CALORIMETRY DETERMINATION OF ^{210}Po IN TARGETS

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ABSTRACT

The polonium-210 activity in raw material targets which was used to make the start neutron source rods of Qinshan Nuclear Power Station was determined in calorimetry. The calorimeter used is a twin-cup isothermal one. It works at room temperature and does not need any device of constant temperature. The instruments used for calorimetry are simple and have good properties. The background is from -1 μV to +2 μV when the room temperature changs between 16 ℃ and 28 ℃. The data gotten in calorimetry are in correspondence within ± 3.4 % with those from liquid scintillation method after the targets were dissolved, additionally in correspondence within ±1.7% with the data given by Amersham Laboratories for ^{241}Am determination.

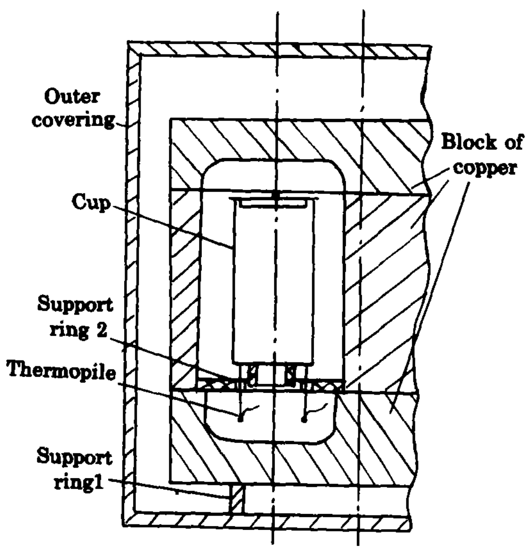
Keywords: Calorimetry determination Polonium-210 Raw material targets Radioactivity Start neutron source rods

1 INTRODUCTION

The polonium-210 is in a aluminium-outer covering which is about 2 mm thick, and has a characteristic that branch ratio of alpha particles is greater than 99 %[1]. The best method to determine ^{210}Po activity in the targets is calorimetry, whose principle is very simple. When the radio-energy is absorbed by an absorbent, its temperature goes up. The level of the temperature is proportional to the energy absorbed under given conditions. Comparing the temperature raised with the calibrated power of the calorimeter, the activity of the radio-source can be determined. There were some difficulties for us to overcome since the sizes of the targets were bigger, the time of heat equilibrium in calorimeter must be longer, for about ten hours according to our experience, and we had to determine about thirty targets in less than fifteen days during the period of making the start neutron source rods. So that the calorimeter used must have good properties in stability and simplicity. The calorimeter's cups must be big enough to hold the targets and so on.

2 EQUIPMENTS

The calorimeter used to determine the activity of ^{210}Po in the targets was specially built for this project, its schematic diagram is shown in Fig.1. The calorimeter is a twin–cup isothermal one. Both of the cups were isolated from each other in a massive block of copper that was placed in a temperature–attenuating enclosure, they did not get in touch with the block of copper. The cups were made of copper having only 0.4 mm thick, and their surface was very smooth. The instrument was literally a balance,



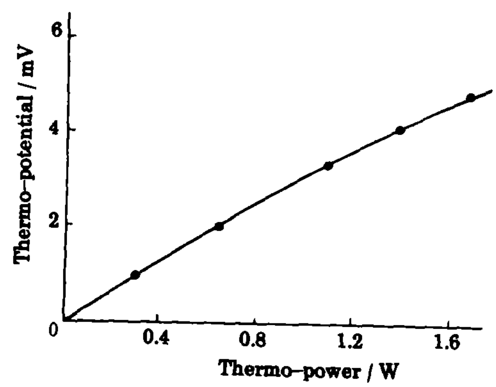


Fig.1 Schematic diagram of the calorimeter **Fig.2 Calibration curve of the calorimeter**

and two nearly equal emission–rate sources can be compared here without using the Peltier junction at all. A target was placed in one cup and a suitable dummy of that target in the other one when the activity of ^{210}Po in the targets was determined. Thermopiles made of copper–constantan at the bottoms of the cups as shown in Fig.1, were used to change the radio–heat absorbed by the cup into electric potential. There were 20 pairs of thermocouple for each of them. The junctures on the one side of the thermopile were even distributed at the bottoms of the cups, the other junctures at the other side were put into the oil contained in hollow at the bottom of the massive block of copper. There was a compensated resistance coil for calibration in each cup, which consisted of the framework and coil. The framework was made of copper and only 0.3 mm thick, the coil was evenly winded outside of the framework. The external diameter of that coil was right matched with the cup. The potential generated by a thermocouple (or thermopile) is most readily measured with a potentiometer. For continuous measurement, the degree of imbalance of a potentiometer may be determined in terms of the deflection of a galvanometer, or continuously recorded by means of a low drift chopper amplifier and a chart recorder. In this calorimetry system, Autocal Digital Multimeter (Model HG1965/A) with Microprocessor was used to measure the potential generated by the thermopile. Its temperature coefficient is

1/10th of 90 day specification ± 0.2 μV/ ℃ (10 ℃ to 40 ℃). The voltage supplier of YJ-300 (0-30 V) was used to graduate and calibrate the calorimeter.

3 RESULTS

The target of polonium-210 raw material consists of polonium-210 and the aluminium outer covering (2 mm thick, 208 mm high, and the diameter: 48 mm). Polonium-210 was produced by reactor activating of bismuth oxide inserted in the alumimium outer covering. The calorimeter had to be calibrated and its parameters had to be determined before the targets were measured.

3.1 Effect of surrouding temperatures on calorimeter

The calorimeter was placed in a room having no windows. The special thermal insulation measures of the door were adopted before. The room temperature was controlled at 16-30 ℃ by a electricity heating system. The experimental data are given in Table 1. It shows that when the surrounding temperature of the calorimeter changes from 16.0 to 28.0 ℃, the potential generated by the thermopile is between -1 μV and +2 μV. This was proved by the later experiments as shown in Table 2. The data in Table 2 were gotten under the natural room temperature from winter to summer in a year. So the calorimeter can be used at room temperature satisfying the measurement of ^{210}Po activity.

Table 1

Influence of surrounding temperature change on the calorimeter

Surrounding temperature/ °C	Keeping time/ h	Thermo-potential / μV
15.0	24	-1.0
18.0	24	-1.0
20.0	24	+1.5
24.5	24	+2.0
26.0	24	-0.5
28.0	24	+1.0

Table 2

Natural influence of surrounding temperature change on the calorimeter

Time (1989)	Room temperature/°C	Measurement times	Thermo-potential/ μV
Jan. 15—28	14.5—17.0	2	-0.5, +1
May 3—10	17.0—20.5	3	-1.0, +2.0, +1.5
Jun. 5—23	21.5—23.5	3	-0.5, +1.0, -1.0
Jul. 25—28	27.0—29.0	2	+2.0, -1.0
Oct. 3—10	18.0—19.5	2	-0.5, -1.0
Dec. 17—20	16.5—18.0	2	+2.0, -1.0

3.2 Calibration of calorimeter

The calorimeter was calibrated with a compensated resistance coil. The calibration curve which was only for examination and compensation the calorimeter is plotted in Fig.2. From which the sensitivity of the calorimeter is about 3.1 μV/mW, and it has a linearity until 1000 mW. For the long-term stability (one year) of the calorimetry system any three points each time were measured and compared them with the corresponding points on the calibration curve. The deviations are within ± 0.5 %.

In the project of the research and making of the start neutron source rods, three batches of the targets were measured, using a simulator of heating coil to calibrate the calorimeter. The heating metal line was evenly distributed along the axis in bismuth oxide that was in the outer covering. Calorimeter is usually calibrated with electricity power. It is assumed that there is no heat resistance in absorbent and temperature distribution caused by the heat source is homogeneous in the absorbent. According to this assumption, the heat source measured is equivalent to the electricity power. But, in fact, any material has heat resistance. Using a simulator of heating coil to calibrate the calorimeter was to decrease the effect from temperature distribution to the measurement results. The temperature distribution effect can be neglected if the simulator of heating coil is well made. It is easy to know the activity of ^{210}Po in the target if we know its thermo-power and the power ratio of ^{210}Po (0.032 W/Ci)[2]. We measured one target that had been activated for a period of time. This measurement was for the purpose of comparing experimental results with the data calculated theoretically, so that the targets could get suitable activation and gave enough polonium-210 for the project. Radioactivity of the target measured was $3.5 \pm 0.074 \times 10^{11}$ Bq (9.5 ± 0.2 Ci). After the measurement the target was put into the activation pipe again.

3.3 Comparison among calorimetry and other methods

Nine targets were measured when the experiment of neutron yield was carried out. This time, the measured results were compared with those from liquid scintillation method after dissolving the targets. The data deviations were within $\pm$ 3.4 %.

Two pots of americium-241 raw material from Amersham Laboratories were measured. The outer covering of the pots was made of stainless steel. One has 5.55 TBq (150.02 Ci), the other has 2.78 TBq (75.00 Ci). The results were in correspondence within ± 1.7 % with the data given by Amersham Laboratories.

3.4 Factors of effect on calorimetry

Experiment results showed that the non-even distribution of ^{210}Po in the targets could effect calorimetry measurement, but the non-even distribution of ^{210}Po in our targets were lower, so the effect of it could not be measured and can be neglected. The effect of the place of the targed can be neglected if the outer covering of the target is getten a good touch with the calorimetry cup.

REFERENCES

1 Fan Shengen. Safe use. Beijing: Atomic Energy Press, 1983; 258
2 Bross A, Criser M, Kross B. Nucl Instr Meth, 1990; A286(1/3):69