Nuclear Batteries

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1. Introduction

I'm reasonably sure that my readers first question is: "What the heck are 'nuclear batteries'? First of all, it's a misnomer. Although they do use nuclear radioisotopes, they are not batteries, as they cannot be charged nor discharged. They are energy converters, and are related to other energy converters like photovoltaic (PV) cells (which convert sunlight to electricity) and thermoelectric converters (which convert heat, that is temperature differences, to electricity). In fact, some "nuclear batteries" use these other two converters (and similar devices) in their design. Nuclear batteries convert nuclear radiation to electricity.

Let's start with the radiation. Nuclear radioisotopes emit three types of radiation: gamma rays, beta particles and alpha particles. Gamma rays are electromagnetic radiation, like light, except they are will deeply penetrate most solids (like you and me) and tend to destroy living tissue. Thus, gamma rays are a very poor choice to power most devices that currently use electro-chemical batteries, and we are left with alpha or beta particles. The radiation of alpha and beta emitters is reasonably easy for an enclosure to shield with a thin layer of metal.

2. Characteristics of Nuclear Batteries

Radioisotopes of nickel, carbon, hydrogen, sulfur, promethium, polonium, and plutonium all emit beta and/or alpha particles and are reasonable options for nuclear batteries. The selected isotope depends on the isotope's half-life and its decay energy.[1]

Some good news is that different radioisotopes emit different types of radiation. Thus Tritium (third isotope of hydrogen), carbon 14, nickel 63 emit beta particles. Polonium 210 and Plutonium 238 emit alpha particles. Some other good news is that the radio-isotopes that power nuclear batteries have half-lives that range from a few years to over five-millennia. The bad news is that nuclear batteries do not produce much power. The specific power (watts per gram) of the above-mentioned beta emitters are: Tritium: 0.33 w/g, carbon 14: 0.0013 w/g, nickel 63: 0.0058 w/g. The champion for specific power is Polonium 210 which yields 141 w/g, but only has a half-life of about a third of a year.

3. Applications

The initial application for nuclear batteries may surprise you: cardiac pacemakers. The first nuclear battery powered pacemaker was implanted in 1970 in France (the French have always been more open-minded when it came to nuclear-applications than any other western nationality). Unfortunately, this led to a lack of traceability for these early devices (which typically used plutonium with a half-life of about 90 years). The last nuclear-battery pacemaker from this first wave was implanted in 1988.

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[1] James Blanchard, IEEE Spectrum, "The Unlikely Revival of Nuclear Batteries," August 25, 2025, https://spectrum.ieee.org/nuclear-battery-revival

Nuclear battery applications started appearing again around Y2K, with applications for space-travel, and other implants. More recently nuclear batteries have been used in robots, drones and remote sensors.

4. Supply

Radioisotopes are expensive. They also are available only in small quantities. Most radioisotopes can be made during nuclear fission by placing a target material in or near the reactor core. They are also made using particle accelerators. Some radioisotopes can be refined from spent nuclear fuel. However, none of these options is simple or inexpensive, because it involves handling radioactive materials.

One gram of tritium costs about US $30,000 and will produce a thermal power of about 0.3 W, which would in turn typically produce an electric power of only a few milliwatts. The supply of plutonium-238 is so limited that NASA must schedule launches of payloads using nuclear batteries that use this radioisotope based on its availability.

5. Converter Design

Betavoltaic batteries use a radioactive emitter and a silicon absorber. As the emitter naturally decays, beta particles strike the absorber. This creates a cascade of electron-hole pairs, which occur when electrons are removed from their original position, leaving a "hole" that generates a small but stable supply of electric current. This process is similar to that of a solar cell, where light produces the electron-hole pairs.

Betavoltaic batteries with silicon absorbers have conversion efficiencies from a few percent up to 10% when they use silicon carbide absorber, and typically operate at around 1 volt. Some manufacturers of these devices indicate that this efficiency can be as high as 23.5 percent. Recent research on betavoltaics uses diamond semiconductors, which offer even higher conversion efficiencies due to their higher bandgap.

Betavoltaics are relatively inexpensive, so they offer an ideal way to produce a low-power option (less than about a milliwatt) for nuclear batteries. They can be used to create higher-power devices, but for those cases it's often better to switch to alpha emitters to achieve a higher power density. But since alpha particles will damage a semiconductor, their use generally require power-conversion to generate heat, then convert the heat via a thermoelectric-generator to produce electricity.

For example, NASA uses thermoelectric conversion in its RTGs (radioisotope thermoelectric generator), which have been used to power Voyager 1 and 2, two Mars rovers and over 40 other NASA missions.

To convert the heat to electricity, the RTGs employ a series of thermocouples, which consist of a junction of two dissimilar conductors. These components produce a potential in the presence of a temperature gradient. The pacemakers of the 1970s also relied on thermoelectric conversion, albeit on a smaller scale.

Other, more-exotic conversion techniques include radio-luminescent conversion, thermionic conversion, and thermophotovoltaic conversion, all of which work well in the lab but require higher operating temperatures or have degradation issues. Most companies are focused on developing betavoltaic technology because it permits the use of the safer beta emitters.

5.1. US Manufacturer

Infinity Power uses nickel-63 in its coin-size battery, but may need less of it because of the novel electrochemical conversion process it has developed. The company says its conversion efficiency exceeds 60% -about six times as efficient as the best radioisotope power generators. In Infinity's design, the isotope is dissolved or suspended in a proprietary liquid electrolyte. The decay of the radioisotope produces high-energy beta particles that ionize the electrolyte, creating a potential difference between the anode and cathode immersed in the solution and driving electron flow through an external circuit to produce electricity.

5.2. UK Government Activity

Academic and government researchers are also pursuing nuclear batteries. The University of Bristol, in England, and the UKAEA (UK Atomic Energy Authority) last year announced they had developed a battery fueled by carbon-14, a radioactive isotope of carbon. With carbon-14's half-life of 5,700 years, the battery could theoretically last for millennia. The U.K. has an ample supply of the fuel because it can be scavenged from the country's graphite-moderated, gas-cooled fission reactors. Carbon-14 produces beta particles with a maximum energy of 156 kiloelectron volts, which should be low enough to prevent damage to the battery's diamond semiconductor.

6. Manufacturer Activity

6.1. Nusano

Nusano is a privately held physics company with HQ in Valencia, Calif (north of Los Angeles on I5). That is committed to bringing supply stability and innovation to the rapidly emerging and critically undersupplied medical radioisotopes market, and to serving industrial and commercial markets dependent on reliable access to high quality radioisotopes for their products and services. They Manufacture in Utah (see 2nd link below). The third link has a good company profile, key employees, etc. The fourth link has contact information.

https://nusano.com/

https://www.utahbusiness.com/press-releases/2025/09/17/nusano-opens-new-state-of-the-art-radioisotope-production-facility/

https://nusano.com/company/

https://nusano.com/contact-us/

Nusano's main service is producing radio-isotopes using their proprietary heavy particle beam accelerator.

Nusano's patented, breakthrough particle beam technology generates heavy ions (He^{++} & $2H^{+}$) on a scale orders-of-magnitude greater than any existing comparable source. This enables the production of a broad array of radioisotopes for medical and industrial applications.

Nusano's ion source is paired with a linear accelerator to create the production platform. Heavy particles are created in the source, and focused into a linear accelerator. A series of magnets direct the particles to one of 12 targets at the end of the beam line. When they collide with the target material, a radioisotope is created.

Nusano's production platform can create more than 40 radioisotopes, including isotopes needed for nuclear battery applications.

The "power" in a nuclear battery is produced by decay of an isotope. Radioisotopes decay at a consistent rate (half-life), which means the lifespan of a nuclear battery is known and can be planned for well in advance.

Batteries powered by a nuclear source are well known within industry circles and have successfully been used in space exploration, microelectronics, and medical devices.

Nuclear batteries can reliably fuel the next generation of remote sensors and actuators, laying the groundwork for a transformational shift in modern logistics and daily routines.

The novel properties of nuclear batteries offer unmatched potential for a wide range of industries and applications, including as healthcare, transportation, manufacturing, and agriculture.

6.1.1. The Internet of Things

When deployed at scale, nuclear batteries could form the backbone of an expanding network of interconnected devices, facilitating seamless communication and task execution. This is often referred to as the Internet of Things (IoT).

Envisioned as a physical network, IoT interconnects sensors and actuators with computing systems, enabling real-time monitoring of various entities, including nature, humans, and machinery.

IoT essentials, such as remote sensors and actuators, demand minimal power for continuous monitoring or sporadic higher-power needs. Therefore, a nuclear battery's compact size and high reliability make it an optimal choice in many IoT applications. Furthermore, nuclear batteries can be integrated into circuit boards produced by micro-scale fabrication methods – making the batteries deployable at scale, directly within the devices they power.

The IoT is estimated to encompass over 200 billion interconnected devices today, impacting diverse sectors like vehicles, offices, city, retail, human health. It is projected to generate between $5.5 trillion and $12.6 trillion in economic value by 2030.

7. NASA and RTGs

NASA has been the most prolific development-sponsor and user of Radioisotope Thermoelectric Generators (RTGs) for many decades. The first RTG launched into space by the United States was SNAP 3B in 1961 powered by 96 grams of plutonium-238 metal, aboard the Navy Transit 4A spacecraft. See image on the next page.

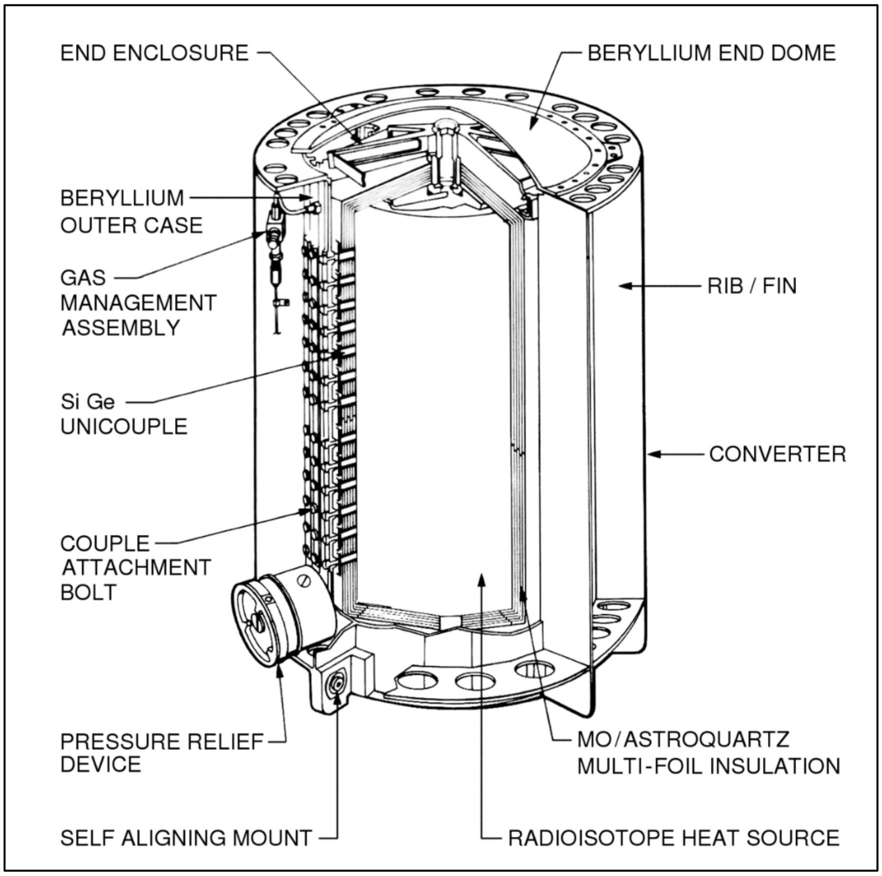

Diagram of RTG shell, showing the power-producing silicon-germanium thermocouples