FUTURE DEVELOPMENT OF THE RESEARCH NUCLEAR REACTOR IRT-2000 IN SOFIA

T. G. APOSTOLOV

Institute for Nuclear Research and Nuclear Energy, BAS,
Bul. Tzarigradsko shousse 72, Sofia 1784, Bulgaria

ABSTRACT

The present paper represents short description of the research reactor IRT-2000 Sofia, started in 1961 and operated 28 years. Some items are considered, connected to the improvements made in the contemporary safety requirements and the unrealizes project for modernization to 5 MW. Proposals are considered for reconstruction of reactor site to a "reactor of low power" for education purposes and as a basis for the country nuclear technology development.

1. Introduction

The IRT-Sofia nuclear research reactor was designed and built between 1959 to 1961. First criticality was reached in September 1961 and it was put into normal operation at 1 MW in November 1961. There were two increasings of its power to 1,5 MW in 1965 and 2 MW in 1970. In the 28 years of operation the reactor has been started 4189 times to run 24 624 hours at different power levels.

The IRT-Sofia nuclear research reactor is situated East of Sofia, 8 km from the city centre. By that time there were no dwelling houses in a radius of 3 km around reactor building. However, at present dwelling houses have been built at a distance of 350 - 500 m of the reactor building.

2. Description of research reactor IRT-2000 Sofia

The IRT-Sofia is a pool-type research reactor with light water used as a moderator, a coolant and a top shield. The reactor core has the shape of a parallelogram with dimensions 527x429x500 mm. It is fixed to the bottom of the reactor pool containing about 60 m^3 distilled water. The lattice is a square with a pitch of 1.6 cm for the fuel rods and 7.15 cm for the fuel assemblies. The initial criticality is achieved with a load of 3.37 kg ^{235}U. Up to 48 aluminium cladded fuel assemblies can be inserted in the core grid.

Two types of cylindrical fuel elements of low ^{235}U enrichment - 10% (EK-10) and 36% (C-36) and three types of fuel assemblies were used during the 28 years of operation.

IRT-Sofia has been operated 34 fuel assemblies core, each containing 14 or 15 or 16 fuel elements, 13 graphite blocks as reflector and one specially designed in-core experimental assembly, used for irradiation of samples at maximum thermal neutron fluxes about $3.2*10^{13}$ $cm^{-2}s^{-1}$.

The reactor shut-down system consist of 7 in-core control rods: 2 safety rods and 4 shim rods, both made of Al-cladded boron carbide, and 1 automatic regulating rod made of stainless steel.

The reactor cooling is achieved by two-loop cooling system. The immediate core cooling involves three pumps and a special water pump (ejector), which drive 180 m^3 of water per hour. This water is continuously purified by purification system that consists of 2 mechanical and 4 ion-exchanging filters and passes through the two heat exchangers of the secondary cooling loop.

At a reactor power level of 2 MW the maximum temperature on the surface of the fuel element does not exceed 90°C while the temperature of reactor pool water reaches 42°C.

The irradiation of samples and production of isotopes is carried out using 12 vertical experimental channels, 11 located in core periphery, one in the core centre. There is one special in-core assembly and two pneumatic transfer tubes. Neutron beam experiments are performed on the 11 horizontal beam ports: 9 radial 100 mm in diameter, one tangential 150 mm in diameter and one radial 150 in diameter, which crosses the thermal column. The shortest beam port is 2.3 m long. All beam ports are equipped with beam shutters driven either manually or remotely by electrical motors.

The principle areas of reactor usage ranged from fundamental and applied research to technological and commercial applications. The reactor has been used for research in the field of nuclear physics, biology, solid state physics, radiation tests of materials, neutron radiography, production of isotopes and others. Moreover, the research reactor was an important place for university and postgraduate education and training.

3. Project for modernization of IRT-2000 and present status

During the period 1982-1986 the operating organisation jointed with Kurchatov Institute of Atomic Energy from Moscow and Energoproject from Bulgaria were prepared the project for modernisation of the reactor and upgrading its power to 5 MW and more. For this purpose 28 new fuel assemblies of type IRT-2M (36% enrich. ^{235}U) was purchased and delivered. They contain tubular co-axial fuel elements (4 or 3 tubes) with shape of square cross section, wall thickness 2 mm and Al cladding with 0.5 mm thick. The modernization project included a new lining of stainless steel, covering the existing one, replacement of some aged reactor systems and use of beryllium as moderator.

Unfortunately, after the Chernobyl nuclear accident the Bulgarian Regulatory Body undertook a re-examination of the rules and regulations so that many remarks and additional requirements had to be responded. On 13 July 1989 the reactor was shut-down by the Regulatory Body. The main reason was to meet the new safety requirements.

At the request of the Bulgarian authorities an INSARR mission of IAEA experts visited the reactor site in August 1990 and in January submitted to the authorities an independent and comprehensive evaluation of the nuclear safety and radiation protection of the existing reactor. The main conclusion of the experts was that the IRT-Sofia research reactor could be operated safely due to its general characteristics of design, low power, good operating experience and procedures.

Some recommendations were given about the installation of an automatic system which will give a necessary threshold for the reactor scram due to seismic events; incorporating of iodine filters in the ventilation system that will subject additional cleaning of the air in cases of abnormal events (release of fission products) and including the additional scram signals in the protection system. These recommendations was completed partially. In 1992 the project for changes in the present active ventilation system has been submitted to the authorities and iodine filters was bought but not installed.

In 1992 very sensitive seismic study was carried out at the reactor building. The reaction of the structures at different levels has been investigated by measuring the vibration spectra generated by means of the reactor's heavy load bridge-crane. All this information has been used to evaluate the threshold for reactor scram due to seismic events. The threshold was specified as 0.035 g. These studies led to a proper choice of an appropriate seismic system and 3 seismic detectors were installed at different places at the reactor. In 1993 was completed the 3^{th} edition of the Safety analysis report.

During the 28 years of operation in the reactor core were loaded 73 fuel assemblies with 1140 fuel elements. Since 1989 73 spent fuel assemblies are stored on racks in a separate storage pool of about 12 m^3 deionized distilled water, connected with the reactor pool by an inclined channel for refuelling operations. The total activity of fuel assemblies is about 2700 Ci and mainly is due to of activity of Cs^{137}, Sr^{90} and Kr^{85}. The maximum heat decay of most loaded fuel assembly is 2.46 W. A special device is used for periodic gamma-spectrometry scanning of the fuel. Also, visual inspections for possible corrosion spots on the fuel surface are carried out using the first hot cell of the radiochemistry laboratory.

It is expected to sign a contract, necessary for the transportation of 57 spent fuel assemblies EK-10 and 16 assemblies C-36 to the producer country - Russia, the transportation of the liquid radioactive wastes and the necessary studies of the IRT-2000 building.

4. Proposals for future development

A detailed analysis was completed in 1998 under request by the Government of the necessity, workability and possible variants for a reconstruction, extended shutdown or decommissioning of the IRT-2000, Sofia. The concluding proposal was finally to stop the operation of the experimental reactor IRT-2000 at power and to examine the opportunities for further utilisation of the reactor site, the available IRT-2M fresh nuclear fuel, the devices and equipment of IRT-2000, also by their reconstruction and modernisation for educational, applied and scientific purposes as a reactor at nominal power 200 kW and maximal power up to 500 kW. The operational parameters and low radiation impact only in the reactor main hall make this powerful source of neutrons, which is suitable for both scientific and applied studies, safe and ecologically admissible at the existing IRT-2000 reactor site.

To this will help the assessment of the reactor made by a consortium of the English firm AEA Technology plc (UK) and the Spanish INITEC SA (Spain), which will perform during this year an independent accurate analysis of the state and further utilisation of the equipment under the PHARE project (PH4. 11/95) "Study on pool type research reactors in countries assisted by the PHARE programme".

In case that the results show impossible further utilization of IRT-2000 site the decommissioning will be too complicated problem because of the lack of National depository for solid radioactive wastes, which is to be put into operation during the next 10-15 years.

Additionally to that our proposal is that in mid-term perspective one should start the prospects for the necessity and expediency of building up a new research reactor at a proper site. This should not be associated with the building up of a nuclear reactor of type "reactor at low power", which is supposed to preserve the intellectual potential, extremely valuable for the country power production and the national prosperity in the course of the next 10-15 years.

Nuclear reactor of type "reactor at low power" will be the only nuclear facility in the country. It is going to be used experimental basis for education of nuclear specialists here and in the region. The Sofia University faculties of physics and chemistry and our Technical Universities need the experimental nuclear reactor as long as the Bulgarian specialists on nuclear energy and nuclear technology, nuclear physics, radiochemistry and radiation chemistry are mainly educated there.

Some more important abilities of nuclear reactor of type “reactor at low power” are related to the following areas:

- Education and qualification of personnel: this basis would make the education in our universities valuable and competitive to the European and international criteria.

- Application in medicine: Horizontal neutron flux could be taken out from the core to equip a clinic for neutron therapy mainly of brain tumors. Production of radioactive isotopes and nuclides - ^{182}Ta, ^{192}Ir, ^{86}Rb, ^{131}I for medical usage, imported at the moment in not sufficient quantities because of lack of assets. Production of ^{99m}Tc using irradiated outside the country target of molybdenum, which is going to diminish by a half the expenditure for import of technetium generators, extremely necessary for early diagnosis of oncological disease.

- Production of short life-time isotopes and application in industry and agriculture (e.g. radioactive bromine for hydrological studies, reservoir leaks etc.)

- Neutron activation analysis; Multielemental analysis of 30 elements in a sample with accuracy up to $1*10^{-9}$ g/g with ability to make 20000 analyses early. Irradiation and analysis of geological and other samples, prospects for petrol included. Samples from the environment will be analyzed, application in criminology, industry, medicine, observance of EC ecological rules.

- Biological studies of radiation impact, also investigation of low dose exposure consequences

- Application of nuclear-physics methods for analysis of processes, materials and examination of radiation impact on environmental objects.

- Study of dozimetry and radiometry methods and appliances, connected with reactor utilization for the metrological requirements of the country nuclear power production.

5. Conclusions

We insist that the prospects for building up of a nuclear rector of type “reactor at low power”, applying the wide international experience in utilising such a units and drawing offers from well known international firms. The unit profitableness and financial items will be analysed in the course of the investigation as it is done in such a projects.