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Design of an alpha-particle counting system at a defined solid angle at Turkish atomic energy authority-Sarayköy nuclear research and training center (TAEK-SANAEM)

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HIGHLIGHTS

- An alpha-particle counting system at a defined solid angle (ACS-DSA) is designed.
- ACS-DSA is an accurate methods for the standardization of alpha emitters.
- Removable components allow versatility and accurate solid angle calculation.
- Sliding piston with digital caliper provides accurate distance measurement.
- A test spectrum is acquired showing relatively good resolution.

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ABSTRACT

The design details of an alpha-particle counting set-up at a defined solid angle (ACS-DSA) constructed in Radionuclide Metrology Department at TAEK-SANAEM for use in the primary standardization of radioactive solutions and determination of nuclear decay data of alpha-particle emitters is presented. The counting system is designed such that the solid angle is very well-defined and directly traceable to the national standards. The design involves mechanical construction of different parts like the source chamber, various coaxial flanges, and circular diaphragms in front of the passivated implanted planar silicon (PIPS®) detector, distance tubes, a digital caliper and a sliding piston to allow for different measurement configurations. All geometric configurations are easily changeable and characterisable with high accuracy which facilitates the solid angle calculation. A mixed alpha source was counted to check performance of assembled ACS-DSA system and good energy resolution and low peak tailing in the alpha energy spectrum was observed for small diaphragm apertures and far source-to-detector geometries.

1. Introduction

Traceable and accurate radioactivity analysis is the main component for the proper evaluation of environmental and health risks related to the use of radioactive materials. The availability of radionuclide standards is essential to calibrate instruments, to monitor radiochemical procedures and to assure quality of the measurements.

Turkey's need for energy led the policymakers decide on nuclear power to supply energy to the industry which in turn triggered the necessity to monitor the environment in terms of radiological protection. Ever increasing numbers of radioactivity measurement laboratories due to these nuclear power projects in Turkey create a strong demand for accurate, traceable and certified activity standards. All laboratories measuring radioactivity in Turkey supply their radioactive reference materials from abroad. This creates major problems such as tiresome and long licensing and customs procedures, shorter usefulness period for the reference material due to the time spent during transport and customs, increased costs and unavailability of certain radioactivity reference materials.

Turkish Atomic Energy Authority-Sarayköy Nuclear Research and Training Center (TAEK-SANAEM) addressed this lack of a reference radiation measurements and calibration laboratory by participating in the European Union IPA (Instrument for Pre-Accession) project titled "TR080209 – Improving Chemical and Ionizing Radiation Metrology". This project was jointly carried out

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with Scientific and Technological Research Council of Turkey – National Metrology Institute (TUBITAK UME) and European Commission-Joint Research Center-Institute for Reference Materials and Measurements (EC-JRC-IRMM) and aimed at knowledge transfer in the fields of radionuclide and dosimetry standardization techniques. This project led to the establishment of a national radionuclide metrology laboratory in TAEK-SANAEM to provide primary and secondary radionuclide standards and measurement services for radioactivity measurement laboratories. TAEK-SANAEM's radionuclide metrology laboratory will be the sole place in Turkey to provide radionuclide standardization and radioactive reference material production. This prospect involves developing national standards and primary measurement methods, provision of calibration services and conducting nationwide proficiency testing programs.

The radionuclide metrology laboratory is spending great effort in order to establish primary and secondary radioactivity measurement techniques. Various precision instruments are designed, constructed and/or installed for measuring radioactivity with high level of accuracy. One of these systems is the alpha-particle counting system at a defined solid angle (ACS-DSA) which is one of the most accurate primary standardization methods for alpha emitting radionuclides and low energy photon emitters in the range of 1–20 keV (García-Toraño et al., 2008; Pommé, 2007). The main advantage of ACS-DSA is it is a primary measurement method, which by definition does not need to use tabulated nuclear data and/or the measurement results do not depend significantly on these data. DSA method has many applications in primary standardization studies, in accurate half-life determination of long-lived radionuclides and emission probabilities of alpha emitting radionuclides. IRMM and several other prominent primary laboratories apply this technique to the activity measurement and nuclear decay data evaluation of alpha emitters (García-Toraño et al., 2008; Pommé and Sibbens, 2008; Pommé et al., 2009; Sibbens et al., 2004).

The defined solid angle method is based on the determination of the solid angle Ω subtended by the detector (García-Toraño et al., 2008; Pommé, 2007). The main objective is to measure the radiation that is emitted in the solid angle subtended by the detector or by the aperture of the diaphragm covering the detector (Pommé, 2007). The system mentioned in this article has been designed and built with the aim of activity standardization with good counting efficiency, low uncertainty and flexible operation. The set-up is based on existing systems in IRMM (Denecke et al., 1999; Pommé and Sibbens, 2008) with several modifications.

2. Design components of the alpha-particle counting system at a defined solid angle (ACS-DSA)

The schematic diagrams of the model design developed by Denecke et al. in 1999, the modified design by SANAEM and an actual picture of the constructed system are given in Fig. 1. The system as schematically illustrated in Fig.1B comprises of a source chamber, two identical distance tubes, anti-scatter baffles, coaxial flange system, rubber and copper vacuum O-rings for air-tightness, high vacuum gate valve and Passivated Implanted Planar Silicon (PIPS) detector. Defined solid angle method depends on strictly controlled geometrical conditions of the set-up to reach a state-of-the-art level of accuracy (Collé, 2009; Pommé, 2004). All of the components are designed almost perfectly concentric by overlapping centering channels with an error margin of 10 µm to meet these conditions. The mechanical structure of the counting system is based on modular vacuum flanges with flat contact surfaces and grooves for O-ring seals and the centering channels. Diaphragm flange is placed in front of the detector flange and centered on the symmetry axis of the detector by a centering channel. The detector is connected to the preamplifier in a vacuum-tight manner with a special connector.

The air in the source chamber is evacuated by the combination of a mechanical pump and a turbo molecular pump to produce a vacuum of 10^{-5} Pa or less. Radioactive source material deposited on a flat substrate is centered on the symmetry axis of the circular diaphragm in front of the detector. The ACS-DSA has a quite versatile construction so as to allow various solid angles by changing the dimensions of the diaphragm aperture and source-to-detector distance and by adding or removing distance tubes.

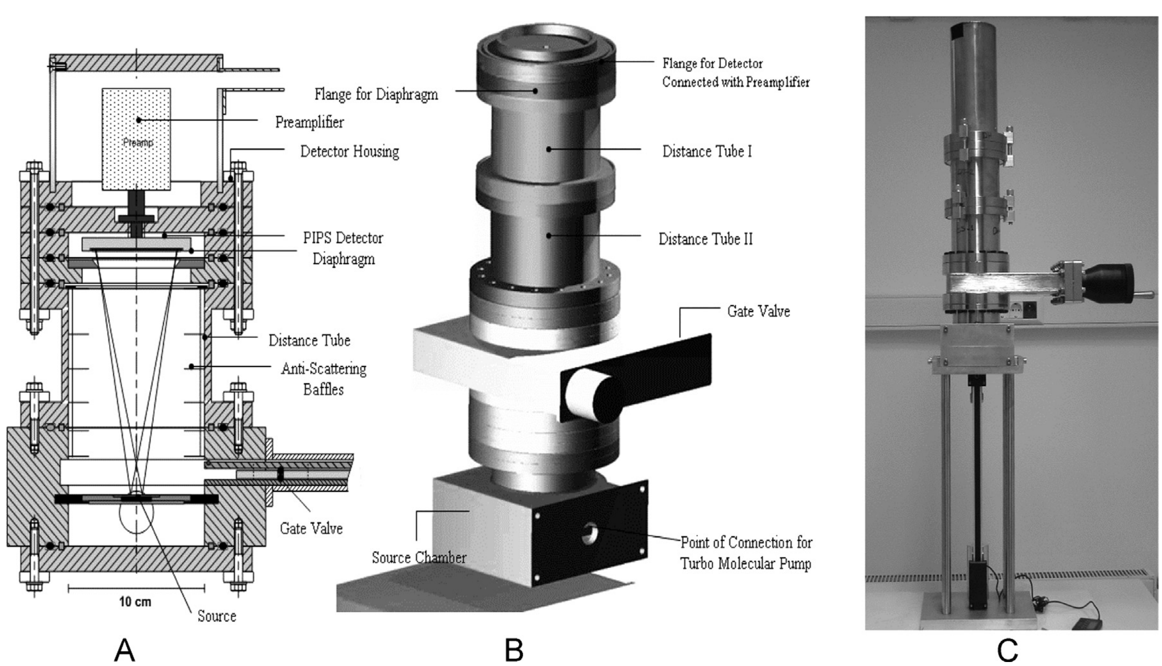

Fig. 1. The schematic diagrams of ACS-DSA; (a) model design taken from IRMM, designed by Denecke et al. (1999), (b) modified design of SANAEM, and (c) a picture of the actual setup constructed in the department of radionuclide metrology at SANAEM.