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Radiation dose level inside the control room of open pool type reactor during emergency situation

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HIGHLIGHTS

- This study calculated the dose rate in the control room due to air contamination.
- The air contamination resulted from fission products release from a degraded core.
- MCNP5 code was used to calculate the dose rate in the control room.
- A suggestion to venting the contaminated air to the environment was studied.
- The suggestion aims to decrease the dose rate in the control room.
- The maximum dose resulting from the venting would locate in a free-inhabitant area.
- The suggestion is adequate.

ABSTRACT

The objective of this paper is to estimate radiation dose level in the control room due to air contamination in the containment of open pool type reactor during emergency situation. A postulated core degradation accident, due to fuel element blockage, causes fission products to release to the reactor containment and then, the ventilation system would convert automatically from the normal situation to the emergency situation to purify the contaminated air by forcing it to pass through a group of filters. The study computed the dose rate in the control room, adjacent to the containment, during the emergency situation. The dose rate level in the control room depends on the degree of the core degradation and so, the maximum dose rate is corresponding to the complete degradation of the core and the minimum dose rate is corresponding to the degradation of one fuel plate. The dose rate in the control room was calculated using MCNP5 code and it ranged from 1.12 to 2.03E-3 Sv/h. The results also show that the dose rate level in the control room would continue having values more than the permissible limit for a long time and so, a suggestion of venting the radioactive isotopes from the containment into the environment was studied to decrease the dose rate level in the control room. The suggestion was possible because the maximum dose, resulting from the contaminated air venting, would fortunately locate in a free-inhabitant area.

1. Introduction

A multi-purpose reactor (MPR) is an open pool type reactor of 22 MW power has two pools; the main pool contain the reactor core, and the auxiliary pool contains the spent fuel storage racks (Abdelhady, 2016). The reactor containment, contents the two pools, is the ultimate barrier between the reactor system and the environment. It is designed to inhibit the spread of radioactive fission products in the event of accidents. It is maintained at sub-atmospheric pressure so that if a leak does develop during normal operation, the flow direction will be into containment, rather than out, to prevent the release of radioactive particles. It is attained by ventilation system which is capable of exhausting air from the building (Abdelhady et al., 2009). The exhaust air is treated by filtration before discharge from a stack at height sufficient to guarantee that the meteorological dispersion will reduce the resulting concentration of radioactive materials to an acceptable limit. The control room in MPR locates adjacent to the reactor containment to enable the operator to observe the events in the containment through a viewing glass window of 3 × 7 m dimensions as shown in Fig. 1 (FSAR: Final Safety Analysis Report of open pool reactor, 2003). Based on the location of the control room, an accidental event in the reactor containment may cause an increase in radiation dose rate in the control room to level more than the permissible limit. Consequently, it obliges the operator on duty to decrease the time of attendance in the control room or to move to the secondary control room depending on the radiation dose level.

One of the accidental events must be studied to determine its radiological effect in the control room is the accidental release of radioactive isotopes from the core into the containment of an open pool reactor. Accidental release of radioactive isotopes is coming mainly from the fission products of a degraded core resulting from overheating of fuel elements due to long term loss of core cooling accident.

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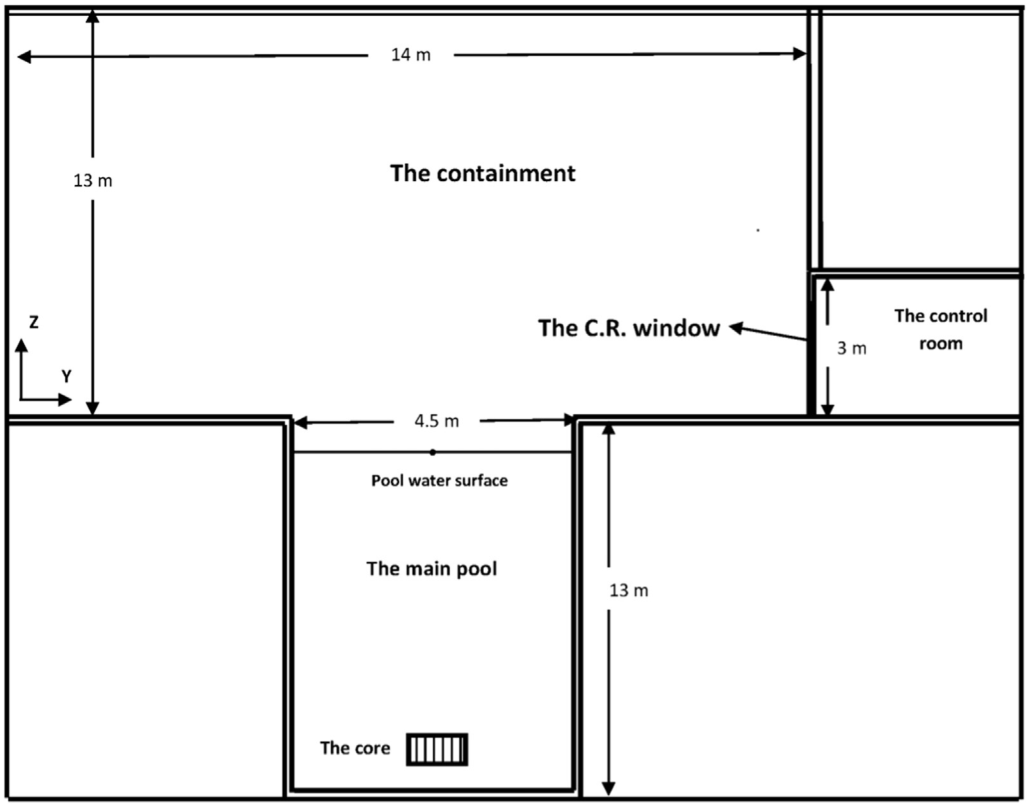

Fig. 1. Schematic diagram for reactor building.

Accidental release of fission products into the containment causes the ventilation system in MPR to be converted to the emergency situation.

This study concentrates on calculating the source term in the containment during the emergency situation and consequently predicting the radiological dose rate levels in the control room during the time of emergency. The dose rate resulting from the released isotopes in the containment depends on the degree of the degradation of the reactor core. The maximum dose rate is corresponding to the complete degradation of the core and the minimum dose rate is corresponding to the degradation of one fuel plate (FP). So, the calculations of dose rate in this study included the two cases. MCNP5 code (X-5 MONTE CARLO TEAM, 2003) was used to calculate the dose rates in the control room during the emergency situation. The study also determines the time required for decaying the activity of the isotopes in the containment to the permissible dose rate limit. The paper studied the effect of venting the radioactive isotopes into the environment as a suggestion to decrease the dose rate levels in the control room. HotSpot 2.07.2 code (HOTSPOT Code Version 2. 07.2 User Manual, 2011) was used to determine the distribution of radiation doses, resulting from the radioactive release, with distances around the reactor. It was found that the maximum radiation dose was located in a fee-inhabitant area which makes it possible to apply the suggestion.

2. Source term calculation

MPR has a core consists of 29 fuel elements and each one consists of 19 fuel plates. Each fuel plate consists of a thin plate of U_3O_8 of 19.99% uranium enrichment dispersed in aluminum and sandwiched between two thin aluminum plates (Abdelhady, 2016). Fission products are generated in the reactor core when the nuclear fuel is exposed to neutron irradiation of flux of 1.4×10^{14} n/cm^2.s. Amount of fission products depend on the residence time of fuel in the core and magnitude of the burn-up. Higher the burn-up and the longer the residence time cause more fission products being built up in the fuel. ORIGEN2.1 code (Croff, 1980) was used to calculate the fission products inventory of the core and FP at time of accident. The source term was calculated using the conservative assumption that the accident occurred at the end of operation cycle (maximum discharge burnup). ORIGEN2.1 provides the inventory of the core and one fuel plate as shown in Table 1.

3. Containment ventilation system of MPR

The confinement and ventilation system (CVS) in MPR has been provided with detectors system to measure the concentrations of the radioactive materials in the air exhausted from the reactor containment to the external environment via the reactor stack. The detectors system includes sodium iodide and plastic scintillate detectors to measure the concentrations of iodine, noble gases, and aerosols in air before exhausting to the stack (Abdelhady et al., 2009). An increasing in the concentrations of the radioactive materials in air to levels more than the permissible limits results in converting the operation mode of the CVS to the emergency mode. During the emergency situation, a system of automatic valves has enforced the contaminated air to exhaust into the containment and prevent outer air from inlet (Abdelhady, 2017). The contaminated air has been enforced to pass through a group of charcoal and absolute filters to remove the radioactive materials from the air and when the concentrations of the radioactive isotopes in air decrease to the permissible limit, the CVS converts and returns to the normal operation mode.

4. The contamination of the containment accident

The radioactive release accident is hypothetically resulting from a coolant flow blockage in the fuel element that contains the hottest fuel plate. This could occur as the result of some foreign material falling into the core tank during a refueling. After the primary pumps are started, the object would be moved to the fuel element nozzle so that flow to the fuel plates was obstructed. The model assumes that the fission products