AN ACTIVE NEUTRON METHOD FOR MEASURING THE INHERENT NEUTRON EMISSION OF SPENT FUEL ASSEMSLY

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ABSTRACT

An active neutron method for measuring the inherent neutron emission of spent fuel assembly is proposed. The count rate of the inherent neutron emission can be determined by changing intensity of neutron irradiating source. The practical meaning of the method is presented. Some attractive features of the method are shown.

Keywords: neutron interrogation, non-destructive techniques, spent fuels, neutron measurements.

TÓM TẮT

Phương pháp mới sử dụng nguồn neutron để đo sự phát xạ neutron vốn có trong các bó nhiên liệu đã cháy

Một phương pháp neutron chủ động để đo lượng neutron vốn có trong nhiên liệu đã cháy được đề xuất. Tốc độ đếm của sự phát xạ neutron có thể được xác định bằng cách thay đổi cường độ của nguồn chiếu neutron. Ý nghĩa thực tiễn của phương pháp được trình bày. Một số tính năng hấp dẫn của phương pháp này được chỉ ra.

Từ khóa: tương tác nơ-tron, kĩ thuật không phá hủy, nhiên liệu đã cháy, các phép đo nơ-tron.

1. Introduction

In nuclear material safeguards the determination of the characteristics of spent fuel assembly such as burn-up, total fissile content, amount of plutonium and original enrichment is important. These parameters are useful for establishing critical safety in spent fuel ponds and in reprocessing plants. There are some different non-destructive methods developed for fuel identification such as: acombination of active neutron interrogation and passive neutron measurement (Shulze G. and Wurz H.,1979), the spectroscope of fission product gamma radiation and passive neutron counting (Vidovszky I. et.al.,1986; Bernard P. et al.,1986), a simple passive neutron and gross gamma measurement (Phillips J.R et al.,1981), a combination of neutron and gamma measurement (Fox G.H. et al., 1987).

Because neutron measurements have advantageous features such as high transparency of the assembly, easy detectability, high neutron emission of the spent fuel and favorable signal- to- background ratio. The measurement systems based on the first method have been developed and tested in actual installations (Wurz H et al., 1990; Simon G.G, Sokcic-Costic M.,2002).

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According to the first method, the inherent neutron emission C_{ne} is determined by passive neutron measurement and the thermal flux multiplication M_{th} by active neutron interrogation measurement after C_{ne} is known. From these quantities the primary neutron emission correlating with the burn-up, the total fissile content, original enrichment of the spent fuel is obtained

This paper presents an active neutron method, with changing intensity of neutron irradiating source, for measuring the inherent neutron emission C_{ne} of spent fuel assembly.

2. The method

The principle of the method is shown in Fig 1.

In a given spent fuel assembly there are the inherent neutrons (C_{ne}) emitting from spontaneous fissions and (α,n) reactions. When the fuel assembly is irradiated by the neutrons of the external source the fission reactions are induced in the fissile isotopes as ^{235}U, ^{239}Pu, ^{241}P. These are detected by measuring the thermalized prompt fission neutrons. Suppose that the fuel assembly is irradiated by the neutron source leaving the intensity I_1, the total count rate C_t^1 of detector is given as

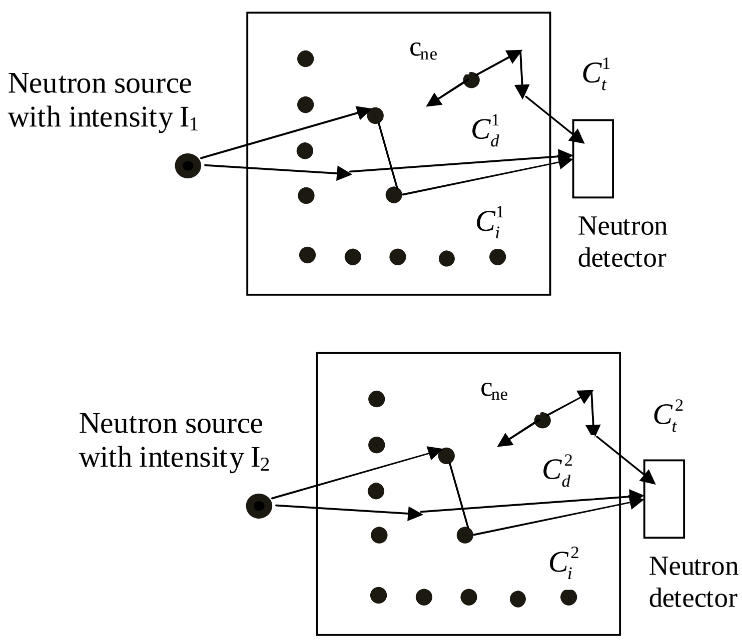

Fig 1. *Principle of the method*

$$C_t^1 = C_i^1 + C_d^1 + C_{ne} \tag{1}$$

Where:

C_i^1 - the contribution of the fission neutrons to the total count.

C_d^1 - the contribution of the direct source neutrons i.e., source neutron penetrating the fuel assembly without being captured

C_{ne} - the contribution of the inherent neutron emission of the spent fuel. For the given fuel assembly C_{ne} is constant.

Similarly, the expression of the total count rate C_t^2 of the same detector when the fuel assembly is irradiated by neutron source having intensity I_2 is given as:

$$C_t^2 = C_i^2 + C_d^2 + C_{ne} \tag{2}$$

The quantities C_i^2 and C_d^2 are similarly defined as C_i^1 and C_d^1, respectively. By subtracting C_{ne} from the total count rate, the neutron flux increase due to induced fission is obtained. The thermal neutron flux multiplication is given as:

$$M_{th} = \frac{C_t^1 - C_{ne}}{C_d^1} = 1 + \frac{C_i^1}{C_d^1} \tag{3}$$

Or

$$M_{th} = \frac{C_t^2 - C_{ne}}{C_d^2} = 1 + \frac{C_i^2}{C_d^2} \tag{4}$$

From the expressions (3) and (4) we have:

$$\frac{C_i^1}{C_d^1} = \frac{C_i^2}{C_d^2} \tag{5}$$

With supposing the intensity I_2 is stronger than I_1 and the quantity C_d^2 is *n* times bigger than C_d^1, i.e., $C_d^2 = nC_d^1$, the expression (5) leads that $C_i^2 = nC_i^1$ and

$$C_i^2 + C_d^2 = n(C_i^1 + C_d^1) \tag{6}$$

Combining Eqs. (1), (2) and (6) result in

$$C_t^1 = (C_i^1 + C_d^1) + C_{ne}$$

$$C_t^2 = n(C_i^1 + C_d^1) + C_{ne}$$

By solving this equation system, the expression for the inherent neutron emission C_{ne} is given as

$$C_{ne} = \frac{nC_t^1 - C_t^2}{n-1} \tag{7}$$

The physical nature of this method is shown in Fig.2. From eq.7 the quantity C_t^2, the total count rate of the detector with intensity I_2, is obtained as

$$C_t^2 = nC_t^1 - (n-1)C_{ne} \quad (8)$$

If n = 0 i.e., the neutron source is removed, so $C_t^2 = C_{ne}$. This is the very passive neutron measurement presented in [1].

If n = 1, i.e., the intensity of the irradiating source is not changed. so $C_t^2 = C_t^1$. This is obvious.

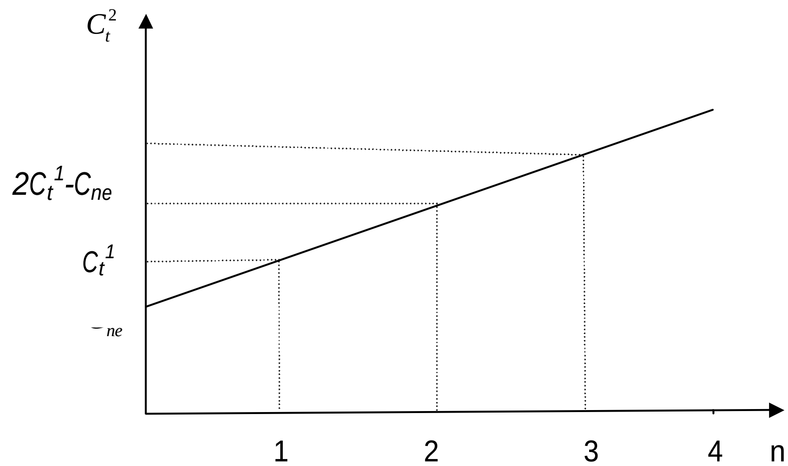

Fig 2. *The C_t^2 versus the change of the intensity of the neutron source*

choosing n>1, the linear functional dependence between C_t^2 and n is given as in Fig 2, and C_{ne} is the very intersection point of the line and the coordinate axis.

The count rate of C_d^1 and C_d^2 due to the direct source neutrons are determined in the laboratory [1], so n is obtained easily.

3. Conclusion

The inherent neutron emission C_{ne} and the flux multiplication M_{th} are two necessary quantities for spent fuel identification. The method combining active and passive neutron measurement has allowed the obtainment of these quantities.

This paper presents the method determining C_{ne} and M_{th} by only active neutron measurements with changing intensity of interrogating source.

This method has attractive features as follows:

- Calibrations for the passive neutron measurements are not necessary. Calibrations for the active measurements are simple.
- The measuring instruments are not complicated or expensive.
- Intensity of the interrogating source can be easily changed by readjusting the window of source.

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(*Received: 10/9/2012; Revised: 22/01/2013; Accepted: 18/02/2013)*

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(Ngày Tòa soạn nhận được bài: 06-9-2012; ngày phản biện đánh giá: 06-12-2012; ngày chấp nhận đăng: 18-02-2013)