



THE BRAZILIAN RESEARCH REACTOR

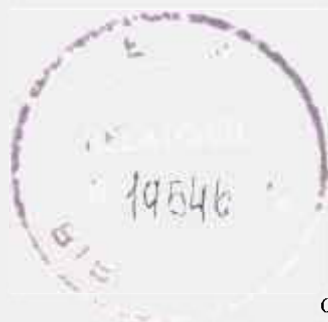
O REATOR DE PESQUISAS BRASILEIRO

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The Brazilian Research Reactor

By M. Damy de Souza Santos and P. Saraiva de Toledo *

The reactor installed at the Institute of Atomic Energy is a swimming pool reactor¹⁻³ designed and built by the Babcock & Wilcox Co., according to specifications furnished by the Comissão de Energia Atômica of the Conselho Nacional de Pesquisas. The reactor is very similar in design to the one which was built by the same company for the University of Michigan: the main differences lie in the alterations which have been introduced in the fuel element design, cooling system, and in the pool dimensions in order to allow continuous operation at a level of 5 Mw.

The important reactor data are tabulated below as furnished by the manufacturer:

Core array = 5 × 5 (H₂O moderated and reflected)

Effective area per element = 8.09625 cm × 7.77875 cm = 62.9787 cm²

Core height = 60 cm

Core volume = 94,468 cm³

U-Al alloy = 11,170 cm³

Aluminum = 23,256 cm³

Water = 60,042 cm³

Volume fractions

Uranium = 0.01036

Aluminum = 0.35406

Water = 0.63558

Element loading

Standard (19 plate) = 160 g U²³⁵, 640 g U²³⁸

Control (9 plate) = 76 g U²³⁵, 304 g U²³⁸

Metal to water ratio

Standard element = 0.59028

Control element = 0.49011

Over-all = 0.57425

Core loading = 3660 g

LOCATION

The reactor was installed in an explosion proof, gas-tight building located at the University City in the

city of São Paulo, in the center of an exclusion area of 320 meters of radius. The University City is located on the northwest border of the city; most of its area is flat and it slopes up at a distance of about 5000 feet from one of the River Pinheiros margins. The flat surface is at a height of about 730 meters above sea level whereas the maximum height of the slopes is 780 meters.

Before deciding on the convenience of locating the reactor at the University City, a study of the possible hazards from the installation was carefully made. The geology of the region and a study of the meteorological conditions, wind distribution and possible contamination of underground water were taken into consideration. In the whole area of São Paulo there are no signs of any movement of tectonic origin and there are no indications of earthquakes.

The building which houses the reactor (Fig. 1) was built by a Brazilian engineering firm in five and a half months: it is a gas-tight, reinforced concrete structure with an internal area of about 2000 m² in which 1600 m³ of concrete were used. Its design was based on the University of Michigan reactor building but there are several important differences which will be described in the following paragraphs.

Since the reactor pool is ten meters high and since the reactor was provided with beam holes and a thermal column (Fig. 2), the pool was designed to be located inside a building 24 meters high provided with a basement and three floors.

BASEMENT

The bottom of the pool is at the basement level and is made up of a large reinforced concrete block 2 meters thick. Through the bottom of the pool run the main primary cooling water stainless steel pipes which are connected to the primary of a 5 megawatt heat exchanger, through a 3600 gpm pump. The heat exchanger, the primary system for water treatment and the equipment for the demineralization of the pool water by continuous circulation through a mixed bed of ion exchange resins are also located in the basement with all the auxiliary equipment such as pumps, stainless steel pipes, etc. A radioactive sump and a radioactive retention tank for radioactive wastes are also located in the same room (Fig. 3).

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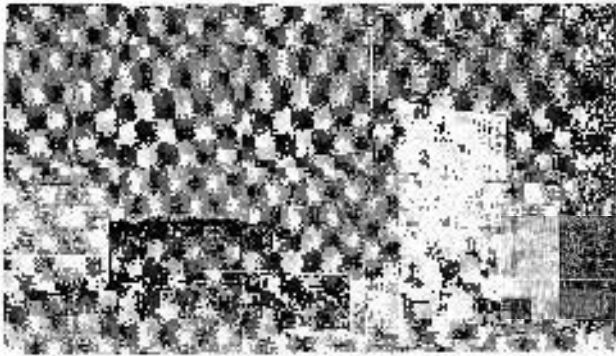


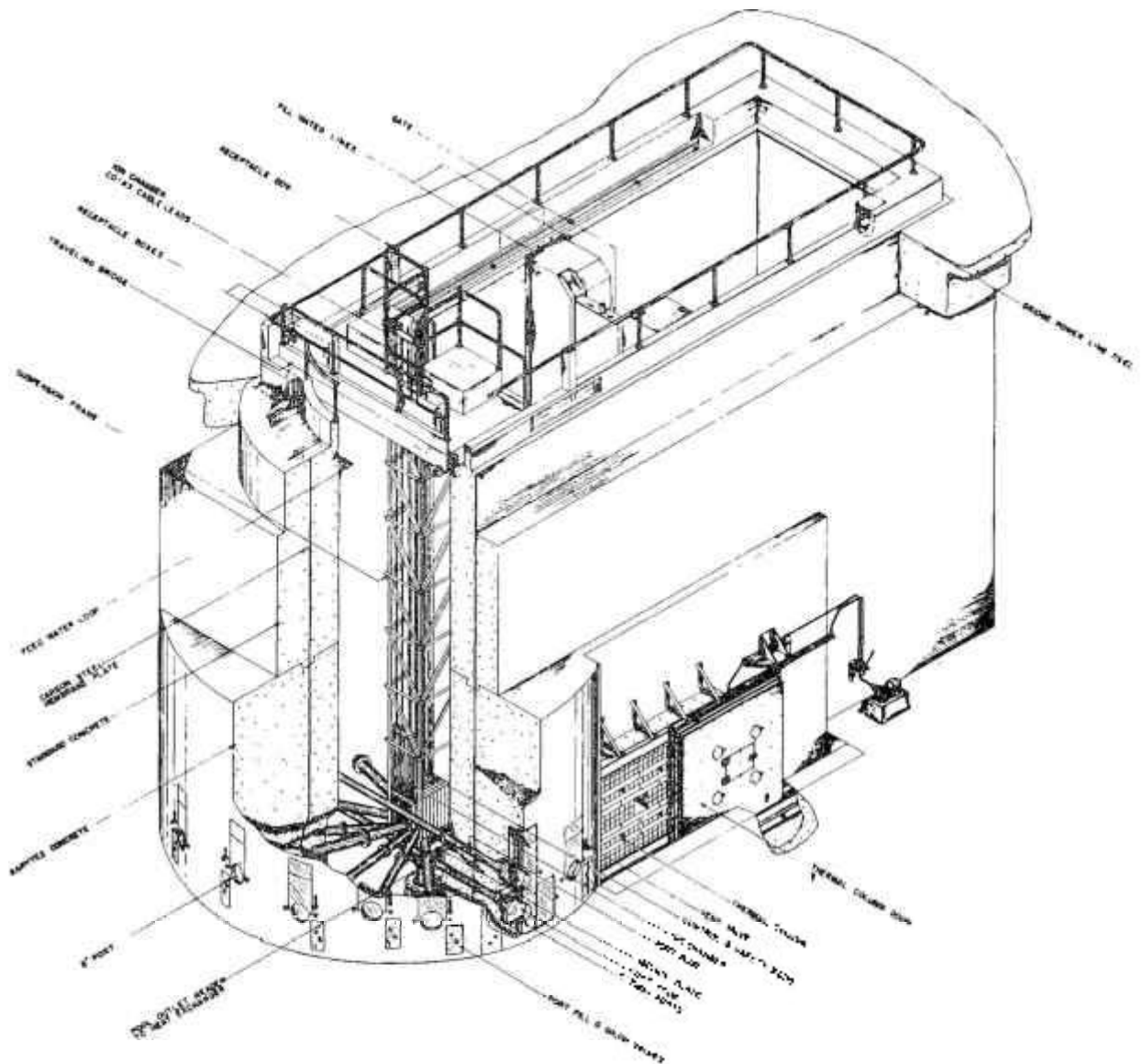
Figure 1

Since the reactor was equipped with a pneumatic rabbit installation, its blower and associated electro-mechanical equipment were also placed in the basement. Movable barytes concrete blocks provide an efficient shield against the radiations from the prim-

ary circulating water (where the activities due to N^{16} and Na^{24} would constitute a health hazard at a high power level operation) and the radioactive demineralizer active carbon and mixed ion exchange resin beds. The basement door is interlocked with the safety rods magnet power.

GROUND FLOOR

The ground floor has an area of 700 square meters; there is ample space around the reactor 14 beam hole doors and thermal column for experiments (Fig. 4). The distance between the beam holes and the wall is 20 meters in order to allow the location of a fast chopper, a slow chopper and equipment for time-of-flight experiments. A flat ground surface extending to 100 meters from the reactor core center was provided for time-of-flight experiments and 6-in. and 8-in. pipes in the appropriate directions were inserted in the south building wall in order to provide a suitable path for the neutron chopped beam.



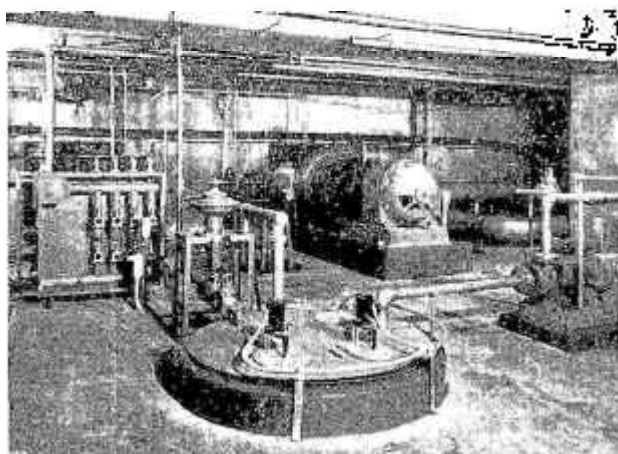


Figure 3

The pool is ten meters high and its top reaches the level of the third floor. It has a capacity of 272 cubic meters of water, and in its construction 350 cubic meters of concrete and 270 cubic meters of barytes concrete, of a density higher than 3.5 g/cm^3 , were required; in order to avoid a possible water leakage through the concrete, a steel diaphragm was constructed, tested for water tightness and then the concrete was poured on both sides.

In the region occupied by the beam holes and the thermal column the pool walls are 2.40 meters thick in order to provide adequate shielding and keep the radiation level below tolerance, even when the reactor is operated at its maximum power (5 Mw).

The reactor can be operated in three distinct positions in the pool:

(a) In the first position (position A, Figs. 5, 6, 7) its core is located at the center of the cylindrical part of the pool; six 6-in. and two 8-in. beam holes are directed towards the reactor core center and two 6-in. through-tubes traverse the pool tangentially to the reactor core south face. There are several kinds of irradiation plugs for the said beam holes which will allow irradiation of samples or the collimation of a neutron beam for beam experiments.

The unused plugs are kept in storage tubes inserted in the cast building wall. There are fifty stainless steel storage tubes in that wall; they are 3.50 meters long, traverse the wall and have their back extremities inserted in a concrete block covered with 4 meters of clay. The back ends of those storage tubes are individually connected to a manifold exhaust system. This system is provided with individual stopcocks for gas sampling and the system is connected to the laboratory radioactive exhaust system. The gases are expelled through a stack 15 meters high situated at the top of the building.

The stack is provided with a Cambridge filter which will avoid the dispersal of the radioactive particulate in the area surrounding the reactor. A system of beta and gamma Geiger counters is connected to a count rate meter whose indication is displayed on an Esterline Angus recorder in the control room cubicle.

The stack is provided also with a damper, controlled by a servo motor, which will close automatically the stack whenever the radiation level will exceed a pre-determined value.

(b) In a second position (position B, Fig. 5), the reactor core can be operated in front of a thermal column for experiments with thermal neutrons. The thermal column is made up of graphite blocks placed inside a rectangular steel box of 1.80 by 2.40 meters; it is provided with six channels of removable graphite blocks for experiments involving different values of the cadmium ratio. The thermal column is shielded by a 16-ton door 12 $\frac{3}{4}$ in. thick (consisting of 11 in. of steel plates, 1 in. lead and $\frac{1}{4}$ in. boral plates). The thermal column door can be displaced on rails by means of an hydraulic system operated by an electric pump.

When the reactor is in the thermal column position, fast neutron irradiation can be obtained by use of two 6-in. beam holes, located at 180° from the thermal column. The maximum operating power of the reactor at the position B is 100 kw; at this power level the reactor does not require forced cooling and the heat developed by radiation at the thermal column will not give rise to a high temperature in the graphite blocks.

(c) The reactor can also be displaced to a third position (position C, Fig. 5) in the back of the pool where spent fuel elements are stored. This back compartment is provided with a storage rack for spent fuel elements and can be used as a gamma irradiation facility, use being made of the radiations from the fission products accumulated in the spent fuel elements. The pool is also provided with a movable aluminum gate so that the reactor can be stored in the back compartment whenever a repair in the main pool compartment is required.

The back compartment can be used as a bulk shielding facility.

SECOND FLOOR

On the second floor are located three offices, a small storage room, the sanitary rooms, and a large machinery room where all the ventilating and conditioning air systems are located.

Since the building does not have any windows, all the rooms are air conditioned; there are two ventilating systems besides the main air conditioning system.



Figure 4

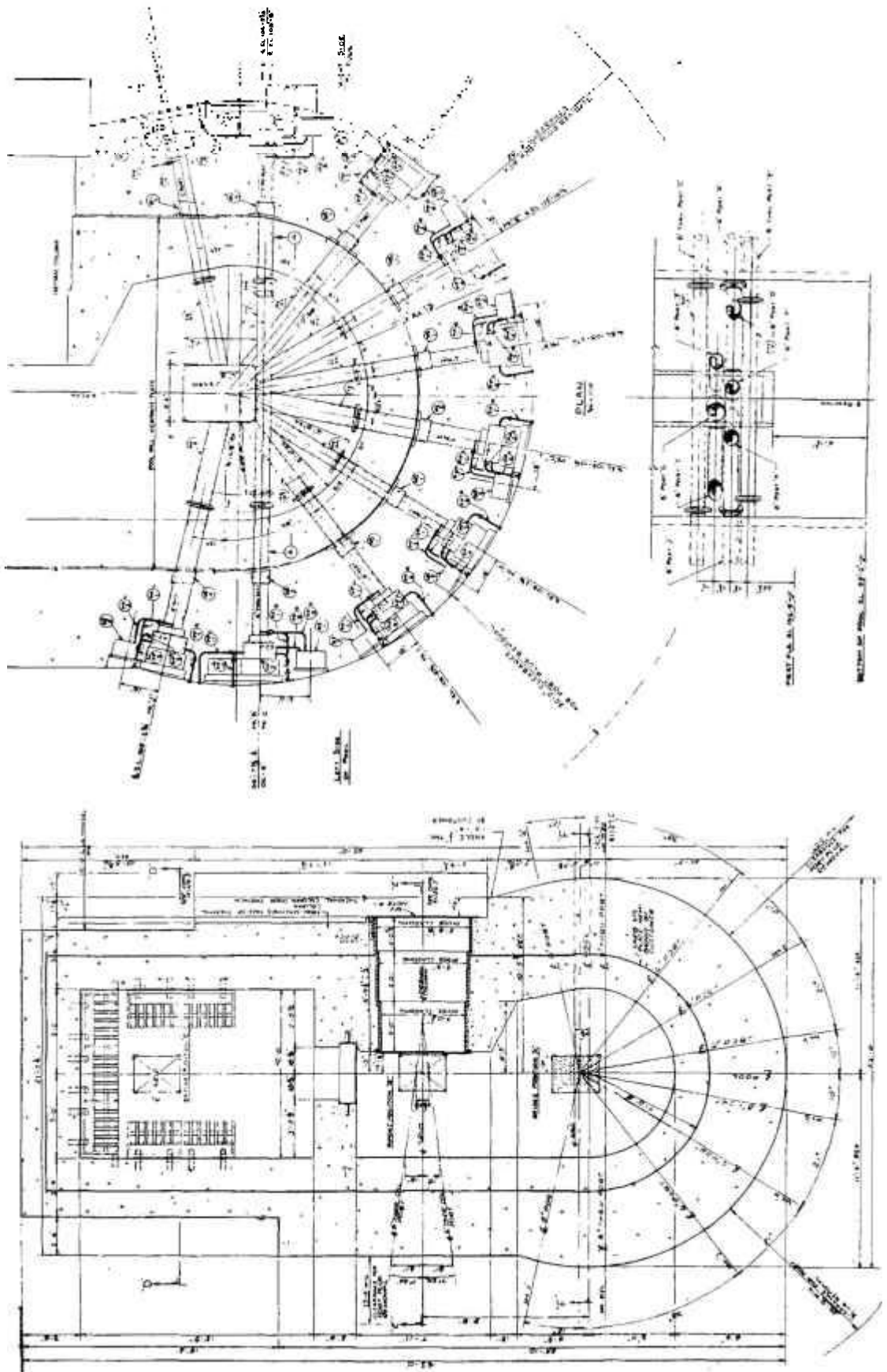


Figure 5

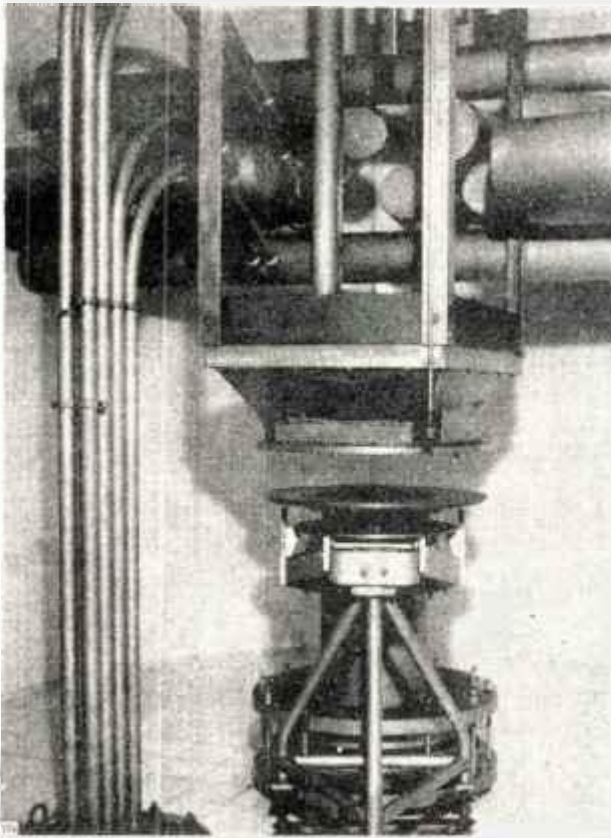


Figure 6

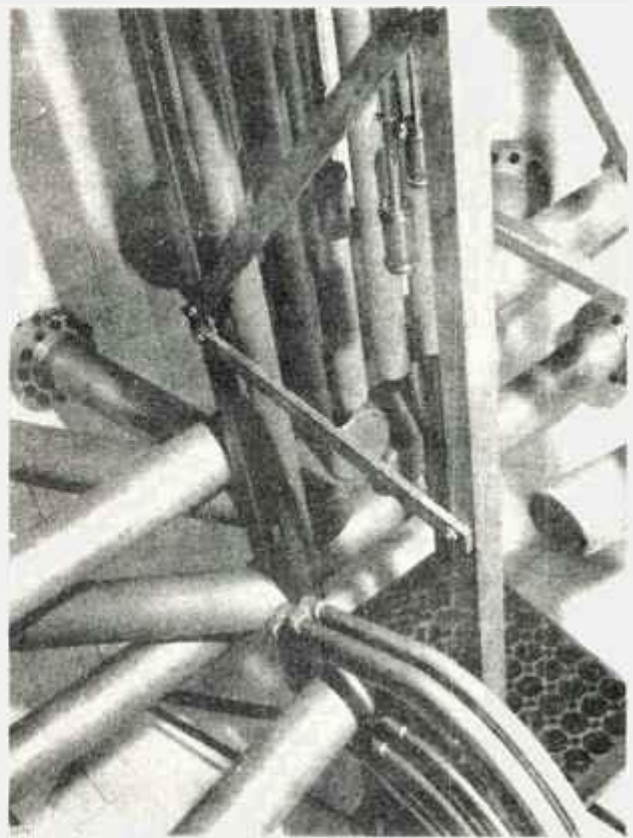


Figure 7

The air conditioning system supplies air at a predetermined temperature and humidity to all the laboratories, reactor control room and the ground floor.

An exhaust system is used for the sanitary rooms and another to suck the contaminated air from storage tubes, from the beam hole doors and from the radiochemistry laboratory hood located on the third floor. In the radioactive exhaust system Cambridge filters are provided in order to avoid contamination of the area around the reactor building by radioactive particulate expelled through the stack. All three systems are equipped with dampers controlled by electromagnetic devices operated by radiation level monitors which will close the air outlet whenever the radiation level reaches a predetermined value.

Special care was taken with the safety devices to avoid the contamination of the surrounding area in case of an accident: all the external doors are made of steel and calculated to withstand a pressure of 500 kg m^2 , and to avoid any gas leakage special neoprene gaskets are used. Special devices are used to avoid gas leakage through either the air, water, sewage or electricity systems.

THIRD FLOOR

On the third floor are located three radiochemistry laboratories, the reactor control room, a small electronic shop for the maintenance of the reactor instrumentation and spares and a vault for storing unused fuel elements. The top of the pool reaches the

third floor and the water surface is at the level of the floor (Fig. 8); a 10-ton crane is provided for the transportation of the fuel elements from the storage racks at the back compartment of the pool to the reactor core and also for loading and unloading an 8-ton shipping coffin, where spent fuel elements will be stored for shipping after they have cooled down in the storage racks. The crane can unload the coffin on the main operating floor (ground floor) by removing steel gates located on both sides of the pool at the floor level. The crane is also used to move the aluminum gates used for closing the back pool compartment. In the main radiochemistry laboratory a terminal pneumatic rabbit station is installed in

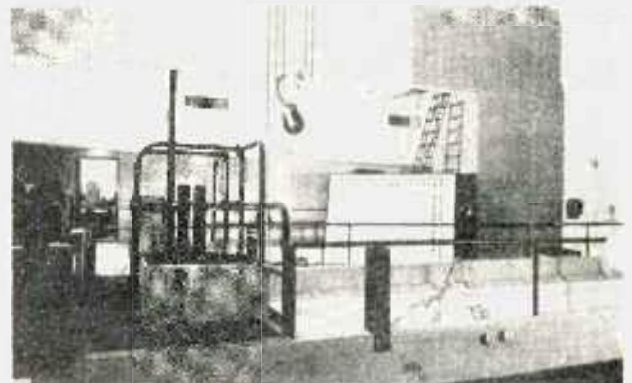


Figure 8

order to allow measurements of activated samples two seconds after the end of the irradiation time.

The reactor control room is also installed on the third floor on the same level as the reactor bridge (Fig. 8). Besides the reactor control system there is some auxiliary equipment which allows the centralization of all the operations and the supervision of the safety conditions. In this way, any alarm due to excessive radiation level, pump failure, abnormal temperatures or fire is directly reported to the control room. There is a system of communication with all the rooms of the building and an alarm system which permits the transmission of orders and instructions to any room inside the reactor building.

ACKNOWLEDGEMENTS

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We want also to express our appreciation for the continuous assistance and interest of Mr. H. Martins de Oliveira and Mr. C. Engel, during the construction of the building.

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