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Annals of Nuclear Energy xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Annals of Nuclear Energy

journal homepage: www.elsevier.com/locate/anucene

Analysis of a fatal accident in a highly enriched uranium facility

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ARTICLE INFO

Article history:
Received 24 April 2015
Received in revised form 4 July 2015
Accepted 6 July 2015
Available online xxxx

Keywords:
Critical accident
Highly enriched
Monte Carlo model
Kinetics equations
Thermodynamics
Power pulse

ABSTRACT

A fatal critical accident in a compact, water moderated and highly enriched (90%) MTR facility is analyzed. A very detailed Monte Carlo model was used to define the initial conditions and the reactivity coefficients. The MCNP code was used to model all the heterogeneities of the facility. Once the reactivity parameters were calculated the kinetics equations were solved coupling them with the thermodynamics conditions of the core and the steady water. The power pulse was then calculated and compared with radiological data.

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1. Introduction

On September 23 1983, a fatal criticality accident occurred at the RA2 facility in Buenos Aires, Argentina (NRC, 1984). The zero power reactor was under the authority of the Comision Nacional de Energia Atomica (CNEA). The facility, up to 0.1 Watts, was essentially a big water tank (approximately 3 m diameter, 1.60 m height) with a bridge over the tank. From this bridge the MTR fuel elements were manually positioned by the operator in an aluminum grid. The fuel elements are described in the next section.

With a configuration of fuel elements already built and with a water level, not known exactly but considered safe by the operator, the operator introduced an extra fuel element which triggered the power accident. Previous analysis (Waldman, 1984), medical and health physics report Dorval et al. (2004) estimated the energy release at the order of 10 MJ (Megajoules).

Beside some not published internal reports there is no a detailed account of the variables of this accident in the open literature or in the web (for example the CNEA web site). Therefore the author decided to collect all the data available and merge them with a very detailed MCNP (2003) model which allows to put the accident in the public domain.

2. Description and modeling of the system

Here we give an overview of the system and its modeling in order to describe how reactivities were calculated. Almost all the heterogeneities are included explicitly in the MCNP model. Because there is an almost one to one correspondence between the real system and the model, the pictures produced by the geometry module of the MCNP system shows the details of the facility.

Two assemblies were calculated in detail: (1) the subcritical assembly (configuration 1) was built with twenty-five boxes of MTR fuel, two of them containing cadmium control plates, and (2) the supercritical assembly (configuration 2) with an extra fuel box.

2.1. Fuel boxes

The dimensions of the fuel box, see Fig. 1, are 7.62 cm (flat to flat boundaries, distance along axis y), 8.04 cm (curved to curved boundaries, distance along axis x) and 75.5 cm (axis z). A fuel box has nineteen fuel plates curved in the (x, y) plane (radius of curvature 14 cm).

Each fuel plate contains 8.53 g of U 90% enriched mixed with 51.53 g of Al. The U–Al mixture has a thickness of 0.52 mm and its extension along the z axis is 61.5 cm; the projection of the curved U–Al mix in the x direction is 6 cm. The U–Al mixture is sandwiched between two Al plates of 0.4 mm thickness and a z extension of 65.5 cm. The resulting fuel plate is then 1.32 mm thick and 65.5 cm length, the upper and lower 2 cm without fuel. The fuel box plates 1 and 19 are 75.5 cm in length.

The 19 plates of the box are held in place by their insertion in two lateral Al walls 75.5 cm in length. The (x, y) cross section of the walls are parallelograms with a base of 80.4 mm (axis x), a thickness of 5.2 mm (axis y) and an angle of 14° with axis y which follows the curvature of the plates. With this assembly the

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http://dx.doi.org/10.1016/j.anucene.2015.07.009
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Please cite this article in press as: Difilippo, F.C. Analysis of a fatal accident in a highly enriched uranium facility. Ann. Nucl. Energy (2015), http://dx.doi.org/10.1016/j.anucene.2015.07.009

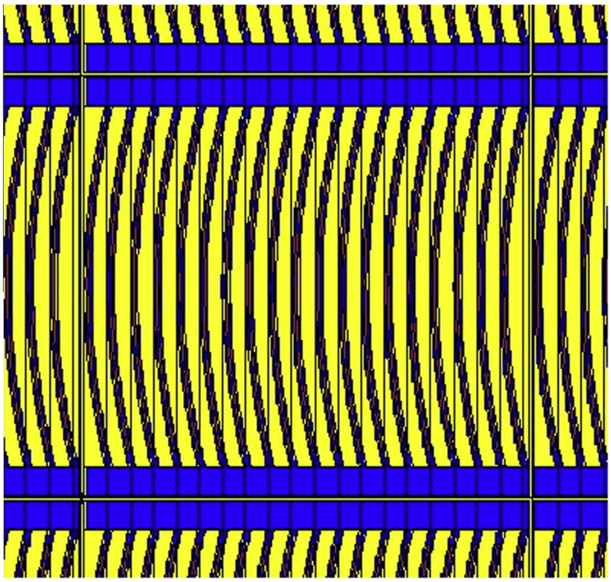

Fig. 1. (x, y) cross section of the fuel box with 19 fuel plates, the control box has 15 fuel plates. The missing ones (plates 3, 5, 15, 16) make room for the cadmium control plates.

separation between plates in the x direction is 2.89 mm which contains the water coolant–moderator. The unit cell of this system is therefore 4.21 mm in the x direction. With a perfect ensemble of boxes the distance between the two contiguous plates of different boxes would be 3.30 mm instead of 2.89 mm.

Four of the fuel boxes were boxes for the positioning of control plates. They contained 15 fuel plates: the missing plates (4 and 5, 15 and 16) make room for two Cd plates.

2.2. Subcritical and supercritical assemblies

Fig. 2 describes configuration 2 that contained 26 fuel boxes: 24 in a 6 by 4 arrangement surrounded by a file of graphite elements with the (x, y) cross section of the fuel boxes; the two extra fuel boxes were located beside the graphite. The 4 boxes at the corners were control boxes: the two at the lower corners (SW and SE) contained the Cd control plates, the two at the upper corners (NW and NE) did not. Water gaps, 0.5 mm, between the boxes are included to model the non ideal mechanical ensemble.

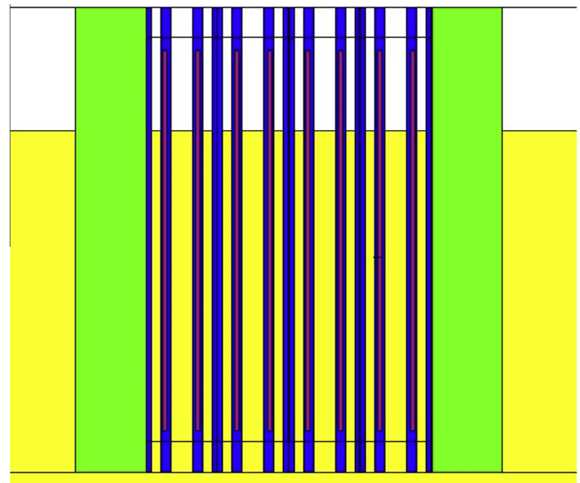

Fig. 3. Vertical cut of the configurations.

The goal of the operator was to assemble the configuration shown in Fig. 2 with the Cd control plates at each corner. Because he believed that the water level was lower enough to maintain subcriticalities the two upper corner control boxes did not contain the Cd plates at the moment of the accident. The subcritical configuration 1 did not contain the NW box (water instead), the accident happened when the operator intended to load the NW control box.

Fig. 3 and Table 1 shows and describes the vertical cross section (x, z) of the calculation model which is a one to one representation of the real assembly along the entire length of the boxes. The grid (water plus aluminum structure), where the boxes are located, was

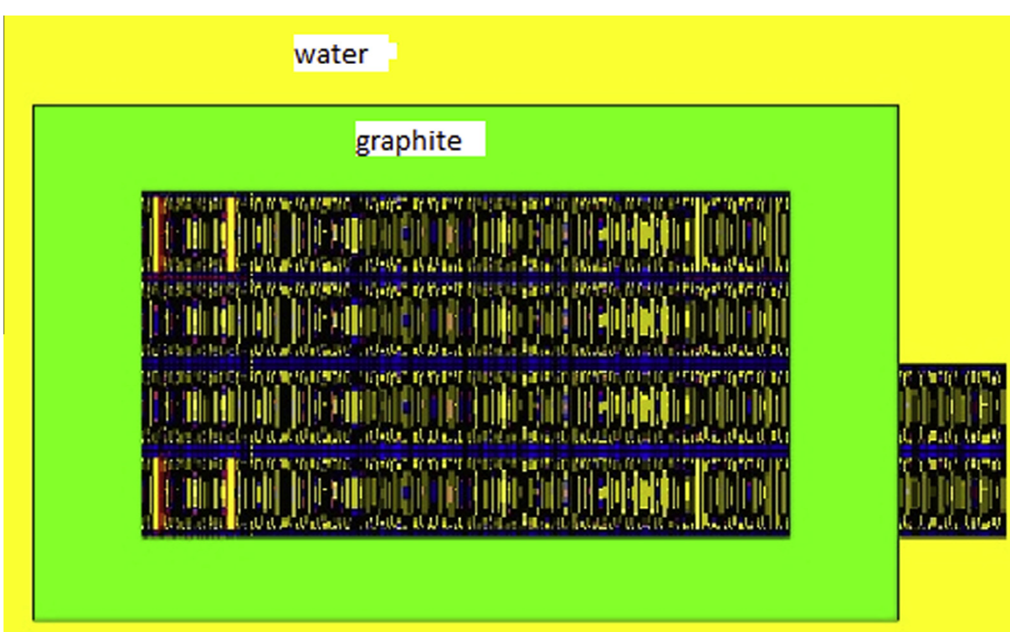

Fig. 2. Configuration 2 corresponding to the supercritical system: 24 (6 × 4) boxes within the graphite and 2 beside. The fuel boxes at the corners are control boxes. Lower two corners contain 2 Cd plates each, two upper corners without the Cd plates. Configuration 1, subcritical, NW corner without the fuel box (water instead).

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