RTG

Radioisotopic Thermal Generator

Project supported by Andra under the "Investments for the Future Programme" ("Investissement d'Avenir") - Selected under the Andra Call for Projects: "Optimisation of post-dismantling radioactive waste management", organised in cooperation with the French National Research Agency (ANR).

Duration: 30 months

Project launch:
05/2017

Total project cost:
€2.4 million

Including funding under the Investments for the Future Programme: €1.2 million

Type of financial support:
Subsidy with ROI guarantees for the State

Locations:
Courbevoie,
Grenoble,
Nancy

Coordinator: Orano

Partners:

- Orano
- HotBlock OnBoard
- Laboratoire d'Energétique et de Mécanique Théorique et Appliquée (LEMTA) CNRS/Université de Lorraine

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BACKGROUND

The Industrial Centre for Geological Disposal (Cigeo) is the project to build a deep geological disposal facility (500 metres deep) for the most highly radioactive, long-lived waste produced in France. The Cigeo facility will operate for around a hundred years. With this in mind, the system deployed to observe and monitor the disposal facility will require a power supply for the sensors installed 500 metres below ground, in the radioactive waste disposal cells. To this end, current research is focused on standalone systems rather than cabled systems, which would not only imply a high intrusion risk given the fact that the power cables would have to penetrate through the different barriers in the facility (disposal cells, seals and surrounding rock), but would also entail the risks associated with deterioration of the cables over time (e.g. power cuts).

Researchers have explored the possibility of using nuclear batteries since the early days of developing nuclear technology, particularly in light of their potentially long operating life and autonomy. In the last few decades, the main technology developed has been radioisotopic thermal generators (RTG), which convert heat from radioisotope decay into electricity by the "Seebeck effect". RTGs have already been successfully deployed for space missions, and also for applications here on Earth (power supply to certain lighthouses, coastal beacons and remote weather stations). Various isotopes, including plutonium-238 and, in particular, strontium-90, have been used as heat sources in these systems. However, neither of these elements is easy to obtain, and they can entail a risk of proliferation.

As part of its spent fuel reprocessing activities, Orano (formerly AREVA) has recovered americium-241: this element is not as powerful as plutonium-238 but has a much longer half-life, thus ensuring long-term energy production.

OBJECTIVES

The RTG project is an industrial research project whose main objective is to design and produce an inactive prototype (i.e. using a simulated radioactive source) for a standalone RTG powered by americium-241.

Americium-241 has never been used before as the heat source in an RTG, meaning that developing this new RTG will first require rethinking the design of existing systems. It will be necessary to study thermal transfer between the RTG and its environment, equipment ageing and robustness, the possibilities for improving energy efficiency, ways to store electricity produced between two measurements and transmissions, the conditions required regarding selective extraction of americium at La Hague, and its subsequent transformation. Operator and environmental safety and protection will, naturally, also be studied.

PROJECT SEQUENCE

An RTG is made up of three main sub-assemblies (**Figure 1**):

1. A radioisotope source (americium-241). This sub-assembly usually consists in a composite material made from radioelements (americium-241) with a protective coating in compliance with the regulations.

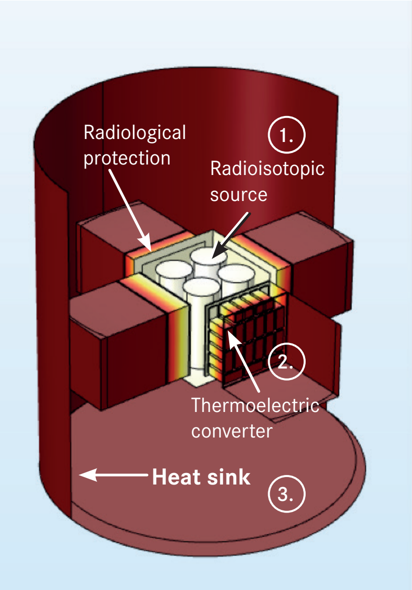

Figure 1: RTG sub-assemblies

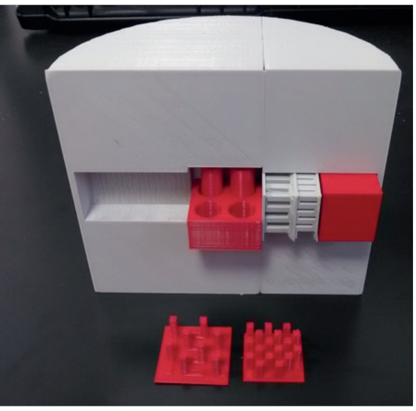

Figure 2: Model RTG produced by 3D printer – for the purposes of illustration only

2. Thermoelectric converters (convert the heat released by the radioelements into electricity) placed between the radioisotope source (1) and the heat sink (3)

3. A heat sink to dissipate any thermal power not converted into electricity (around 95%). A heat shield is placed between the radioisotope source and the heat sink to reduce loss.

The first stage of the project will involve designing a thermoelectric converter (2) functioning with americium, focusing on the materials to be used to ensure optimal conversion of heat into electricity (semi-conducting metals). The materials are in fact sensitive to the operating temperature.

Secondly, the thermocouple assembly will be modelled to obtain a plan of the full system.

Next, as per the specifications provided as a result of the design stage, manufacturing the americium source (1) will be studied (separation, processing and forming of the americium). The project will also define the tests (active tests, in a laboratory to be specified which possesses the technical and administrative capabilities to handle significant quantities of material) that will be performed to validate ageing of the system in a heated and irradiating environment.

Last, based on the design studies, an inactive prototype (with a thermo-electric source to simulate the americium pellets) of the full system will be produced, which may be used for validation tests.

These four stages must be completed within a period of 30 months.

EXPECTED RESULTS

Innovation

Thermoelectric conversion has been understood for over a century, but its low efficiency has meant that its use has been restricted to just a few niche markets.

This project aims to innovate in two ways: first, it involves a new design of the RTG subsystems – particularly given the use of americium-241 (a source that has never been studied for use in an RTG). Second, the performance expected of the end product will be fully reviewed to ensure optimal efficiency over an even longer period of time than that of models developed in the past.

Economic impact

This project is being developed with HotBlock OnBoard and will thus boost the SME's development in the transport market and industrial applications in general, since the project involves improving thermal energy recovery systems.

Nonetheless, at this stage there are no plans to deploy generators with americium sources for the disposal of radioactive waste.

Impact on radioactive waste management

Americium, which is currently treated as a waste product, would thus find a use in Cigeo, which is its ultimate disposal site in any event. The RTG project thus proposes to re-use this radioisotope in the nuclear sector.

If successful, the project could provide a power supply solution for Cigeo during the monitoring phase.

APPLICATION AND TRANSFER TO INDUSTRY

The space sector has long been looking for the development of americium-powered generators, which would be heavier than those operating with plutonium-238 but probably less expensive. Preliminary discussions with the European Space Agency (ESA) are underway with a view to their possible use on space missions.

Other radioactive waste disposal and management agencies outside France may also be interested in this application.