RADIATION INTENSITY LEVELS AND AIR AND WATER ACTIVITIES OBSERVED WITH THE IEAR-1 SWIMMING POOL REACTOR AT 5 Mw

NÍVEIS DE RADIAÇÃO E ATIVIDADES OBSERVADAS NO AR E NA ÁGUA DURANTE A OPERAÇÃO DO REATOR DE PISCINA IEAR-1 NA POTÊNCIA DE 5 Mw

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Radiation Intensity Levels and Air and Water Activities Observed with the IEAR-1 Swimming Pool Reactor at 5 Mw

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Preliminary results of the radiation levels observed during the operation of the Brazilian IEAR-1 swimming pool reactor at power levels of 1, 2.5 and 5 Mw are described.

The details of the reactor and its building have been described in another paper.[1] The reactor shielding consists of light water and barytes concrete and was designed to reduce the radiation level to 1 mr/hr in all the working areas and to 3.75 mr/hr at the surface of the pool above the core when the reactor is operated at 5 Mw.

The pool is thirty feet deep and the side walls, at the first floor level, are constituted of eight feet of barytes concrete of a density higher than 3.5 g/cm^3 plus 4.5 feet of water in the radial direction at the core level. Most of the activity found in water for powers smaller than about 1 Mw is due to N^{16} formed by a (n, p) reaction in O^{16}. Due to the short half-life (7.3 sec) of this isotope its activity can be prevented from contributing greatly to the dose at the surface by using a long return path for the water leaving the core. The installation of a retention tank was considered, but was later discarded in favour of a different system which should be more efficient. Such a system consists of spraying hot water on the pool surface in order to form a hot water cushion of about two feet thickness above the pool circulating water. Such a system should also be very efficient for decreasing the activities due to Na^{24}, fission products and other impurities existing in water, which could be activated either by fast or slow neutron irradiation.

RADIATION LEVELS AT HIGH POWER OPERATION

Results at 1 Mw Level

With the core arrangement described in another paper[2] the power was raised in hundred kilowatt steps until a power level of 1 Mw was attained. A complete survey of the radiation levels in the interior of the building was made and the air activities were measured by means of Milipore filters and a MAP-1 air particulate detector. The activities from the filters were measured by means of a Geiger counter, a scintillation counter and a scintillation spectrometer. Water samples from the pool water were measured by means of a well crystal scintillometer. During these measurements the reactor power, at the different power level steps, was kept constant. Up to power levels of the order of 500 kw the radiation level in the building and at the pool surface was within the tolerance level. The gamma-ray dose at the surface of the pool was found to be 0.75 mr/hr.

A survey was made in the basement with the following results: input to the heat exchanger 400 mr/hr; main pool water circulating inlet 200 mr/hr. The neutron level observed at the bottom of the pool in a position adjacent to the primary circulating water pipe was 1.5 mrep/hr (fast) and 5 nv (thermal). The radiation level in the basement room averaged 10 mr/hr.

At 1 Mw power level the radiation intensity on the pool surface was found to be a maximum in the neighbourhood of the position corresponding to the thermal column, where it was found to be 10 mr/hr; this intensity was higher than the one observed at the bridge position and was due to a large turbulence produced by the water returning from the heat exchanger. Under the bridge the radiation level was 5 mr/hr and on the bridge it was smaller than 1 mr/hr. At the pool side rails the gamma activity was found to be smaller than 1 mr/hr.

The instantaneous air-borne particulate activity as measured after one hour of continuous operation of the air pumps at 1.4 ft^3/min was 2500 c/min. This activity is higher than the background and the same increasing activity was found with the MAP-1. The water activity, as measured in a well scintillator with a 3 cm^3 water sample, was found to be 1700 c/min. In the control room the radiation level was slightly

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higher than background whereas the particulate air activity was within tolerance.

On the ground floor the radiation intensities were found to be below tolerance level with the exception of the area in the neighbourhood of the beam hole A where the gamma radiation intensity was 1.5 mr/hr and the fast neutron intensity about 2 *nv* with a thermal neutron level about five times higher than the fast level. Such an intensity was found to be due to a faulty beam hole plug which produced a stream of neutrons and gamma rays over an area of about 5 cm^2. It was definitely not due to irregularities in the concrete. The beam hole plug is being repaired.

The radiation intensities were also measured in the basement. When these measurements were made, the primary water piping, the heat exchanger and the radioactive ion column were not protected by barytes concrete blocks and, therefore, the radiation levels were fairly high: heat exchanger water inlet: 850 mr/hr; outlet: 350 mr; radioactive ion exchange resin beds: 80 mr/hr. The average value in the basement was about 40 mr/hr. The thermal neutron intensity near the heat exchanger was about 25 *nv* and the fast neutron level was below tolerance.

The efficiency of the radioactive ion exchange resin bed was tested and it was found that whilst the activity of the water entering the system had an intensity of 690 c/min the water leaving the system had an activity of 80 c/min.

The observed activities in the pool water decreased rather rapidly and, after the third day, they were below 10 c/min above background.

Results at 2 Mw Level

The results obtained at 1 Mw power level which were quoted above have been confirmed by a new series of experiments to test the reactor behaviour at 2.5 Mw. The reactor power was raised steadily until the 1 Mw power was attained and kept at that value for two hours during which a complete survey of the radiation levels was made leading essentially to the same results which have been found in the previous experiments.

At a power level of 2.5 Mw, the radiation level at the pool surface was found to be 35 mr/hr near the thermal column position whereas its intensity under the bridge was only 6 mr/hr. This large difference in intensity is due to the contribution of the N^{16} gamma radiation from the returning primary circulation water which reaches the pool surface rapidly owing to water turbulence. The air activity, as measured with a Milipore filter under the same conditions as in the previous experiments, was 16,500 c/min (instantaneous), whereas the water pool activity as measured with the well scintillator counter was 30,000 c/min.

On the ground floor, the radiation level was within tolerance with the exception of the area around the beam hole A, where the irregularities of the plug resulted in a gamma intensity of 4 mr/hr and a neutron level of 100 *nv* (thermal) and 30 *nv* (fast).

In the basement the gamma activity reached the values of 3 r/hr in the heat exchanger water inlet and 1.2 r/hr in the outlet. In the resin beds the activity level observed was 50 mr/hr whereas the average intensity in the basement was 100 mr/hr. Such a high level is, of course, due to the absence of any shielding blocks during the experiments. Thirty minutes after shutdown the gamma activity in the heat exchanger water inlet was 2 mr/hr.

Results at 5 Mw Level

In the preliminary survey at a power level of 5 Mw, the reactor was brought up to full power after keeping the power level steady for about one hour at 1 and 2.5 Mw. The results obtained at these power levels were in agreement with the previous values found in the experiments described above.

At the 5 Mw power level successive surveys have shown that the radiation levels were increasing with time and only reached a steady value after about two hours of continuous operation. After this steady state was reached, the activity on the pool surface was found to be 250 mr/hr whereas at the pool sides it was 80 mr/hr. At a distance of about 2 metres from the pool edges the radiation was 3 mr/hr.

The air activity, as measured with Milipore filters and the MAP-1 air-borne monitor, has shown that the particulate activity was about 3 times higher than tolerance level; in view of this high value of the radiation level, gas masks were worn during the experiment.

On the ground floor the radiation level was 0.5 mr/hr whereas in the region near the beam hole A the gamma radiation intensity was 7.5 mr/hr with a fast and slow neutron flux of 80 *nv* and 300 *nv*, respectively. In all the other beam holes the gamma radiation level was of the order of 1.5 mr/hr at the beam hole doors with a thermal neutron flux of 5 *nv*.

In the basement the radiation levels were very high since no shielding was available at that time; in the heat exchanger water inlet, the gamma intensity was 10 r/hr with 7 r/hr in the output. The thermal neutron flux at the heat exchanger input was 800 *nv* and the average gamma ray intensity in the basement was found to be 0.5 r/hr.

A complete analysis of the nuclides responsible for the high level of activity found in water was carried out by the Radiochemistry Division;[3] special attention was paid to finding out whether some activity in air or water could be due to iodine. This gave negative results. It was found that most of the activity found in water could be ascribed to a decay of the gaseous fission products and their descendants. These experiments have also shown that the fission product activity observed in water was not due to a possible failure of the fuel element cladding.

CONCLUSION

The high level of the radiation in the neighbourhood of the pool surface is due to the turbulence observed in the water arising from a faulty design of the primary water outlet in the base of the pool. The amount of turbulence observed has destroyed the hot water cushion in about 5 minutes after the start of the main circulation water pump. Since most of the activity was due to N^{16} and in part to Cr^{51} (due to the alodising process used in the fuel elements) it is hoped that the new design which will be used for the water return outlet will provide a steady hot water cushion which will decrease the observed intensities to tolerance level.

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