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INDC(IAE)*011G

International Atomic Energy Agency

INTERNATIONAL NUCLEAR DATA
SCIENTIFIC WORKING GROUP

INDSWG/68 E

November 1964

Original: RUSSIAN

THE OBNINSK POWER-PHYSICS INSTITUTE
(FIZIKO-ENERGETICHESKY INSTITUT)

64-6175

The Fiziko-Energetichesky Institut (FEI - Power-Physics Institute) of the State Committee on the Use of Atomic Energy is situated in Obninsk, 107 kilometres south-west of Moscow. Set up in 1946-47 for the purpose of carrying out research in the peaceful uses of atomic energy, the Institute has played an important part in the development of nuclear power in the Soviet Union. During the first years of the Institute's existence a number of nuclear-physics investigations of fundamental importance were carried out and the results of these investigations were used to work out practical programmes of work. This phase of the Institute's work culminated in 1954 when the world's first nuclear power station - based on a thermal reactor - went into operation. The start-up of this first nuclear power plant marked the beginning of a new era, the era of nuclear power production. Operational experience with this station was used subsequently in the design of more powerful nuclear power plants.

Parallel with work on the development of thermal power reactors, investigations were carried out with a view to the construction of fast reactors and this gradually became the dominating trend in the Institute's activities. Over the last few years a series of fast reactors (BR-1, BR-2, BR-3, BR-5, BFS) have been built providing the scientists at the Institute with the necessary experience to embark on the development of industrial-scale power plants based on fast reactors.

In order to obtain information on the various technological problems arising in connection with reactor construction, large-scale investigations are carried out on heat physics and the study of materials. At the same time experimental and theoretical investigations are continuing in nuclear physics, and in the last few years a start has been made on experimental and theoretical investigations in the field of solid-state physics.

A brief description follows of the basic facilities and laboratories of the Institute and of the scientific work being carried out in them.

FIRST NUCLEAR POWER PLANT

The world's first nuclear power plant (5000 kW(e)) came into operation on 27 June 1954. The station is centred on a heterogeneous thermal graphite reactor with a power of 30 MW(th). The reactor's tubular fuel elements are cooled from inside by water flowing at a pressure of 130 atm. All technological processes in the station are automatically controlled. To make it possible to study different heat-removal designs in single-circuit, two-circuit and $1\frac{1}{2}$-circuit reactor facilities of similar types and also to test fuel elements for large-scale power stations which are planned or under construction, the plant is equipped with loops and installations for nuclear physics investigations. In the reactor various materials are irradiated and gamma-preparations are produced for photoneutron sources. A neutron beam is extracted from a reactor channel and is fitted with a neutron chopper, which is used in the measurement of neutron cross-sections in the intermediate-energy range.

The operation of the first nuclear power plant has provided the experience vital to the design of other large-scale nuclear power plants of the same type. With the help of this experience and a series of specially designed investigations it has been possible to draw up plans for the Beloyarsk Nuclear Power Station, which operates at a high thermal efficiency (over 40%). The power start-up of the first unit of this 100 000 kW(e) station took place at the beginning of 1964.

Side by side with important technological research at the first nuclear power station, a training programme is also being carried out to provide operating personnel for new power plants.

THE BR-1 REACTOR

The BR-1 reactor was the first fast reactor to be built at the Institute. The reactor came into service in 1955 and is used for numerous investigations on fast-reactor physics and also for research on nuclear physics.

This reactor has a compact core 13 cm high and 13 cm in diameter, composed of plutonium rods in stainless steel cladding. The critical load of the reactor is about 12 kg and its maximum power is 100 W. Thanks to the provision of a removable shield the composition of the reflector can be altered for different experiments. The reactor can be brought up to power and kept at a given operational level by manual or automatic controls.

The reactor is used not only for work on fast-reactor physics but also for nuclear-physics investigations (measurement of cross-sections in neutron spectrum in core and in the asymptotic spectrum of the reflector, etc.).

ENGINEERING REACTOR BR-5

The 5000 kW(th) fast reactor BR-5 - the first European reactor to operate with a sodium coolant - came into operation in January 1959.

The reactor was built - in place of the dismantled mercury-cooled BR-2 - for the purpose of studying engineering problems of importance in connection with the design of power plants based on high-power fast reactors. The basic reactor parameters are as follows: operating material - plutonium oxide; load - about 50 kg; fuel-element diameter - 5 mm; core dimensions - 280 x 280 mm; power density - 50^{0}kW/l; maximum neutron flux at centre of core - 8×10^{14} n/cm^2.s; maximum thermal flux - 1.2×10^6 kcal/m^2.h; mean sodium temperature at core outlet - $500^{\circ}C$; sodium flow through core - 24 m^3/h.

The main types of work carried out with BR-5 are as follows:

1. Testing of fuel-element specimens for industrial systems under simulated operating conditions.
2. The accumulation of experience with the operation of a multi-circuit system with a liquid-metal coolant and the testing of individual components.
3. Study of kinetics of fast-neutron power systems.
4. Nuclear physics research and investigation of materials at intense fast-neutron fluxes.

Since it came into operation, the reactor has generated more than 40 million kWh of power. A maximum burn-up of over 5.5% has been achieved - this is 2½ times higher than the design value. Considerable operating experience has been gained with the reactor which is of value in connection with the building of similar systems operating at higher powers.

THE BFS PHYSICS REACTOR

The BFS (large physics facility) reactor is designed for research on the physics of fast industrial reactors with large diluted cores of varying compositions.

The reactor vessel is a vertical steel tank 2 m in diameter and 8 m high. The tank contains 1500 steel or aluminium tubes 50 mm in diameter; these are loaded with fuel discs and diluents (about 100 000 in all). The tubes can be loaded and unloaded manually or by means of special remote-control apparatus. The facility is easily reassembled so that it can be used over a relatively short period of time to study many variants of reactors with differently composed cores and reflectors. The clearances between the tubes are filled with metal displacers. On one side of the reactor tank and adjacent to it there is a metal column designed for carrying out research on neutron spectra at large distances from the core.

For experiments the reactor is fitted with a system of vertical channels placed at various distances from the axis of the core and also with one horizontal channel which penetrates through to the centre of the facility. Detectors (fission chambers) can be introduced at a given level into any of the vertical channels by remote control. This makes it possible to obtain a complete picture of the neutron-flux distribution along the radius and the vertical axis of the core and the reflector. The reactor is also equipped with an oscillator and a rabbit system which supplies irradiated specimens to the measurement laboratory.

MOBILE POWER PLANT TES-3

The TES-3 facility, which came into operation in 1961, is an experimental model of a low-power atomic power plant. It has been built with a view to obtaining experimental data needed for the development of mobile nuclear power plants of similar types capable of supplying electricity to remote and inaccessible areas of the country.

The plant is based on a two-circuit system with an 11 000 kW(th) water-moderated and water-cooled reactor (coolant water at 130 atm) and reactor inlet and outlet temperatures of 280 and 305°C respectively. The flow rate in the primary circuit is 320 t/h.

The reactor core - a cylinder 600 mm high and 660 mm in diameter - contains 74 fuel assemblies consisting of annular fuel elements of highly enriched uranium. The reactor has a mean thermal load of 0.6×10^6 kcal/m^2.h and a maximum load of 1.3 x 10^6 kcal/m^2.h. The duration of one run is 200 days and up to one year in the case of additional fuel-element loading.

Three uniflow steam generators provide steam at a pressure of 20 atm and a temperature of 285°C in quantities sufficient to generate turbine-shaft powers of 2000 kW.

The entire equipment of the plant is housed on four caterpillar-track, power-driven conveyances. Two of the conveyances carry the reactor and the steam-generating unit and the two others carry the turbogenerator, the control desk and the auxiliary equipment. The total weight of the equipment transported is about 220 t.

For shielding purposes the first two conveyances are surrounded during operation by a barrier of earth. In addition, the reactor conveyance is equipped with a transportable biological shield which makes it possible to carry out assembly and dismantling operations within a few hours of reactor shutdown and also to transport the reactor with a partially or completely burnt-out core. During transport the reactor is cooled by means of an air radiator, which is able to extract up to 0.3% of the nominal power of the installation.

HOT LABORATORY

This laboratory is mainly concerned with radiochemical research and the study of irradiated materials. Work at the laboratory includes studies on the changes produced by radiation in the physical and mechanical properties of fissionable and structural materials, research on the regeneration of nuclear fuel, and systematic analyses of coolants, gases, effluents, deposits on piping, etc.

Irradiated samples and spent fuel elements are packed in special containers, placed on flat trucks, and are then sent through the unloading room into one of the laboratory's 16 hot cells.

Seven of the cells are arranged one after the other in line and are used for chemical investigations. They are fitted with remote-control equipment and are used for a variety of operations (extraction, precipitation, dissolving, filtration, evaporation, etc.).

The nine other cells are used for research on metals. They have equipment for preparing samples and for carrying out investigations on the properties of materials. This equipment includes remote-control lathes and milling machines, tensile-testing machines, hardness gauges, metal microscope, apparatus for determining heat conductivity, density and gas evolution, a unit for X-ray diffraction studies, etc.

The laborabory also has special "semi-hot" facilities for operations with low-activity samples (up to 10 μc).

CALCULATIONS AND THEORETICAL SECTION

This department carries out the following activities:

1. Work on the theory of thermal and fast reactors and reactors with complex neutron spectra. This includes work on the general theory of reactors and transport equations, reactor kinetics, the theory of neutron interaction with matter with allowance for resonance effects, the theory of reactor shielding and also reactor and shielding calculation methods.

2. Work on theoretical nuclear physics. This includes mainly work on the theory and methods of neutron-nucleus interaction cross-section calculations and especially the theory of fission processes, radiation capture, elastic and inelastic scattering of neutrons by the nuclei of various elements.

3. Research on solid-state theory, including work on the effects of radiation on the crystalline structure of matter (theory of nuclear fuel swelling and the surface evaporation of matter as a result of exposure to fluxes of fast particles), investigations on theory of exitons, etc.

Calculations for these and other investigations are performed by computers at the Institute Computer Centre.

ACCELERATOR LABORATORY

The Institute laboratory has four high-voltage ion accelerators for carrying out precise investigations on the physics of the atomic nucleus. Two of these are of the Van de Graaff type (5 and 25 MeV) and two are cascade generators (1.2 and 0.25 MeV). These accelerators are basically used as sources of neutrons operating on the basis of the (p,n) and (d,n) reactions.

One of the cascade generators (250 kW) was recently - in 1962 - converted into a pulsed source of neutrons for time-of-flight measurements. The parameters of this device are as follows: pulse current - 500 μA sec; pulse duration - 3-4 nsec; repetition frequency - 3 MHz.

The large Van de Graaff accelerator is able to accelerate protons to energies of 5 MeV with an analysed-beam current at the target of 15 - 30 μA. Thanks to a stabilization system which can maintain proton energies with an accuracy of 0.1%, it is possible with this device to carry out extremely accurate nuclear-physics measurements.

CYCLOTRON

The Institute's cyclotron is used mainly to produce radioisotopes and also for carrying out nuclear-physics investigations.

The main parameters of the cyclotron are as follows: diameter of poles of magnet - 1.5 m; distance between poles - 21 cm; maximum intensity of magnetic field - 17 000 Oe; amplitude value of voltage between duants - 200 kV. The cyclotron can accelerate protons to energies of 18 MeV, deuterons to energies of 21 MeV and alpha particles to energies of up to 42 MeV.

NUCLEAR-PHYSICS INVESTIGATIONS

In line with the general programme of work with the Institute, activities in the field of nuclear physics are centred on studies of the interaction of slow and fast neutrons with nuclei. Particular attention is paid to work on fission processes, radiation capture, elastic and inelastic neutron scattering (including work on small-angle neutron scattering) and also reactions of the (n,p), (n,α), (n,2n) types, etc. Generally speaking, a variety of methods are used for these investigations, ranging from the well-known spherical-geometry and activation-measurement techniques to the time-of-flight method. The neutron sources used are the above-mentioned reactors and accelerators as well as the usual Ra-Be, Po-B and photoneutron sources. For investigations with the latter type of source there is a speical room at the Institute which is equipped with an automatic remote-controlled device for moving the sources. Thanks to the provision of thick concrete walls, measurements with sources of up to 1000 c can be carried out in this room.

Considerable attention is paid at the Institute to the development of new systems for recording neutrons and gamma rays. Various items of equipment developed by the Institute's physicists - fission chambers, small spectrometers filled with helium-3 and large liquid scintillators with a capacity of up to 600 l - have proved extremely serviceable and have made it possible to carry out a number of valuable and interesting investigations.

In addition to the normal industrially produced electronics equipment, the Institute uses special apparatus developed and produced by the Radioelectronics Department for its measurement work. This special apparatus includes multi-dimensional analysers with up to 16 000 channels, time analysers, special computing facilities for preliminary data processing and many other pieces of equipment.

RESEARCH ON HEAT PHYSICS

Large-scale research is carried out at the Institute on the heat physics and technological properties of water and alkali metals (sodium and alloys of sodium and potassium) used as coolant materials in reactors.

These alkali-metal studies involve work on heat-transfer processes in heat-transfer equipment in reactors, the measurement of temperature fields and investigations of heat-transfer processes in channels made up of clusters of rods or tubes, etc. Various investigations are also carried out in connection with the purification of alkali metals from oxides and the development of methods for keeping a check on the impurity content of such metals. These alkali-metal investigations are carried out in BR-5 and also in special flexibly designed facilities which can be adapted for a variety of purposes.

Research on water as a coolant material is performed in two high-pressure (up to 200 atm) facilities. Each of these facilities consists of a circulation loop operated by two pumps (one centrifugal-circulation pump and one piston feed pump). These facilities are used for investigations on critical heat loads over a wide range of water parameters, heat-transfer processes with boiling and non-boiling water, and hydraulic resistances, and also for testing experimental models of fuel-elements for reactors under development.

In addition to the laboratories and installations described above, the Institute has a number of auxiliary services and production units including well-equipped mechanical workshops.

Thanks to its highly developed experimental facilities and to the large number of qualified staff employed, the Institute is in a position to tackle some of the major problems arising in connection with the development of nuclear power in the Soviet Union. The Institute can therefore be justifiably considered as one of the leading scientific establishments in this field in the USSR.

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