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VERIFICATION OF SURFACE SOURCE'S CHARACTERISTICS USING LARGE-AREA 2π GAS FLOW COUNTER

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VERIFICATION OF SURFACE SOURCE'S CHARACTERISTICS USING LARGE-AREA 2π GAS FLOW COUNTER

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要　旨

動力炉・核燃料開発事業団（動燃）東海事業所では、α線またはβ線を放出する面線源の放射能測定用大面積2πガスフローカウンタを所有している。放射線管理用機器の校正用に多数の面線源を使用しているが、使用しているうちに線源の表面状態が劣化したり傷がつくなどして放射能強度が変化する恐れがある。そこで、放射線測定機器の校正結果を適切なものにするために、大面積2πガスフローカウンタによりこれら線源からの表面放出率を定期的に確認している。

今回臨時に、東海事業所で使用されている数多くの校正用面線源から8つのU_3O_8線源を選び、これらの線源の放射能を2πガスフローカウンタにより測定した値を日本アイソトープ協会が線源購入時に発行する成績書に記載されている値と比較した。今回の比較試験の結果は両者はよく一致しており8つの面線源は良好な状態であることを確認した。また、2πガスフローカウンタの検出器感度分布が良好であることが明らかとなった。

なお、本件は平成10年6月から8月の3か月間、科学技術庁原子力研究交流制度にもとづき研修員として受入れ、動力炉・核燃料開発事業団東海事業所安全管理部放射線管理第一課にて研修を行ったM.M.Abu Naser Waheed氏の研修報告の一部である。

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1)バングラデシュ原子力委員会
2)安全管理部　放射線管理第一課

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ABSTRACT

Power Reactor and Nuclear Fuel Development Corporation (PNC) has large-area 2π gas flow counter for the purpose of measuring activity of surface sources of alpha or beta ray emitter. Surface sources are used for the calibration of radiation measuring equipment for radiation control. Due to frequent use of sources, the surface of these sources are inclined to go in bad condition because of unwanted accidental incidents. For the better calibration achievement of radiation measuring instruments the rate of emission of these sources are to be checked periodically by the large-area 2π gas flow counter.

In this paper described that eight U_3O_8 surface sources were selected from many sources of PNC Tokai Works and activity of these sources was measured by the 2π gas flow counter. The results were compared with the values certified by Japan Radio Isotope Association (JRIA). It is evident from the result of comparison that the surface sources are in good condition, i.e., the sources are reliable to calibrate the radiation control instruments.

1. INTRODUCTION

In Tokai Works, PNC, a large number of radiation monitoring instruments such as survey meter, area monitor, monitoring station are used for radiation monitoring of the work-place, radiation workers and outside of the sites. For the better performance of the radiation monitoring instruments it is necessary to calibrate frequently the modules and equipment. 1st Radiation Control Section, Health and Safety Division, Tokai Works is responsible for the calibration of radiation monitoring instruments including field monitoring equipment using surface sources. Among the surface sources the major one is U_3O_8.

PNC purchases these sources from Japan Radio Isotope Association (JRIA). The characteristics of these sources are certified by JRIA. PNC has the confidence on those certified values. But due to the daily use and unwanted accidental occasions, the condition of surface sources changes. For this, it is necessary to verify the rate of emission with certified values. This paper describes an experimental set up to verify the characteristics of surface sources with the values certified by JRIA[1].

2. EXPERIMENTAL INSTRUMENTS

The following instruments are used for this experiment:

a) 2π gas flow counter, Model: BS - R74 - 2754, SL. NO. 94R011, Aloka.
b) Preamplifier, Model: PAM - 521, SL. NO. 82R071, Aloka.
c) Universal scaler, Model: TDC 511, SL. NO. 83R411, Aloka.

3. COUNTING SYSTEM

Counting system setup is shown in Figure 1. Detector is the 2π gas flow counter without window. It has 150mm X 300mm large effective area. This counter is used to determine the activity i.e., the rate of emission of α and β particles of surface sources (large area). Counting gas is PR gas (Argon - Methane). Specifications of counting system are as follows [2]:

Sensitivity distribution ≥ 95% and counting efficiency ≥ 95% / 2π.

For α, plateau length ≥ 200V.
plateau slope ≤ 5% / 100V.
background count is approximately ≤ 2 cpm.

For β, plateau length ≥ 100V.
plateau slope ≤ 10% / 100V.
background count is approximately ≤ 400 cpm.

At the beginning, after closing the shielded doors gas is allowed to pass through the chamber at a constant pressure of 800cc/min. During counting, gas pressure is maintained at a constant pressure of 100cc/min.

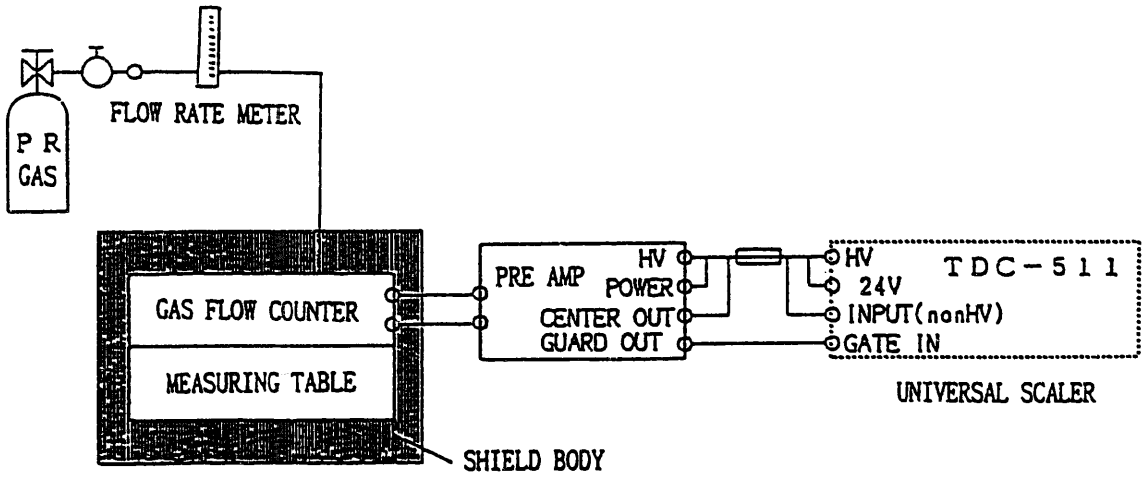

Figure 1 Block diagram of counting system.

Pressure is observed on the flow rate meter connected between counter and gas cylinder. The measurement conditions are selected according to measurement objective[3]. For this experimental setup, measurement conditions were:

i) Pre/Amp: Input conditions and amplifier data

DETECTOR	:	PROP
Input	:	Amp
Shaping	:	Gauss
Gain	:	40
Polarity	:	Pos IN
Polarity	:	Neg OUT

ii) SCA/COIN: Pulse height analysis conditions and coincidence mode

SCA mode	:	INT
LL	:	10%
COIN mode	:	INT

iii) HV: High voltage output

HV mode	:	Counting
HV	:	Required voltage for experiment
LIMIT	:	3000V

iv) PT/PC: Counting conditions

Preset	:	PT
PT min	:	As per requirement
REPEAT	:	As per requirement

To begin next count, after changing the source, the gas is allowed to flow at a pressure of 800cc/min for 20 minutes.

4. TESTS OF COUNTER

4.1 Plateau test for α and β particles

Setup Menu of universal scaler for the plateaus of α and β particles is as given bellow[3]. The source is U_3O_8 (KYO-1692) and active area, øA = 45mmø[1]. Table 1 represents measurement data for high voltage plateaus. Figure 2 shows the high voltage plateaus for α and β particles.

SCA Mode :	INT
COIN Mode :	ANTI
LL :	10%
PROP:	Amp
PT :	1 Minute
Gain :	40

The performance of a counter is expressed in terms of slope of the plateau[4], that is,

$$\text{Plateau Slope} = \frac{1}{r}\left(\frac{\Delta r}{\Delta v}\right) \quad \text{(i)}$$

where, r = counting rate and $\Delta r / r$ is the relative change of (r) for the corresponding change in high voltage, i.e., Δv.

Since the plateau slope is expressed in percent change of (r) per 100V change, therefore,

$$\text{Plateau Slope} = \frac{1}{r}\left(\frac{\Delta r}{\Delta v}\right) \times 10^4 \quad \text{(ii)}$$

According to equation (ii), for α particle the maximum plateau slope is

$$\frac{10^4(r_2 - r_1)/r_1}{V_2 - V_1} = \frac{10^4(7182 - 5699)/5699}{1650 - 1150} = 5.2\% \approx 5\%$$

and for β particle the maximum plateau slope is

$$\frac{10^4(15960 - 9667)/9667}{2390 - 1750} = 10.17 \approx 10\%$$

The plateau lengths are 500V and 640V respectively.

TABLE 1: Measurement data for high voltage plateaus.

OBSERVATIONS	HIGH VOLTAGE (volt)	COUNT (cpm)
1	900	2
2	950	2
3	1000	1454
4	1050	4819
5	1100	5505
6	1150	5699
7	1200	5863
8	1250	5878
9	***1300***	5860
10	1350	5823
11	1400	5858
12	1450	5917
13	1500	6035
14	1550	5998
15	1600	6325
16	1650	7182
17	1700	8081
18	1750	9667
19	1800	10859
20	1850	12100
21	1900	12866
22	1950	13507
23	2000	14203
24	2050	14519
25	***2100***	14730
26	2150	14773
27	2200	14660
28	2250	14930
29	2300	15050
30	2350	14770
31	2400	16778
32	2450	180660
33	2500	180738

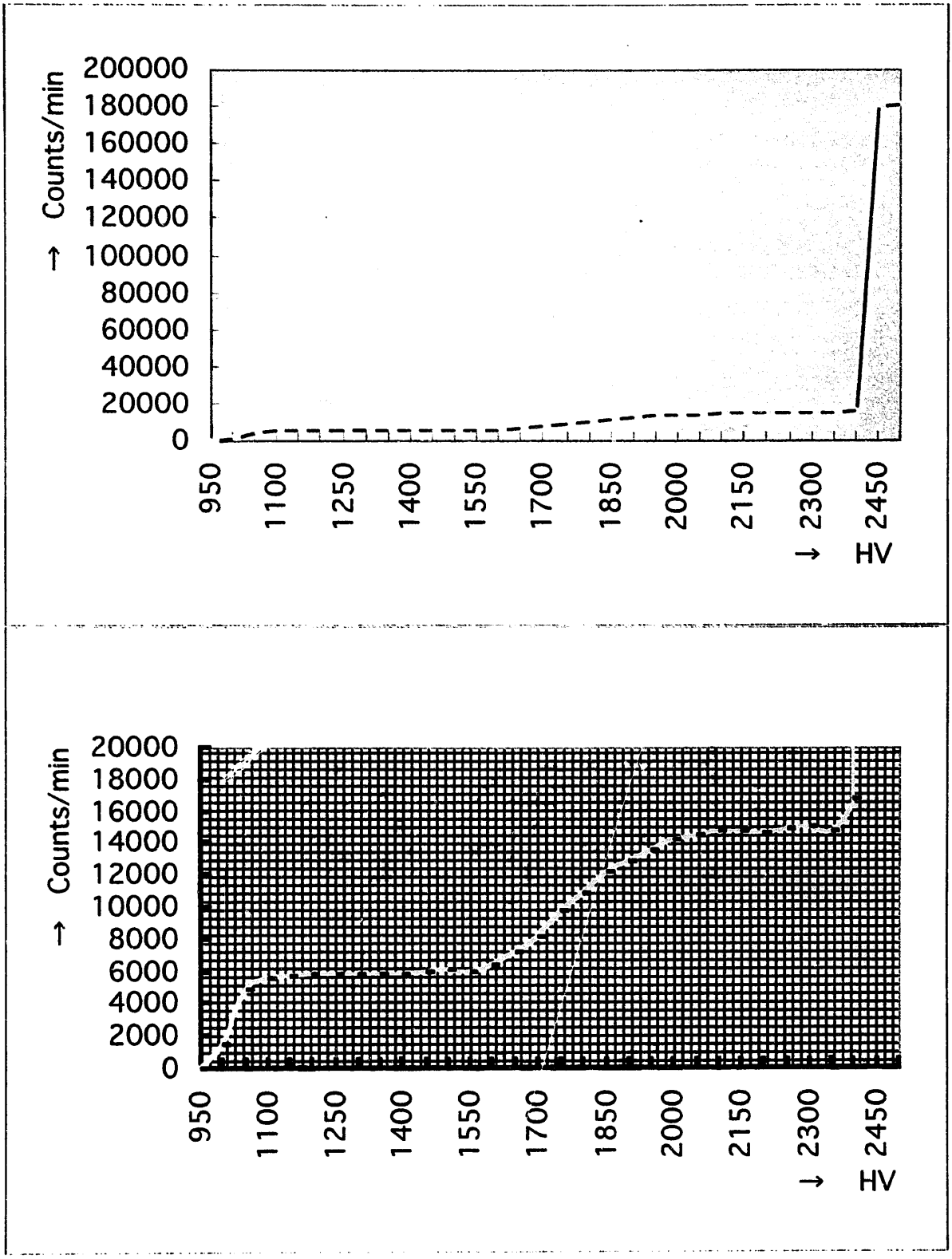

Figure 2 α and β plateaus of 2π gas flow counter.

4.2 Efficiency and sensitivity distribution tests

For these tests the measurement data was taken for 15 different positions (Figure 3) of surface source, Number: KYO-1692, inside the counter. Measurement data is shown in Table 2. Background count for α and β particles were 0.58 cpm and 64.7 cpm respectively. Count time was 10 minutes. The following expressions are used to calculate measurement data in the unit of cpm[2]:

$$Net\ Counting\ Rate = \frac{Total\ Count}{Measurement\ Time} - BG\ Counting\ Rate \quad \text{(iii)}$$

For α rays,

$$Counting\ Efficiency = \frac{Net\ Counting\ Rate}{Bq\ value \times 60} \times \frac{1}{Factor} \times 100 \quad \text{(iv)}$$

where, Factor = 1.

For β-rays of U_3O_8, the counting efficiency is given by

$$Counting\ Efficiency = \frac{Net\ Counting\ Rate}{\beta - ray\ Emission\ Rate(2\pi) \times 2} \times 100 \quad \text{(v)}$$

Sensitivity distribution is estimated by following expression. Figure 3 represents the sensitivity distribution of counter.

$$Sensitivity\ distribution = \frac{Minimum\ counting\ efficiency}{Maximum\ counting\ efficiency} \times 100 \quad \text{(vi)}$$

5. RESULTS

Sources of different sizes were chosen to collect the measurement data for α and β particles of source U_3O_8. Since these sources are used for the calibration of different types of radiation measuring equipment that are used in Tokai Works. Source number: KYO-1721 and KYO-1722 are used for the calibration of ZnS(Ag)α surface contamination monitor. Number: KYO-1317, KYO-1403 and KYO-1502 are used for the calibration of hand, foot and cloth monitor. Number: KYO-1534, KYO-1691 and KYO-1692 are used for the calibration of radiation monitoring instruments, e.g., dust and stack monitors installed in Reprocessing Facility and Plutonium Fuel Development Facility, PNC.

For calculating Bq value and β-ray emission rate in the unit of cpm for area 2π following expressions[2] are used.

$$Bq\ value = \frac{Net\ Counting\ Rate}{Counting\ Efficiency/100} \times \frac{1}{60} \times 2 \quad \text{(vii)}$$

$$\beta - ray\ Emission\ Rate = \frac{Net\ Counting\ Rate}{Counting\ Efficiency/100} \times \frac{1}{2} \quad \text{(viii)}$$

$$Relative\ Standard\ Deviation(\%) = 2 \times \frac{\sqrt{\frac{Total\ Count}{(Measurement\ Time)^2} - \frac{BG\ Count}{(BG\ Measurement\ Time)^2}}}{Net\ Counting\ Rate} \times 100 \quad \text{(ix)}$$

TABLE 2: Measurement data of efficiency and sensitivity tests for α particles.

SOURCE POSITION	COUNT TIME (Mins.)	ALPHA COUNT	AVERAGE COUNT	NET COUNTING RATE (cpm)	COUNTING EFFICIENCY (%)	COUNT RATEX100 / CENTER RATE (%)
1-(1)	5	29135 29084 29430	29216.33	5842.69	98.36	100.17
2-(1)	5	29116 29195 28937	29082.67	5815.95	97,91	99.71
3-(1)	5	29304 29197 28967	29156	5830.62	98.16	99.97
4-(1)	5	29172 29078 28930	29060	5811.42	97.84	99.64
5-(1)	5	29147 28993 29296	29145.33	5828.49	98.12	99.93
1-(2)	5	29243 28972 29470	29228.33	5845.09	98.40	100.21
2-(2)	5	28887 29120 29009	29005.33	5800.49	97.65	99.45
3-(2)	5	29226 29108 29165	29166.33	5832.69	98.19	100.00
4-(2)	5	29474 29090 29306	29290	5857.42	98.61	100.43
5-(2)	5	29134 28941 29056	29043.67	5808.15	97.78	99.58
1-(3)	5	29469 28990 29426	29295	5858 42	98.63	100.45
2-(3)	5	29250 29273 29096	29206.33	5840.69	98.33	100.14
3-(3)	5	29265 29175 29195	29211.67	5841.75	98.35	100.16
4-(3)	5	29214 29292 28979	29161.67	5831.75	98.18	99.99
5-(3)	5	29379 29425 28975	29259.67	5851.35	98.51	100.33

Sensitivity distribution = (0.9765/0.9863) X 100 = 99%

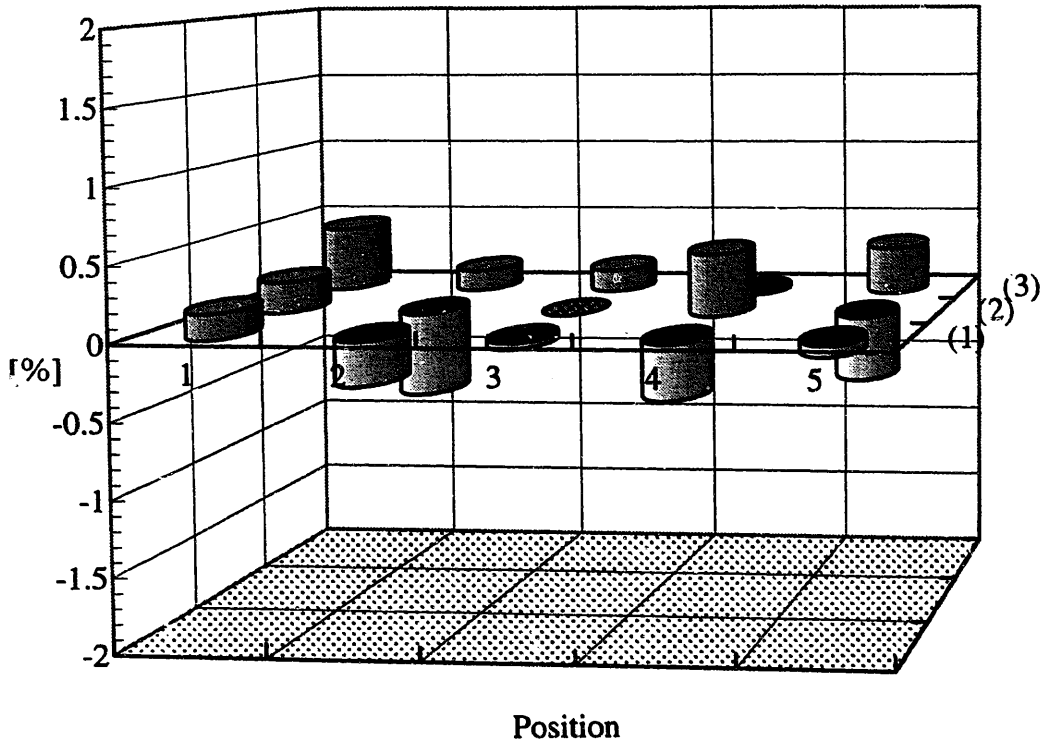

Figure 3 Sensitivity distribution of 2 π gas flow counter.

Measured Bq value for alpha particles and emission rate for beta particles of each eight sources were compared to its certified values. The results of comparison showed good agreement. Source number KYO-1692 is considered as standard source. Experimental results are shown bellow:

TABLE 3: Measurement data for the source number: 1721.

Source	: U_3O_8	Measurement Time	: 3 Mins.
Certified value	: α = 581 Bq	Repeat	: 3
	β = 8870 cpm / 2π	Position	: Center of chamber
Date of certificate	: 18 November, 1993	Standard counting efficiency (%)	: 98.19(α) & 54.06(β)
Area	: T=120mm X 70mm;	BG counting rate	: 0.58cpm(α) & 64.7cpm(β)
	A=100mm X 50mm	Detection limit counting rate	: 3.6cpm(α) & 17.5cpm(β)

TABLE 3(a): Measurement data for alpha particles.

OBSERVATION	TOTAL COUNT	AVERAGE COUNT	NET COUNTING RATE cpm	MEASURED Bq VALUE	RELATIVE STANDARD DEVIATION (%)
1	50891				
2	50432	50628.33	16875.53	573.35	0.9
3	50562				

TABLE 3(b): Measurement data for beta particles.

OBSERVATION	TOTAL COUNT	AVERAGE COUNT	NET COUNTING RATE cpm	MEASURED EMISSION RATE cpm / 2π	RELATIVE STANDARD DEVIATION (%)
1	27320				
2	27338	27424.67	9076.86	8395.17	1.2
3	27616				

TABLE 4: Measurement data for the source number: 1722.

Source	: U_3O_8	Measurement Time	: 3 Mins.
Certified value	: α =579 Bq	Repeat	: 3
	β =8890 cpm / 2π	Position	: Center of chamber
Date of certificate	: 24 November, 1993	Standard counting efficiency (%)	: 98.19(α) & 54.06(β)
Area	: T=120mm X 70 mm;	BG counting rate	: 0.58cpm(α) & 64.7cpm(β)
	A=100mm X 50 mm	Detection limit counting rate	: 3.6cpm(α) & 17.5cpm(β)

TABLE 4(a): Measurement data for alpha particles.

OBSERVATION	TOTAL COUNT	AVERAGE COUNT	NET COUNTING RATE cpm	MEASURED Bq VALUE	RELATIVE STANDARD DEVIATION (%)
1	50524				
2	50322	50532	16843.42	572.26	0.9
3	50750				

TABLE 4(b): Measurement data for beta particles.

OBSERVATION	TOTAL COUNT	AVERAGE COUNT	NET COUNTING RATE cpm	MEASURED EMISSION RATE cpm / 2π	RELATIVE STANDARD DEVIATION (%)
1	27373				
2	27399	27345	9050.3	8370.61	1.2
3	27263				

TABLE 5: Measurement data for the source number: 1317.

Source	: U_3O_8	Measurement Time	: 3 Mins.
Certified value	: α =297 Bq	Repeat	: 3
	β =4630 cpm / 2π	Position	: Center of chamber
Date of certificate	: 6 April, 1988	Standard counting efficiency (%)	: 98.19(α) & 54.06(β)
Area	: T=50 mm;	BG counting rate	: 0.58cpm(α) & 64.7cpm(β)
	ØA=46 mmØ	Detection limit counting rate	: 3.6cpm(α) & 17.5cpm(β)

TABLE 5(a): Measurement data for alpha particles.

OBSERVATION	TOTAL COUNT	AVERAGE COUNT	NET COUNTING RATE cpm	MEASURED Bq VALUE	RELATIVE STANDARD DEVIATION (%)
1	22011				
2	22118	22010.67	7336.31	249.25	1.3
3	21903				

TABLE 5(b): Measurement data for beta particles.

OBSERVATION	TOTAL COUNT	AVERAGE COUNT	NET COUNTING RATE cpm	MEASURED EMISSION RATE cpm / 2π	RELATIVE STANDARD DEVIATION (%)
1	12792				
2	12873	12775.33	4193.74	3878.79	1.8
3	12661				

TABLE 6: Measurement data for the source number: 1403.

Source	: U_3O_8	Measurement Time	: 3 Mins.
Certified value	: α =1.09 KBq	Repeat	: 3
	$\beta = 1.66X10^4$ cpm / 2π	Position	: Center of chamber
Date of certificate	: 16 April, 1990	Standard counting efficiency (%)	: 98.19(α) & 54.06(β)
Area	: T=120mm X 120mm;	BG counting rate	: 0.58cpm(α) & 64.7cpm(β)
	A=100mm X 100mm	Detection limit counting rate	: 3.6cpm(α) & 17.5cpm(β)

TABLE 6(a): Measurement data for alpha particles.

OBSERVATION	TOTAL COUNT	AVERAGE COUNT	NET COUNTING RATE cpm	MEASURED Bq VALUE	RELATIVE STANDARD DEVIATION (%)
1	95804				
2	95564	95603.67	31867.31	1082.71	0.6
3	95443				

TABLE 6(b): Measurement data for beta particles.

OBSERVATION	TOTAL COUNT	AVERAGE COUNT	NET COUNTING RATE cpm	MEASURED EMISSION RATE cpm / 2π	RELATIVE STANDARD DEVIATION (%)
1	51095				
2	51381	51170.33	16992.08	15715.94	0.9
3	51035				

TABLE 7: Measurement data for the source number: 1502.

Source	: U_3O_8	Measurement Time	: 3 Mins.
Certified value	: α =1000 Bq	Repeat	: 3
	β =15300 cpm / 2π	Position	: Center of chamber
Date of certificate	: 7 February, 1992	Standard counting efficiency (%)	: 98.19(α) & 54.06(β)
Area	: T=120mm X 120mm;	BG counting rate	: 0.58cpm(α) & 64.7cpm(β)
	A=100mm X 100mm	Detection limit counting rate	: 3.6cpm(α) & 17.5cpm(β)

TABLE 7(a): Measurement data for alpha particles.

OBSERVATION	TOTAL COUNT	AVERAGE COUNT	NET COUNTING RATE cpm	MEASURED Bq VALUE	RELATIVE STANDARD DEVIATION (%)
1	88161				
2	87806	87985	29327.75	9964.42	0.7
3	87988				

TABLE 7(b): Measurement data for beta particles.

OBSERVATION	TOTAL COUNT	AVERAGE COUNT	NET COUNTING RATE cpm	MEASURED EMISSION RATE cpm / 2π	RELATIVE STANDARD DEVIATION (%)
1	47231				
2	47116	47290.67	15698.86	14519.84	0.9
3	47525				

TABLE 8: Measurement data for the source number: 1534.

Source	: U_3O_8	Measurement Time	: 3 Mins.
Certified value	: α =228 Bq	Repeat	: 3
	β =3470 cpm / 2π	Position	: Center of chamber
Date of certificate	: 27 February, 19992	Standard counting efficiency (%)	: 98.19(α) & 54.06(β)
Area	: T=50mm;	BG counting rate	: 0.58cpm(α) & 64.7cpm(β)
	ØA=42mmØ	Detection limit counting rate	: 3.6cpm(α) & 17.5cpm(β)

TABLE 8(a): Measurement data for alpha particles.

OBSERVATION	TOTAL COUNT	AVERAGE COUNT	NET COUNTING RATE cpm	MEASURED Bq VALUE	RELATIVE STANDARD DEVIATION (%)
1	20014				
2	20073	20126.67	6708.31	227.92	1.4
3	20293				

TABLE 8(b): Measurement data for beta particles.

OBSERVATION	TOTAL COUNT	AVERAGE COUNT	NET COUNTING RATE cpm	MEASURED EMISSION RATE cpm / 2π	RELATIVE STANDARD DEVIATION (%)
1	11394				
2	11210	11391.33	3732.41	3452.1	1.9
3	11570				

TABLE 9: Measurement data for the source number: 1691.

Source	: U_3O_8	Measurement Time	: 3 Mins.
Certified value	: α =166 Bq	Repeat	: 3
	β =2740 cpm / 2π	Position	: Center of chamber
Date of certificate	: 29 October, 1993	Standard counting efficiency (%)	: 98.19(α) & 54.06(β)
Area	: T=50mm;	BG counting rate	: 0.58cpm(α) & 64.7cpm(β)
	ØA=40mmØ	Detection limit counting rate	: 3.6cpm(α) & 17.5cpm(β)

TABLE 9(a): Measurement data for alpha particles.

OBSERVATION	TOTAL COUNT	AVERAGE COUNT	NET COUNTING RATE cpm	MEASURED Bq VALUE	RELATIVE STANDARD DEVIATION (%)
1	14628				
2	14614	14706.33	4901.53	166.53	1.6
3	14877				

TABLE 9(b): Measurement data for beta particles.

OBSERVATION	TOTAL COUNT	AVERAGE COUNT	NET COUNTING RATE cpm	MEASURED EMISSION RATE cpm / 2π	RELATIVE STANDARD DEVIATION (%)
1	8531				
2	8457	8440.33	2748.74	2542.31	2.2
3	8333				

TABLE 10: Measurement data for the source number: 1692.

Source	: U_3O_8	Measurement Time	: 3 Mins.
Certified value	: α =198 Bq	Repeat	: 3
	β =3100 cpm / 2π	Position	: Center of chamber
Date of certificate	: 20 October, 1993	Standard counting efficiency (%)	: 98.19(α) & 54.06(β)
Area	: T=50 mm;	BG counting rate	: 0.58cpm(α) & 64.7cpm(β)
	ØA=45 mmØ	Detection limit counting rate	: 3.6cpm(α) & 17.5cpm(β)

TABLE 10(a): Measurement data for alpha particles.

OBSERVATION	TOTAL COUNT	AVERAGE COUNT	NET COUNTING RATE cpm	MEASURED Bq VALUE	RELATIVE STANDARD DEVIATION (%)
1	17408				
2	17418	17410	5802.75	197.15	1.5
3	17404				

TABLE 10(b): Measurement data for beta particles.

OBSERVATION	TOTAL COUNT	AVERAGE COUNT	NET COUNTING RATE cpm	MEASURED EMISSION RATE cpm / 2π	RELATIVE STANDARD DEVIATION (%)
1	10208				
2	10248	10249.33	3351.74	3100.02	2
3	10292				

6. CONCLUSIONS

Plateau lengths, efficiency and sensitivity distribution results are acceptable and reliable according to recommendations of manufacturer.

For α particles, efficiency of center position is taken for calculation. Counting efficiency for beta rays of U_3O_8 must be 30% or more for 4π area[3] and the result is acceptable as well as reliable. The α particles are separated by a aluminum sheet of thickness 27mg/cm^2.

Bq value and the beta ray emission rate are certified by JRIA[1]. The counting system specifications are standardized by the manufacturer. It is evident from the result of experiment and a comparison with the certified values that the mentioned surface sources are quite reliable to calibrate the radiation monitoring instruments.

REFERENCES

[1] Certificates of JRIA, 93-655(December 2, 1993), 93-656(December 2, 1993), 93-657(December 2, 1993), 93-658(December 2, 1993), 88-331(April 11, 1988), 88-245(March 16, 1988), 90-263(May 24, 1990), 90-264(May 24, 1990), 92-177(March 5, 1992), 92-178(March 5, 1992), 92-181(March 5, 1992), 92-182(March 5, 1992), 93-603(November 8, 1993), 93-604(November 8, 1993), 93-601(November 8, 1993), 93-602(November 8, 1993).
[2] Instruction Manual, 2π gas flow counter, Model BS - R74 - 2754, Aloka Co., Ltd.
[3] Instruction Manual, Universal Scaler, Model TDC - 511, Aloka Co., Ltd.
[4] Nicholas Tsoulfanidis, Measurement and Detection of Radiation, Hemisphere Publishing Corporation, p. 184.