Radioactive Batteries

A Battery That Lasts For minimum of 20 Years

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***Abstract*: Nuclear batteries run off of the continuous radioactive decay of certain elements. These incredibly long-lasting batteries are still in the theoretical and developmental stage of existence, but they promise to provide clean, safe, almost endless energy. They have been designed for personal use as well as for civil engineering, aeronautics, and medical treatments. The almost magical production of electricity in nuclear batteries is made possible by the process of betavoltaics. Through this technology, the electrons that radioactive isotopes regularly lose due to decay can be harnessed and directed into a stream of electricity. A semiconductor, possibly made from silicon, catches the flying electrons and directs them into a steady power source. Even a small amount of radioactive material will provide a charge for a very long time before it expires.**

***Index terms:* Radioactivity, RTG, Battery, Betavoltaics, Isotopes.**

I. INTRODUCTION

The terms atomic battery, nuclear battery, tritium battery and radioisotope generator are used to describe a device which uses energy from the decay of a radioactive isotope to generate electricity. Like nuclear reactors they generate electricity from atomic energy, but differ in that they do not use a chain reaction. Compared to other batteries they are very costly, but have extremely long life and high energy density, and so they are mainly used as power sources for equipment that must operate unattended for long periods of time, such as spacecraft, pacemakers, underwater systems and automated scientific stations in remote parts of the world.

Nuclear battery technology began in 1913, when Henry Moseley first demonstrated the beta cell. The field received considerable in-depth research attention for applications requiring long-life power sources for space needs during the 1950s and 1960s. In 1954 RCA researched a small atomic battery for small radio receivers and hearing aids.

Batteries using the energy of radioisotope decay to provide long-lived power (10–20 years) are being developed internationally. Conversion techniques can be grouped into two types: thermal and non-thermal. The thermal converters (whose output power is a function of a temperature differential) include thermoelectric and thermionic generators. The non-thermal converters (whose output power is not a function of a temperature difference) extract a fraction of the incident energy as it is being degraded into heat rather than using thermal energy to run electrons in a cycle.

II. THERMAL CONVERTERS

A. *Thermionic Converter*

quickly from the radium to the inside surface of the sphere. As late as 1945 the Moseley model guided other efforts to build experimental batteries generating electricity from the emissions of radioactive elements.

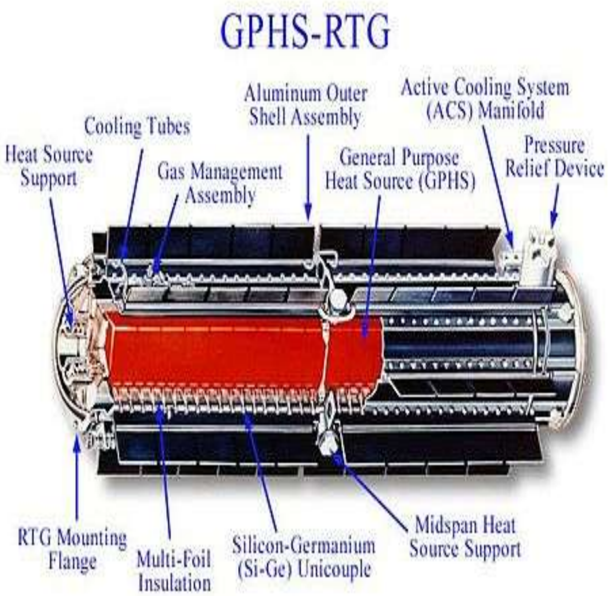
B. Betavoltaics

Betavoltaics are generators of electrical current, in effect a form of battery, which use energy from a radioactive source emitting beta particles (electrons). A common source used is the hydrogen isotope, tritium. Unlike most nuclear power sources, which use nuclear radiation to generate heat, which then generates electricity (thermoelectric and thermionic sources), betavoltaics use a non-thermal conversion process, using a semiconductor p-n junction.

Betavoltaics are particularly well-suited to low-power electrical applications where long life of the energy source is needed, such as implantable medical devices or military and space applications.

C. Alphavoltaics

Alphavoltaic power sources are devices that use a semiconductor junction to produce electrical particle from energetic alpha particles.



IV. RADIOISOTOPE THERMOELECTRIC GENERATOR

A Radioisotope Thermoelectric Generator (RTG, RITEG) is an electrical generator that uses an array of thermocouples to convert the heat released by the decay of a suitable radioactive material into electricity by the Seebeck effect.

RTGs have been used as power sources in satellites, space probes and such unmanned remote facilities as a series of lighthouses that the former Soviet Union erected inside the Arctic Circle. RTGs are usually the most desirable power source for robotic or unmaintained situations that need a few hundred watts (or less) of power for durations too long for fuel cells, batteries, or generators to provide economically and in places where solar cells are impractical. Safely using RTGs requires containing the radioisotopes long after the productive life of the unit.

V. DESIGN

The design of an RTG is simple by the standards of nuclear technology: the main component is a sturdy container of a radioactive material (the fuel). Thermocouples are placed in the walls of the container, with the outer end of each thermocouple connected to a heat sink. Radioactive decay of the fuel produces heat which flows through the thermocouples to the heat sink, generating electricity in the process.

A thermocouple is a thermoelectric device that converts thermal energy directly into electrical energy using the Seebeck effect. It is made of two kinds of metal (or semiconductors) that can both conduct electricity. They are connected to each other in a closed loop. If the two junctions are at different temperatures, an electric current will flow in the loop.

VI. FUEL

The radioactive material used in RTGs must have several characteristics:

- It should produce high energy radiation. Energy release per decay is proportional to power production per mole. Alpha decays in general release about 10 times as much energy as the beta decay of strontium-90 or cesium-137.
- Radiation must be of a type easily absorbed and transformed into thermal radiation, preferably alpha radiation. Beta radiation can emit considerable gamma/X-ray radiation through bremsstrahlung secondary radiation production and therefore requires heavy shielding. Isotopes must not produce significant amounts of gamma, neutron radiation or penetrating radiation in general through other decay modes or decay chain products.
- Its half-life must be so long that it will release energy at a relatively continuous rate for a reasonable amount of time. The amount of energy released per time (power) of a given quantity is inversely proportional to half-life. An isotope with twice the half-life and the same energy per decay will release power at half the rate per mole. Typical half-lives for radioisotopes used in RTGs are therefore several decades, although isotopes with shorter half-lives could be used for specialized applications.
- For spaceflight use, the fuel must produce a large amount of power per mass and volume (density). Density and weight are not as important for terrestrial use unless size is also restricted. The decay energy can be calculated if the energy of

radioactive radiation or the mass loss before and after radioactive decay is known.

VII. SELECTION OF ISOTOPES

The first two criteria limit the number of possible fuels to fewer than 30 atomic isotopes within the entire table of nuclides. Plutonium-238, curium-244 and strontium-90 are the most often cited candidate isotopes, but other such isotopes as polonium-210, promethium-147, caesium-137, cerium-144, ruthenium-106, cobalt-60, curium-242, americium-241 and thulium isotopes have also been studied.

VIII. EFFICIENCY

RTGs use thermoelectric couples or "thermocouples" to convert heat from the radioactive material into electricity. Thermocouples, though very reliable and long-lasting, are very inefficient; efficiencies above 10% have never been achieved and most RTGs have efficiencies between 3–7%.

IX. HISTORY

A pellet of 238PuO2 to be used in an RTG for either the Cassini or Galileo mission. The initial output is 62 watts. The pellet glows red hot because of the heat generated by the radioactive decay (primarily α). This photo was taken after insulating the pellet under a graphite blanket for several minutes and then removing the blanket.

RTGs were developed in the US during the late 1950s by Mound Laboratories in Miamisburg, Ohio under contract with the United States Atomic Energy Commission. The project was led by Dr. Bertram C. Blanke.

The first RTG launched into space by the United States was SNAP 3 in 1961, aboard the Navy Transit 4A spacecraft. One of the first terrestrial uses of RTGs was in 1966 by the US Navy at uninhabited Fairway Rock in Alaska. RTGs were used at that site until 1995.

In addition to spacecraft, the Soviet Union constructed many unmanned lighthouses and navigation beacons powered by RTGs. Powered by strontium-90 (^{90}Sr), they are very reliable and provide a steady source of power. Critics argue that they could cause environmental and security problems as leakage or theft of the radioactive material could pass unnoticed for years, particularly as the locations of some of these lighthouses are no longer known due to poor record keeping. In one instance, the radioactive compartments were opened by a thief. In another case, three woodsmen in Georgia came across two ceramic RTG heat sources that had been stripped of their shielding. Two of the three were later hospitalized with severe radiation burns after carrying the sources on their backs. The units were eventually recovered and isolated.

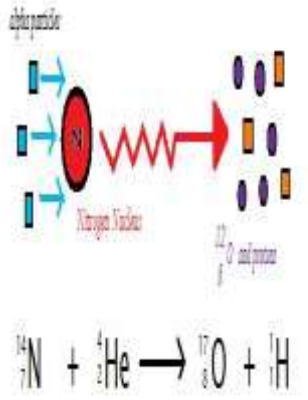
There are approximately 1,000 such RTGs in Russia. All of them have long exhausted their 10-year engineered life spans. They are likely no longer functional, and may be in need of dismantling. Some of them have become the prey of metal hunters, who strip the RTGs' metal casings, regardless of the risk of radioactive contamination.

The United States Air Force uses RTGs to power remote sensing stations for *Top-ROCC* and *Save-Igloo* radar systems predominantly located in Alaska.

In the past, small "plutonium cells" (very small ^{238}Pu-powered RTGs) were used in implanted heart pacemakers to ensure a very long "battery life". As of 2004, about 90 were still in use.

X. ARTIFICIALLY INDUCED RADIOACTIVITY

In a nutshell, radioactivity is described as the interaction with matter by heavier elements to produce ions. Although radioactivity is observed as a natural occurring process, it is a process that can also be artificially induced. Radioactivity is artificially induced through the bombarding atoms of a specific element by radiating particles, thus creating new atoms existing from another type of element.



Ernest Rutherford was a prominent New Zealand scientist, and a winner of the Nobel Prize in chemistry in 1908. Amongst his vast list of discoveries, Rutherford was also the first to discover artificially induced radioactivity. Through the bombardment of alpha particles against the nuclei of ^{14}N (7 protons/electrons) Rutherford produced ^{17}O (8 protons/electrons) and protons. Through this observation, Rutherford concluded that atoms of one specific element can be made into atoms of another element through the this discovered process of artificially induced radioactivity

Rutherford was the first intellectual to create protons outside of the atomic nuclei, and ^{17}O which was a nonradioactive isotope of oxygen.

XI. CONCLUSION

Don't let yourself be put off by the name "nuclear" batteries. You would not be coming in contact with a miniaturized nuclear reactor. In fact, once engineered to everyone's satisfaction, they could be much safer than ordinary chemical batteries. The radioactive elements are fairly rare, distributed as they are across a semiconductor, and would be very well insulated. Unlike alkaline batteries, these wouldn't corrode. We can use artificially induced radioactive materials.

Scientists are still working out the kinks in nuclear batteries before they can be widely implemented. Of course, they have long theorized that radioactive decay could provide a low-cost source of energy, but there are many problems with getting a current that is strong and dependable enough. One of the latest developments is to use silicon wafers with a large surface area, accomplished with texturing that puts pits and valleys across the thin semiconductor. This seems to boost the usable electrical output, as it catches more electrons rather than letting the radioactive isotope re-absorb them.

And we can use artificially radio activated materials to achieve more power and also achieve more radioactive fuels for the need of forth coming generations.

XII. REFERENCES

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