CHAPTER 13

RADIOISOTOPE POWER SYSTEMS

A. General Information

This chapter provides guidance for determining if historical records containing DOE NSI, pertaining to radioisotope power systems (RPS) are to be declassified or have their classification retained beyond 25 years in accordance with the provisions of E.O. 12958. ***Documents containing RD and FRD are not addressed by this document and retain present classification.***

RPS consist of radioactive power sources that convert decay heat to electric power. The RPS are useful for terrestrial and space missions with relatively low power requirements, or in remote regions such as the ocean floor, where conventional power generation methods are infeasible. There are two main components involved in the production of heat or power for these systems: (1) type of fuel and (2) thermoelectric converter. Missions with a lifetime requirement of 8 to 12 years are effectively restricted to a fuel selection of plutonium-238 (Pu^{238}) because of the need for a long lifetime heat source. Thermoelectric converters are used to convert the heat to electrical power. The benefit from the lack of moving parts outweighs the low conversion efficiency.

In the early 1970s, small radioisotope thermoelectric generators (RTGs) were fueled by metallic Pu^{238}. Subsequently, plutonium-238 dioxide ($Pu^{238}O_2$) heat sources were developed and optimized over time. The fuel form consisted of oxide microspheres contained in triple encapsulated high-temperature metals.

Previous space missions that have used RPS include the Apollo lunar surface scientific packages and Pioneer, Viking, Voyager, Galileo, and Ulysses spacecrafts. The Pioneer and Viking missions were fueled with molybdenum /plutonium-238 ($Mo/Pu^{238}O_2$) cermets in puck form. Hot pressed, plutonium pellets were used as the heat source for the multihundred watt (MHW) and general purpose heat source (GPHS) RTGs. Other isotopes that have been used are polonium-210 (Po^{210}) and curium (Cm^{242}), which have half-lives of less than 6 months. These isotopes can provide higher electric power output for a limited lifetime but are not useful for longer missions. As of November 2001, DOE has provided 44 RTGs for use on a total of 24 missions to provide some or all of the onboard electric power.

The first RTGs produced about 2.7 watts of electric power. The most recently designed system, the General Purpose Heat Source RTG (GPHS-RTG), generates about 290 watts of electric power. The first system launched, a Space Nuclear Auxiliary Power (SNAP) unit, designated SNAP-3B provided only partial power for the Navy Transit 4 satellite. DOE provided three RTGs for the National Aeronautics and Space Administration's (NASA) Cassini mission to Saturn. The Cassini spacecraft, launched to Saturn on October 15, 1997, required three GPHS-RTGs (approximately 870 watts electric). The RTGs are the only source of onboard electric power.

Newer designs of solid-state RTGs include stacked heat source modules for increased power output. Future developments in heat transfer and insulation are expected to enhance thermal efficiency.

Radioisotope power generators convert the heat (thermal energy) generated from the decay of radioisotopes into electricity. Converters are composed of thermopiles that consist of thermoelectric material [e.g., silicon-germanium (SiGe) unicouples]. The efficiencies of the converters are functions of the thermoelectric characteristics of the couples and the thermal economy achieved by the insulation system.

Thermoelectric converter designs can be separated into three general types: (1) the SNAP series used lead telluride materials (PbTe) as their thermoelectric elements and operated at moderate hot junction temperatures of 780 to 890 Kelvin (K); (2) the Transit-RTG also used PbTe thermoelectric elements, but operated at a lower hot junction temperature of 673 K to control sublimation; and (3) SiGe unicouples with negative (doped with phosphorus) and positive (doped with boron) couple legs powered the MHW and GPHS RTGs at a higher hot junction temperature of about 1270 K.

The fuel form and heat source technology has steadily improved over the years to operate at higher temperatures and to meet the stringent aerospace nuclear safety requirements for increasingly larger heat sources. As power levels of RPS have increased, improved heat sources, thermoelectric materials, and thermal insulation have been developed to increase performance. Other converters that offer higher conversion efficiency, such as the Alkali Metal Thermal to Electric Converter (AMTEC), thermophotovoltaic, and Small Stirling Dynamic Isotope Power System are being investigated. The dynamic converters have moving parts and may use redundancy for reliability. As mission planners require more power, longer mission duration, and/or more resistance to hostile natural or man-made environments, improved RPS will be required.

B. Broad Guidance

Generally, information about RPS is unclassified unless the system is for military use and the release of the information would reveal classified information about other programs. Information relating to the use of RPS is unclassified unless classified by topics of this guide.

Energy conversion technologies, including the thermoelectric materials and couples, are unclassified unless they are specifically cited in a classified program. The composition, capabilities, and properties of shielding materials that provide vulnerability protection may be FRD if nuclear weapon effects are involved, or NSI if related to vulnerability or capabilities of systems, installations, projects, or plans related to national security.

Safety information is unclassified unless it reveals other classified information. Information extracted from classified sources will retain the classification of the source document unless declassified by the originating agency.

Historical records, 25 years or older, containing DOE/NNSA RPS NSI not covered by the specific guidance below are unclassified. This does not include records containing information classified by statute such as RD and FRD (AEA of 1954, as amended). These records shall be handled, protected, classified, downgraded, and declassified in accordance with the provisions of the AEA and regulations issued under that Act. Reviewers who are not authorized by DOE/NNSA to classify or declassify such documents should not attempt final determinations. Refer to appendix A for information on identifying and handling documents containing potential RD/FRD. In all cases where there is a question concerning the sensitivity of the information, it should be referred to the DOE HQ classification office for a classification determination.

Topics describing information likely to contain or closely related to RD or FRD are marked "(potential for RD/FRD)".

C. Topics

13.0 RADIOISOTOPE POWER SYSTEMS

13.1 General

13.1.1	Meaning nicknames, acronyms, or other designators, [e.g., SNAP (Systems for Nuclear Auxiliary Power), GPHS (General Purpose Heat Source)], provided no information classified by other guidance is revealed	**U**
13.1.2	Identification of offices, contractors, subcontractors, vendors, or individuals with the program or with the description of work, provided no information classified by other guidance is revealed	**U**
13.1.3	Programmatic Information	
13.1.3.1	Schedules for the production of RPS (including number produced and delivery dates) for DoD *NOTE:* Refer to DoD for declassification review.	**Refer**
13.1.3.2	Mission-related information, including orbits and trajectories *NOTE:* Refer to DoD and/or NASA for declassification review.	**Refer**
13.1.4	Hardening	
13.1.4.1	Fact of interest in hardening RPS against nuclear weapons effects	**U**
13.1.4.2	Fact that RPS, their components, or support systems are or are not hardened against nuclear weapons effects	**U**
13.1.4.3	Program design goals and protective measures against nuclear weapons radiation *NOTE:* Refer to DoD and/or NASA for declassification review.	**Refer**
13.1.4.4	Results of environmental testing, provided no information classified by other guidance is revealed	**U**
13.1.4.5	Protective measures against natural radiation environment	**U**
13.1.5	Association of Multihundred Watt (MHW) Heat Source RTG with	
13.1.5.1	Officially released information	**U**
13.1.5.2	NASA or other unclassified applications	**U**
13.1.5.3	All other applications *NOTE:* Refer to DoD and/or NASA for declassification review.	**Refer**

13.2 Heat Sources

13.2.1	Quantities of reactor products other than deuterium, tritium, Pu^{239}, and U^{235} allocated for military use *NOTE:* Refer to DoD for declassification review.	**Refer**
13.2.2	Heat source fuel (procedures, processes, and characteristics)	**U**
13.2.3	Capsule design and technology	**U**

13.3 Energy Conversion

13.3.1	Thermoelectric materials	**U**
13.3.2	Thermoelectric couples	**U**
13.3.3	Thermoelectric converters	
13.3.3.1	Information concerning integration of thermoelectric conversion materials with nuclear reactor fuels or using the reactor as a heat source *NOTE:* Refer to DoD and/or NASA for declassification review.	**Refer**
13.3.3.2	Thermoelectric converters as end items of hardware	
13.3.3.2.1	If no classified information is revealed by the converter, regardless of operational use	**U**
13.3.3.2.2	Association of a specific converter with a specific unclassified operation	**U**

13.4 Thermoelectric converter ancillary equipment

13.4.1	Composition, capabilities, and properties of shielding materials that provide improved vulnerability protection	
13.4.1.1	Officially released information	**U**
13.4.1.2	NASA or other unclassified applications	**U**
13.4.1.3	Otherwise *NOTE:* Refer to DoD and/or NASA for declassification review.	**Refer**

13.5 Safety systems

13.5.1	Prelaunch estimates of probabilities of exposure to ionizing radiation or concentrations of radioactive material from fallen debris following the deliberate or accidental destruction of the launch vehicle during abort or post-operational disposal, including any casualty estimates	**U**
13.5.2	Predicted impact locations, including probabilities of debris impact following abort *NOTE:* Refer to DoD or DOS for declassification review.	**Refer**

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