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Calibration standard for nuclear decommissioning

Grey cast iron tubes containing ^{60}Co and ^{108m}Ag

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Abstract

In the frame of support of decommissioning activities, JRC-GEEL produced a set of 12 grey cast iron tubes. These tubes contain known amounts of activity of ^{60}Co and ^{108m}Ag. The tubes are intended to be used as a calibration standard for the detection efficiency of measurement facilities dealing with clearance (free release) and/or characterisation of waste generated from decommissioning of nuclear facilities/installations. Following to their characterisation the SI-traceable activity standards will contribute to enhance reliability of these kinds of measurement systems.

Introduction

In Europe and even globally we are facing the challenges of decommissioning of old nuclear power plants and other nuclear installations. After the removal of the nuclear fuel, the nuclear installation needs to be decommissioned. The remaining materials need to be managed and/or cleared from regulatory control in a safe and reliable way. A lot of the remaining radioactivity is present in the primary circuit of the reactor. However, radioactivity is also encountered in the surroundings of the primary circuit. The levels of radioactivity in the surroundings are lower but the amount of the material to be managed is much higher.

The two most important streams of waste are concrete and metals. As an example, a Pressurised Water Reactor (PWR) built in 1970s, is constructed with around 75000 m^3 of concrete and 36000 metric ton of steel and iron [1]. The vast majority of this material needs to be characterised before safe disposal or free release.

Taking into consideration the large amount of material and the high cost of safe radioactive waste disposal, the European commission issued Council Directive 2011/70/Euratom [1] stating that: "Generation of radioactive waste shall be kept to a minimum which is reasonably practicable in volume and activity by means of appropriate design measures and of operating and decommissioning practices including the recycling and reuse of materials."

The activity concentration (expressed in Bq kg^{-1}) values for clearance of materials which can be applied by default to any amount and to any type of solid material during the decommissioning of a power plant are laid down in Council Directive 2013/59/Euratom [3]. These values are set per radionuclide.

In order to comply with legislation a lot of measurements need to be carried out for the segregation/characterisation and/or free release of all the materials present on the nuclear sites. To validate and calibrate the various systems/set-ups used to perform such measurements, SI-traceable activity standards are needed. Such standards need to represent, as much as possible, the geometries, matrices, radionuclide content of interest in the practice. The routine free release involves normally measurement of bulk quantities of materials (often placed in europallet sized containers for measurement) of three types: metal, concrete or light materials. It is therefore critical to have suitable calibration standards of such types available. The need for a resembling reference standard is even more pronounced for metals due to the strong effects of self-attenuation of radiation. Such a standard should resemble in matrix and geometrical configuration the routinely measured metal waste.

A NPP has to manage large components and in particular a lot of piping system parts. In order to fill the gap in availability of such standards to the European community, JRC-Geel has included in its work-programme the development of a standard consisting of metal tubes.

The feasibility of the production and characterisation of this material has been proven by previous work led by JRC-Geel. This work had been carried out in the context of the MetroRWM project. The outcome was a traceable activity standard, for free release measurement facilities, consisting of iron tubes [4], [5] (and references therein).

These tubes contained ^{60}Co and ^{110m}Ag. Silver-110m has a major drawback in this context that its short half-life, only 250 days, limits the time during which the calibration standard can be used. There was a concern that the activity of ^{110m}Ag would not be sufficiently homogeneously distributed, as silver does not form a solid solution with iron as cobalt does. In the MetroRWM project we showed that indeed there is a small inhomogeneity of about 2% of the ^{110m}Ag in the radial direction. However the nuclide is homogeneously distributed along the major axis of the tubes. Thereby the activity distribution fulfilled the requirements. Cobalt-60 was, as predicted, perfectly homogenously distributed.

The radionuclide ^{108m}Ag has the same chemical properties as ^{110m}Ag. It also emits several intense gamma-rays of suitable energy. It has a longer half-life, 438 years, compared to ^{110m}Ag. Therefore, it is more suitable for this type of calibration standard.

1 Requirements of the materials

1.1 Technical specifications

JRC-Geel set up a contract with an industrial metal melting facility to produce the material for the metallic standard: a set of 12 grey cast iron tubes containing homogeneously distributed radionuclides: ^{60}Co and ^{108m}Ag.The tubes were produced from a batch of grey cast iron (Standard DIN 1691 GG10, GG15, GG20 or GG25) [4] contaminated with ^{60}Co and ^{108m}Ag. The homogeneity of the batch material in density and radioactivity distribution was specified. In addition, representative samples, of the raw material and of the individual tubes, were requested. These samples were in the shape of disks and machining swarfs. These samples will be used for the characterisation of the standard.

Twelve disks were made from the smelts used to cast the tubes. These disks should have the same homogeneity in density and activity distribution as the tubes. From the 12 tubes, 36 samples of swarfs were collected (3 samples per tube each sampled at a different height) during machining. All the specifications of the tubes, disks and swarfs are listed in Table 1.

The contaminated waste metal, obtained from the tubes/disks machining process, was re-melted in order reduce the amount of radioactive waste. From this smelt 20 iron waste-disks were produced. These disks are to be characterised as an activity standard for other applications (e.g. radioactivity monitoring in the metallurgical sector). The massic activity concentration of the two radionuclides in the waste-disks is expected to be slightly lower, compared to the one of the disks, and/or swarfs obtained during the tubes' production. The specifications of the 20 waste-disks are listed in Table 2.

Table 1 Specification of the iron tubes, disks and swarfs

	Parameter	Unit	Value
A.	**One tube/casting data**		
	Length	*mm*	400 +0 -0.2
	Diameter (outer)	*mm*	200 +0 -0.2
	Mass	*kg*	20.5 ± 0.5
	Thickness	*mm*	12 ± 0.4
B.	**Tubes/casting set of 12 data**		
	Mass	*kg*	246 ± 6
	Total Activity ^{108m}Ag	*kBq*	100 ± 40
	Total Activity ^{60}Co	*kBq*	1800 ± 400
	Average density in occupied container volume	*g/cm^3*	1.28 ± 0.03
C.	**Batch material**		
	Density homogeneity	*% variation*	2
	Homogeneity in specific activity	*% variation*	^{108m}Ag: 7 ^{60}Co: 2
D.	**Disks from tubes**		
	Diameter (outer)	*mm*	80 ± 1
	Thickness	*mm*	10 ± 1
E.	**Swarfs (specs. for one sample)**		
	mass	*g*	10-20

Table 2: Specifications of waste-disks

Parameter	Unit	Value
Diameter (outer)	*mm*	35 ± 0.5
Thickness	*mm*	10 ± 0.5
Contents of radionuclides	-	^{60}Co, ^{108m}Ag
Homogeneity in specific activity	*% Variation*	^{60}Co: 2 ^{108m}Ag: 10

1.2 Sample numbering

For the production of the contaminated tubes, disks and swarfs, it is of utmost importance that all items produced are uniquely identified and traceable to their origin. A schedule for numbering the items was agreed upon with the contractor producing the material. The schedule is shown in Figure 1.

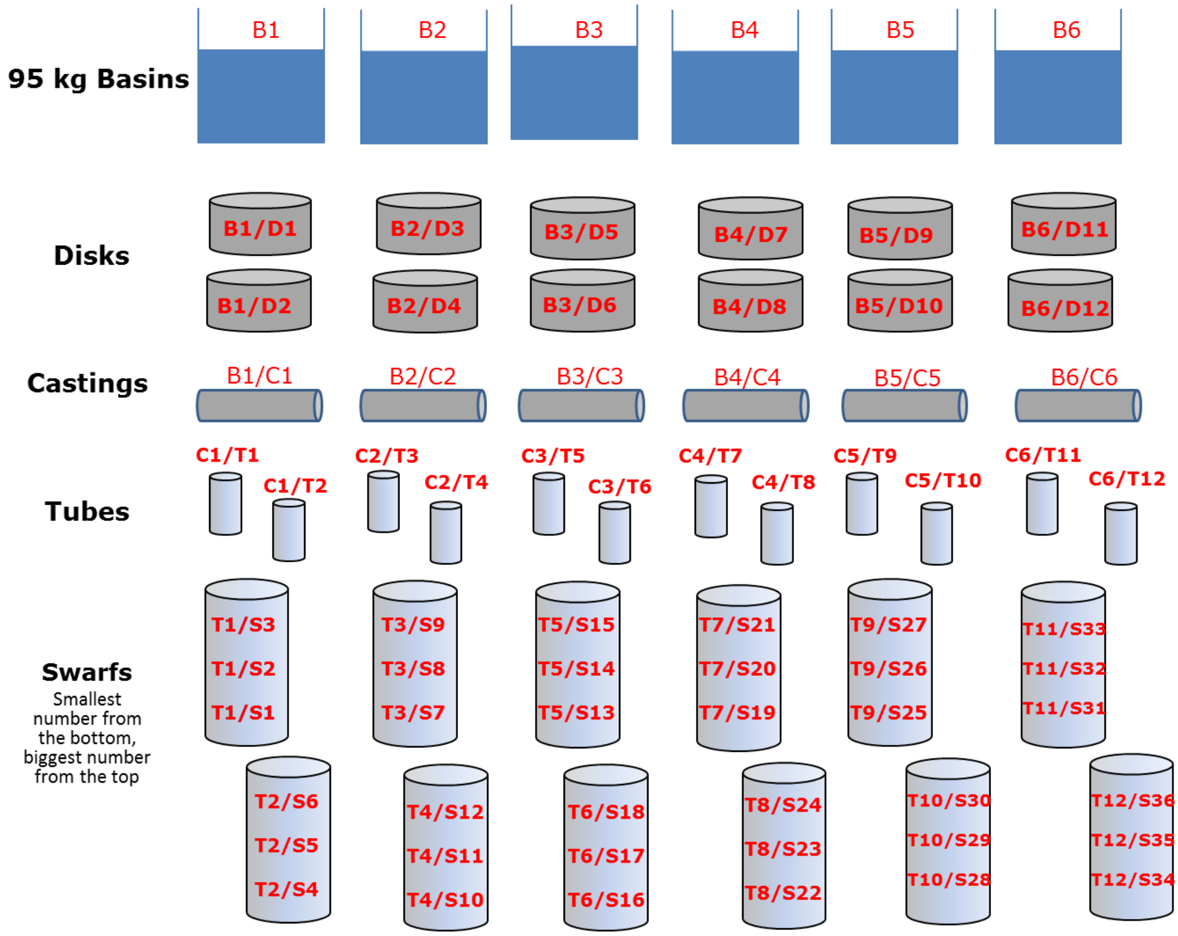

Figure 1: Numbering of the samples during the production of the tubes

The 20 waste-disks also need to be uniquely numbered according to the schedule in Figure 2.

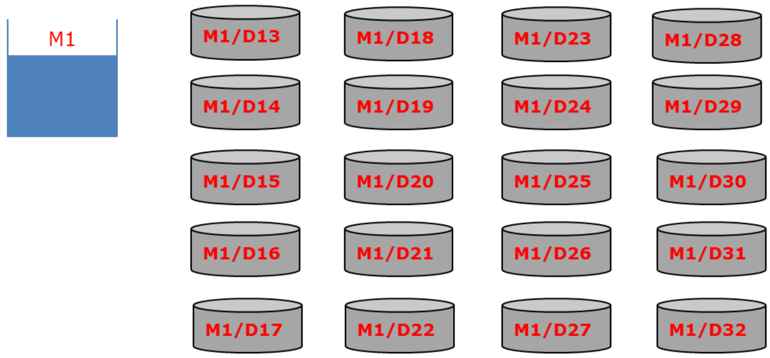

Figure 2: Numbering of the 20 waste-disks

2 Production

The production of the tubes and the collection of the samples took place in the industrial melting facility of VUHZ in Trebic, Czech Republic [7]. For the production of the tubes it was not possible to use conventional technologies due to the fact that high amounts of materials are needed causing contamination in the production plant. Centrifugal casting was considered the most suitable for producing the material as it needs less material input and generates relatively small amounts of waste.

In centrifugal casting, a permanent mold is rotated continuously around its axis at high speeds as the molten metal is poured on. The molten metal is centrifugally thrown towards the inside mold wall, where it solidifies after cooling. The casting is usually a fine-grained casting with a very fine-grained outer diameter, owing to chilling against the mould surface. A schematic view of the production process is shown in Figure 3.

The mold used for the production of the castings had a diameter of 170 mm and a length of 1131 mm. One smelt (basin) per casting was prepared. From each casting 2 tubes were produced by machining them to their final dimensions.

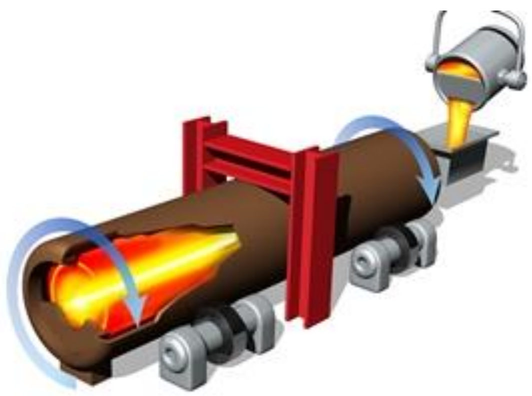

Figure 3: Schematic view of horizontal casting

Two disks were produced from each smelt (basin). Each disk was casted in a mold and machined to its specified dimensions. In total 12 disks were produced from 6 smelts (basins). Pictures of the tubes and disks are shown in Figures 4 and 5.

Figure 4: 12 cast iron tubes

Figure 5: 12 cast iron disks

JRC-Geel supplied VUHZ with two standard solutions of ^{108m}Ag containing in total an activity of 740 KBq in the total volume of 10 mL [8]. The ^{60}Co in the tubes was readily available at VUHZ. A master alloy containing both radionuclides, ^{60}Co and ^{108m}Ag, was prepared. This master alloy was distributed over each smelt (basin) of production of the individual raw castings.

From the collection of all the swarfs an additional smelt was made. From this smelt 20 additional disks were made.

3 Conclusion

In the frame of the support to nuclear decommissioning, a set of 12 grey cast iron tubes, containing known amounts of ^{60}Co and ^{108m}Ag, was produced. Disk-shaped and swarfs samples were produced in order to be used for the characterisation of the material. All the produced materials were identified by a unique code.

The produced materials will be tested against their specifications. Activity measurements of the tubes, disks and swarfs will lead to a new SI-traceable metal standard in the shape of tubes. The standard will contribute to enhance reliability of free release and waste characterisation measurements in the field of nuclear decommissioning.

References

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[6] Standard DIN 1691 Flake graphite cast iron (grey cast iron) Properties

[7] VÚHŽ a.s., 739 51 Dobrá 240, Czech Republic

[8] Certificates of calibration gamma standard solution, Eckert&ziegler ref 1867-17, 1827-38

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