XA9848803

THE APATITY NUCLEAR HEATING PLANT PROJECT: MODERN TECHNICAL AND ECONOMIC ISSUES OF NUCLEAR HEAT APPLICATION IN RUSSIA

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Abstract

Traditionally Russia is a country with advanced structure of centralized heat supply. Many thermal plants and heating networks need technical upgrading to improve their technical and economic efficiency. Fossil fueled heating capacities have a negative influence on ecology, which can be seen especially in the northern regions of Russia. Furthermore, fossil fuel prices are rising in Russia.

The above factors tend to intensify the need for alternative heat sources being capable of solving the problem. Nuclear heat sources may be the alternative. In this paper, the main features of a proposed NHP in the Murmansk region are summarized.

1. INTRODUCTION

More than 35% of primary energy resources are consumed for heat supply to towns and villages in Russia. It illustrates the fact that the heating market in Russia is vast, and the demand for thermal energy is vast too. At present this demand is mainly satisfied by using fossil fuel heat sources. Some district heat is supplied by cogeneration NPPs, thus covering a very small fraction of the heat market.

During the last few years the trend of rising fossil fuel prices and transportation costs is clearly seen. These factors lead to increasing thermal energy costs. Heat cannot be transported over a long distance and must be consumed near the place of its generation. The burning of fossil fuel leads to ecological problems and an adverse impact on the health of people. Therefore, in Russia, the population sometimes protest against new fossil-fired power plant construction (e.g. public protest in Moscow against construction of the North power plant in 1993). In the face of public opposition some local governments in Russia adopted ecological laws which obliged the power plant operators to pay compensation for environmental pollution. This is another reason for thermal energy to become more expensive.

The above mentioned obstacles make it imperative to find an alternative to existing energy sources. The nuclear option was considered a reasonable one; therefore, the construction of AST-500 NHPs was started in Nizny Novgorod and Voronez. The State Program of North Regions development was adopted in Russia. This Program considers the nuclear option for improving the North region's heat supply. Russia has a positive experience of nuclear heating. For more than 20 yrs, in the small town Bilibino in Chukotka, the four water-graphite reactors of Bilibino co-generating NPP (4 x [12MW(e)+18.6 MW(th)]) have been supplying the town with ecologically clean electricity and thermal energy.

However, the severe accidents at Three Mile Island and Chernobyl shook the public trust in nuclear energy and in spite of the fact that the designs of AST-500 NHPs were examined by international experts they were not commissioned and the construction suspended.

During the last decade, one can observe a rising tendency of terrorism and local military conflicts in Russia and elsewhere. As a result, the public feel like being hostages of the nuclear establishment. Such a situation raises additional objections against the construction of NPPs in spite of economic and environmental advantages. To meet these concerns, the Russian State Programme on Environmentally clean power foresees the underground location of NPPs. Underground location of nuclear facilities

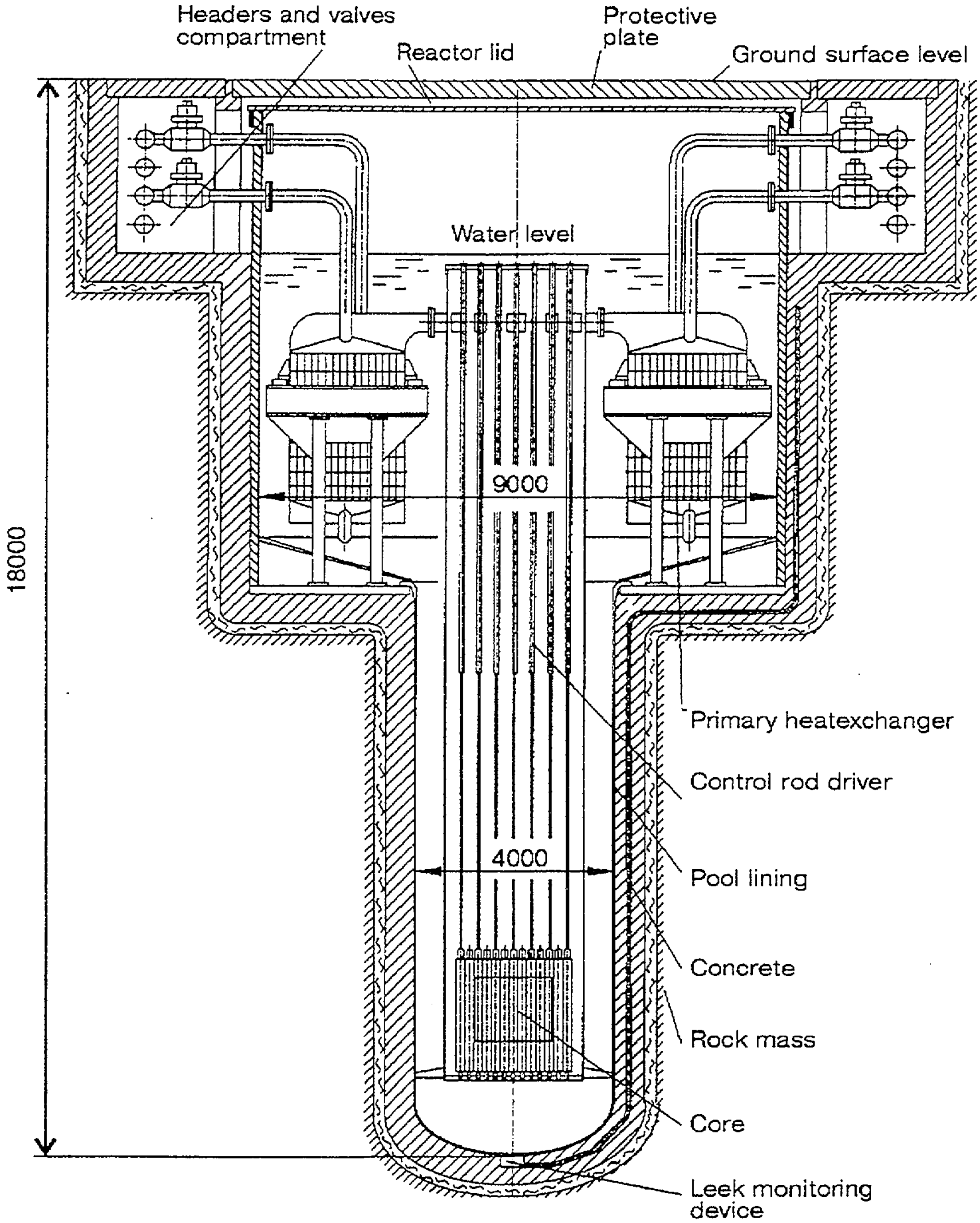

Fig. 1 Reactor RUTA 55

makes the physical defense of the plant very strong and it may withstand internal and external severe impacts.

The Research and Development Institute of Power Engineering (RDIPE) developed the concept of a safe NHP with the following main features:

- The nuclear source must be as simple as possible and supported by proven technologies.
- The nuclear source must be cheap and competitive in comparison with other types of heat sources.
- The nuclear source must posses inherent safety characteristics as far as possible at the present level of nuclear technology development.
- The nuclear source must be protected against diversion and military conflicts.
- For the aim of acceptability, the design of NHP must be well-understood, in other words, it must be well understandable by people without deep technical knowledge.

These considerations led to the idea of a pool-type heating reactor RUTA (Ref.1 and 2). The RUTA reactor design is based on existing pool-type research reactors. It was found that the RUTA reactor is convenient for underground location.

A decision on underground location of a NHP (UNHP) depends considerably on the local conditions of the site, including the following:

- Local fuel price including transportation.
- Availability of heating network at the site.
- Environmental conditions.
- Availability and readiness of local industry.
- Public attitude to nuclear power.

The above mentioned considerations were used in the design of the RUTA UNHP for Apatity, Murmansk region (Kola peninsula).

2. THE APATITY UNDERGROUND NHP RUTA PROJECT

2.1. REACTOR DESIGN

The RUTA.55 reactor unit is a simple nuclear heat source designed to supply 55 MW of thermal energy as water at 85°C. As shown in Fig.1, it is a pool-type reactor designed to operate at atmospheric pressure, thus eliminating the need for a pressure vessel.

The reactor core and primary heat exchangers are in the pool contained inside a steel-lined concrete vault. Pool water serves as the moderator, heat transfer medium and shielding. Primary heat transport from the core is by natural circulation of the pool water through plate-type heat exchangers located in the pool.

The secondary circuit delivers heat to the distribution system by way of the secondary plate-type heat exchangers. The pressure in the secondary circuit is higher than that in primary circuit and the pressure in the distribution system is higher than that in the secondary circuit. Thus, customer protection from a radioactivity leakage is ensured.

Computer controlled absorber rods are used for load following. Periodic adjustment of these absorbers compensate for fuel burnup. All the absorber rods will fall down to the core in case of accidents or when fast reactor shut-down is required. Pool water is continuously pumped through ion exchange columns to maintain water chemistry and to control corrosion.

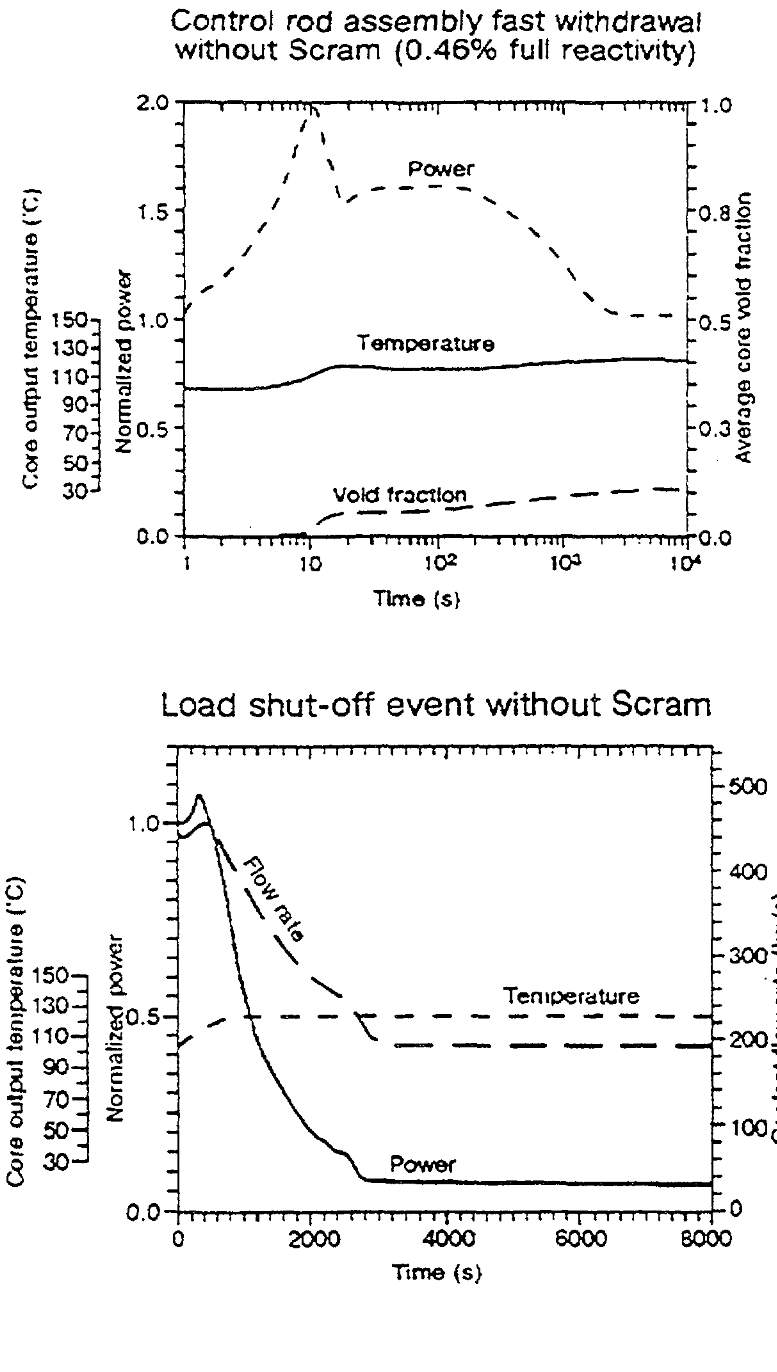

Fig. 2 Transients of RUTA 55

The reactor pool is covered by a lid enclosing a gas space over the pool. The air and water vapor are continuously circulated through a purification system and hydrogen recombiner.

The inherent safety characteristics of the RUTA reactor design include a negative fuel temperature reactivity coefficient and negative coolant temperature and void reactivity coefficients, all of which alleviate power transients following loss-of-regulation. Fig. 2 shows some of the transients. In addition to the inherent safety features:

- Large volume of water in the pool delays the core temperature rise for a long period.
- Natural circulation of water in the pool ensures core cooling under all accidents.
- Atmospheric pressure in the pool makes it impossible for loss-of-primary coolant cased by depressurization.

Major parameters of the RUTA.55 reactor design are presented in Table I.

TABLE I. MAJOR RUTA.55 CHARACTERISTICS

Parameter	Value
Power, MW(th)	55
Coolant pressure, Mpa:	
in primary circuit (above the pool level)	atmosphere
in secondary circuit	0.4
in heating network	0.6-2.0
Coolant temperature, ^{O}C (inlet/outlet):	
in primary circuit	75/100
in secondary circuit	66/90
in heat-supply system	60-85
Number of secondary circuit loops	2
Water circulation in secondary circuit	Forced
Dimensions of the core, m:	
height	1.2
equivalent diameter	2.03
Fuel	UO_2
Enrichment, %	3.6
Fuel burnup, MW day/kg	27.5
Number of fuel assemblies	169
Time interval between partial refuelling, years	3
Fuel lifetime, full power days	2970
Linear heat flux, W/cm	
average	50
Maximum	102

2.2. THE APATITY NHP DESIGN

The town of Apatity is located in the peninsula Kola in northern Russia, close to the Hibiny mountain massif. The Apatity UNHP would consist of 4 RUTA.55 reactor units. As shown in Fig.3, these units are arranged in a horizontal drifting mined into a mountain. This mountain is located in the close vicinity of the town center (less than 4 km.).

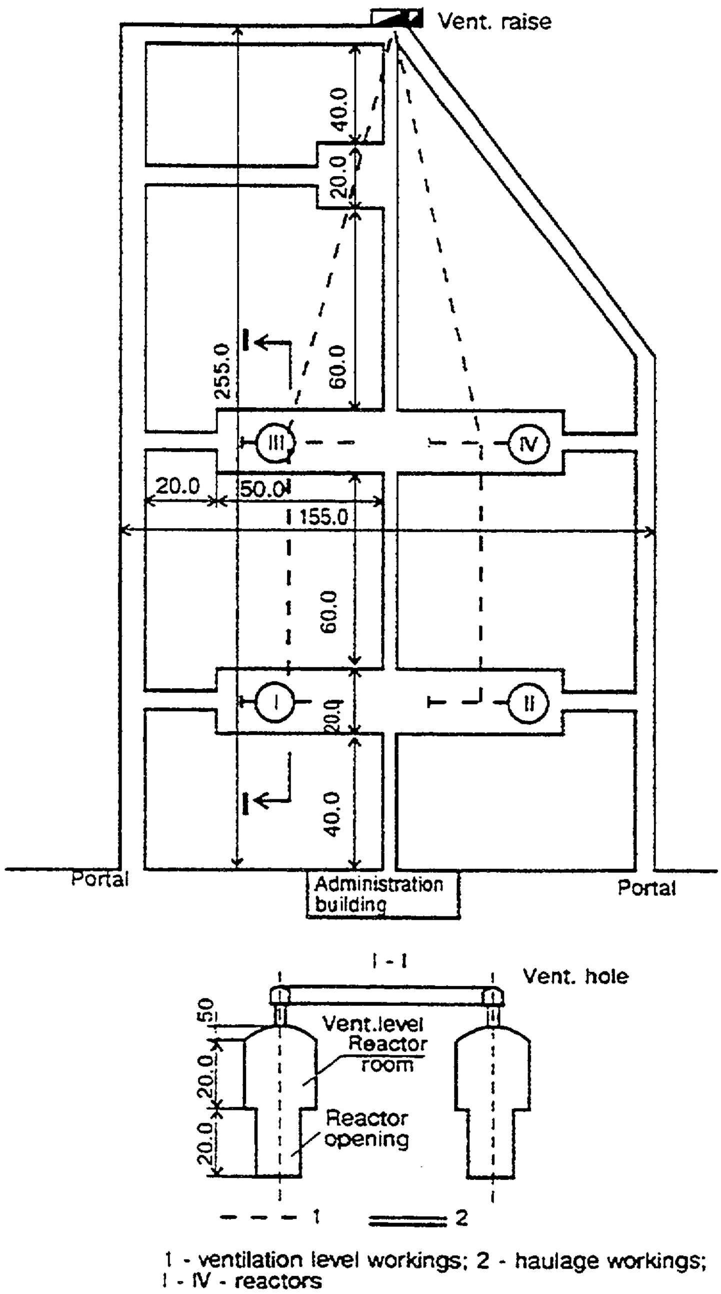

Fig. 3. Principal component plan of RUTA UNTP in Apatity

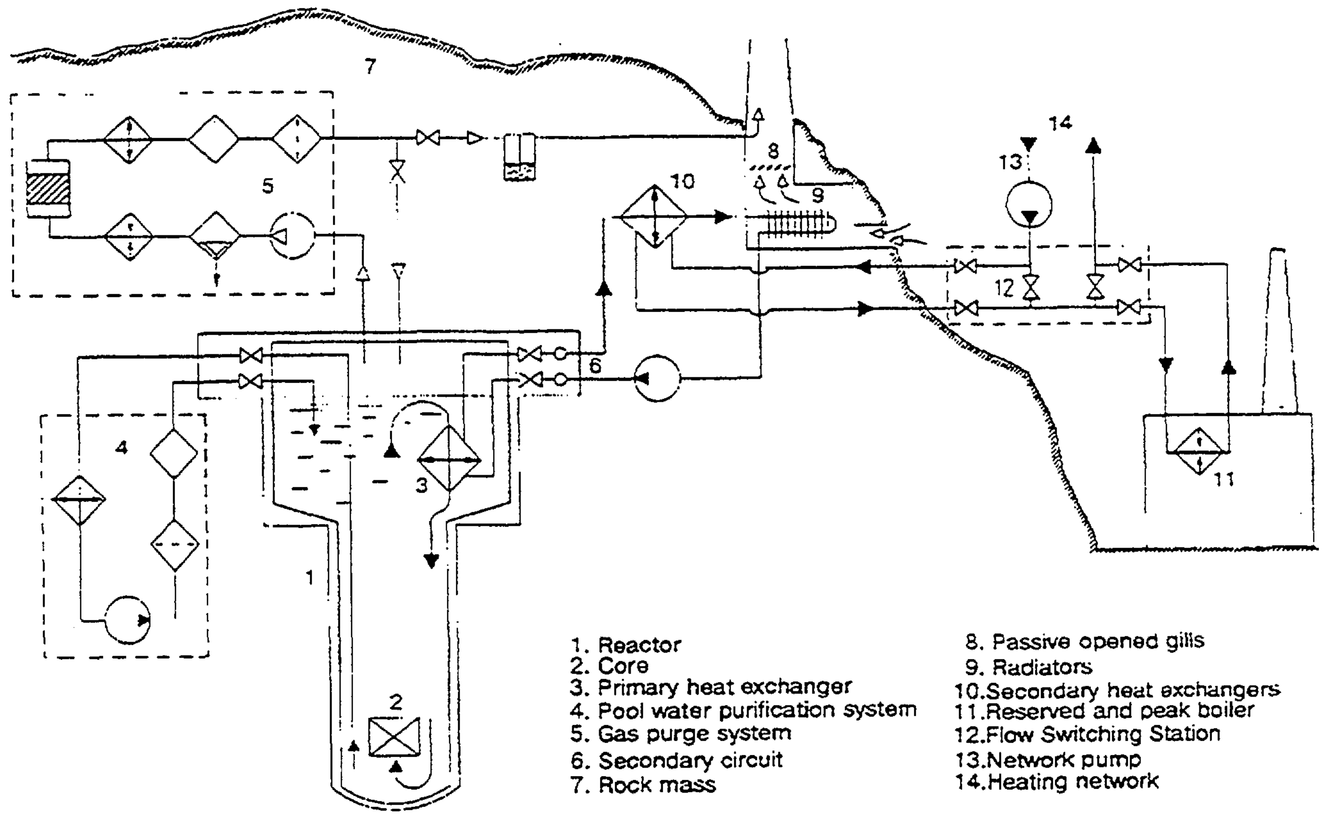

Fig. 4. RUTA NHP flow diagram

The UNHP would supply heat to the existing heating network. The heated water from the UNHP would be pumped to the existing coal-fired power plant for heating up, if necessary, to ensure the required temperature level (Fig.4). The UNHP is designed for a load factor of more than 90% and to supply 75-80% of the annual heating demand of the town.

Two long-term options were analysed:

- Continuation of the existing coal-fired power plant operation (old mode).
- Incorporation of the UNHP RUTA in the local heating network and its operation along with the existing coal-fired power plant (new mode).

The comparisons show that the energy cost in the new mode will be about half that of the old one. As shown in Fig. 5, the thermal energy cost of the UNHP depends on the unit power and if the unit power is more than 20MW(th), the UNHP will be competitive in comparison with alternate heat sources (coal- or gas fired).

The existing Apatity coal-fired power plant with a thermal power 700MW for heat supply (annual electricity output is 500 GW(e)h and heat output 2300 GW(th)h (=2 x10^6 Gkal)) consumes about 10^6 ton of Pechora coal. The coal contains sulphide and has a high ash content. Annually, the power plants emit about 10 000 tons of ash, 31 000 tons of SO_2, 5000 tons of NO_2 and other pollutants. The application of RUTA UNHP would allow to drastically improve the town environment.

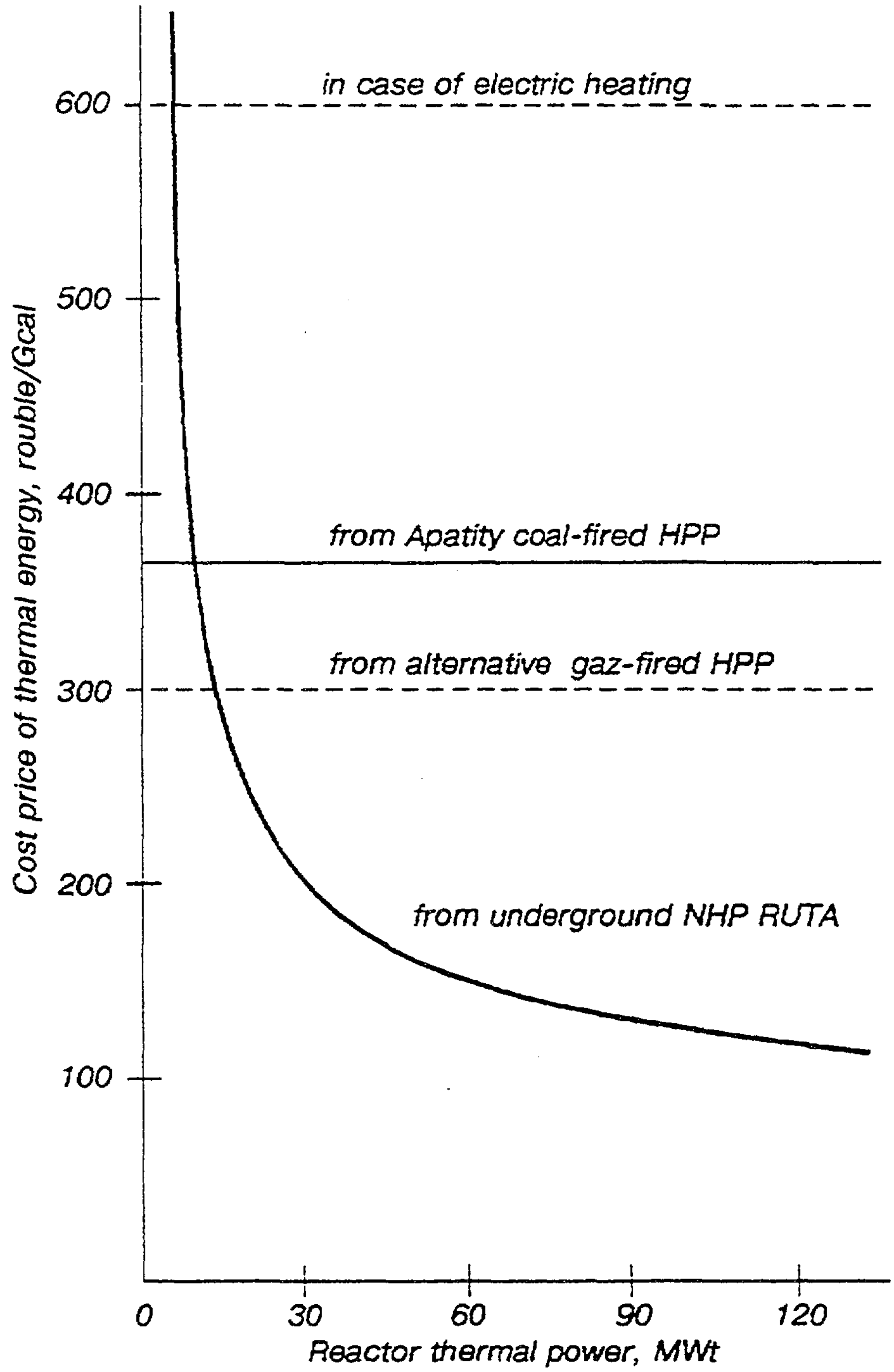

Fig. 5 Cost of heat from different sources (1992)

2.3. PROJECT STATUS

Technical and economical investigation of the project was performed during 1992-1994. In late 1994 a local government adopted the project. In the middle of 1995 the RUTA Joint-stock company was founded in the Apatity town for project implementation.

3. PROSPECTS FOR THE USE

The analysis of annual schedule of heat load shows that there is a considerable reserve of thermal power at the NHP during the summer period. This excess thermal power can be used for centralized production of cold water in an absorption refrigerating machine to be installed at the NHP site.

The refrigerating capacity of a single reactor of 55MW(th) would attain 15MW(th). Cold water at a temperature of 8^{o}C would be transported to customers through the standby line of the heating network and used for air conditioning or special room cooling (vegetable storehouses, storage facilities, etc.). The second line of the heating network system would be used for hot water supply.

The reactor can be used as a thermal power source to desalinate sea water by using standard desalinating plants. In this case the desalinating plant capacity will be 815 t/h of fresh water per reactor of 55MW(th).

Electricity production was considered in the RUTA NHP project for regular power supply and supply to the public (not industry) in the heating region. For this purpose, a special ampule (modular channel) is submerged into the reactor pool to produce steam for the turbine. The modular channel is a special pressurized tube-type structure with a nuclear fuel assembly in the bottom and an internal steam generator in the top of the sealed vertical tube, filled with water. The design provides natural water circulation inside the channel and water temperature expansion. The pressure inside the channel is about 9.8 MPa and maximum water temperature is 275 C. Lower side of channels surrounds the core of the reactor. This kind of a structure is the single core from neutron is point of view. Using 78 channels per reactor, it is possible to increase the heating power of the unit up to 65 MWt and electrical power up to 4 MWe. The safety of the reactor will be high in spite of using components with high pressure because the rupture of one channel does not influence the reactor due to the small volume of water in the channel (about 70 liters) and the availability of adequate cooling during the accident.

The project also enables increasing the temperature of NHP water by using thermal transformers. In this case there is no need for peak boiler units, but the heat costs would increase.

4. CONCLUSIONS

- The heating market in Russia is vast, but the nuclear contribution to this market is presently very low.
- Heat is becoming more expensive due to rising fossil fuel price.
- The burning of large quantities of fossil fuels leads to local ecological problems and public protests.
- The nuclear alternative seems to be reasonable, but contrary to the earlier development period, it has become much less popular.
- Underground arrangement of NHPs would allow bringing nuclear heat closer to customers without a significant risk.
- Russian State Programs foresee increasing non-electrical application of nuclear energy.
- Nuclear heat generation plants must be simple, cheap and safe.
- Pool-type reactors have a big potential for district heating, sea water desalination, and air-conditioning.
- The simplicity of pool-type reactors, ease of maintenance and manufacturing make this type of heat source attractive for countries without a developed nuclear industry.