International Journal of Latest Engineering and Management Research (IJLEMR)
ISSN: 2455-4847
www.ijlemr.com || Volume 03 - Issue 04 || April 2018 || PP. 71-76

Nuclear Battery

Ajay Mahato, Ajay Kumar Pal,
Dr. Bhagwan Shree Ram (Prof.), Mr. Basavareddy (Prof.)
Electrical and Electronics Engg
MVJ College of Engineering
Bangalore, India

Abstract: There is a huge need for power supply from devices which are small, compact lightweight and reliable. This type of power supply is required for applications such as electric vehicles, homes, industrial machines, agriculture, remote monitoring systems, spacecraft and deep-sea probes. The need for this type of power source is especially high for military purpose, radar technology and satellites. For very high power generation Nuclear reactor might be used but for intermediate power range of 10 to 100 kilowatts (KW), the nuclear reactor presents huge technical problems along with significant financial problem. Due to the short andunpredictable lifespan of chemical batteries, they can't be used. Also, the amount of chemical fuel to provide 100 KW of energy for any significant period of time would be too large in size. Althoughfuel cells and solar cells require little maintenance, but fuel cells are too expensive for such small, low-power applications, and solar cells need plenty of sun. Thus it is the need of the hour to find ways to convert small amount of radiation to produce electricity.

INTRODUCTION

Nuclear battery technology was first established 1913, when **Henry Moseley** demonstrated the beta cell. The field received considerable research and attention for applications requiring long-life power sources for space needs during the 1950s. In 1954 RCA (**Radio Corporation of America)** developed a small nuclear battery for small radio receivers and hearing aids.Nuclear battery is a device which uses energy from the decay of a radioactive isotope to generate electricity. Like nuclear reactors nuclear batterygenerate electricity from radiation energy, but differ from them as they do not use a chain reaction. Also known as Atomic Battery and Radioisotope Generator, these batteries generate power in the range of 10 KW to 100 KW. Nuclear batteries has a life span of decades and has the potential to be almost 200 times more efficient than presently available batteries.

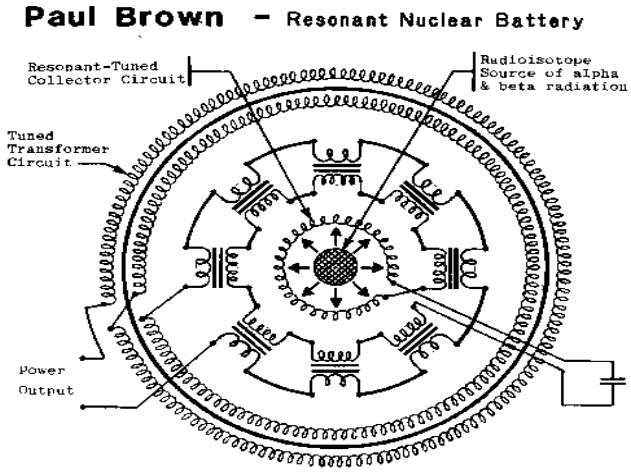


Fig.1

I. Theory of Nuclear Battery

A nuclear battery is simply a decaying Radioisotopic material whose Beta and Alpha emissions is used to generate energy. In laymen's term the emission of Beta and Alpha particles provide the main source of the battery. These emissions are introduced into the electrode which develop the potential difference making the current to flow through the load. There are two ways to convert this decaying radiation to useful electrical energy. They are called as:

- Thermal Conversion- In this conversion technique the output power is a function of the temperature difference.
- Non-Thermal Conversion- In this conversion technique the outputpower does not depend on the temperature difference.

These conversion techniques can be further divided as shown below.

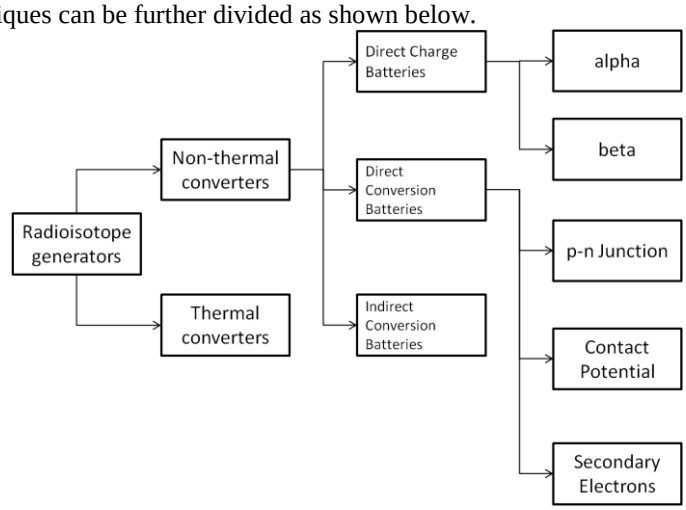


Fig.2

II. Thermal Conversion

- Thermionic Conversion- A thermionic converter consists of twoelectrode one of which thermionically radiates electrons as it is heated to a high temperature. The other electrode collects these electrons. The space between the electrodes is usually vacuum but sometimes it is filled with cesium vapour to increase the efficiency of the electrodes.

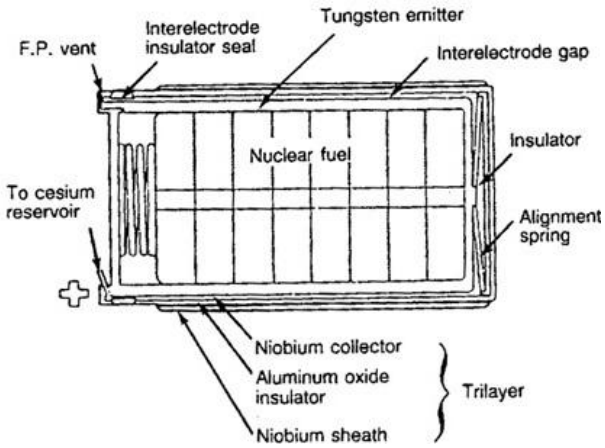


Fig.3

- Radioisotopic Thermoelectric Generator (RTG)-It is a thermoelectric converter which uses thermocouples to convert the heat energy to electric energy. Each thermocouple is formed from two wires of different metals (or other materials). A temperature change along the length of thewire produces a voltage change from one end of the wire to the other. It is a static generator with no moving parts. It is the most sought after energy source for unmanned machines and remote location facilities.

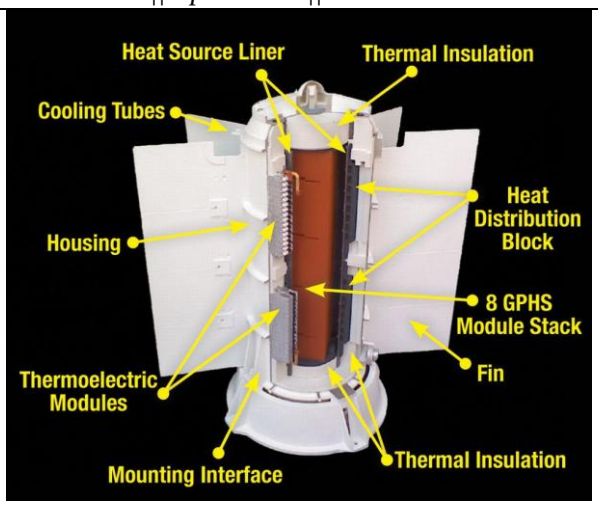


Fig.4

- Thermo Photovoltaic Cell- Thermo photovoltaic cells work on the same principle as a photovoltaic cell, except that they convert infrared light (rather than visible light) emitted by a hot surface, into electricity. These photo cells have an efficiency which is slightly higher than thermoelectric couples and can be laid over the thermoelectric couples, potentially doubling their efficiency. The Alpha and Beta emission from the isotope is made to fall on thermal emitter from which infrared rays (IR) emission are given out. These emission are made to fall on the thermo photovoltaic cell generating electricity.

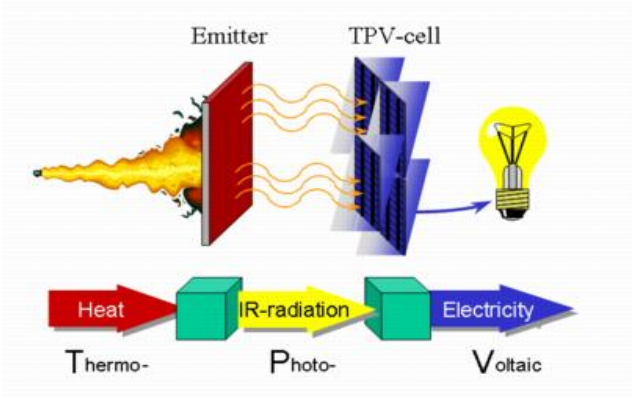


Fig. 5

III. Non-Thermal Conversion

- Betavoltaics- Betavoltaics are generators of electrical current, in fact they are a form of battery, which utilizes energy from a radioactive source which emits beta particles (electrons). A common radioactive source used is the hydrogen isotope (tritium). Betavoltaics generate electricity from a non-thermal conversion process. They use a semiconductor p-n junction to generate electricity. When the Beta emission are introduced to the electrode it generates electrons holes pairs causing the potential to increase between the electrode and flow of current.

Type	Power (mW)	Total Energy (mWh)	Volume (cm^3)	Weight (g)	Total Energy Density (mWh/g)
Lithium AA Battery	~1 (1.5 V)	4,350	7.9	14.5	300
Betavoltaic 1 cm^2	~0.3 (2 V)	10,512	0.025	0.08	131,400

Fig. 6

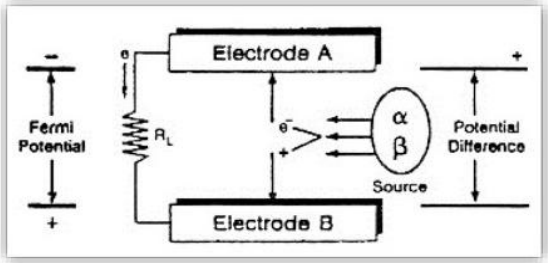
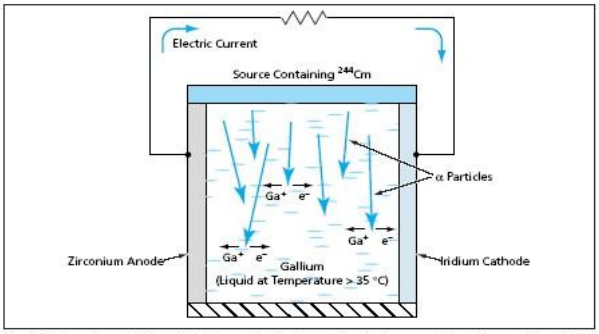


Fig. 7

- Alphavoltaics- Alphavoltaics power sources are devices that use a semiconductor p-n junction to produce electrical energy from high energy alpha particles. It works on the same principle as Betavoltaics but they differas it uses a radioisotope which emits Alpha particles.



Liquid Gallium in an Electrolytic Cell would be ionized by impinging α particles. The resulting electric charges would be collected at the electrodes.

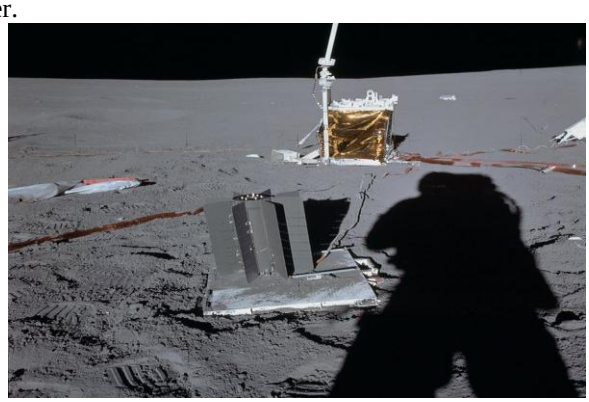
Fig. 8

- Optoelectric- A beta-emitter (such as technetium-99) which when stimulates an excimer mixture, and the light is made to power a photocell. Precise electrode assemblyis not needed, and most of the beta particles escape the finely-separated bulk material to contribute to the battery's net power. It converts the emissions to light and then again converts it to electrical energy.

IV. Applications

Nuclear battery have an extremely long life and high energy density so they are used mainly as power sources for equipment that must run attended for periods of time and high power requirement. These should be used in places where there is little presence of human to protect them from the radiation.

- Deep Space Exploration- It is used in satellites and robots for space exploration. Their power density combined with their long life make them the perfect choice for these kind of instruments. They can be left unattended for decades powering the instruments and taking up little space and add little weight compared to other sources of power.



A photograph of the RTG that NASA's Apollo 14 mission carried to the Moon. The RTG is the gray colored device with cooling fins.

Fig. 9

- Underwater System- Nuclear battery are used in under water machines and robots used to locate or analyse things deep below the water level. With this power source the underwater robots can be made compact and light weight so that they can travel further down examining the ocean surface and sending data to the surface.

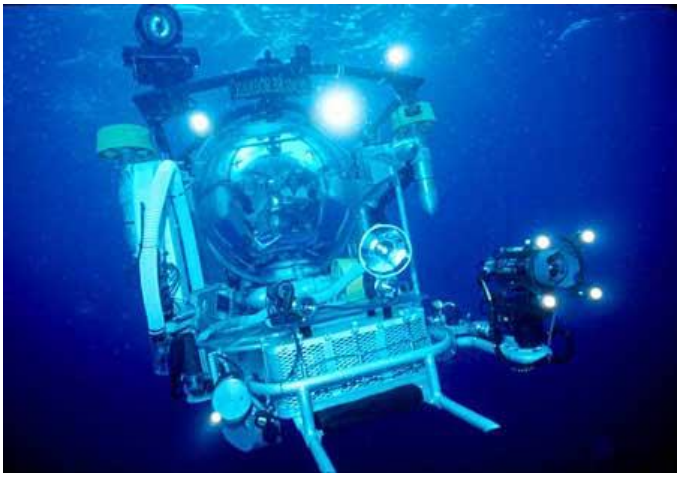


Fig. 10

- Pacemakers- Nuclear battery are used in pacemakers to power them. Pacemakers are medical devices which generates electrical impulses delivered by electrodes to contract the heart muscles and regulate the electrical conduction system of the heart.

Fig. 11

V. Advantages

- Unlike regular battery they have a life span of decades and can power a device for a long time.
- It is a reliable source of energy and can be used for a long time without and maintenance.
- It delivers a very high density of power and is very light weight.
- It produces little to no waste and does not give out greenhouse gases.
- The fuel used is the waste from a nuclear reactor and is recycled and used as a source for nuclear battery.

VI. Disadvantages

- It has a very high initial cost for the production of energy as it is still in experimental stage.
- The energy conversion methodology is not much advanced.
- The Radioisotopic source does not allow it to be used everywhere at least not in the present.
- The exposure to Alpha and Beta radiation are a big health concern. This can be prevented by covering the battery in a thin layer of aluminium to prevent the leakage of radiation.

VII. Conclusion

Clearly the future of long lasting battery lies in nuclear battery and it shows a lot of potential for future uses. With further research and experiments nuclear battery can be made safe enough to be used everywhere. With the replacements of electrodes it can be made cheap enough for normal people to use it for day to day use, but for this to occur we have a long way to go.

References

[1]. Prototype Rhenium Component for Stirling Engine Power Conversion - Scientific Figure on Research Gate. Available from: https://www.researchgate.net/Stirling-Radioisotope-Generator-SRG_fig1_252282159 [accessed 12 Feb, 2018]
[2]. The Daintiest Dynamos - Spectrum, IEEE BY AMIT LAL & JAMES BLANCHARD
[3]. Atomic Batteries: Energy from Radioactivity. Suhas Kumar. Department of Electrical Engineering, Stanford University, Stanford, CA 94305, USA, email: su1@alumni.stanford.edu 17 Nov, 2015