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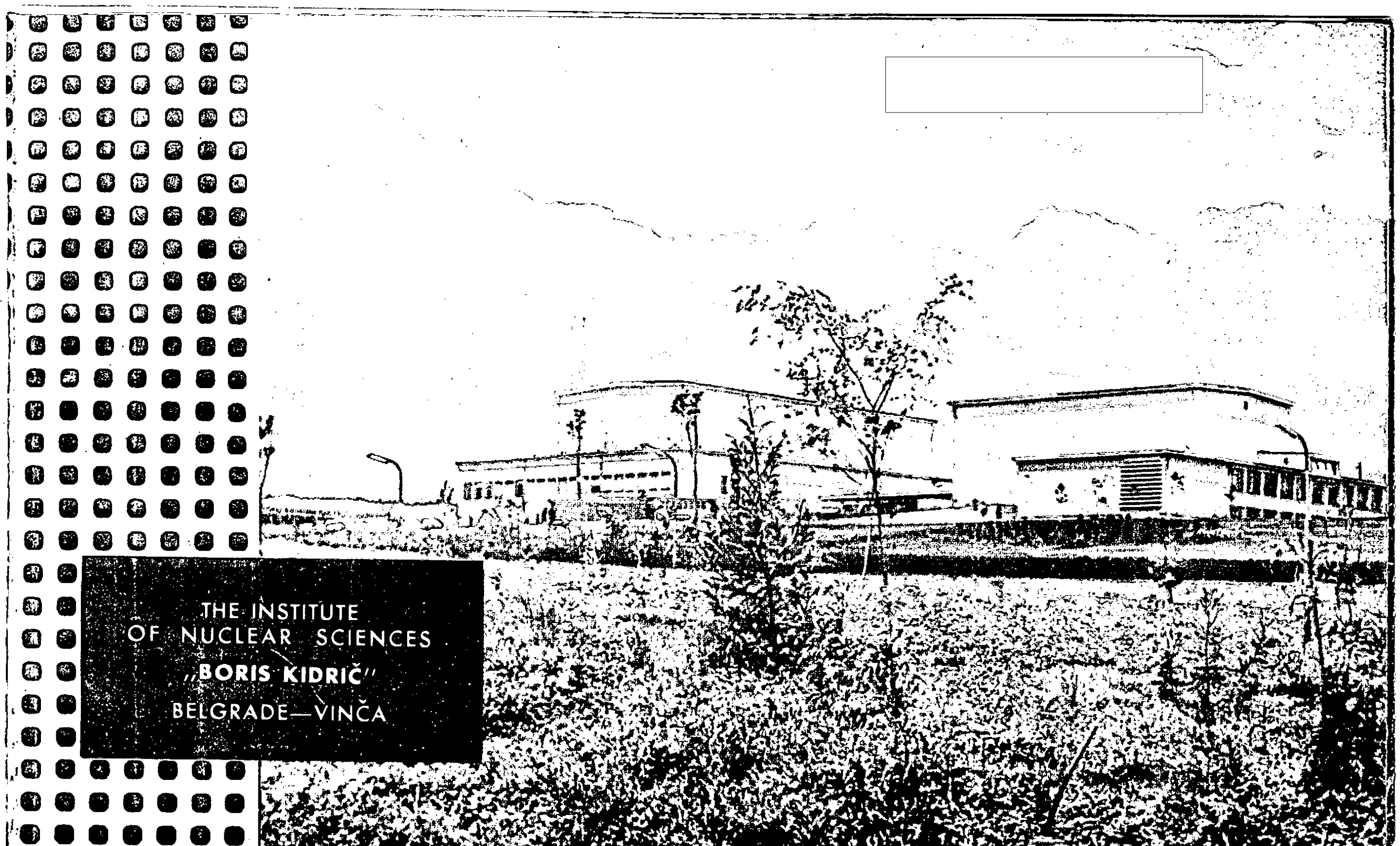

THE INSTITUTE OF NUCLEAR SCIENCES „BORIS KIDRIČ" BELGRADE—VINČA

THE INSTITUTE OF NUCLEAR SCIENCES
„BORIS KIDRIČ"

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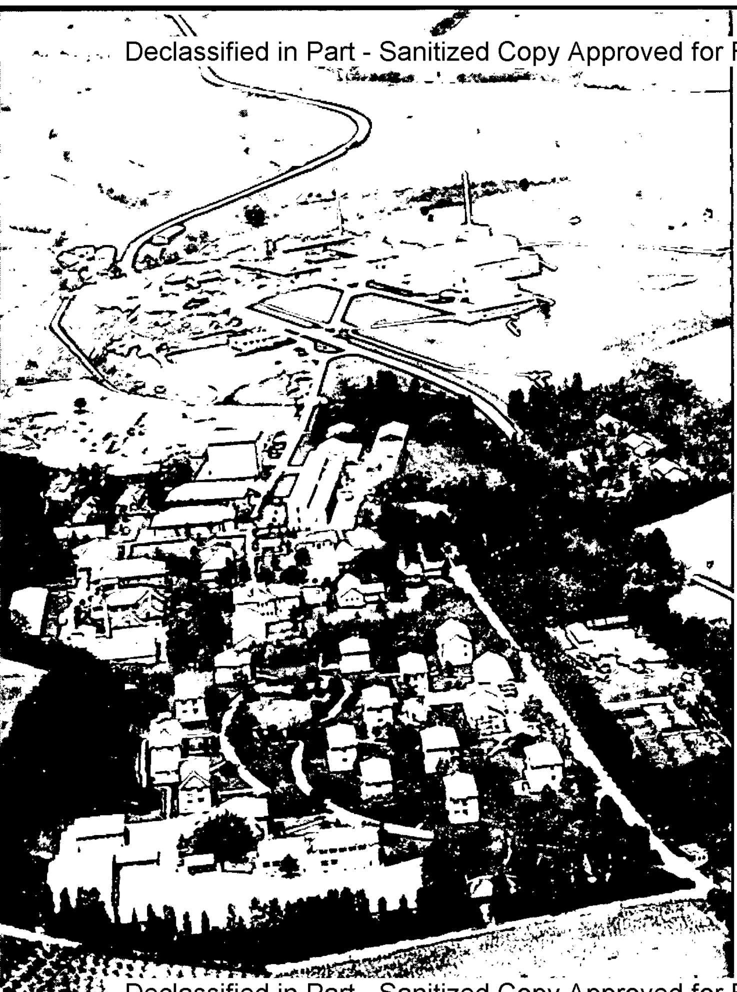
Belgrade, P.O.B. 522

Teleph. 40-871 and 44-961



Air-photo of the Institute made in July 1961

Yugoslavia ranks among those countries where the development of nuclear science and technology was initiated in the years immediately following the Second World War.

The activities in the field of nuclear energy in Yugoslavia are concentrated mainly in the nuclear institutes of Belgrade, Zagreb and Ljubljana which are actually centres of fundamental and technical research carried out on an up-to-date level. Over 800 scientists and technicians with highest qualifications are employed in these institutes.

The Institute of Nuclear Sciences „Boris Kidrič" was founded in 1947. The Institute was given its name in memory of Boris Kidrič, the great revolutionary and political leader, who took active part in creating the conditions for the development of scientific and research work in Yugoslavia.

The „Boris Kidrič" Institute is the largest and the most comprehensive research institution in Yugoslavia with over 1300 workers and employees, about 300 of whom are research associates.

The Institute is situated 13 kilometers eastward of Belgrade and covers an area of about 48 hectares. The Institute is directed by a Council which has a Scientific Committee as its advisory body for scientific problems.

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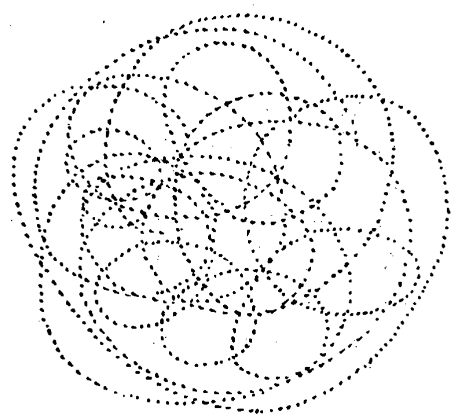


THE PROGRAMME OF WORK OF THE INSTITUTE covers

FUNDAMENTAL RESEARCH in nuclear physics, radiochemistry and radiobiology

ENGINEERING RESEARCH in the fields of nuclear reactors, nuclear fuels, nuclear electronics, production and application of radioactive isotopes and protection against ionizing radiations.

The research work in the Institute is directly connected with the implementation of the Nuclear Energy Development Programme in Yugoslavia.

The 1.5 MeV Cockcroft-Walton accelerator

RESEARCH IN PHYSICS

Research in physics covers nuclear physics, solid state physics and ion physics.

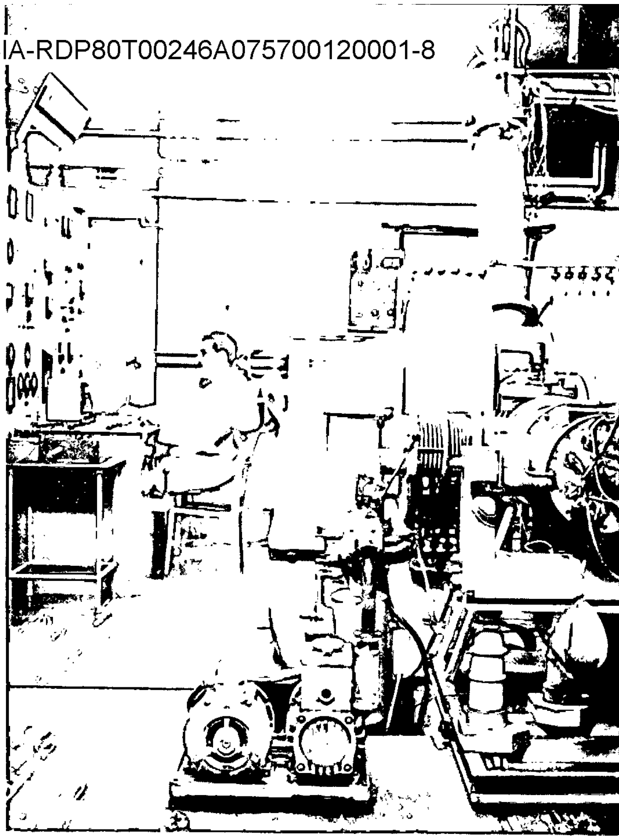
Investigations in the field of nuclear physics have a ten year old tradition. They are devoted mainly to the exploration of the atomic nucleus by measuring the beta and gamma spectra of radioactive isotopes. As the result of this research work, many new lines have been discovered in the nuclear spectra of osmium, platinum, disprosium and other elements. Entirely new schemes of radioactive decay for certain isotopes have been worked out. Mechanisms of nuclear reactions are another field of study. By means of deuterons produced in the accelerator, the atomic nuclei of light elements are being explored. The effect of polarisation was found in the reaction of deuterons with the carbon nuclei. The study of nuclear reaction with fast neutrons has yielded valuable results.

The activities of the group engaged in theoretical nuclear physics cover the study of models of nuclear structures and nuclear reactions. In interpreting the nuclear reactions with low energy deuterons, valuable conclusions have been drawn and a new interpretation of details of the mechanism of these reactions was suggested.

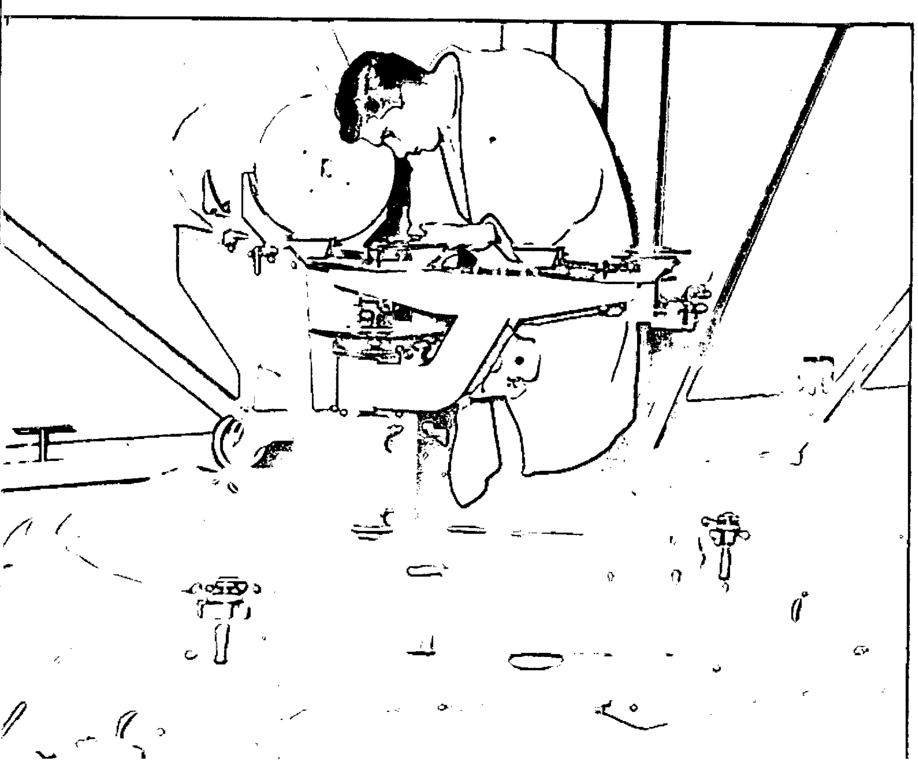
Research in·the solid state of matter is carried out by using neutrons in the nuclear reactor. Information on the structure of solids, particularly when crystals are involved, is obtained by observing the interaction of neutrons with solids. More comprehensive research in this field is of recent date. The research in solid state physics has been successful thanks to the good experimental facilities of the reactor and to the construction of the double-crystal neutron spectrometer.

In the field of ion physics the activities are restricted to the ionizing medium of comparatively lov temperatures. Interesting results have been obtained in the study of ion interactions of heavy elements with various monocrystal targets.

The Laboratory of Physics which is the centre of this research, is equipped with several nuclear machines and instruments. The most important of these are the 1.5 MeV and the 0.2 MeV accelerators, beta and gamma spectrometers, Wilson cloud and diffusion chambers, neutron spectrometers, electromagnetic isotope separators and the mass spectrometer. Further equipment is available for absolute and relative measurements of all types of radioactive rays.



The electromagnetic isotope separator built in the Institute in 1957



The double-crystal neutron spectrometer constructed in the Institute in 1960 and installed on the horizontal experimental channel of the research reactor. The monocrystals of the instrument were also produced in the Institute

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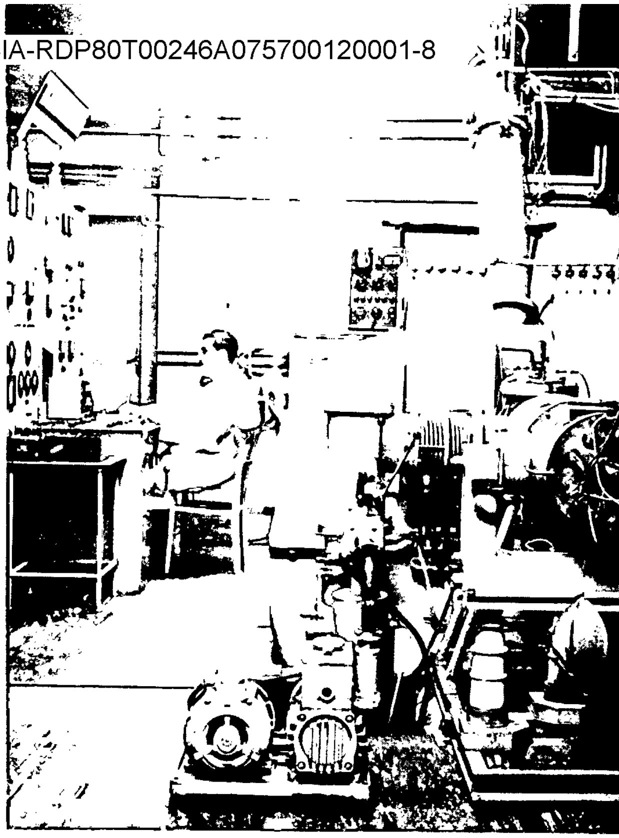

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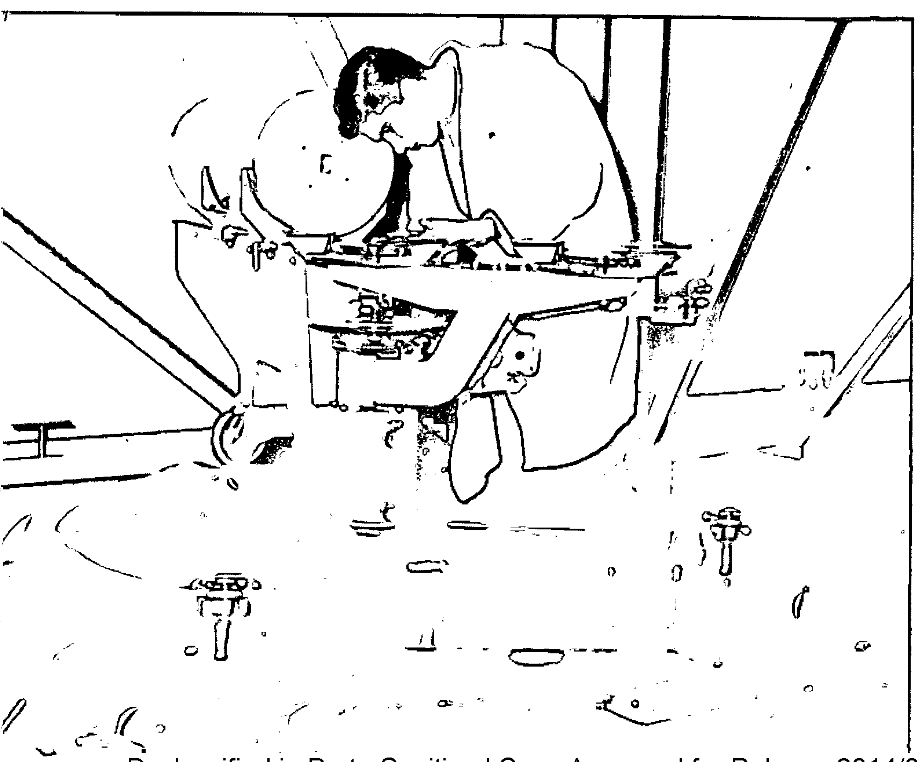

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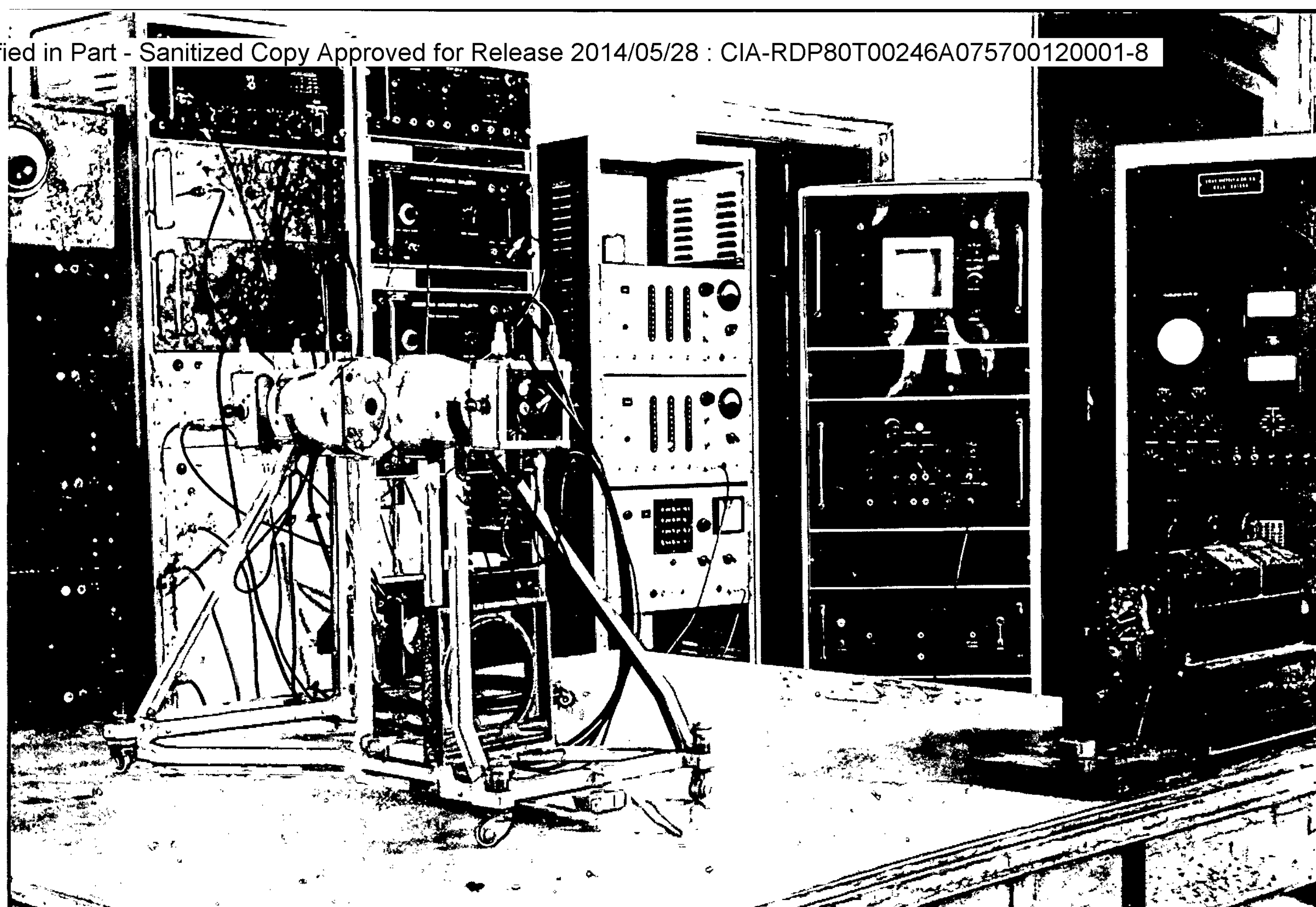

Equipment for the measurement of gamma spectra and angular distribution of gamma rays

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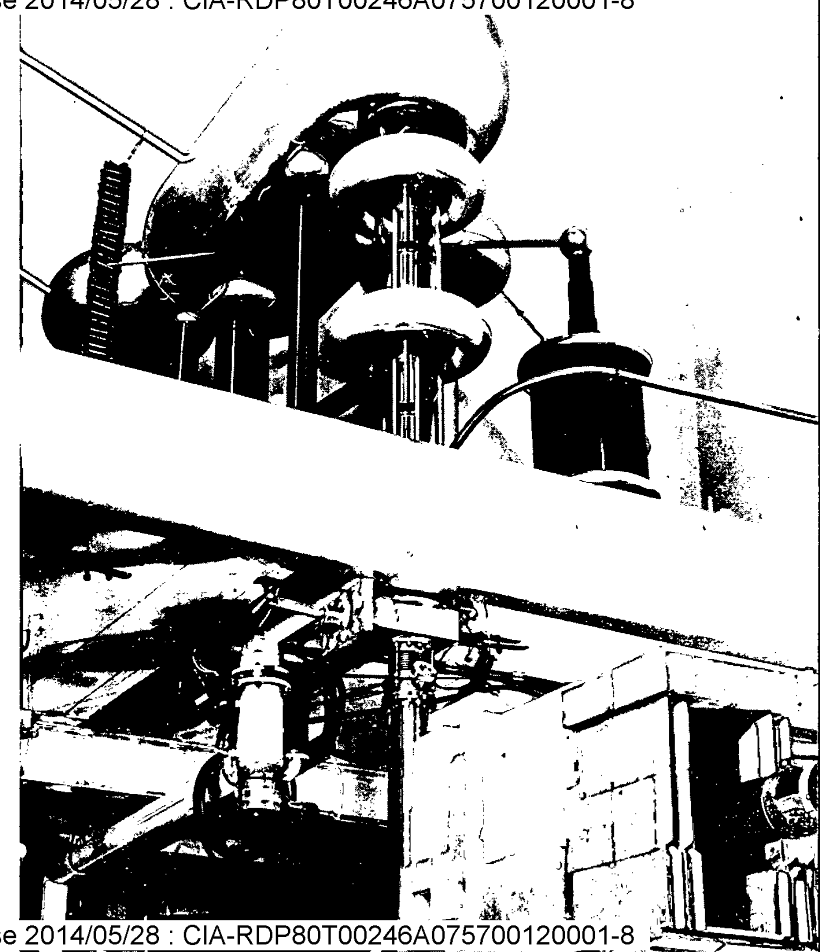
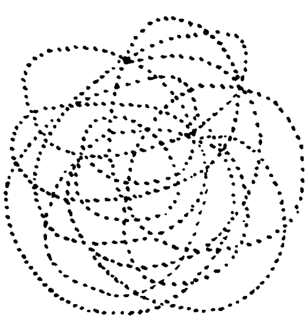
Equipment for the study of nuclear reactions with the 0.2 MeV accelerator





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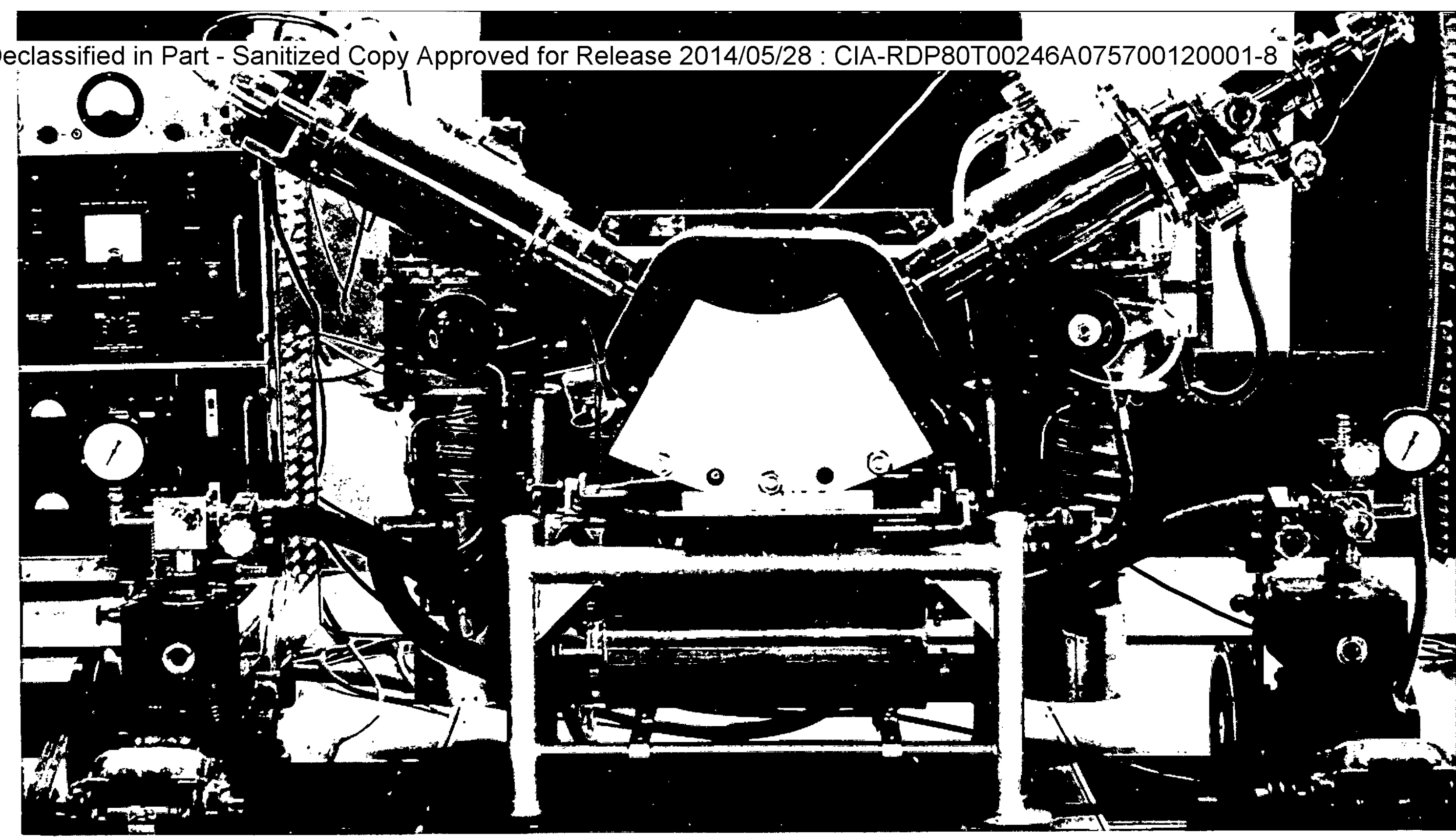


The mass spectrometer constructed in 1960

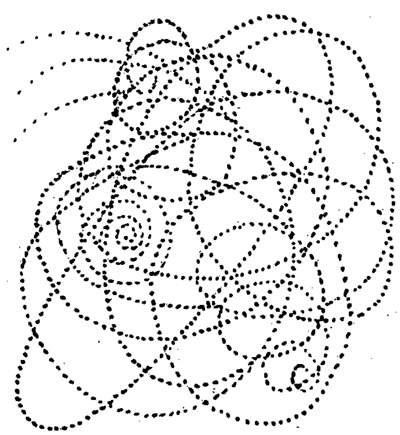
RESEARCH IN RADIOCHEMISTRY

The Hot Laboratory was set up in 1958 for the production of radioactive isotopes and for work on transuranic elements. The characteristic of the Laboratory is the shift from „work with the test tube" to work with „hot" materials. To this effect facilities are under construction or have been constructed and are already used in the production of radioisotopes. They will be particularly useful in the new laboratory which is nearing completion.

In addition to the production of radioactive isotopes, the programme of the Laboratory includes the reprocessing of irradiated nuclear fuel on a laboratory scale. This work is closely connected with the chemistry of transuranic elements, primarily plutonium, and the chemistry of fission products.

Along with these activities, methods of analytical control under conditions of high activity are being developed.

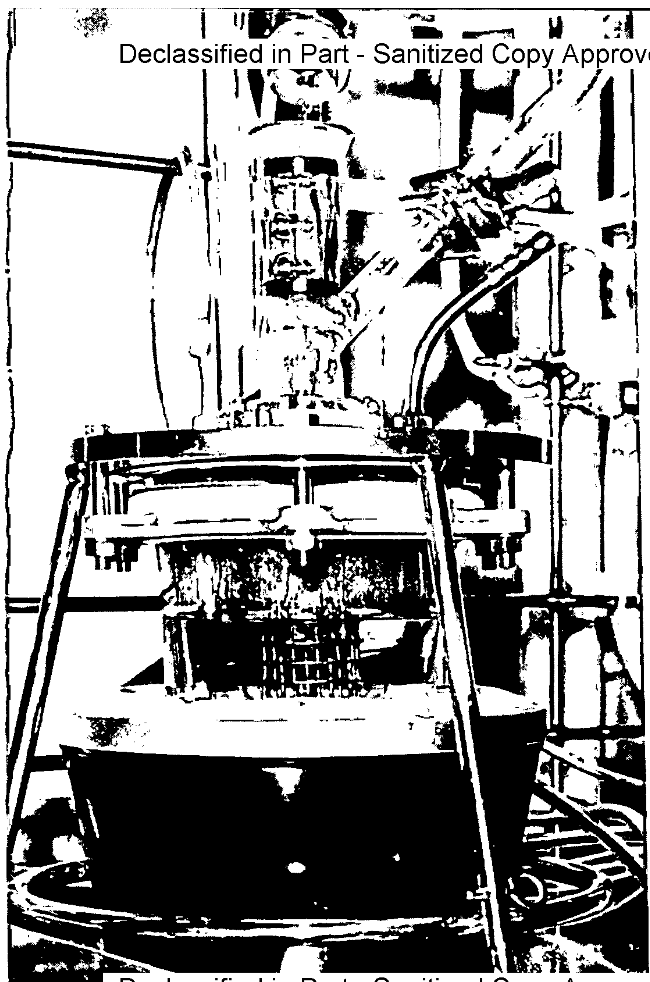
Part of the equipment for the reprocessing of irradiated uranium on a laboratory scale



RADIATION CHEMISTRY

Particular attention is devoted to the study of radiation effects on chemical reactions, the possibility of industrial application of radiation chemical reactions and the measurement of high doses of radiation.

In addition to the large nuclear machines, the facilites available for this work comprise a cobalt source of 2.000 curies.



ANALYTICAL CHEMISTRY

A group of research workers in the Institute is concerned with the investigation of reactor materials by physico-chemical methods. Conditions are being studied for the separation of uranium from other elements such as rare earths, zirconium, niobium, etc. Procedures are being developed and new methods of analysis of reactor materials introduced.

In the field of spectrochemistry, the arc and spark processes are investigated, and methods of high temperature measurements developed. Considerable activity is concentrated around the process of spectrochemical analysis of refractory oxides.

In view of the wide application of stable isotopes in nuclear technology, chemistry, biology and physics, particular attention is devoted to the problems of separation of stable isotopes. For the time being activities are directed towards the study of conditions for the chemical separation of light elements. Methods have been developed for the separation of boron, lithium and hydrogen isotopes. Highly accurate methods of isotope analysis have been developed with mass spectrometers.

The activities concerned with structural analysis are directed towards the application of X-ray and neutron diffraction phenomena in crystals.

A special service is available for chemical analyses, applying the latest physico-chemical methods of analysis, such as spectrographic, X-ray-spectrographic, mass spectrographic, polarographic, etc

RESEARCH IN RADIOBIOLOGY

The activities in this field are mainly concerned with the study of radiation sickness, its diagnosis and treatment.

Significant results have been achieved in the study of the haemorrhagic syndrome in acute radiation sickness and its biological treatment. Valuable information on the immunological reactions of the irradiated organism has also been obtained. This work is partly financed by the International Atomic Energy Agency.

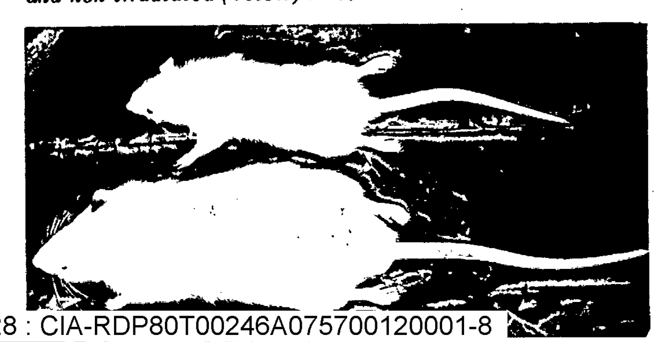
Among the highly satisfactory results in the field of experimental embryology, particular mention should be made of successful attempts of auto-, homo- and hetero-transplantation of the fore-brain regions of birds in early embryogeny.

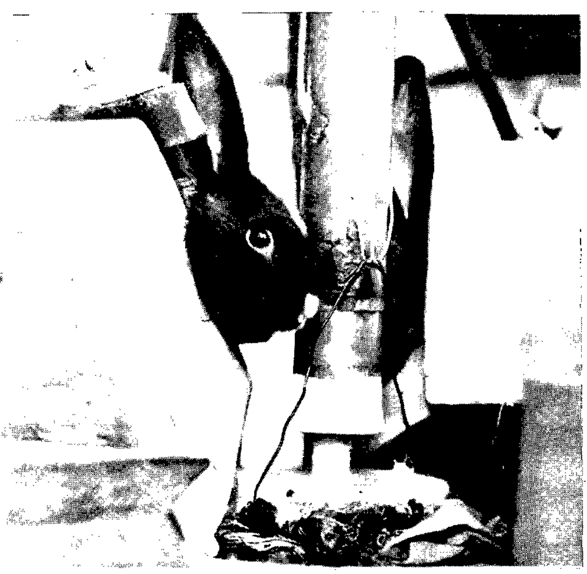
Further extensive research is being pursued in the genetic effect of ionizing radiation, the physiological functions of the irradiated organism and the effect of radiation on isolated organs, the endocrine system of mammals, etc.

Interesting somatic changes have been observed on the progeny of birds when studying the effects of the highly polymeric (biologically active) desoxyribonucleic acid on the gene.

A large farm with several species of experimental animals is available for biological studies.

Descendents of irradiated (above) and non-irradiated (below) rats.





The accelerator target used for the investigation of the effects of neutron irradiation on the eye

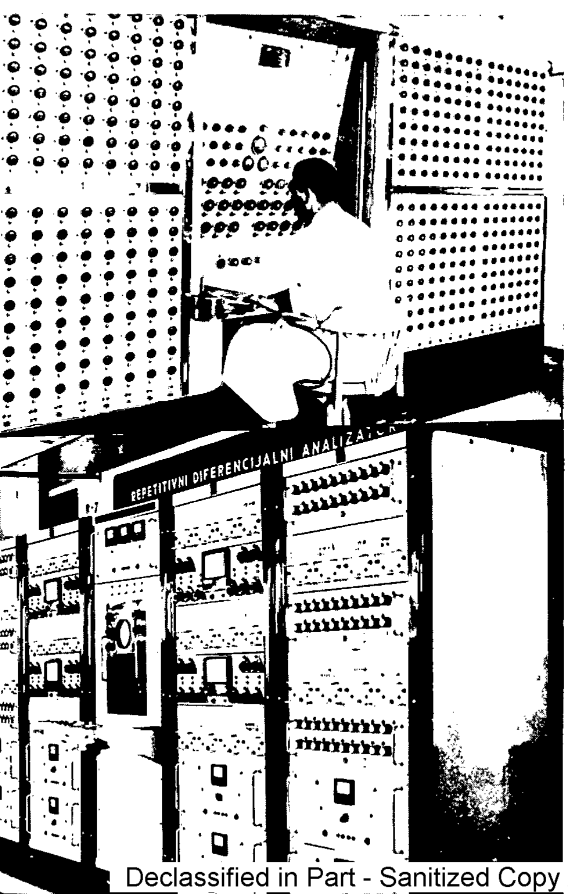
NUCLEAR ELECTRONICS

An important part is assigned to nuclear electronics in almost all the investigations in the field of nuclear energy. Every experimental work requires the use of special electronic equipment. Nuclear power plants and nuclear machines are provided with a variety of electronic instruments and measuring and automatic control devices. Radiation control and the industrial application of radioactive isotopes also depend on electronic instrumentation.

The activities in the field of nuclear electronics are directed towards the development of electronic circuits, the construction of equipment and the study and analysis of systems whose dynamic behaviour is controlled by electronic circuits.

The basic research and development problems embrace

- conversion of direct current signals into alternating current signals using various types of converters, and the improvement of highly stable direct current amplifiers for the measurement of very small currents;
- development of counting instruments based on the use of cold cathode tubes and transistors;



The analogue computer for solving systems of linear algebraic equations and the repetitive differential analyzer

- prototype production of radiation monitoring instruments for personal and local control, and the control of radioactive aerosols and gases;
- work on multi-channel analysers for amplitude and time-of-flight analysis, and on the data processing equipment;
- development and improvement of new electronic circuits.

Further research work is devoted to

- the dynamic analysis of reactor systems by electronic computers and the development of simulation methods and circuits;
- the study of optimum control programmes for nuclear power plants and the design of control systems;
- the development of special instrumentation for the control and measurement of reactor parameters;
- the study of reactor safety systems and circuits.

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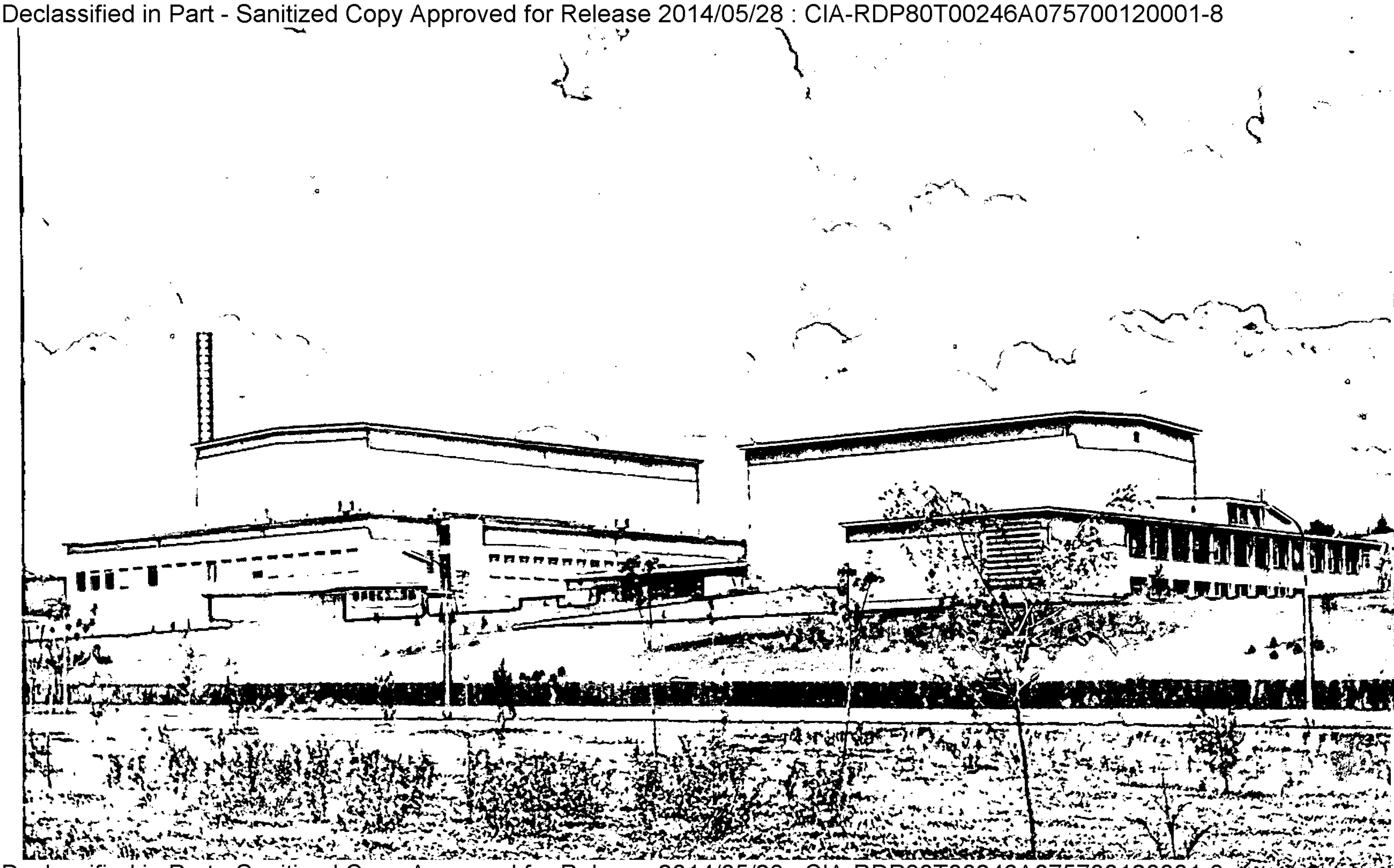

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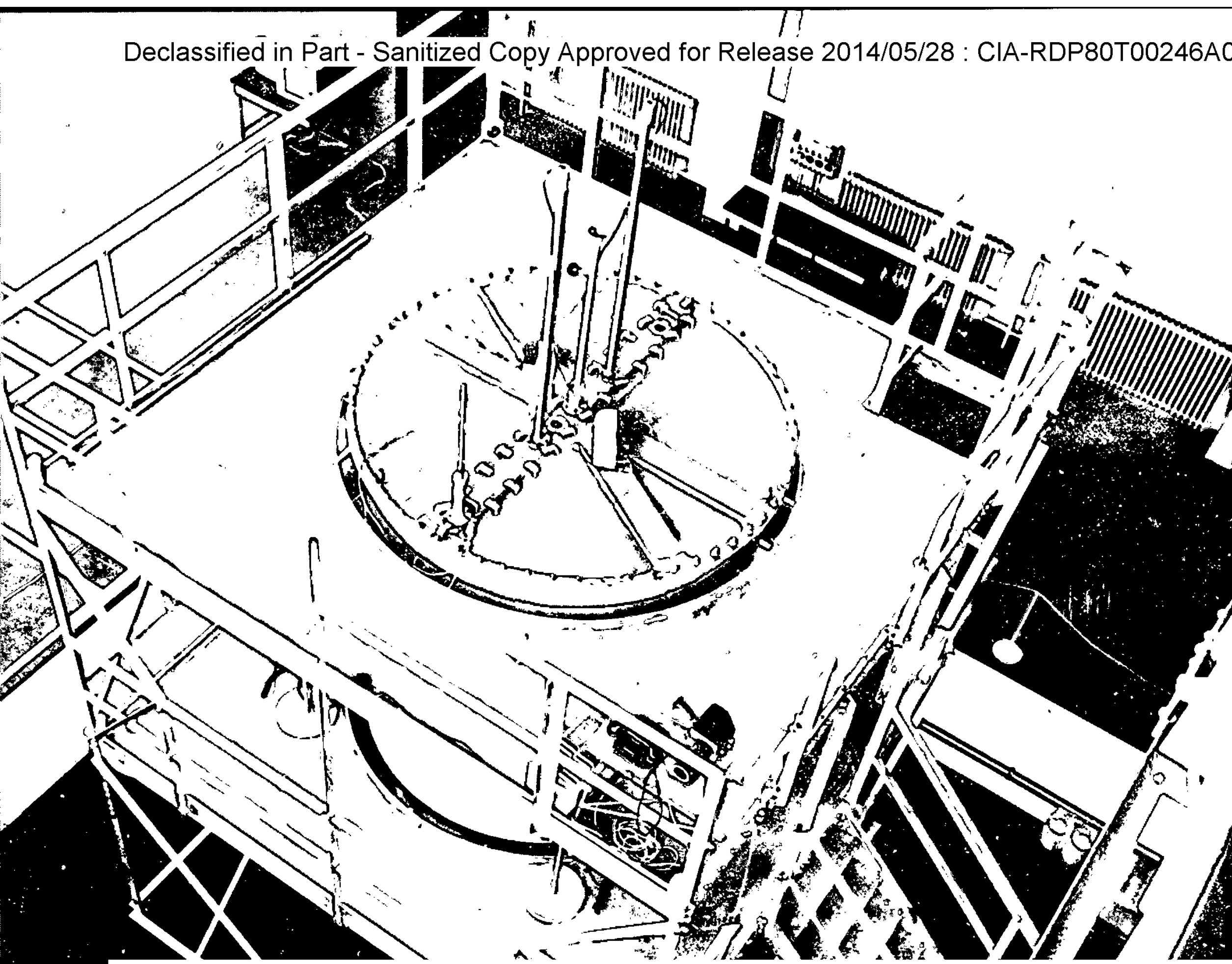

The zero power RB reactor

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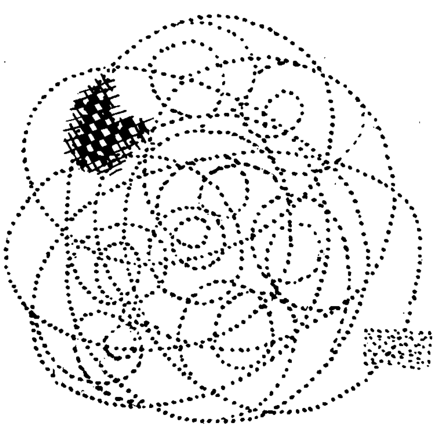

REACTOR PHYSICS

The main fields of activity in reactor physics are concerned with

- the theory, calculation and analysis of dynamic characteristics of nuclear reactors;
- the determination of reactor parameters by critical and subcritical experiments;
- the measurement of performance characteristics of the reactor;
- the determination of nuclear characteristics of reactor materials.

Highly accurate methods of determination of reactor parameters are applied in making standard calculations of the reactor cores. These methods are applied in the calculations of reactors both in operation and under design by making use of digital and analogue computers, some of which have been constructed in the Institute.

The first fission chain reaction in Yugoslavia was effected in April 1958 on the RB reactor of the Institute. The RB reactor is a zero-power heterogeneous reactor with natural uranium and heavy water. It is a typical „bare system", without reflector and shielding, very suitable for the study of lattice parameters and reactor behaviour under different working conditions. The design of equipment for the measurement of parameters of uranium-graphite lattices is now in progress.

REACTOR HEAT TRANSFER

The basic activities of the Heat Transfer Laboratory are directed towards the investigation of the thermal behaviour of fuel elements. In addition, other problems concerning the thermal properties of reactors are studied.

These activities include the following:

- fundamental research in boiling heat transfer and fuel burn-out;
- heat transfer from gas cooled fuel elements including investigation of a new concept of pebble bed fuel elements;
- development of a new concept of steam superheating channel;
- inpile and out-of-pile loops for testing the fuel elements and reactor materials in the reactor RA.

The available nominal power for rheoelectric heating is 300 kW obtained from a rectifier (30 V, 10 000 A) which can be smoothly varied from zero to maximum power.

There are now two low pressure out-of-pile loops in operation. One is gas cooled for high flow resistances and the other is water cooled for testing heat transfer and flow conditions of the RA reactor elements (in order to increase the reactor nominal power). There is also a high pressure loop under construction for steam superheating.

The manipulator and the lathe in the hot cell →

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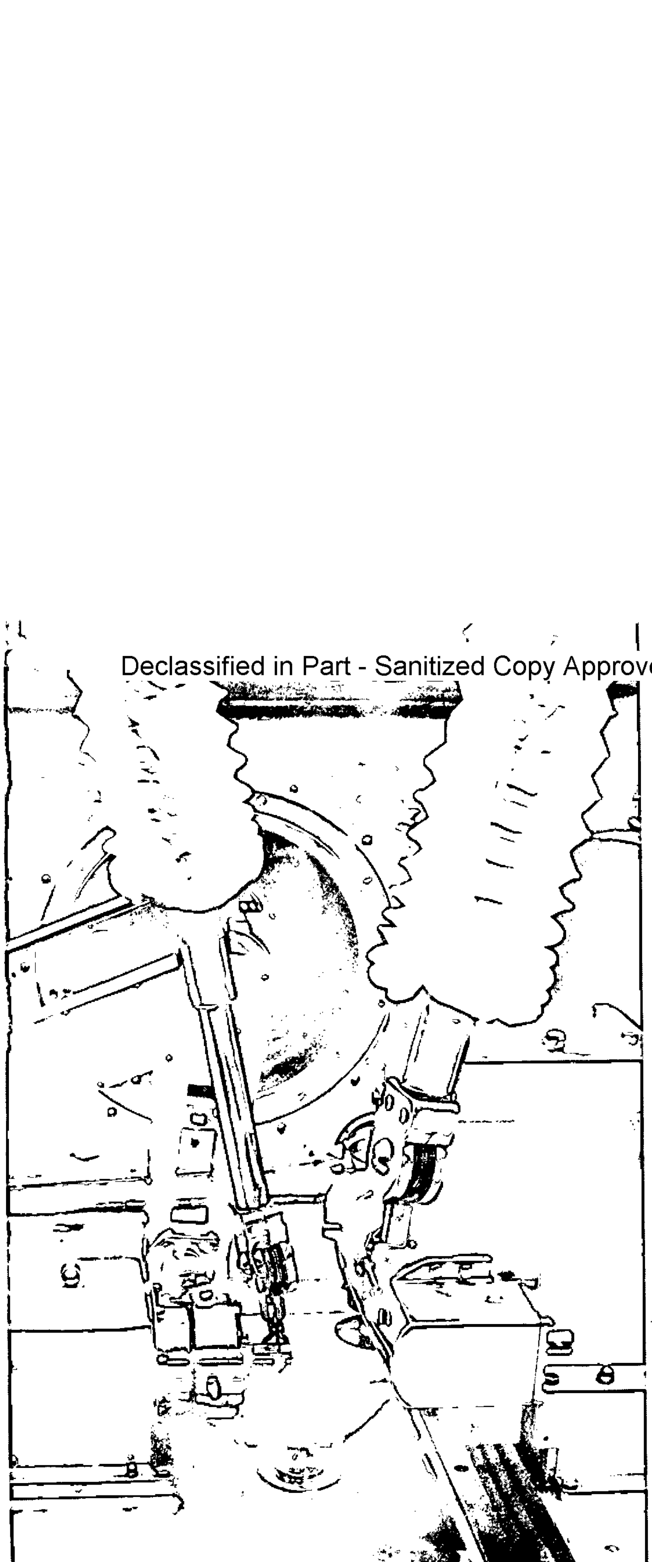


METALLURGY OF REACTOR MATERIALS

The activities in the field of metallurgy are concentrated on the production of metal and ceramic fuels and the investigation of their properties, particularly the effect of low concentrations of foreign elements on the stability of fuel. Study of certain binary alloys of uranium is in progress. The technology of sintered UO_2 pellets production has been introduced, while other methods are under development.

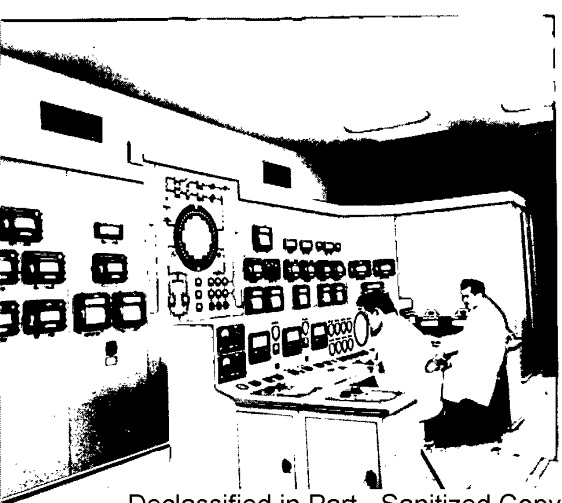
Comprehensive studies and tests concerned with the production of fuel elements for the existing reactors in the Institute are also being made.

Up-to-date equipment is available for the laboratory production of both metal and ceramic fuels and for the study of their properties under static and dynamic stresses, and of their microstructure. Further activities are concerned with the metallographic investigation of reactor materials, primarily of nuclear fuel and aluminium, as well as with the study of the corrosion effects on aluminium.

Irradiated reactor materials are investigated in the hot metallurgical cells of the RA reactor. In addition to the study of mechanical properties of materials, other more comprehensive tests will be undertaken in these cells. A new large building for the Metallurgical Laboratory is now under construction.

THE RESEARCH REACTOR RA

The control room of the RA reactor

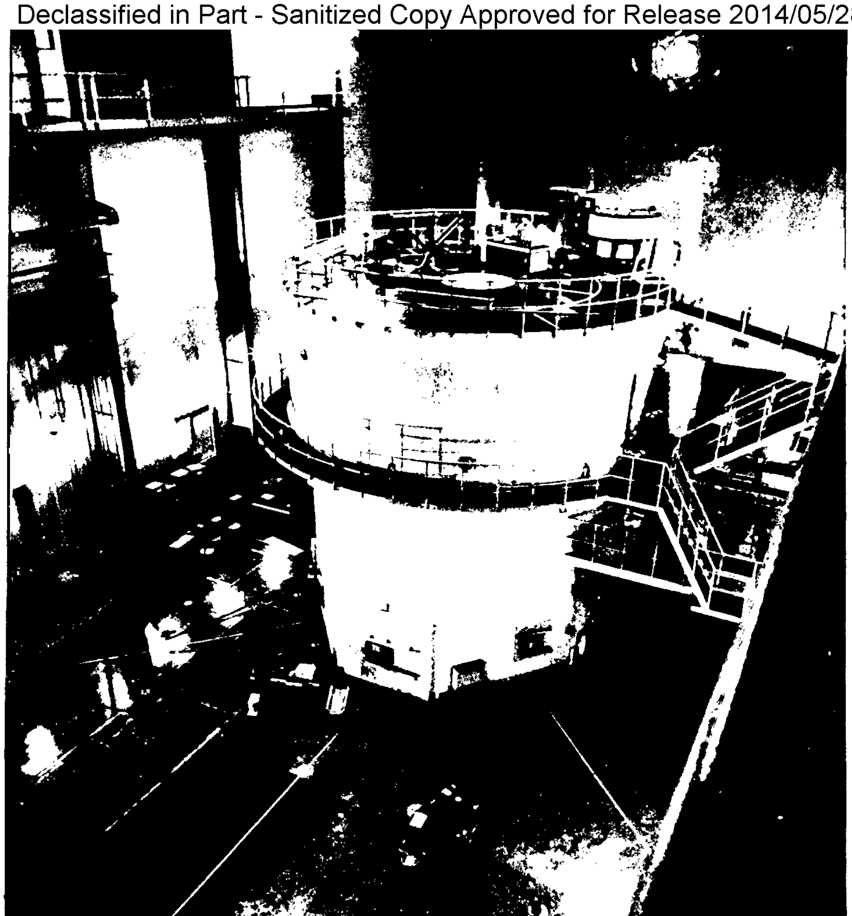


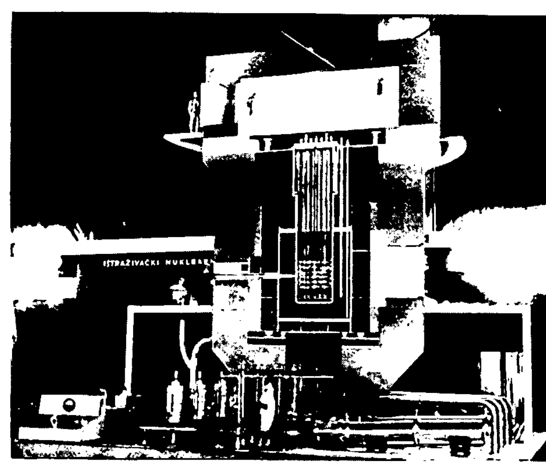
At a certain stage of development of the Institute there arose the need for a nuclear machine of great potentialities and multiple use. Thus, on the basis of an agreement on cooperation between Yugoslavia and the USSR, the designs and the basic equipment for the RA research reactor were bought in the USSR in 1956. In the same year, with the technical assistance of the USSR, the construction of the reactor started and was completed in 1959 since when it has been in regular operation.

The reactor RA is a heterogeneous heavy water reactor, using 2% enriched natural uranium as fuel. Heavy water serves both as moderator and coolant, while the reflector is of graphite.

The nominal power of the reactor is 6.5 MW with a mean thermal neutron flux of 3.10^{13} neutrons/sq.cm.sec. The maximum power of the reactor is 10 MW.

There are nine vertical experimental channels inside the reactor tank and thirty-four in the reflector. Six horizontal channels and one thermal column run through the biological shield. The reactor becomes critical with about 30 out of the 84 fuel channels, which points to the great irradiation potentialities of the reactor. The reactor is a highly automatic machine provided with all necessary equipment for irradiation and measurements.





The model shows a cross-section of the reactor. On the upper part of the model one can see the reactor core, graphite reflector and the concrete and water shields. On the lefthand side is the horizontal experimental channel and on the right side the room for withdrawal of irradiated fuel. The bottom part of the model shows the heavy water pumps on the left side and the heat exchangers on the right side.

The research reactor RA is a machine with versatile experimental facilities. Most of the reactor equipment is located beneath the reactor hall.

The reactor which is a powerful source of radiation is intended for fundamental and technological research directly connected with the application of nuclear energy, and for production of radioactive isotopes.

Extensive experiments are being carried out on the RA research reactor to establish the characteristics of radiation and the operating parameters of the reactor. These experiments are based on activation methods, while a chopper of the energy order of 10^{-4} to 1 eV was constructed for the analysis of the neutron beam. The chopper is provided with a rotor of straight paths and with a 10-channel time-of-flight analyser.

The reactor is suitable for „loop" experiments with reactor materials, particularly with fuel elements used in various types of nuclear reactors. The first loops are now under construction. The four hot cells equipped for work with activities up to 10.000 curies make possible further investigation of reactor materials.

The research reactor RA: a top view of the reactor tank

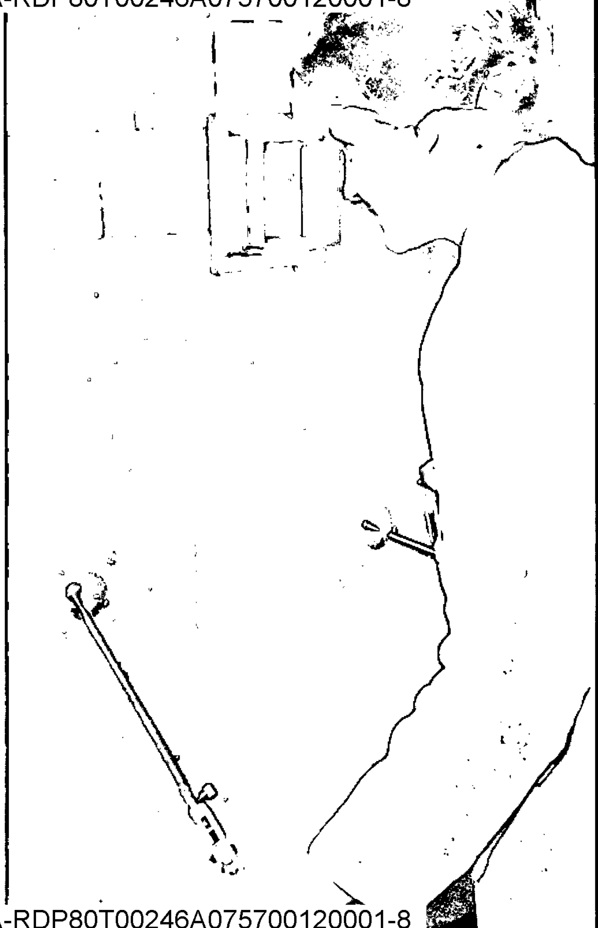
PRODUCTION OF RADIOACTIVE ISOTOPES

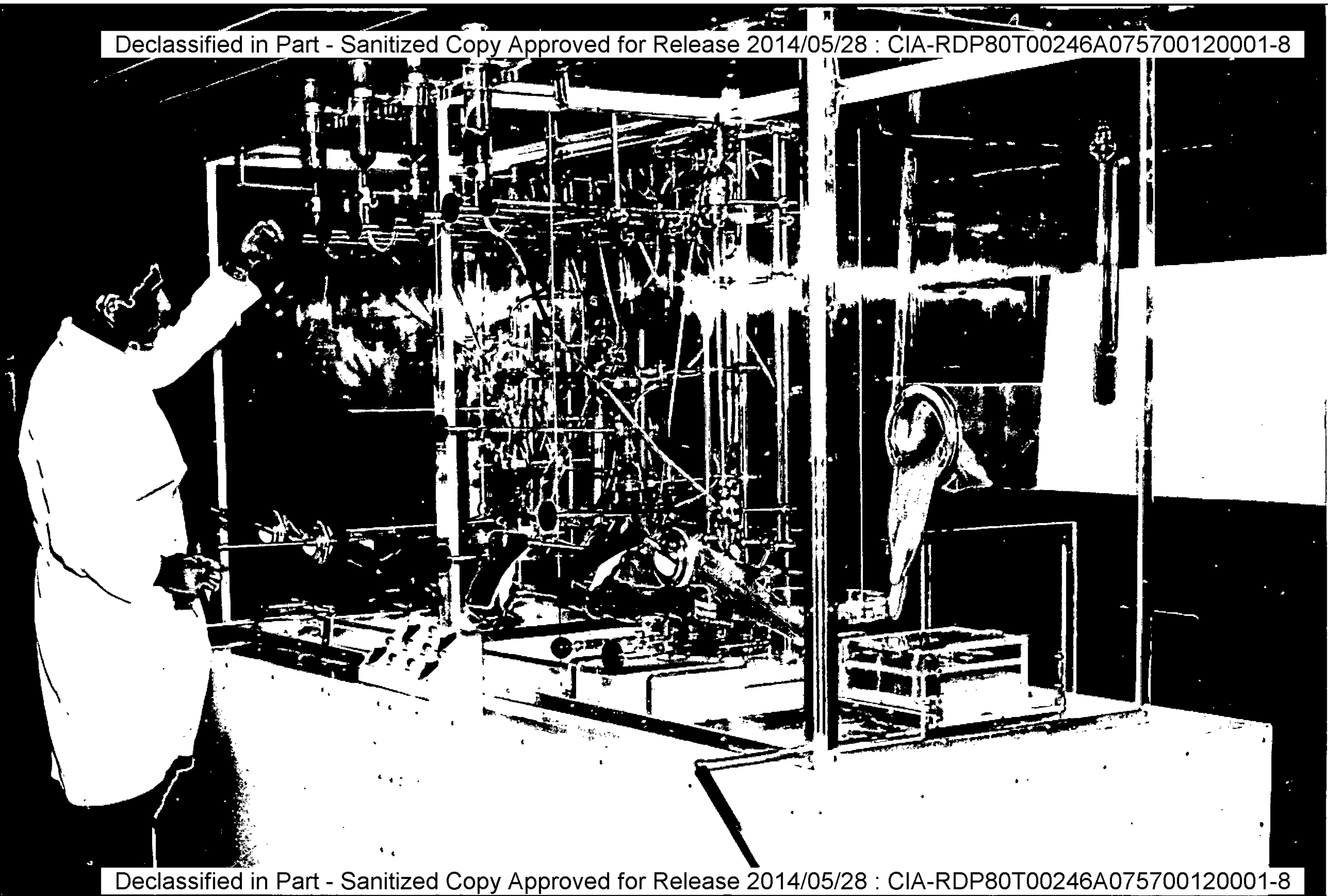
The new laboratory for the production of radioactive isotopes and radioactive compounds is now under construction.

Temporarily the radiochemistry building has been adapted and equipped for the production of the following isotopes: carrier-free sulphur 35, carrier-free iodine 131, phosphorus 32, radiographic cobalt 60 sources ranging up to 1 curie and iridium 192 sources up to 20 curies,, the standard sources of certain important alpha, beta and gamma emitters, etc. The production of colloidal gold 198 and of other medical compounds is in progress as well as the production of carrier-free phosphorus 32 and of $Ba^{14}\ CO_3$.

Sulphur 35 is produced after the method developed at the Institute by using the small aluminium-trioxide column for the separation of sulphur 35 from phosphorus 32 and chlorine 36, while the small column with the Dowex-50 ion-exchange resin is used for the final purification of $^{35}SO_4^{2-}$. The production proceeds in a special box made of plexi-glass equipped for safe work. For the production of iodine 131, phosphorus 32 and of colloidal gold 198, cells with 50 mm thick lead shields have been constructed. Cells with thicker lead shielding are used for the production and packing of cobalt 60 and iridium 192.

Since the production of radioisotopes may proceed only along with their consumption, a group of research workers at the Institute is responsible for instructing the potential consumers as to the methods of applying radioactive isotopes in various fields.





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← *The equipment for separation of radioactive sulphur 35*

For several years now a school has been run for the training of staff in handling radioactive isotopes. There, students acquire basic knowledge in nuclear physics and chemistry and receive training in the handling of radioactive isotopes, the measurement of radioactivity and the protection against radiations.

RADIOLOGICAL PROTECTION

The Radiological Protection Service is responsible for the introduction and maintenance of appropriate protective measures in the work with the reactors, accelerators and radioactive materials as well as for the control against possible environment contamination in the Institute. The service is also responsible for systematic medical examination of the staff and for decontamination in the case of accidents. A special team within the service is dealing with the problems of radiation monitoring, treatment of radioactive wastes and radiation medicine.

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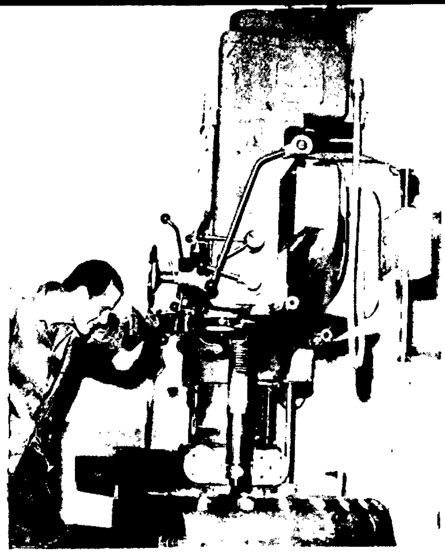
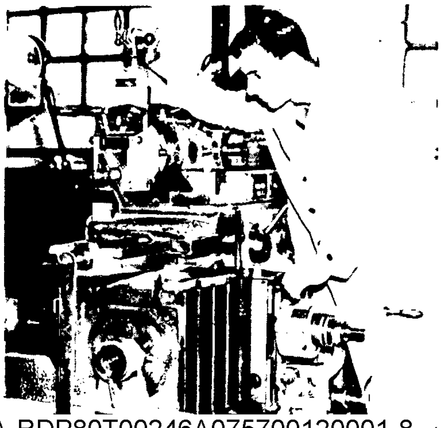
TRAINING

Nuclear sciences and nuclear energy require highly trained specialists for various branches of activity. In the early development stage of the Institute the staff was trained mainly in research centres and schools abroad. Now this training assumes the aspect of a wide and fruitful international cooperation and exchange of research workers, particularly with corresponding institutions of the countries with which Yugoslavia has international agreements on cooperation in the field of nuclear energy. Efforts have also been made to set up chairs in the various faculties of the Belgrade University where the fundamental training of the staff in nuclear sciences and nuclear engineering could be provided. This cooperation between the Institute and the University proved to be valuable to both parties. One of the results of this cooperation are also special courses and postgraduate studies that have been introduced at the University. The laboratories, research machines and equipment of the Institute are at the disposal of the trainees.





A great deal of complex equipment and components for large nuclear machines, reactors, accelerators and isotope separators as well as numerous mechanisms for experimental work have been constructed in the workshops of the Institute, which are equipped with modern machines. About 300 skilled workers work in these workhops

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