EMISSION RATE MEASUREMENT OF A Cf-252 NEUTRON SOURCE BY MANGANOUS SULFATE BATH METHOD

Sun-Tae Hwang
Korea Standards Research Institute
P.O. Box 3, Taedok Science Town, Taejon, Korea

Kun Jai Lee
Korea Advanced Institute of Science and Technology
P.O. Box 150, Cheongryang, Seoul, Korea

1. INTRODUCTION

The manganous sulfate($MnSO_4$) bath method has been in use over two decades for the most accurate measurement of neutron emission rate. The $MnSO_4$ bath has been developed accordingly and the bath system has been operated for the standardization of neutron measurements at the Korea Standards Research Institute(KSRI) since 1986. There are three types of the radioactive neutron sources: (γ,n), (α,n) and spontaneous fission. In this research work, a spontaneous fission source, Cf-252, as the reference neutron source calibrated by the standard neutron source, Am-Be, is introduced to determine the characteristics of the bath system in terms of the bath efficiency (E), the saturated manganese activity (A_s), the inverse manganese(^{55}Mn) neutron capture fraction (f^{-1}) and eventually the bath system correction factor (C_F).

2. PRINCIPLE OF THE METHOD

Figure 1 shows the events which take place in the $MnSO_4$ bath during a Cf-252 neutron source calibration. The neutron source is

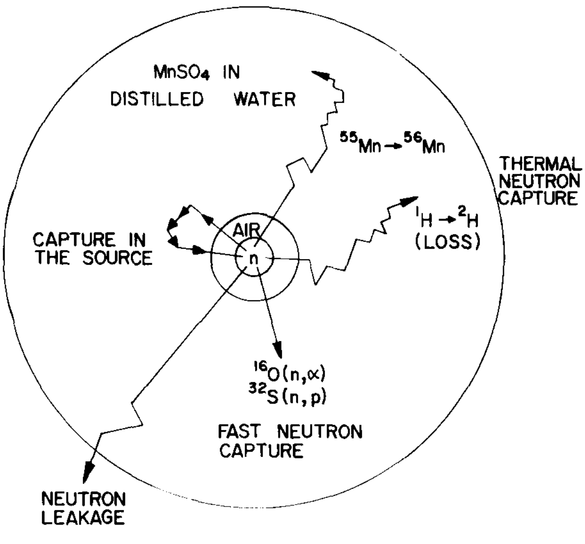

Fig. 1. Schematic Diagram of Principle of $MnSO_4$ Bath Method

mounted at the center of a spherical bath containing an aqueous solution of manganous sulfate. The solution is continuously stirred by the impellers and at the same time pumped in a closed circulation circuit through a detection system. Figure 2 shows the schematic arrangement for the bath system. Neutrons from the neutron source are thermalized in the $MnSO_4$ solution and captured by the various nuclei. The ^{56}Mn resulting from the capture of neutron by ^{55}Mn is measured by the counting system in the bath system.

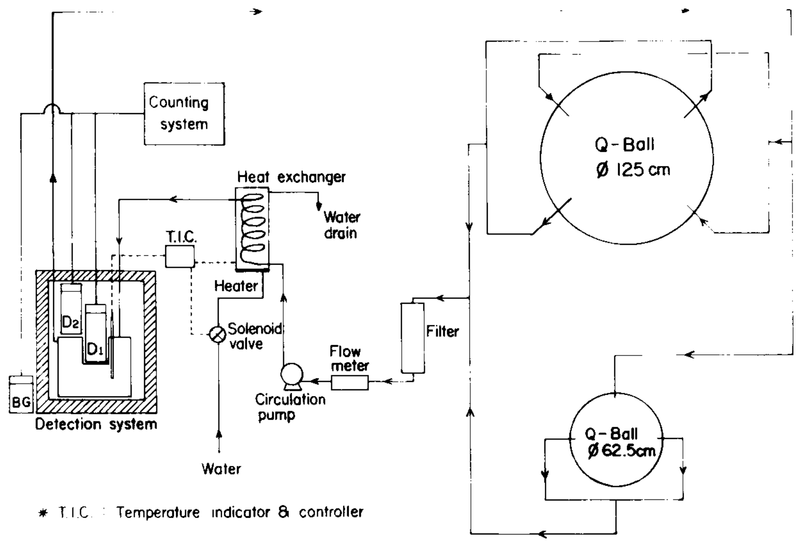

Fig. 2. Schematic Diagram of $MnSO_4$ Bath Circulation System

The neutron emission rate of a Cf-252 source, Q, is given by

$$Q = (^{A}s/E) \cdot (f^{-1}) \cdot C_F \qquad (1)$$

where f is the fraction of neutrons captured by ^{55}Mn. In the existance of impurities in the solution, the inverse ^{55}Mn capture fraction becomes(1)

$$f^{-1} = 1 + (^{N}Im/N_{Mn}) \cdot (^{\sigma}Im/\sigma_{Mn}) \cdot (^{(1\ +\ \bar{r}s)}Im/(1 + G\bar{r}s)_{Mn}) +$$
$$(1 + (^{N}Im/N_{Mn})) \times (^{\sigma}S/\sigma_{Mn}) \cdot (^{(1\ +\ \bar{r}s)}S/(1 + G\bar{r}s)_{Mn}) +$$
$$(^{N}H/N_{Mn}) \cdot (^{\sigma}H/\sigma_{Mn}) \cdot (^{1}/(1 + G\bar{r}s)_{Mn}) \qquad (2)$$

where N_{Mn}, N_H, and N_{Im} are the respective concentrations of manganese, hydrogen and impurities in the solution. The factor $1 + G\bar{r}s$ allows for the resonance capture in manganese. In the notation of Westcott et al.(2), s is the resonance activation integral, $\bar{r}$ is the the epithermal flux parameter averaged over the $MnSO_4$ bath and G is the resonance self-shielding factor for the solution. Rearranging eq. (2), a straight line is fitted to the data(3).

3. EXPERIMENTAL PROCEDURE

3.1 Measurement of Bath Efficiency, E

A quantity of radioactive ^{56}Mn of high purity is divided into portions by weight, some of which are used to activate the bath and others are absolutely measured by the $4\pi\beta$-γ coincidence counting technique to determine the specific activity. To obtain the efficiency, the mean counting rate of ^{56}Mn γ-rays measured by the $MnSO_4$ bath counting system and corrected for decay back to a suitable refence time is divided by the ^{56}Mn activity measured absolutely and corrected to the same reference time. Since this quantity is concentration dependent, E is determined at least once for each concentration.

3.2 Calculation of Saturated Manganese Activity, A_s

The ^{56}Mn activity produced during neutron irradiations in the $MnSO_4$ bath is counted by the two 1.5" ϕ x 1.5" NaI(Tl) scintillation detectors equipped in a 12.5-liter detector bath of s.s. Marinelli beaker-type. A third detector monitors the room background. The saturated activities are calculated using the computer program taken from the Gilliam model(4) in the growth and decay phases of ^{56}Mn activity. The parameters used in the calculation are the total number of counts (C_i) observed during the counting period which began at a time after insertion of the neutron source into the bath, the duration of the neutron irradiation, the decay constants of ^{56}Mn and Cf-252 and the mixing constants.

3.3 Calculation of Inverse ^{55}Mn Neutron Capture Fraction, f^{-1}

To obtain the inverse ^{55}Mn capture fraction from eq. (2), the necessary data are taken from Mughabghab et al.(4) and Hwang et al. (5). The N_H/N_{Mn} ratio is determined by the gravimetric method by drying and weighing weighed samples of the $MnSO_4$ solution.

4. EXPERIMENTAL RESULTS

The neutron emission rate of the reference source, Cf-252, calibrated by the comparative method to the standard source, Am-Be is determined to be 2.232×10^7 n/s at the reference time, 12:00 on November 15, 1987(6). The bath efficiency and the inverse ^{55}Mn neutron capture fraction, the saturated manganese activity are given in Table 1 and Table 2, respectively.

According to the data, the following empirical formulae as a function of N_H/N_{Mn} are derived by the least squares fitting method:

From Table 1, $Y_E = X^{-4.348}$ and $Y_{f^{-1}} = 0.024842\ X + 1.025252$

From Table 2, $Y_G = -0.8270\ X + 166.3797$ (Growth phase of ^{56}Mn)

$Y_D = -0.8292\ X + 165.5645$ (Decay phase of ^{56}Mn)

Substituting these results into eq. (1), the bath system correction factor, C_F is obtained at a reference time.

Table 1. Bath Efficiency, E and Inverse ^{56}Mn Neutron Capture Fraction, f^{-1}

X (N_H/N_{Mn})	E (10^{-5} cps/dps)	f^{-1}
45.034295	—	2.147862
58.191625	1.433550	2.470228
71.586090	1.502855	2.798636
94.411795	1.457515	3.370241
111.04887	1.476193	3.786437

Table 2. Saturated ^{56}Mn Activity, A_S

X (N_H/N_{Mn})	A_S (cps) in Growth Phase	A_S (cps) in Decay Phase
45.034295	133.8850	131.20900
58.191625	115.32310	—
71.586090	102.67140	101.21610
94.411795	89.45201	—
111.04887	76.07417	75.49648

5. CONCLUSION

From the graphic analysis of data obtained by the manganous sulfate bath method, the bath system correction factors to the neutron emission rate can be determined as a function of the N_H/N_{Mn} ratio. Figure 3 shows the straight lines fitted to the data in order to determine the unknown correction factor of a Cf-252 neutron source at the given ratio of N_H/N_{Mn} in a $MnSO_4$ solution. In comparison of the line in ^{56}Mn growth phase with the line in ^{56}Mn decay phase, the difference of the correction factors between them turns out to be a range of 0.77 % to 1.44 % to the growth phase activity.

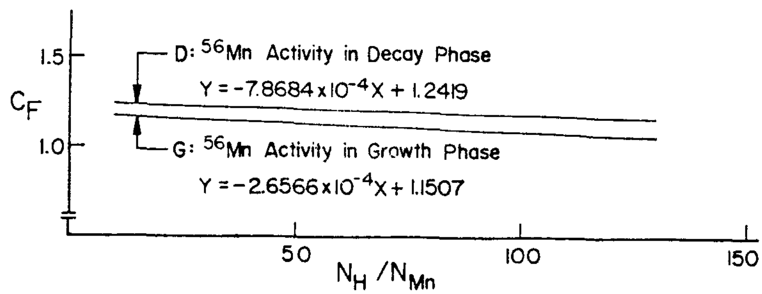

Fig 3. Bath System Correction Factor

REFERENCES

(1) E. J. Axton and A. G. Bardell: Metrologia 18, 97 (1982).
(2) C. H. Westcott, W. H. Walker, T. K. Alexander: Proc. 2nd International Conference on the Peaceful Uses of Atomic Energy, Geneva, United Nations (1979).
(3) E. J. Axton, P. Cross, J. C. Robertson: J. Nucl. Energy Parts A/B 19, 409 (1965).
(4) J. R. Smith, S. D. Reeder, R. J. Gehrke: EPRI NP-3436, (1984).
(5) S. T. Hwang, K. J. Lee, K. O. Choi: J. Korean Assoc. Radiat. Prot. 12(1), 48 (1987).
(6) S. T. Hwang and K. J. Lee: Japanese Ionizing Radiation 13(3), 138 (1987).