

CONF-960706--12

# A Compendium of the Radioisotope Thermoelectric Generator Transportation System and Recent Programmatic Changes

Prepared for the U.S. Department of Energy  
Assistant Secretary for Environmental Management



**Westinghouse**  
**Hanford Company** Richland, Washington

Management and Operations Contractor for the  
U.S. Department of Energy under Contract DE-AC06-87RL10930

Copyright License By acceptance of this article, the publisher and/or recipient acknowledges the  
U.S. Government's right to retain a nonexclusive, royalty-free license in and to any copyright covering this paper.

Approved for public release

**MASTER** *De*

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

CONF-960706--12

# **A Compendium of the Radioisotope Thermoelectric Generator Transportation System and Recent Programmatic Changes**

D. L. Becker  
J. C. McCoy

Date Published  
March 1996

To Be Presented at  
PVP 1996  
1996 ASME/JSME Pressure Vessels and Piping Conference  
Montreal, Canada  
July 21-26, 1996

To Be Published in  
*Proceedings*

Prepared for the U.S. Department of Energy  
Assistant Secretary for Environmental Management



**Westinghouse  
Hanford Company**

P.O. Box 1970  
Richland, Washington

Management and Operations Contractor for the  
U.S. Department of Energy under Contract DE-AC06-87RL10930

---

Copyright License By acceptance of this article, the publisher and/or recipient acknowledges the U.S. Government's right to retain a nonexclusive, royalty-free license in and to any copyright covering this paper.

Approved for public release

**LEGAL DISCLAIMER**

---

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

---

This report has been reproduced from the best available copy.

Printed in the United States of America

DISCLM-2.CHP (1-91)

# A COMPENDIUM OF THE RADIOISOTOPE THERMOELECTRIC GENERATOR TRANSPORTATION SYSTEM AND RECENT PROGRAMMATIC CHANGES

David L. Becker

John C. McCoy

Westinghouse Hanford Company  
Transportation and Packaging  
P.O. Box 1970 G1-11  
Richland, Washington 99352  
USA  
Phone: 509-376-6206  
or: 509-373-0170  
Fax: 509-376-7551

## ABSTRACT

Radioisotope Thermoelectric Generators (RTGs) convert heat generated by radioactive decay to electricity through the use of thermocouples. The RTGs have a long operating life, are reasonably lightweight, and require little or no maintenance, making them particularly attractive for use in spacecraft. However, because RTGs contain significant quantities of radioactive materials, normally Plutonium-238 and its decay products, they must be transported in packages built in accordance with Title 10, Code of Federal Regulations, Part 71 (10 CFR 71, 1994). To meet these regulatory requirements, the U.S. Department of Energy (DOE) commissioned Westinghouse Hanford Company in 1988 to develop a Radioisotope Thermoelectric Generator Transportation System (RTGTS) that would fully comply with 10 CFR 71 (1994) while protecting RTGs from adverse environmental conditions during normal conditions of transport (e.g., mainly shock and heat). The RTGTS is scheduled for completion in December 1996 and will be available to support the National Aeronautics and Space Administration's Cassini mission to Saturn in October 1997. This paper provides an overview of the RTGTS Project, discusses the hardware being produced, and summarizes various programmatic and management innovations required by recent changes at the DOE.

## INTRODUCTION

Radioisotope Thermoelectric Generators are typically fueled with Plutonium-238 oxide that generates approximately 0.40 W/g of thermal energy. Thermocouples convert this thermal energy into electricity. Although the efficiency of RTGs is low, generally less than 7%, they are very reliable, have long operating lifetimes, and are reasonably lightweight. These features make RTGs suitable for use in spacecraft when other power sources are not feasible. The first planned uses of the RTGTS are to transport RTGs to support the National Aeronautics and Space Administration (NASA) Cassini mission to Saturn, scheduled for

launch in October 1997, and the Pluto Fast Flyby scheduled for launch in 1999.

Because RTGs contain several kilograms of Plutonium-238 and other radionuclides, they must be packaged in containers meeting the requirements of 10 CFR 71 (1994) for transport over public highways. If the containers are unable to meet the 10 CFR 71 (1994) requirements, they must be specifically exempted. Although exemptions may be granted by the U.S. Department of Transportation (DOT), the DOE has determined that future RTG shipments will comply with 10 CFR 71 (1994).

To develop a transportation system that would meet the regulatory requirements as well as RTG operational requirements, the DOE assigned the RTGTS Project to Westinghouse Hanford Company (WHC) in 1988. At that time, the RTGTS Project was part of the Hanford Space Power Systems mission and RTGs were to be fueled at the Hanford Site. However, in 1989 the DOE halted the production of plutonium, and in 1993 decided to fuel the RTGs at EG&G Mound Applied Technologies, Inc. (EG&G Mound), Miamisburg, Ohio. EG&G Mound was also designated to be the RTGTS ultimate custodian; however, responsibility for the design, analysis, fabrication, and testing remained with WHC.

Currently, the RTGTS Program is nearing completion with a delivery date of December 15, 1996. The program deliverables consist of two complete RTGTSs. Each system will consist of one RTG Package, one custom-built semi-trailer, and one set of special tools and support equipment. An extra RTG Package with necessary special tools and support equipment will be provided for training or for use as a spare.

## PROGRAM DESCRIPTION

### System 100, Systems Integration

Systems Integration, System 100, is the focal point of the entire program. System 100 comprises the project management activities, overall systems testing, and integration control for the other systems. System 100 also designates a complete RTGTS.

### System 120, RTG Packaging

An assembled RTG Package, System 120, with a General Purpose Heat Source (GPHS) RTG payload is illustrated in Figure 1. The GPHS is the RTG type to be used for the Cassini mission. System 120 meets all DOT requirements for the transport of RTGs and is designated a Type B(U) radioactive materials package. Because the GPHS RTG package is designed to transport up to  $5.4 \times 10^{15}$  Bq (147,000 Ci) of plutonium, the package has an inner containment vessel (ICV) and an outer containment vessel (OCV), both made of stainless steel. The ICV and OCV are sealed with O-ring face seals in a bolted flange on the bottom of each vessel. These seals have a leak rate of less than the allowed  $10^{-7}$  standard  $\text{cm}^3/\text{s}$  of air. The package is equipped with a high-density, foam-filled impact limiter that protects the package flanges and seals. A loaded System 120 weighs approximately 4,355 kg (9,600 lb). This design has been shown to meet, through analysis and/or testing, the regulatory requirements of both the normal conditions of transport and hypothetical accident conditions specified in 10 CFR 71 (1994). The RTG Safety Analysis Report for Packaging (WHC, 1995), or SARP, provides a complete discussion of the package design and conformance to the regulatory standards. The DOE Office of Facility Safety Analysis is now reviewing the SARP (WHC, 1995) and is expected to issue a Certificate of Compliance (CoC).

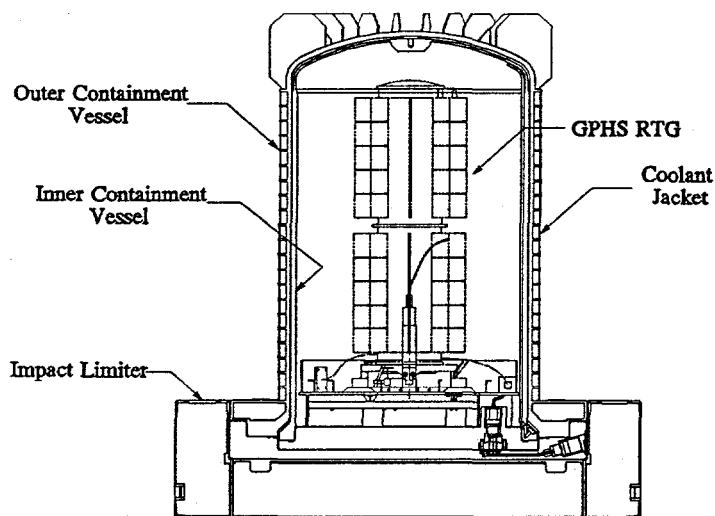


FIGURE 1. RTG Packaging, System 120, with GPHS RTG Payload (Simplified View)

The GPHS continuously generates approximately 4,500 W of thermal energy that must be dissipated to prevent damage to RTG

components. To remove the heat from the container, the OCV has two parallel, spiral, liquid coolant channels welded to its outer surface. These channels contain a 70 percent water and 30 percent propylene glycol mixture that is cooled and circulated by an external chiller system. To facilitate heat removal, the package void spaces are pressurized with helium.

### System 140, Trailer

System 140, shown in Figure 2, consists of a Custom Semi-trailer, Subsystem 141; a Power Supply System, Subsystem 142; an Instrumentation and Data Acquisition System (IDAS), Subsystem 143; a Package Temperature Control System, Subsystem 144; and a Package Mounting System, Subsystem 145. The trailer also carries special tools and equipment required to assemble and disassemble the package.

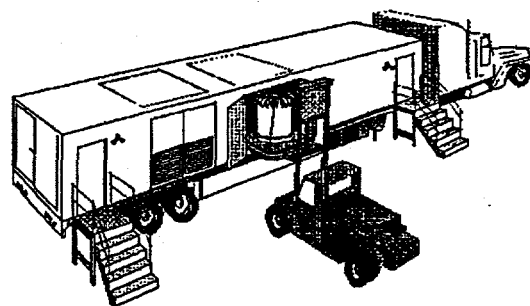


FIGURE 2. Trailer, System 140

The Custom Semi-trailer, Subsystem 141, consists of a specially built, 53-ft-long, light-weight trailer assembly. The trailer has a self-leveling air-ride suspension to limit shock to the payload, and is mounted on spread axles to improve the weight distribution. The trailer is constructed mostly of aluminum and has provisions for transporting two RTG Packages, which can be loaded from the curb side or through roof hatches.

The Power Supply System, Subsystem 142, consists of two independent power supply systems that use separate 40-kW diesel generators, separate power distribution systems, and separate fuel tanks. The generators supply 208 V 3-phase and 110 V single-phase power to the power distribution systems. Either of the diesel generators will function as a backup unit and automatically start if the primary unit fails. Shore power can also be provided by connecting an external power source to the semi-trailer.

The IDAS, Subsystem 143, is used to monitor and record RTG temperatures, coolant supply temperatures and flow rates, and

accelerations using a triaxial accelerometer mounted on the package. The IDAS is connected to a remote alarm system in the tractor and will annunciate an off-normal condition to the driver with an alarm and panel light. The IDAS has a battery backup for maintaining data storage in case of a power supply interruption.

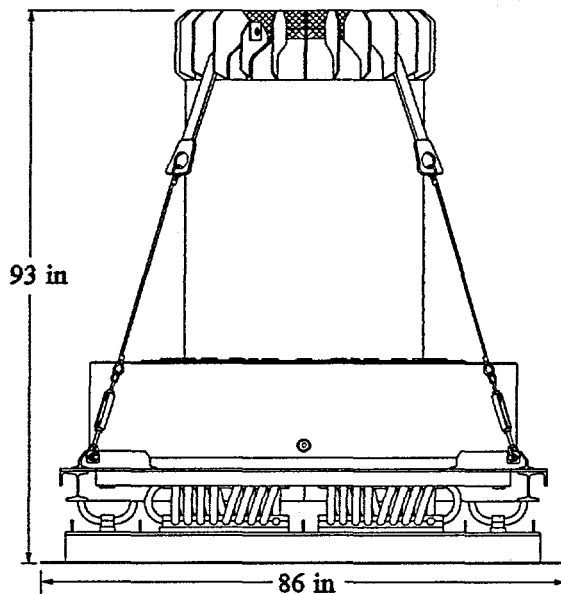


FIGURE 3. Package Mounting System

The Package Temperature Control System, Subsystem 144, consists of a standard high-volume heating/air conditioning unit and two custom-built, 7.5-kW-capacity chiller units, each of which has two pumps. The chiller units cool the water/propylene glycol mixture to 4 °C (40 °F) and pump it through the RTG package at a flow rate of 18.9 L/min (5 gal/min) at a pressure of 344.7 kPa (50 lb/in<sup>2</sup>). Only one chiller will operate at a time. If a chiller fails, human intervention is required to determine the cause of the failure and start the backup. The heater/air conditioning unit maintains an acceptable environment within the semitrailer.

To limit shock to the RTGs, the trailer is equipped with air-ride suspension and the RTG Packages are mounted on a Package Mounting System, Subsystem 145 (Figure 3). The mounting consists of two structural pallets separated by a spring suspension system. It has been shown through testing that the Package Mounting System will limit shock to a RTG to less than 15-G for frequencies below 100 hZ if subjected to a 45.7-cm (18-in.) edge or bottom drop.

#### System 160, Operations and Ancillary Equipment

The Operations and Ancillary Equipment, System 160, consists of the RTGTS operations and maintenance manuals and special tools and support equipment necessary for the assembly and disassembly of the RTG Package, a Portable Data Acquisition System (PDAS), and a Set-down Device. Special tools include torque wrenches, special adapters, sockets, guide pins, spacer blocks, and set-down pads that support the

assembly and disassembly of the RTG Package. The support equipment consists of a cart-mounted Gas Management System (GMS) and a low-clearance sling. The GMS is used to evacuate and fill the inner vessel and the annulus between the inner and outer vessels of the RTG Package with helium; it does not support leak testing of the package seals. Three portable IDAS units, one per RTG Package, will be supplied to monitor and record the RTG temperatures during loading/unloading operations or when the package is not being monitored by the IDAS. The Set-down Device, like the package mounting, provides 45.7-cm (18-in.) drop protection for the package during lifting or operations.

#### System 180, Facility Transporter System

The Facility Transporter System, System 180, was designed to move the RTG package into a facility after unloading from the semitrailer, and vice versa before loading onto the semitrailer. Because of facility modification, however, the transporter is no longer required. Hence, the design was completed but not built.

#### PROGRAM MANAGEMENT

Technical challenges and recent changes within the DOE in the post-Cold War era have significantly impacted the RTGTS Project. For example, the decision to fuel RTGs at EG&G Mound rather than the Hanford Site changed the program workscope and direction in 1993. In addition, the Hanford Site mission change has resulted in significant workforce and budget reductions in Fiscal Years 1994 through 1996 that have impacted the availability of resources. By early 1995, it was clear that the December 1996 delivery date was in serious jeopardy and program activities would have to be accelerated. To meet these challenges, a concerted effort was made to remove as much of the administrative and procedural burden from the RTGTS Project as possible. In removing these requirements, some risk was added to the Project.

The original RTGTS Project schedule allowed for certification of the RTG Package prior to fabrication of the production packages. Early in the certification process it was decided that conformance to the 10 CFR 71 (1994) hypothetical drop and puncture bar requirements would be met by testing, which was scheduled to be completed before receipt of a CoC and before start of fabrication of the three production units. Initial testing of the package design was inconclusive; thus, a second test article had to be fabricated and tested. To accomplish this additional scope of work and still meet the delivery date for fabricated production units necessitated that the project proceed at risk — that is, that the production packages be fabricated before completion of certification testing of the second test article and before receipt of the CoC.

Initial changes consisted of eliminating the requirement that all design work be placed in the WHC control system prior to fabrication. The main benefit of this change was seen in fabrication of the trailer systems. Because it was decided that commercial equipment was to be used where possible within the trailer, reliance on the manufacturer's procedures and design experience controlled costs and conserved schedule time. The manufacturer's as-built

drawings will be put in the WHC document control system after fabrication and testing are completed.

Next, the design review and fabrication process was changed. Extensive design reviews involving not only WHC, but the RTG User Community, had been required prior to the start of fabrication of most components and systems. The schedule could not continue to support such extensive reviews. Therefore, the process was changed to allow design and fabrication to proceed concurrently on many systems and subsystems using the RTGTS specification and functional design requirements as a guide. These documents had been reviewed and approved by the RTG User Community and provided the baseline program requirements. Additionally, a system allowing design changes to be made as required was instituted. This allowed fabrication to continue quickly with the formal design changes to be posted after fabrication was complete. In some cases, components were fabricated in parallel with design and as-built drawings were produced at completion of fabrication. To ensure that multiple units would be alike, the as-built design drawings were completed after fabrication of the first unit. These changes carried a small risk that systems might not interface or requirements could be overlooked. In order to prevent such errors, intense management and coordination was required, especially as fabrication was carried out in several locations within WHC and among several subcontractors. When problems were encountered, they were dealt with by referring to the user-approved specifications and requirements. If the guidance was incomplete, problems were then referred to the RTG User Community for resolution. To limit decision turn-around time, the preferred course of action was recommended and a time limit for comment was instituted. If no objections were voiced by the deadline, the preferred course of action was adopted.

In conjunction with the changes to the design and fabrication processes, unnecessary quality assurance (QA) standards were removed. The RTGTS Program has been encouraged to make the maximum use of commercial equipment to limit cost, but some QA standards that were originally imposed were not consistent with commercial practices. Although some RTGTS systems, such as the RTG Packaging, require strict adherence to various codes and standards, other systems do not. The relaxation of the QA requirements was especially beneficial in the procurement of the trailer systems. Without relaxation of QA requirements, completion of the trailers would have required an additional two to six months.

The acceptance testing philosophy for the RTGTS was also changed. The original testing concept was to deliver all the RTGTS hardware to WHC for integration testing and, following the testing of each individual component, final system acceptance testing of the entire System 100. Much of the component testing, however, would have been duplicated in the Final System Acceptance Test (FSAT) of System 100. To eliminate this duplication of effort, the verification testing of individual components was acknowledged as sufficient for final acceptance. In addition, to ensure that each component could be successfully integrated into the overall system, a Functional Assessment (FA) was planned. The FA will be an informal, undocumented series of activities conducted at Mobilized Systems, Inc., Cincinnati, OH, the trailer manufacturer, to evaluate each component's ability to perform in System 100 and to prepare for the FSAT. Accordingly, the FSAT has been rescope to require testing of

only those components not previously tested and will be performed in conjunction with a road test from KSC to EG&G Mound. Because of these changes, the number of RTGTS tests was reduced by approximately 50 percent, resulting in considerable savings of time and money.

## CONCLUSIONS

The RTGTS is one of the most innovative radioactive materials packages ever conceived. It is the only transportation system that provides a Type B(U) package that meets the requirements of 10 CFR 71 (1994) and provides active cooling and shock mitigation for the payload. In the process of completing the RTGTS, challenges were met through the use of innovative approaches not normally implemented in programs of this type. The success of this program thus far would not have been possible without the close coordination and cooperation of many diverse organizations. Among these are various DOE management elements and operations offices, the RTG User Community, WHC subcontractors, WHC support organizations, and the WHC team assigned to the RTGTS Program. The lessons learned from the RTGTS Project should be considered in the future for facilitating similar programs.

## REFERENCES

- 10 CFR 71, 1994, "Packaging and Transportation of Radioactive Material," Code of Federal Regulations, as amended, Office of the Federal Register, National Archive and Records Administration, Washington, D.C.
- WHC, 1994, Radioisotope Thermoelectric Generator Transportation System Safety Analysis Report for Packaging, Document Number WHC-SD-RTG-SARP-001 (Draft), Westinghouse Hanford Company, Richland, Washington.
- McCoy, J.C., and Becker, D.L., 1996, "An Overview of the Radioisotope Thermoelectric Generator Transportation System Program," Space Technology and Applications International Forum, Albuquerque, NM.