Calibration of silver lined proportional counter for yield measurement of 14 MeV pulsed neutron source

P.M. Dighe[1]*, Ankita Pathak[1], L.P. Kamble[1], R. Pal[2], A.K. Bakshi[2], P.V. Bhatnagar[1]and D. Das[1]
[1]Electronics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA
[2] RP&AD, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA
* email: pmdighe@barc.gov.in

Introduction

The importance of neutron yield measurement for pulsed neutron sources in thermonuclear conditions is well known. Conventional neutron detectors fail to resolve the neutron pulse and severely underestimate the dose. Therefore activation counter technique is frequently exploited for these applications.

The Silver activation counter is a neutron detector utilized to obtain the total neutron yield by activation of short-lived beta radioactivity in silver given by following reactions,

$^{107}Ag + n \rightarrow {}^{108}Ag \rightarrow {}^{108}Cd + \beta^-$ ($T_{1/2}$ =2.37min)
$^{109}Ag + n \rightarrow {}^{110}Ag \rightarrow {}^{110}Cd + \beta^-$ ($T_{1/2}$ =24.6sec)

GM based silver activation counters for pulsed neutron detection, widely described in literature have limitations because of long dead time. Activation counter operating in proportional mode has better resolving time and hence larger measurement range compared to GM based detectors.

Detector design

An annular shape silver lined proportional counter[1] is developed in two halves as shown in Fig. 1, to cover > 3π solid angle of the source. Table 1 gives the main specifications. Silver foil of 0.25 mm thickness is lined on the internal cathode surface of the detector.

Fig. 1 Picture of the detector

Table.1 Main Specification of detector

Outer housing	SS 235mm OD X 314mm length
Internal diameter	150mm
No. of anodes	10Nos. (5nos. on each half) 25μm tungsten wire
Gas-fill	Ar (90%) + CH_4 (10%) at 30 cm Hg
Neutron sensing material	0.25mm thick silver foil

Calibration Method

Calibration of activation counter for pulsed neutron source is challenging. In the absence of standard pulsed neutron source, the continuous neutron source of known yield can be used to estimate the calibration constant of the detector. Reference 2 describes various methods of calibration. In the present work, source removal method and integration of decay counts over a given time period is used and calibration factor is derived for the 14 MeV D-T neutron source. The detector was irradiated with accelerator based continuous D-T source of known yield.

The neutron yield, Y(n/pulse) is related to beta counts, G_{01} ,by $Y=KG_{01}$, where K is the calibration constant which is to be determined.

Let the pulse from plasma focus device starts at T_o and ends at T_E , G_{01} and G_{23} are the integrated decay counts measured for time interval T_E to T_1 and T_2 to T_3 respectively. Let the counter be irradiated with the continuous DT source of known yield I_0 (n/sec) until saturation is reached. N_{CR} is the counts measured between time T_r and $T_s=T_r+T_{CR}$ where T_r is the time at which continuous source is removed . λ_1 and λ_2 are the decay constants of the ^{108}Ag and ^{110}Ag respectively. K is estimated by

$$k = \frac{I_o}{N_{CR}} \times \frac{\lambda_1^{-1}(1 - e^{-\lambda_1 T_{CR}}) + \alpha\lambda_2^{-1}(1 - e^{-\lambda_2 T_{CR}})}{(1 - e^{-\lambda_1 T_1}) + \alpha(1 - e^{-\lambda_2 T_1})} \quad (1)$$

Where,

$$\alpha = \frac{e^{-\lambda_1 T_2} - e^{-\lambda_1 T_3} - A_C(1 - e^{-\lambda_1 T_1})}{A_C(1 - e^{-\lambda_2 T_1}) - (e^{-\lambda_2 T_2} - e^{-\lambda_2 T_3})} \quad (2)$$

The ratio of the counts measured after the pulse is given by A_c ,

$$A_c = \frac{G_{23}}{G_{01}} \quad (3)$$

Yield Measurement with CR-39

The neutron yield of the continuous D-T source was also estimated by irradiation of CR-39 foils for comparison. The CR-39 detectors were exposed to 14 MeV neutrons produced by D-T generator at different distances from the source. After exposure detectors were chemically etched in 7N KOH in a water bath and viewed under microscope. The tracks counted were converted to yield using the calibration factor and applying inverse square law. The calibration factor for CR-39 is 3.01E+03 n/track for chemical etching. The neutron yield of the D-T source estimated by CR-39 is 1.13 x 10^9 n/sec.

Calibration of silver counter

The silver counter was tested at the continuous D-T source of IPR, Gandhinagar. The detector was irradiated for 120 s with an Yield , I_0 = 2 X 10^9 n/sec ; averaged from the CR-39 data, Cu foil activation and the yield given by the source operating parameters. The decay data was recorded after switching 'OFF' the source. This data was used to derive calibration constant using equation (1).The calibration constant K was estimated to be (24.65±0.03)x10^3 neutrons/pulse count. Estimated error is significant upto source yield of 10^6 n/pulse. The detector was used to estimate the yield of D-T plasma focus devise producing 14 MeV neutron pulse of 20 nsec duration. For comparison, the source yield was also measured with commercial detector. Fig. 2 gives the decay data recorded by the annular silver counter. Table.2 gives the neutron yields measured and estimated.

Conclusion

In this work Annular shaped silver lined proportional counter is calibrated by using continuous D-T source. Calibration constants is estimated as (24.65±0.03)x10^3 n/pulse count using source removal method and integration of the decay counts over a given time period. This method of calibration gives better counting statistics and improves accuracy. The neutron yield measured by the annular silver counter and the commercial detector compared well within the deviation of < 8%.

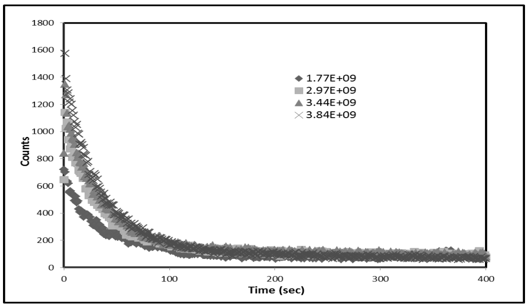

Fig.2 Decay curves of 20nsec pulses for different yield.

Table.2 Measured and estimated yield for a 20nsec D-T neutron pulse

Yield measured by commercial detector(n/pulse)	Yield estimated from the count rate data of annular silver counter (n/pulse)	Differenc e (%)
1.77E+09	1.92E+09	7.93%
2.97E+09	3.02E+09	1.50%
3.44E+09	3.42E+09	-0.46%
3.84E+09	4.06E+09	5.40%

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References

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