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THE POLISH ATOMIC REACTOR EWA AT SWIERK

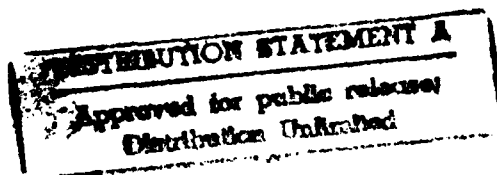
by Tadeusz Berens

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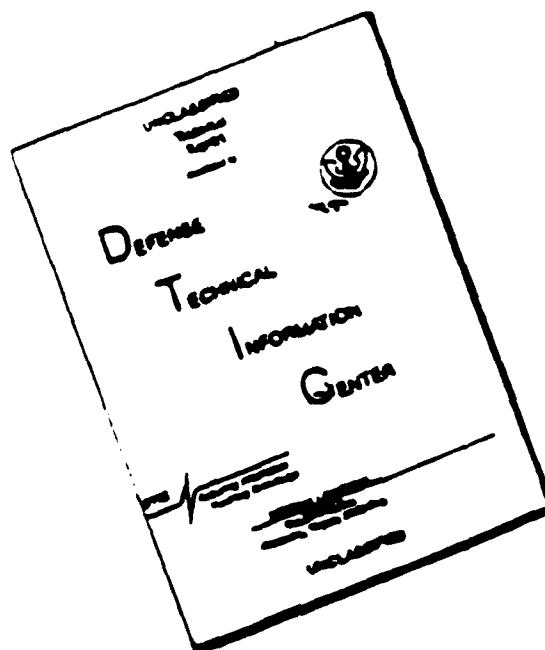
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by Tadeusz Berens

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THE POLISH ATOMIC REACTOR EWA AT SWIERK

[Following is a translation of an article by Magister Engr Tadeusz Berens in the Przegląd Mechaniczny (Mechanical Review), Vol XIX, No. 17, Warsaw, 10 September 1960, pages 510-516.]

In June of this year, two years elapsed since the starting of operation of the first Polish atomic reactor, at Swierk near Warsaw.

The present article gives a general discussion of the reactor installation as a whole and a more detailed account of its structural and mechanical part and other auxiliary equipment used for operation of the reactor.

General Description of Reactor Installation

The basic aim of experimental reactors is the production of thermal neutrons (those of low energies) which may be used for various purposes.

The equipment of the reactor makes possible the controlled and guided progress of nuclear reactions and technological processes taking place in the core of the reactor, and also ensure safe working conditions at the reactor and in its surroundings.

For these reasons, experimental reactors are provided with a large amount of equipment, depending on their size, type, and purpose.

The majority of the equipment and rooms of the reactor installation are located in one building. Outside the main building are the ventilation rooms, the secondary circuit pumping station with coolant basin, discharge basins for radioactive waste liquid, and a storage area (burial ground) for permanent waste.

The main building houses the technological and administrative-laboratory equipment.

The technological equipment includes: the reactor itself with its shield, primary circuit pumping station, shelter for spent fuel, systems for special drainage ventilation, and safety devices with control room, dosimetric protection with metering panel and pumping station for air specimen intake, distillation equipment, engine houses, electric switch rooms, etc.

In addition, the installation is equipped with a repair and production shop, a repair point for dirty work, equipment shops, and its own chemical and photography laboratories.

The laboratories occupy a number of laboratory and measurement rooms. We should also include among the rooms of the laboratory type the area of the hot cells (laboratories for carrying out work behind a shield at a distance).

The installation is also equipped with administrative rooms, a library, lecture hall, warehouses, appropriate dressing rooms, decontamination chamber, and social installations.

Following are some of the basic data characterizing the "Ewa" reactor: thermal power -- 2000 kw; maximum neutron flux -- 2.10^{13} neutr/cm² sec; uranium fuel enriched to a value of 10% U²³⁵; amount of fuel at beginning of run -- 4.0 kg U²³⁵; distilled water is used as the coolant, moderator, and reflector; the minimum critical mass of the U²³⁵ with the established division and construction of the fuel rods is about 3 kg.

The introduction of structural materials into the core, removal of the side reflector, certain deviations from the optimum shapes, a surplus of neutrons necessary for conducting experimental work, and levelling of the sterile absorption of neutrons as a result of increase in the cooling water temperature and of the Xenon-135 occurring in the fuel have occasioned a increase in the amount of Uranium 235 to 4.0 kg at the beginning of the run. This quantity is increased in the course of the reactor's operation by periodic supplementary charging of fuel.

Rods which absorb neutrons are introduced into the core in the intervals between charging of fresh fuel, to compensate for the changes in reactivity in the core. The function of the rods is to maintain the prescribed intensity of the neutron flux (and thus the thermal power).

Three of the nine rods protect the reactor against breakdown. On signal the rods are introduced into the core at high speed and shut the reactor down.

The distilled water used in the reactor weakens the energy of the fast neutrons, cools the fuel rods, participates in physical phenomena as a "reflector," and protects the personnel working near the reactor from radiation.

The reactor is designed for tests in physics, tests in the field of radiation chemistry, and for the production of isotopes.

For the removal of neutron beams from the core of the reactor or for charging target materials destined for irradiation, the reactor is equipped with horizontal channels run out by way of the thermal column, which is introduced in the vicinity of the core, and a number of vertical water-filled (wet) and dry channels. The fuel from the reactor may be used for further investigations in the sphere of radiation chemistry as a powerful source of gamma rays.

"Power circuits" may be installed in the core of the reactor for the study of other types of fuel, another coolant, or for testing the other parameters by which the work of the reactor is planned.

Design and Mechanical Features of the Reactor

A tank containing a cylindrical separator together with fuel sections is inserted into a concrete block which represents the shield of the reactor proper.

A number of channels for wet and dry irradiation and measuring channels are located around the fuel sections (core). The channels of the regulating and safety rods pass through the core. The channels are secured to the support plate of the tank, while the rods are driven from outside the concrete shield.

The tanks is covered with rotary plates which represent the top shield of the reactor. Nine experimental channels are run through the concrete shield into the tank. In addition, the thermal column, which is the tenth horizontal channel, is introduced into a recess in the concrete shield. A general view of the reactor and a part of the hall are shown in Figure 1, and Figure 2 gives a vertical cross section of the reactor.

Fuel and core (separator). The fuel elements are made in the form of rods 6 mm in diameter and 500 mm in length and containing 10% uranium 235. The fuel rod is loded in an aluminum casing having a wall thickness of 2 mm, the diameter of the casing being 10 mm (Figure 3).

Sets of 16 rods are contained in the sections. The rods in the sections are placed in two plates with guide openings and openings for water discharge. The rods are protected by a jacket of sheet aluminum, eloxadized provided with a grip used for transportation of the sections by the charging device. At the bottom the jacket assumes a conical shape, to facilitate introduction into the recess of the reactor.

Three basic section shapes are used to allow for placing regulating and safety rods between the sections: square, square with two corners cut off, and square with three corners cut off. For the same reason, the spacing of the fuel rods in the sections varies from 13.5 to 17.5 mm.

The fuel sections are placed in the core at a distance of 71.5 mm from one another. Proper arrangement of the sections is ensured by two lattices (upper and lower) made of aluminum strap plates enclosed in an aluminum cylinder (Figure 4); this unit is called the separator.

Openings guiding the channels of the regulating and safety rods are also provided in the separator. At the bottom of the separator replaceable choke bushings are mounted; with them it is possible to regulate the individual flow of cooling water through each section.

The maximum number of sections which may be charged is 51. The total load toward the end of the run is 816 rods, this corresponding to about 65 kg of uranium (including 6.5 kg of uranium 235). At the beginning of the run, 24 sections are loaded, while the empty outer sockets are filled with aggregates which have an air cushion at the height of the core (see Figure 3). This prevents change in the characteristics of the neutron flux. If such a change is permissible, aggregates without cushions are used, owing to which fact the loading capacity is increased for the isotopes placed inside the aggregates.

In addition to the regulating and safety rod channels, eight channels for irradiation of the isotopes and one channel for short irradiation run through the separator (and accordingly through the core). Of these eight channels, four are short and correspond to the height of the separator, while the remaining ones are long and reach the closing covers of the tank. These channels are filled with cooling water, while the short radiation channel is dry and runs all the way through the reactor. The container with the irradiated material (also called target material) is lowered through this channel and falls directly into the first hot cell under the reactor.

Vertical reactor channels. A number of openings, hot and auxiliary channels, are arranged around the separator. Their arrangement is shown in Figure 5.

The irradiated specimens (isotopes) are lowered through transfer holes to the hot cells for further treatment or for recharging. The channels run all the way through the tank and are connected with an inlet pipe which ends in an elastic buffer in the first cell.

Sloped channel 1 is made of two pipes, one within the other. The inner pipe is welded to the inner aluminum tank, while the outer one is welded to the outer acid-resistant shield tank. The channel is filled with water having the same level as in the shield.

The reactor tank, which has an outer diameter of 2300 mm and a height of 5700 mm, is made of sheets of an aluminum alloy and inside has cylindrical partitions dividing it into three parts. The inner part of the tank is limited by a cylinder enclosing the separator. This cylinder reaches only up to the upper surface of the separator, that is, about 0.3 m above the plane of the core. There is one other cylindrical partition in the tank between the central and outer parts, reaching to the very top of the tank. The whole tank is filled with distilled water, which flows through the central part (core) from top to bottom.

The water between the outer cylinder and the first partition represents a shield against radiation.

There are in the shield two pipe channels which run all the way through the reactor and under it. The piping of the power or measuring circuits may be run through these channels to the primary circuit pumping station.

At a point where the central partition approaches the separator, a recess is cut into the outer wall of the tank which comes very near the core. The thermal column, made up of graphite rings and designed to receive the powerful beam of thermal neutrons, is introduced into this recess.

At the height of the core, horizontal channels are also cut into the concrete. They are continued in the form of coaxial channels run through to the tank.

Above the tank on the support plate under the rotating covers are the pulleys and cables of the ionization chambers (Figure 6). The cables are run outside the concrete shield through special passages. The driving and control mechanisms are located outside the concrete shield.

Concrete shield of the tank. The tank is mounted on a cast steel plate. The bottom of the tank is opposite the core and its top is shielded by cast iron rings which represent the thermal shield and the initial shield against gamma radiation. These rings are the inner portion of the concrete cylinder.

The concrete surrounds the entire tank to the full height of the latter, the thickness of the concrete reaching 2.5 m. Heavy concrete containing limonite ore (containing bound water) and scrap iron is used for the shield.

The mechanisms for closing the horizontal channels, three biological experimental holes at varying distances from the core, the lining of the thermal column, and ventilating ducts and electric conductors are mounted in the concrete.

On top of the reactor there are in the concrete a number of auxiliary pipes (channels) used for storage, e.g., for the charging mechanism, periscope, and protective plugs.

Four channels intended for storage of the power circuit pipes are mounted in the concrete on the side of the cable bridge. They are also used as flushing ducts (two of these channels have a drainage installation, hence the possibility exists of creating a flushing circuit).

Horizontal channels and thermal column. A set of five disks filled with heavy concrete with lead inserts is secured at the exit from each channel. The disks are actuated manually or mechanically (and remote control is possible).

After being rotated 60° , the first of the five disks engages the following one, which has an opening shifted 60° in relation to the preceding one. When the gate has been fully rotated, the openings of the disks are in alignment, and access to the channel is thereby afforded. After the gate is closed, the channel is covered by the concrete and lead inserts of all the disks, which provide adequate protection.

Opening of the channel is possible after unlocking of the drive at the central dosimetric point. The position of the disks is signalled by means of lights at the channel, at the central dosimetric point, and in the laboratory building connected to the channel.

Great possibilities for conducting tests are afforded by a horizontal channel having a diameter of about 1,000 mm which leads to the immediate vicinity of the core. The thermal column is introduced into this channel.

The thermal column consists of a conveyer which moves on rails, five graphite disks encased in aluminum, and a cooling system consisting of 8 field pipes run through to the graphite rings. The rings have a central opening with a bore of $\phi 120$.

In addition, four vertical channels are introduced into the thermal column from the upper working surface of the reactor. The thermal column may be removed from the recess and brought outside the reactor. Hence it is possible to replace the graphite disks with others, as well as to install any desired experimental equipment there.

The channel of the thermal column is shielded by a cast iron shield set on a conveyer which moves crosswise with respect to the direction of travel of the column conveyer. The weight of the shield with the conveyer is about 30 tons.

In the shield is a channel whose axis coincides with that of the column channel when the shield is shifted. This channel is shielded by a gate similar in design to the gate of the horizontal channels. Both these devices are driven by mechanisms using cables, and the mechanisms may be remote controlled. This installation is equipped with a signal system and limit switches.

Hoists with manual drives run outside the reactor are installed in the vertical channels of the thermal column, the entrance to which latter is located under the rotating covers of the reactor. A solution of this type permits loading and unloading of the target materials with the reactor in operation, and without the necessity of bringing the charging equipment near the core. This would result in their activation.

Rotating covers. The upper shield of the reactor is the water located above the fuel sections and cast iron rotating covers. The concrete shield, in which the reactor tank is mounted, has its top surface faced with rust-proof sheet metal.

A large rotating cover is mounted on ball bearings in the center above the tank, and a smaller cover, also on ball bearings, is mounted off center in the larger one. There a number of manipulator holes closed by plugs in both covers.

The covers and plugs give the layer of 80 cm of iron an equivalent "biological" shield. Rotation of the covers and their position are observed on corresponding dials.

Also mounted on the covers is a container with its own winch and bucket used for removing the sections and for all operations inside the core (with the reactor shut down). The loading-unloading devices are also used for this purpose.

Loading devices. A pole with a claw gripper or grappler suspended on a portable tension rod is used for loading-unloading work in the channels and core.

The pole is lowered into the channel by means of manually driven rubber rollers, while the clamping claws of the pole are controlled by a bushing inside the pole.

Gripping of the container by the grappler is automatic, while release from the grappler ensues after cutting in of an electromagnet (release mechanism). The grappler works in conjunction with the shield container and the winch mounted on the container. The device is equipped with a system signalling gripping and exit of the grappler into the container.

Observation is conducted with a periscope and lamp illuminating the core during work with the pole or grappler. Observation of the support plate, and thus of the entrances to the channels, is also possible, owing to the mounting of a mirror under the periscope. The mirror is

secured so that it pivots, and is driven by a small electric motor. In its limiting position it shows the core in front of the periscope. While the reactor is in operation, the lamp is lifted upward so that it will not be damaged or activated.

Another instrument is used for performing most of the loading-unloading work in the horizontal channels. The instrument is set coaxially through the channel.

To facilitate setting of the loading device, its front claw rests on the plate of the channel. Only one support, regulated according to the readings of a gage, is used for levelling. A pole, at the end of which an open gripper is mounted, runs through the bed of the device. The pole may be shifted manually by means of a crank or mechanically by means of an electric drive (also remote controlled) to any depth in the channel. The latter case involves the operation of limit switches which limit the displacement of the pole.

A container provided with two gates set on the device and with their faces fitting against the channel works in conjunction with the device. After first opening the two gates of the container, we introduce the head with the target material into the center of the container from the channel and leave it in the center. After removal of the pole and closing of both gates, the head remains in the center. In addition to the small devices for work at a distance, such as grapplers, grippers, claws, and manipulators of different types, the reactor also has a ten-ton crane which may be controlled from a special station protected by a thick shield and having an observation port of lead glass.

The shelter designed for fuel storage is located in the vicinity of the reactor and connected to it by a slanting shielded transfer tube. The shelter is located under the level of the floor and covered with cast iron plates with handling plugs. It is sheathed in concrete and made in the form of two tanks, the inner one of an aluminum alloy and the outer one of acid-resistant steel.

The shelter is filled with distilled water, which represents its shield. A receptacle into which sections are lowered is built into the inner tank. Sockets into which the fuel is inserted are secured on the bottom of the tank. If the need arises to unload the core, a full fuel unit from the reactor may be inserted in the shelter. Manipulations in the shelter are carried out with the aid of a winch with a bucket, dredges, and a lamp.

Primary water circuit. About $900 \text{ m}^3/\text{hour}$ of cooling water are required in the reactor when working at full power. The average water temperature in the core is 33°C , and the temperature increase in the core 2°C . Water is drawn in by two of the five centrifugal pumps at the pump station installed in the basement (three of the pumps being held in reserve.) The pumps are made of acid-resistant steels; they have special seals which prevent leakage. The water from the pumps is forced through the heat exchangers into the reactor tank.

The temperature of the pump bearings and any leaks are signalled at the main control post. The pumps and valves on the delivery pipe may be remote controlled from the control post, where the rate of flow and water temperature are also registered.

There are also auxiliary circuits at the pump station, in addition to the main circuit. About 200 cubic meters per hour of water is directed to the degasifier after passing through the exchangers. The oxygen and hydrogen (detonating gas) arising as a result of radiolysis are removed from the water in the former by air purging.

Whenever it becomes necessary, because of high activity of the impurities in the water, an ion-exchange filter, which passes about 10 cubic meters per hour of water, is connected in the water circuit. The filter is located in a shield consisting of cast iron rings and is dismantled if necessary together with the shield. Also installed at the pump station is a measuring vessel used for measurement of the activity of the water washing the section under study.

The piping is made of two materials. The sections connected to the reactor are made of an aluminum alloy, and the remainder of acid-resistant (austenitic) steel. All valves are also made of acid-resistant steel. At the joints of the two types of materials there are inserts of an aluminum alloy which are provided for replacement.

The reactor, degasifier, and shelter have down and overflow pipes connected to a common special drainage system. All these tanks, as well as the exchangers and filters, are protected by baths with drains against possible leakage.

The pump station room is sealed off by thick sealed steel doors, and the walls are made of heavy concrete. The devices which control the manual valves and drives of the mechanical valves are located in passages adjoining the pump station, as a result of which the operator is protected against radiation by the thick concrete wall.

All contact between the water and the atmosphere is prevented by special seals and filters. A water purity ranging from 2 to 6 mg/l (permanent contaminants) is generally achieved. In addition to activation of the contaminants, short-lived oxygen activity of the water also occurs while the reactor is in operation. The (active) nitrogen isotope deriving from the oxygen decays rapidly if it has no permanent activated contaminants. The pump station may be entered several minutes after the reactor is shut down.

Auxiliary Technological Devices

A secondary circuit with an output of about 350 m³/hour of water is used for cooling the primary water. The secondary water is cooled in a basin by the use of spray nozzles. The graphite disks of the thermal column are cooled by an independent water circuit.

A special drainage system connected to storage tanks is provided in the installation for all radioactive liquid waste. The tanks, which have a capacity of 300 m³ each, are made of sheet metal plated with acid-resistant metal sheeting.

A "burial ground," made in the form of several tanks of acid-resistant sheet metal sheathed in concrete, is used for the storage of permanent waste. The openings of the tanks are closed with thick sealed plugs.

The ventilation system in the building ensures heating and replacement of the air in the rooms. The basic function of the ventilation is to create circulation of air from clean rooms to rooms in which active contaminants may appear and in which filters are installed.

Hot Cells

The hot cells represent a set of rooms and devices making it possible to carry out activities with highly active objects. The design and equipment of the cells permit prepacking, distribution, and control measurements of active materials. With the installation of other devices, it is possible to carry out other work, such as processing of target material.

The hot cells are located in the basement of the reactor building (Figure 7). The area of the cells is divided into three isolated zones. The operators' rooms (clean part) are situated parallel with the cells. At the end of the corridor connecting these rooms is the exit of the conveyor which makes communication between the cells possible.

On the other side of the cells is the so-called repair corridor. This area of the hot cells is counted among the "dirty" ones, and together with certain technological rooms of the reactor is separated from the others by special sanitation compartments and a dosimetric lock. Also located in this corridor is the reception point for active materials, from which irradiated materials are also dispatched. The control rooms have no open connection with the cells and dirty part.

The operations in the cells are carried out at a distance and observed through an observation port (Figures 8 and 9). All passages in the walls are sealed, and the pipe culverts are arched. The only connection among the cells is the through conveyor with two branches which connect the cells with each other and with the clean space. The tray of the right branch is used for loading. After introduction of the conveyor into the channel, a heavy cast iron block is lowered which protects against direct clearance along the channel.

Each of the cells is connected with the repair corridor by an entrance protected by heavy iron shield doors (Figure 10). The doors are sealed with rubber. The cell is separated from the conveyor channel by small leakproof doors, this preventing contamination of the conveyor and channel and transmission of dust from one cell to the other.

There is also in the first hot cell another movable shield block which closes the exit to the transfer hole (similar to the one located on the side of the clean channel). In the fourth cell is an unloading and receiving port closed by shield doors through which the drawer of the receiving (transfer) container is introduced.

A number of closed ports intended for maintenance of the lighting installed above the leakproof glass partition of the cell lead from the repair corridor to the space separated by the glass partition.

The operator is separated from the cell by a cast iron shield wall which at the center is 45 cm thick for the first cell and 38 cm for the one further on. Manipulator holes and an observation port of lead glass are located in this plate. The cast iron plate located in the center of the wall is sheathed in heavy concrete. The cells are also partitioned off by a layer of concrete.

Penetration by dust is prevented by seals and the ventilation system, which establishes the appropriate ranges of pressure and direction of the movement of air to the dirtiest rooms, that is, into the interior of the cells. All the cells are lined with polished acid-resistant steel. The structural elements built into the cell are made of the same steel.

Each of the cells has an observation port with a wiper actuated in the control room, two manipulators (Figure 11) with a set of replaceable tools (the first cell has the most versatile equipment), an ionization chamber, gas, water, and compressed air feeds, hot water and washing solution feed, reserve pipe feed lines, a power supply cabinet with connectors for 330/220 and 220/127 volts alternating current and 48 and 6 volts direct current, and a filter for the air taken in from the cell (two larger filters in the first cell).

In addition, there are reserve channels in the partition on the operator's side. All the cells have drain pipes and are connected to a special drainage system.

The largest cell, cell I, has the widest range of potential uses. This cell receives the active materials from the reactor (the sloping channel through which the containers are dropped leads to it). Removal of the target material and any necessary storage and unloading are carried out in it.

Cell I is equipped with additional devices, a shaping tool, a small crane, and a shelter with a winch.

The shaping tool is made of acid-resistant and rust-proof materials. The target cutter is mounted in a rotating head which may be fed longitudinally, laterally, and vertically. The shaping tool has six feeds ranging from 0.5 to 16 mm/min and spindle speeds varying automatically from 10 to 200 rpm. The object to be machined is secured in a self-centering double-jawed tool which may be driven at six rotary speeds from 0.1 to 0.24 rpm. The shaping tool may be used to machine objects having diameters of ϕ 9 to ϕ 40 mm and lengths of up to 140 mm, in cutting up to 600 mm.

Since all the clamping and adjusting bolts are arranged on one plane of the machine which is visible through an observation port, all the adjusting operations can be carried out outside the cell by means of a special jointed manipulator with a socket wrench.

All the drives of the machine are located in the operator's room. Power is transmitted to the mechanisms of the machine by means of articulated joints and shafts running through channels in the wall.

The designers of the shaping tool had additional difficulties connected with the acid resistance (the problem of lubricating and sealing the bearings of the tool), remote control, adjustment and securing of the tools and objects, and drives at a distance.

A small crane having a lifting capacity of 150 kg works with the shaping tool. There are also machine drives outside the cell for lifting, travel of the winch, and rotation of the crane.

There is a shelter built into the floor of the first cell for storing waste and temporarily holding target materials. The shelter is covered with a plate (shield) on which small racks are suspended. A special winch, also driven from outside, is installed in the cell for lifting the plate.

Cells II and III are designed for diversified activities. Cell IV is the shipping cell, as a rule clean, where measurements and packing prior to shipment are carried out. Access to the area of the hot cells may be gained from the "dirty" side after passage through the auxiliary rooms (dressing rooms and decontamination chambers).

FIGURE APPENDIX

Figure 1. not reproducible⁷

figure 1. Overall view of reactor and part of hall.

- . movable water wall
- . Neutron trap set through channel
- . Shield wall of asphalt-iron brick (movable shield)
- . Entrance to channel (gate mechanisms visible)
- . Neutron spectrometer
- . Rotating covers
- . Periscope
- . Loading mechanism for vertical channels in position of rest
- . One of air intake points
- . Ionization chamber and signal indicator

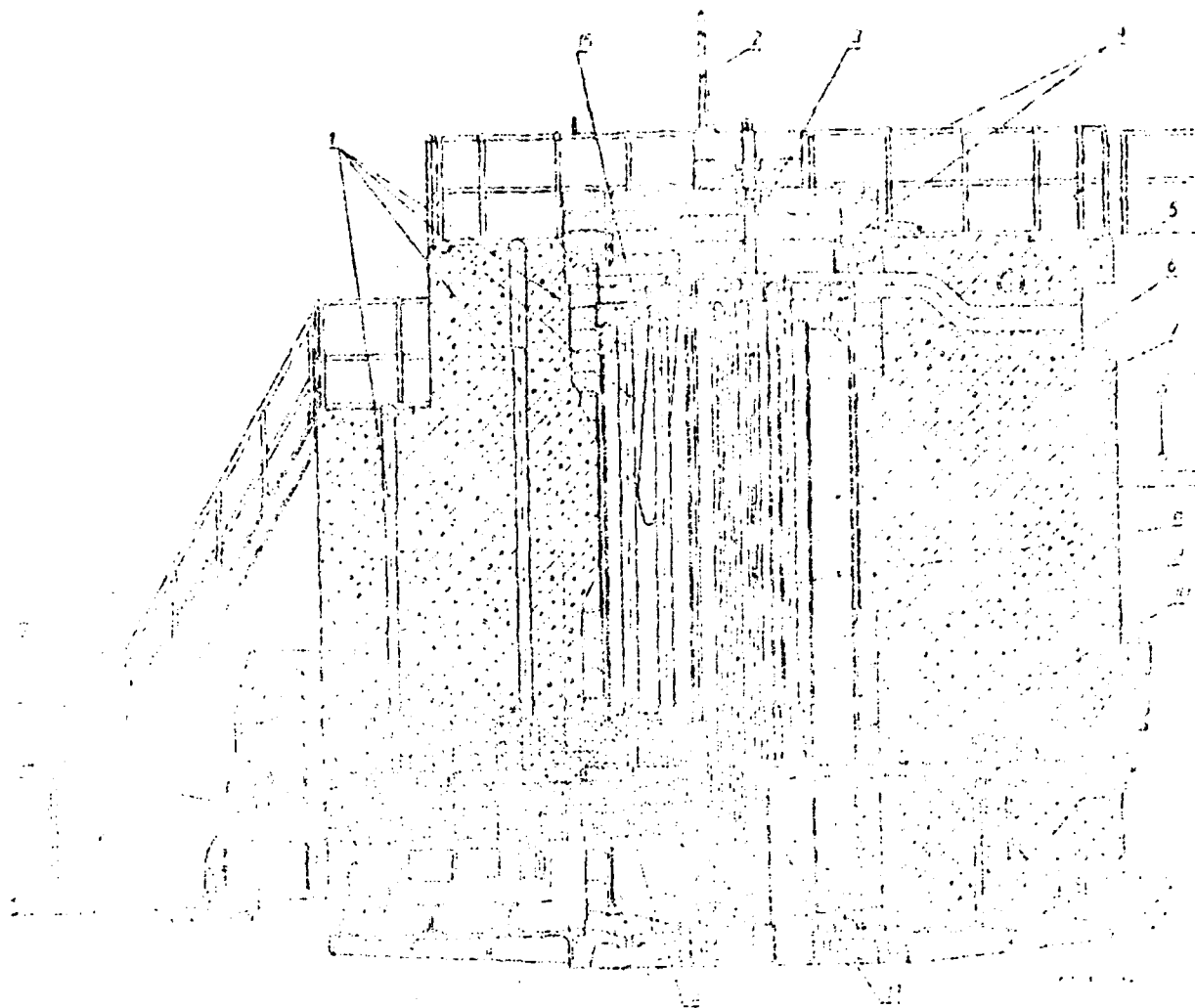


Figure 2. Vertical section of reactor

1. Dry vertical channels of thermal column
2. Periscope
3. Drive disks of regulating and safety rods
4. Rotary covers with central manipulator hole
5. Cast iron shields
6. Heavy concrete shield
7. Water shield
8. Outer tank
9. Channels of regulating and safety rods
10. Horizontal channel with gate
11. Separator (core)
12. Thermal column
13. Gate of horizontal thermal column channel
14. Noses for cooling thermal column
15. Thermal column shield
16. Support plate

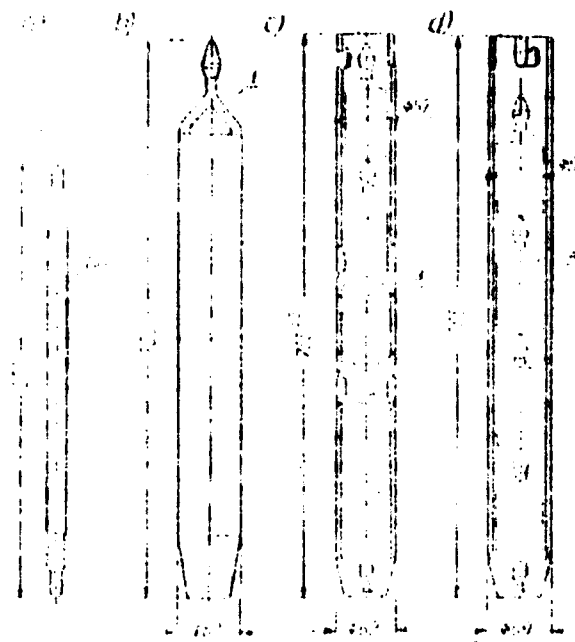


Figure 3. (a) Fuel rod. (b) Fuel section. (c) Filler with air cushion. (d) Filler without air cushion. (1) Grip of section. (2) Casing of section. (3) Air cushion of filler. (4) Containers with target material. (x) plane of symmetry of core.

Figure 4. ~~Figure 4. not reproducible~~

Separator without fuel sections and regulating and safety rod channels. 1. Sockets of fuel sections, limited by strap plates of separator. 2. Long isotope channels. 3. Short irradiation channel. 4. Short isotope channels. 5. Sockets of regulating and safety rod channels. 6. Replaceable liners for regulation of discharge of water through sections located in bottom of separator. 7. Outer wall of separator.

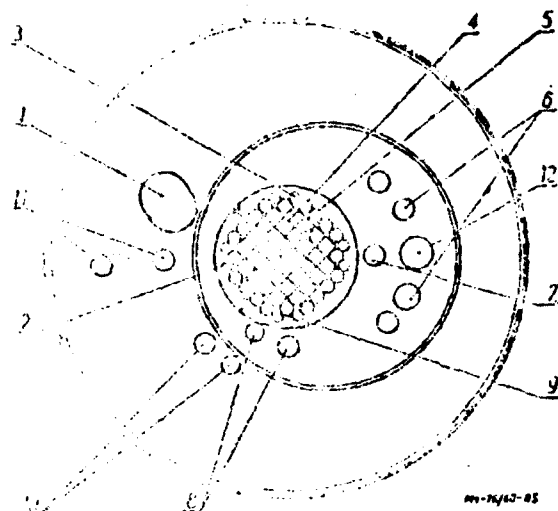


Figure 5. Arrangement of channels and ports in core and tank.

1. Sloping transfer hole for fuel sections, leading to shelter.
2. Regulating and safety rod channels (9 in all), arranged to form a cross.
3. Isotope (wet) channels, 8 in number, located at the corners.
4. Fuel sections.
5. Fillers located at edge of core.
6. Initial loading channels.
7. Manipulator holes; one larger one for container bucket.
8. Additional channels for research and irradiation.
9. Short irradiation channel.
10. Vertical channels of thermal column.
11. Vessel used in conjunction with container.

Figure 6. not reprinted

Figure 6. Section of support structure and core during removal of
and after installation.

1. Shielding transfer with shielding in position
2. Shielding and boxes of shielding and safety rods shielded in
position.
3. In position shielding rods
4. Fuel rods
5. Shielding
6. Shielding rods
7. Shielding channels
8. Shielding channels
9. Shielding rods
10. Shielding channels
11. Shielding rods
12. Storage for shielding containers in support cover
13. Drives of shielding rods

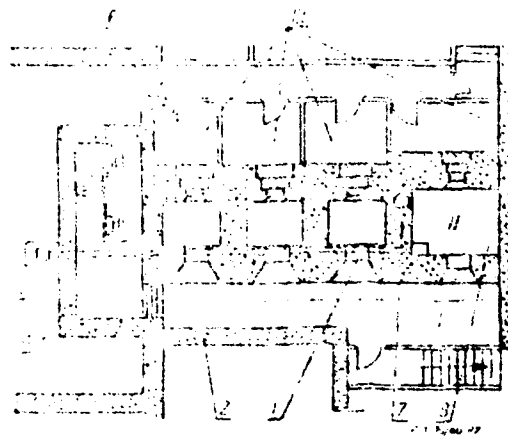


Figure 7. Arrangement of hot cells.

1. Repair corridor (dirty zone). II. Hot cells (first cell).
- III. Control rooms
1. Conveyor channel. 2. Iron door. 3. Dispatch cabinet - clean tray of conveyor. 4. Place for setting horizontal transfer container. 5. Unloading port from fourth cell. 6. Observation port of lead glass. 7. Transfer port from hall to first cell. 8. Point of receipt of container ejected from reactor.

/Figure 8. not reproducible/

Figure 8. View of cell through observation port.

1. Protective cabinet with electrical connections. 2. Manipulator.
3. Leakproof door to repair corridor. 4. Port for conveyor.
5. Connection with special drainage system. 6. Conveyor with replaceable manipulator tools.

/Figure 9. not reproducible/

Figure 9. View of hot cell through door to repair corridor.

/Figure 10. not reproducible/

Figure 10.

1. Ionization chamber. 2. Point for taking air specimens. 3. Filters from air specimen installation. 4. Signal indicators. 5. Shield door for illuminating cell. 6. External filter of hot cells, for purifying air drawn in. 7. Shield door to cell.

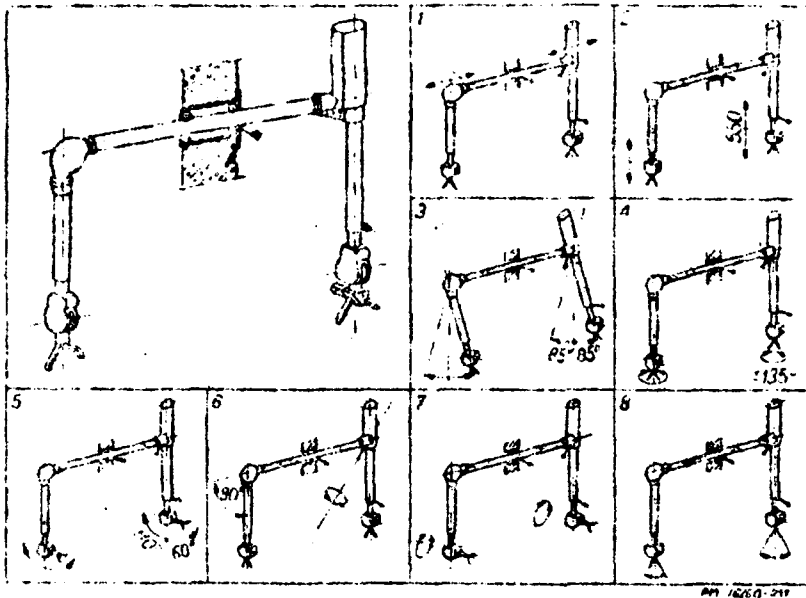


Figure 11. Possible operating motions of manipulators.

1. Longitudinal motion. 2. Up-down motion. 3. Swings to sides.
4. Rotation of tool about vertical axis. 5. Swing of tool to side.
6. Forward swing (drop) of shoulder of tool. 7. Rotation of tool about horizontal axis. 8. Squeeze motion of tool.

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- END -