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Spent Fuel Storage Criticality Safety

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خلاصة

يتناول البحث دراسة حروجية مخزن وقود مفاعل أبحاث مصر الأول، عند تخزين الوقود المحترق بدرجات مختلفة، كذا افتراض تخزين الوقود الفعال. استخدمت المقاطع الالكترونية من مكتب المقاطع ذات 15 مجموعة، كما استخدمت المقاطع الالكترونية للوقود المحترق باستخدام كود ويمز د4.
تم حساب الحروجية باستخدام كود أنسن وديسكي 2. درس تأثير كل تغير المسافات بين حزم الوقود وإضافة ممصات النيترونات على حروجية المخزن. أوضحت النتائج امكانية زيادة سعة المخزن في حالات مختلفة.

Abstract

The present work treats the criticality safety of the fuel storage pool of Egypt First Test and Research Reactor ET-RR-1. Conservative calculations using fresh fuel and burned fuel has been performed. EURLIB 15/5 cross section library was used in addition to cross section generated using WIMSD4. ANISN and DIXY2 codes were used to calculate Keff. The critical separation for fresh and burned fuel have been determined. Methods for extending the pool capacity, namely, by decreasing spaces between stored fuel cells, or introducing boron absorber have been studied. In each case the effect on the criticality have been determined.

1 - Introduction

The spent fuel storage problem is worldwide recognized as an important step within the nuclear fuel cycle [1,2]. The Egypt Research reactor ET-RR-1 is now over 30 years of operation. The discharge fuel batches from the reactor, especially the early ones, have stayed considerable time in the spent pool. The ET-RR-1 reactor is still in operation and is expected to operate for another period of time due to the recent overall maintenance operation and updating.

The long storage period of ET-RR-1 spent fuel represents challenge to the fuel integrity. Moreover, with new discharged spent fuel batches, the storage capacity may not be enough in the future. Accidental criticality may occur as a result of the presence of residual fissionable uranium and plutonium and the presence of water moderator if proper spacing were not maintained. For the above reasons and in order that the spent fuel storage problem would not cause hindrance to reactor operation, and /or cause health hazard, the problem of overall safety of the spent fuel storage of ET-RR-1 has to be investigated.

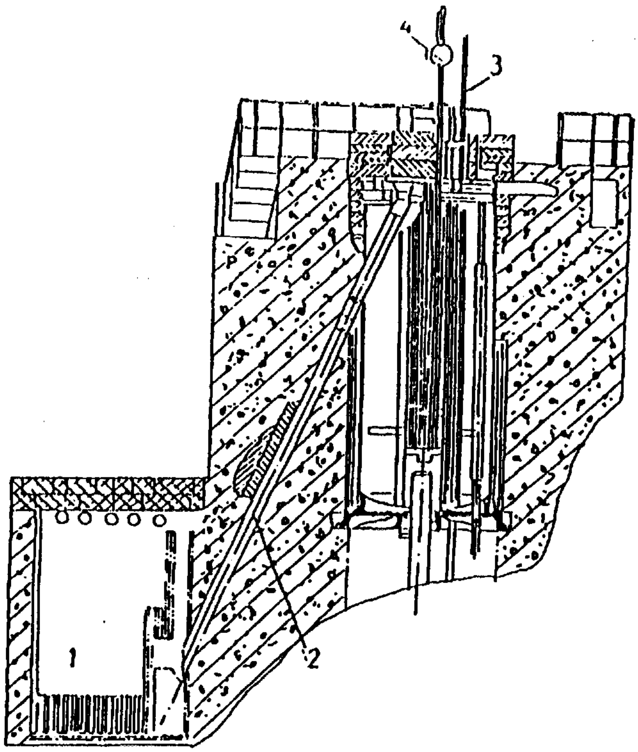
The overall safety evaluation of the ET-RR-1 spent fuel requires comprehensive study of the following areas:

* The engineering requirements.
* Environmental impacts.
* Radioactive emission to the environment.
* Occupational radiation doses.
* Nuclear safety.

The former areas were subjected to studies underway by different authors[3,4]. The nuclear safety is to be addressed in the present paper. The key elements affecting nuclear safety of the pool are: the fuel type; the fuel irradiation history; storage medium (water -air- or gas) and temperature of the storage pool. These elements are to be investigated in the present study. A safety analysis report SAR for ET-RR-1 has been recently completed and was presented in a recent workshop sponsored by Arab Atomic Energy Agency AAEA and Atomic Energy Authority AEA of Egypt in december 1993. The present study is to be a part of the above effort.

2-ET-RR-1 Spent Fuel Storage Description

The spent fuel storage pool of ET-RR-1[5] is located in the corner of the reactor hall, at a level of 5 m depth from the ground level (hall floor). It has an internal dimension of 2.9x1.0x9.25 m, with walls of heavy concrete of 1.1m thickness and specific weight of 3.2 t/m^3. It consists of two tanks one within the other: a receiver, and block of cells. Fig 1 and Fig 2 shows vertical view and plan of the wet storage tank. The inner tank is made of aluminum alloy and is filled with a distillate water of 10 m^3 for cooling fuel baskets, diminution of radiation hazards. The outer tank is made of stainless steel.



1_ Fuel-element graveyard (storage tank)
2_ Dump chut for spent-fuel assemblies
3_ Optical viewing equipment
4_ Manipulating devices

FIG.1 CROSS SECTION THROUGH THE REACTOR AT THE DEPTH OF THE FUEL - ELEMENT DUMP CHUTE

A slopping spout leads technological sections from the reactor tank to storage pool. They are sunk through this spout into the receiver set at the bottom of the inner tank. To maintain a constant level of the distillate water in the storage tank of 390 cm, an overflow pipe with a hydraulic seal is fastened to the inner wall of the tank. The block of cells is placed at the bottom of the tank, there are 60 equally spaced cells in the block, one technological section may be placed in each cell.It should be noted that the full capacity of the core is 51 fuel baskets. The storage tank top is covered by a cast iron shield of 30 cm thickness. An air rarefaction of 7 mm water is created.

3-Criticality Assessment Calculations

3-1 Calculation Models

In a recent report [6] different methods for criticality of spent fuel criticality safety have been described. The method of calculation used in the present report is similar, although the computer codes used are not the same. As it is reported in the above reference and elsewhere[7], the first step in the calculation methodology is the preparation of the group cross sections suitable to the ET-RR-1 reactor fuel.

The ET-RR-1 fuel is UO_2 enriched 10% in U-235 and dispersed in magnesium, the fuel is of rod type. The different assemblies of ET-RR-1 fuel types are shown in Fig.3. The one, two, or three cut corner assemblies are designed to allow for the control rods. As it is shown from Fig.3 the number of rods in each assembly is the same=16 rods arranged as shown in the mentioned Fig. Though the moderator to fuel ratio differs from assembly type to another.

For the cross section generation typical to ET-RR-1, the computer code WIMSD4 [8] is used in the pin cell option. The pin cell geometry together with Wigner Sitez representation is shown in Fig.4. The WIMSD4 code is used to generate cross section homogenized over the cell for different U-235 concentration (burnup) and for all materials, that to be used either in DIXY2 diffusion calculation or suitable to discrete ordinate transport code ANISN [9].

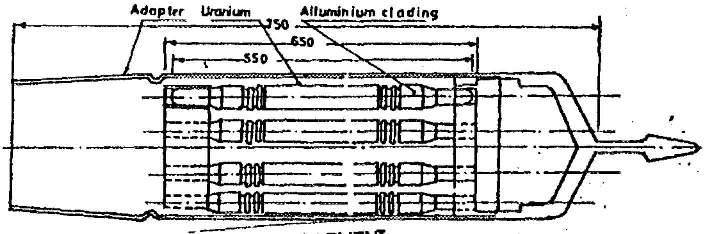


Fig. 2 FUEL ELEMENT ASSEMBLY

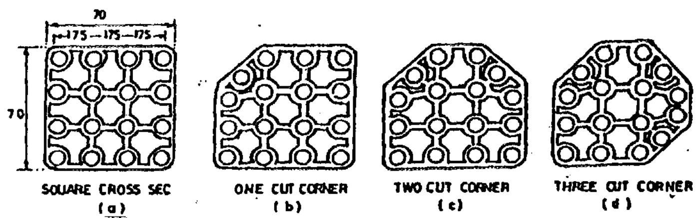
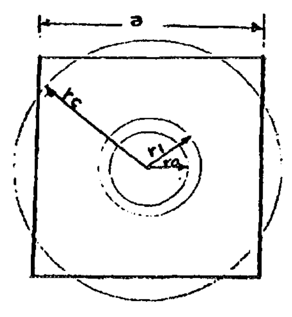


FIG 3 : Horizontal cross sections of the fuel element boundles.



a=17 mm r1=5.0 mm
ro=3.5 mm r(cell)=9.59 mm

Fig 4 Pincell Geometry for WIMSD4

For criticality calculation one and two dimensional models are used in the calculations. The one dimension model is used in the parametric studies.

The code ANISN-W is used. The code version was installed and adopted to the VAX6000 computer. The code version validation studies were reported in [10]. Either the WIMSD4 cross section and/or EURLIB 15/5 group cross section are used. The EURLIB 15/5 cross section ,although, is not typical for ET-RR-1, however because of the relatively large number of groups, fifteen energy groups, that covers the energy range from 14 mev to 0.0 ev, it is expected to give good results for ET-RR-1.

The ANISN calculation was performed in P0 S6 and P3 S6 approximations in cylindrical geometry. The rectangular pool was modeled in equivalent cylinder with conserving the volumes and fuel to water ratio. The pool was also modeled in two dimensions for the two dimensional diffusion code DIXY2[11]. The DIXY2 code is a member of the NC-NSRC code packages. The WIMSD4 four group cross section were used in DIXY2 calculation. In each of ANISN, DIXY2 or WIMSD4 calculation the following cases have been studied:-

- The criticality of the present pool geometry filled with fresh fuel.
- The effect of assembly separation on the pool criticality .
- The effect of different burn up level on the pool criticality
- The effect of the presence of absorber on the pool criticality.

4-Results and Discussions

Case 1 examines the criticality safety of the pool filled with fresh fuel baskets Fig.5 The fresh fuel rod of Ek-10 type composition is given in table 1. The atomic density of a homogenized cell with dimension shown in Fig 4, is given in table 2. EURLIB 15/5 cross section library was utilized for 15 group structure in ANISN criticality calculation with P3 S6 approximation. An equivalent cylinder of diameter 79.9cm was obtained for the rectangular pool geometry,keeping the volume ratios constants.

The results show that for critical pool ,Keff =1.00 and the fuel assembly spacing Xc =4mm. The variation of pool criticality ,Keff, with assembly spacing is shown in Fig.6. It is declared from the figure that Keff decreases rapidly and then slowly with increasing Xc. This is explained as a result of increasing of the moderator/cell (Vm/Vc) volume ratio with decreasing of fuel/cell volume ratio (Vf/Vc).

Table 1 ET-RR-1 Fuel Element Composition

Element	Weight (gm)
U235	8.05
U238	73.50
Mg	13.03
02	12.2
Impurities	.22

Table 2 Atomic Density of Storage cell

Element	Atom/cc(cell) x10E24
H	.04593
O	.02613
Al	.01125
Mg	.002261
U235	.000146
U238	.001287

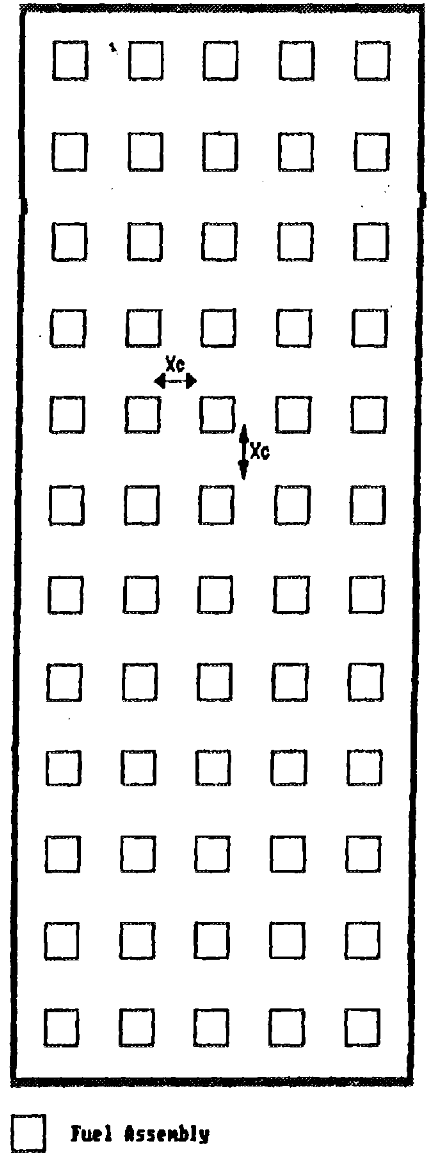


Fig 5. Schematic Diagram of ET-RR-1 Fuel Storage

Table 3 Volume Ratios of Storage cell

Region	Value
Fuel/cell	.1331
Clad/cell	.18006
H2O/cell	.6868

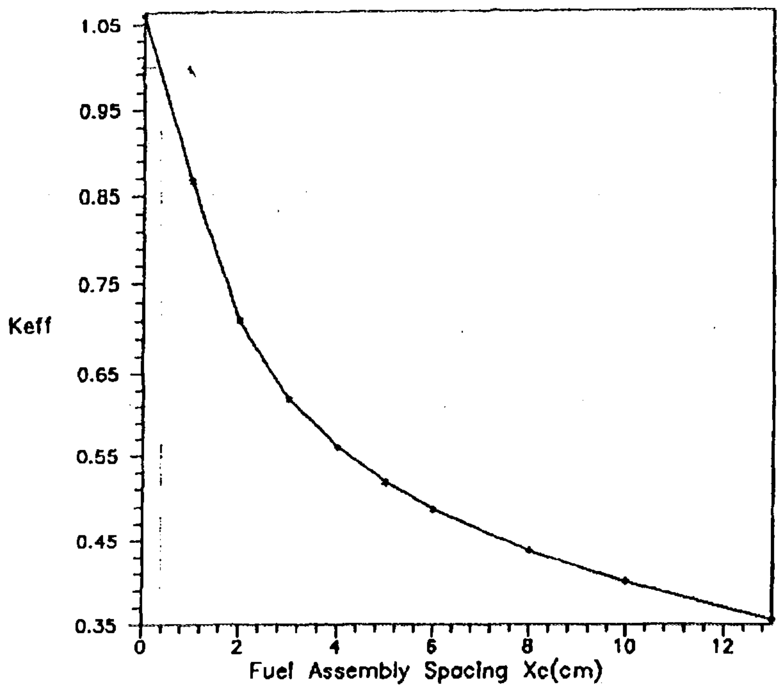


Fig. 6 Criticality dependence on Fuel Spacing (Fresh)

Case 2 investigates insertion of boron absorber of different concentrations on the critical pool (keff =1.00) with fresh fuel. WIMSD4 was used to generate boron cross sections of 15 group structures applicable to ANISN. P0 S6 approximation was used, the results gives that Keff drops from 1.00 to 0.92923 when inserted boron with concentration 0.123g/cm^3.The reason is refer to the poisoning effect of boron which tends the pool to be subcritical i.e criticality safe.

Case 3 examines the criticality of the pool filled with depleted fuel baskets with different burnup values ranging from 50MWD/T to 300MWD/T. WIMSD4 was used to generate the suitable cross section for ANISN for the different burnups. The variation of Keff with burnup for Xc=13.0cm (Designed value) is shown in Fig.7.

Case 4 investigates the possibility of increasing pool capacity for spent fuel of 100MWD/T (Fig.8) The results indicate that the pool capacity may increase up to 400% which corresponds to keff << 0.80, Criticality was determined using DIXY2 code for fresh fuel, the result has an error=0.05 compared with ANISN.

5-Conclusions

From the discussions and the given figures it is concluded that:

1-The assemblies spacing has an important contribution on the criticality of the pool (critical separation =4mm for fresh fuel).

2-Introducing absorber like boron reduces criticality of the pool which in turn causes pool to be subcritical (criticality safe).

3-The criticality of the pool reduces byincreasing the burnup level which increases permissible capacity of the pool.

4-WIMSD4 is adequate for generation group cross sections for different depletion values.

Fig. 6 Criticality dependence on Fuel Spacing (Fresh)

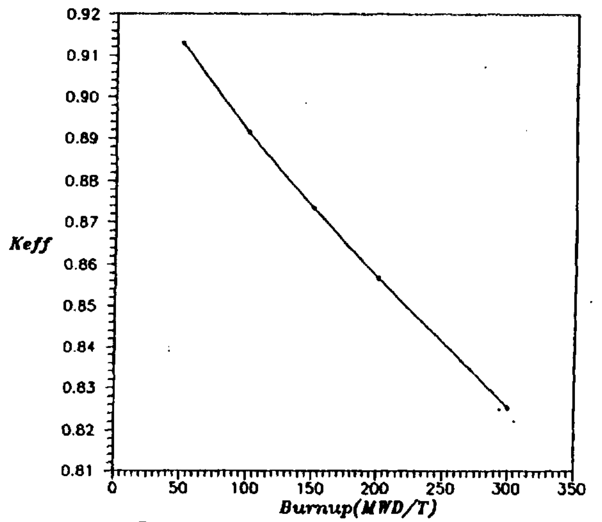


Fig. 7 Variation of criticality with burnup

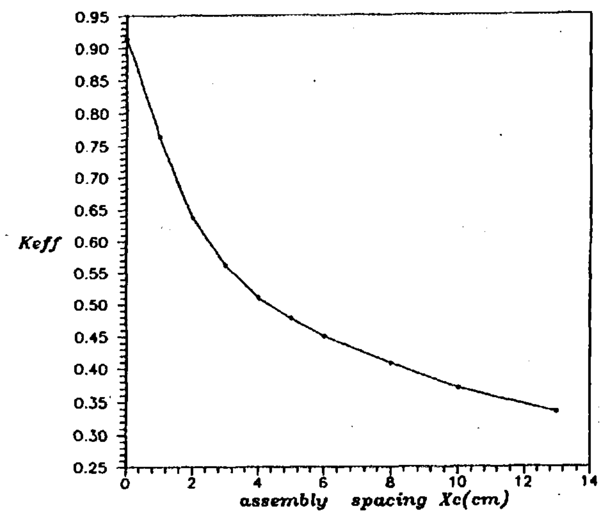


Fig. 8 Criticality of 100MWD/T Burned Fuel

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