchanger; 7 – heat exchanger of the emergency air cooling down system; 8 – secondary circulation pump; 9 – tertiary circulation pump; 10 – self-evaporator; 11, 12 – units of evaporating stages of DDP (BT1 and BT2); 13 – deaerator flash steam condenser; 14 – last stage flash steam condenser; 15 – deaerator; 16 – water-ejection unit; 17 – descaler dosing system; 18 – distillate cooler

## VI. Evaluation of technical and economic characteristics of NEDC

| Design configuration: RUTA-70+MED |        |        |        |        |        |
|-----------------------------------|--------|--------|--------|--------|--------|
| TDS=35 000 ppm, Tsw(Tsm) = 30 °C  |        |        |        |        |        |
| Tmb, °C                           | 90     | 85     | 80     | 75     | 70     |
| Max WPC, m3/d                     | 40 000 | 37 000 | 34 000 | 30 000 | 25 000 |
| Water cost, \$/m3                 | 0,93   | 0,97   | 1,02   | 1,09   | 1,21   |

# Conclusions (1)

---

1. Thanks to technical characteristics of reactor design and low coolant parameters, the RUTA-70 features high reliability and high level of safety. This allows deployment of NHPs in the immediate vicinity to heat consumers. The design simplicity of the reactor ensures acceptable economic with relatively low capital costs contributing to reducing the cost of thermal energy.

2. Developing and introducing innovative nuclear technologies to ensure medical and industrial applications of RUTA reactors may be promising in Obninsk and at other deployment sites. Cities relating to nuclear power in Russian as well as territories of scientific centers are most attractive sites for such applications.

# Conclusions (2)

---

## **3. Sensitivity study for design configuration of NEDP RUTA-70 + MED**

**with variation of “maximum brine temperature” results in water cost in the range from 0.93 to 1.21 \$/m<sup>3</sup> and maximum achievable production capacity of about 40 000 m<sup>3</sup>/d.**



THANK YOU