INL/EXT-10-18869

Evaluation of Storage for Transportation Equipment, Unfueled Convertors, and Fueled Convertors at the INL for the Radioisotope Power Systems Program

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The INL is a U.S. Department of Energy National Laboratory
operated by Battelle Energy Alliance

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Prepared for the
U.S. Department of Energy
Office of Nuclear Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

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APPENDIX

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ACRONYMS

ASRG	Advanced Stirling Radioisotope Generator
CFA	Central Facilities Area
DOE	Department of Energy
DOE-ID	Department of Energy – Idaho Office
DOT	Department of Transportation
EDL	Engineering Design Laboratory
GPHS	General Purpose Heat Source
HVAC	Heating and Ventilation Air Conditioning
IDAS	Instrumentation and Data Acquisition System
INL	Idaho National Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
KSC	Kennedy Space Center
MHW	Multi-Hundred Watt
MFC	Materials and Fuels Complex
NEPA	National Environmental Protection Agency
NHS	National and Homeland Security
OPF	Outer Planet Flagship
RPS	Radioisotope Power System
RTGTS	Radioisotope Thermal Generator Transport System
SARP	Safety Analysis Report
SNM	Special Nuclear Material
SSPSF	Space and Security Power System Facility
TREAT	Transient Reactor Test Facility

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EVALUATION OF STORAGE FOR TRANSPORTATION EQUIPMENT, UNFUELED CONVERTORS AND FUELED CONVERTORS AT THE INL FOR THE RADIOISOTOPE POWER SYSTEMS PROGRAM	Identifier: INL/EXT-10-18869 Revision: 0

1.0 INTRODUCTION

This report contains an evaluation of the storage conditions required for several key components and/or systems of the Radioisotope Power Systems (RPS) Program at the Idaho National Laboratory (INL). These components/systems (transportation equipment, i.e., type 'B' shipping casks and the radioisotope thermo-electric generator transportation systems (RTGTS), the unfueled convertors, i.e., multi-hundred watt (MHW) and general purpose heat source (GPHS) RTGs, and fueled convertors of several types) are currently stored in several facilities at the Materials and Fuels Complex (MFC) site. For various reasons related to competing missions, inherent growth of the RPS mission at the INL and enhanced efficiency, it is necessary to evaluate their current storage situation and recommend the approach that should be pursued going forward for storage of these vital RPS components and systems. The reasons that drive this evaluation include, but are not limited to the following: 1) conflict with other missions at the INL of higher priority, 2) increasing demands from the INL RPS Program that exceed the physical capacity of the current storage areas and 3) the ability to enhance our current capability to care for our equipment, decrease maintenance costs and increase the readiness posture of the systems.

1. Transportation Equipment

1.1 Description of System

The semitrailer is the backbone of the RTGTS. It provides a secure, mobile, environmentally controlled enclosure, as well as a focal point for integrating all of the other subsystems into a complete support system for transporting the RTG package.

To meet the requirements for transporting Category III Special Nuclear Materials, the semitrailer is required to be used exclusively for the purpose for which it was designed, and to be locked and sealed for security during shipment. The semitrailer system will accommodate transport of up to two Type B fissile RTG packages with a total maximum heat load of 5000W. Maximum heat load for a single package is 4,500W. When loaded, the semitrailer is required to meet U.S. Department of Transportation's (DOT) size and weight requirements.

Two roof hatches are provided for crane removal of the packages in normal use and emergency situations. These one-piece hatches are centered over the package mounting locations in the main compartment of the semitrailer. The hatches are equipped with lifting and locking mechanisms.

Two sets of double doors on the curbside are provided for access to packages and equipment using a forklift. Double rear doors provide access to the diesel generator compartment. Curbside personnel doors are located at the front (instrumentation) and main (cargo) compartments.

The semitrailer includes a liquid collection and retention system that provides the means to collect any condensate or coolant-line leaks. It also includes lights, smoke detectors, carbon monoxide detectors, package monitoring and RTGTS system alarms, fire extinguishers, leveling jacks, pedestrian stairs and platforms, and a full complement of en route equipment.

The semitrailer is equipped with an HVAC system to maintain compartment internal temperature at a level consistent with safe transport of RTG packages. The HVAC system is designed to maintain the semitrailer internal temperature at sea level within the range 50-90°F and the relative humidity to <85%. During non-transport operation, the system is designed to maintain the internal temperature within the range 50-80°F and the relative humidity <85%. The HVAC system is powered by onboard electrical generators during transport and either a docking power cable or the electrical generators when parked. The air conditioner unit is mounted externally on the front of the semitrailer, above the diesel generator.

To provide fuel for the two electric generators that form the core of the power supply system, the semitrailer is equipped with two separate diesel fuel (grade 2) storage and distribution systems consisting of fuel tanks, filters, and distribution lines. The two fuel tanks and distribution systems are located below the semitrailer floor in the belly bay.

The semitrailer is equipped with a power supply system to operate the integral electrical support systems. The electrical system provides power to the HVAC unit, the package chillers, the Instrument Data Acquisition System (IDAS), and the onboard lighting and receptacles. Power to the semitrailer is three-phase, four-wire, 208Y/120 V. All utilization equipment in the package is compatible with this supply without additional transformers. The power supply system includes two separate diesel-driven generator sets and the capability of accepting power supplied from an external source. The system is capable of operating from either of the diesel generators or the externally derived docking power. The docking power is intended to provide a low-maintenance source of electrical power during the times that the semitrailer is not on the road and electrical power is required for loading/unloading operations or standby/maintenance reasons.

A) Requirements

- Adequate shore power for the 2-RTGTS of 220 V 3-phase (100 A per phase)
- Floor space of roughly 30’ x 60’ for both trailers to be accommodated indoors
- Overhead crane with 5 ton capacity for working with 9904 cask
- Floor space of a minimum of 20’ x 20’ with a desirable space of 20’ x 40’ for cask disassembly situated directly in the area accessed by the 5 ton-overhead crane
- Floor loading capacity of 5 tons with a footprint of 8’ x 8’

B) Current Situation

The two RTGTS are stored outside the reactor building at the Transient Reactor Test (TREAT) complex. It is connected to shore power (220 V, 3 phase-100 A). The three 9904 casks are either stored within the RTGTS, inside the TREAT reactor building or inside another nearby structure at the MFC site. Each RTGTS has the capacity to store up to two 9904 casks. Maintenance is done primarily on a quarterly and annual basis with checks of most systems performed on a weekly and monthly basis. Additionally, the RTGTS is taken for a several mile, over-the-road test with a semi-tractor on a monthly basis when it is not actively engaged with a mission. The DOT inspection is performed on an annual basis, or as required prior to use, to comply with federal regulations.

The 9904 casks are subjected to an annual certification, or as required based on use, to maintain compliance with the Safety and Analysis Report for Packaging (SARP). Training with the 9904 casks is typically performed in TREAT for remote operations. These operations require the use of a 5-ton overhead crane with a minimum hook-to-floor distance of 15’.

C) Reason/Rationale for Change

The RTGTS is stored outside as it has been since it was procured in the mid-1990’s in Ohio and then since 2003 in Idaho. Increased maintenance concerns over the last several years are driving the consideration for providing indoor storage. Maintenance issues which could be mitigated or eliminated by storing the RTGTS systems indoors include: 1) degradation of door and roof hatch seals which allow the ingress of water, 2) the constant cycling of the HVAC system during the winter months to protect the electronic systems of the IDAS which are housed in the RTGTS, 3) the incursion of dust and grime into the front mounted diesel generator which has no protective housing and 4) degradation of the air ride suspension system through collection of condensate caused by excessive temperature cycling. The use of the RTGTS systems is such that approximately 80-90 % of their total time “in service” is spent at rest in Idaho. This condition does not enhance their “road-readiness” even with relatively constant attention to maintenance. The ability of the RTGTS to exhibit performance with a reliability of 99.9999% (design parameter) is uncertain due to the degradation of their systems from exposure to the elements during inactive periods. The ability to retrieve deployed RPS systems from the field with the RTGTS is an activity that the INL is directed to be ready to perform on an “as needed” basis every year. This ability could be compromised if the systems are degraded by outside storage that requires longer than desired maintenance prior to use for retrieval of deployed systems.

It is likely that the DOE will pursue the establishment of nuclear transient testing in the US in the near future. One of several sites that will be considered for this testing will be the TREAT facility at the INL. If this occurs, the RTGTS equipment will be required to be relocated.

Furthermore, the high bay area of TREAT, for the annual cask certification of the 9904 cask, will be unavailable. The high bay area is also used for 9904 cask handling training for remote operations such as those that take place at Kennedy Space Center (KSC). Any actions regarding the use of TREAT for transient testing must undergo the NEPA process and this action will give the RPS Program some warning that a move will be required.

The TREAT complex has been used for various National and Homeland Security (NHS) purposes for many years. This typically involves training with actual radioactive sources and involves exclusive use at 1-2 week intervals. This training takes place many times during the year (more than 10 times annually) and has been the cause of several conflicts for facility use for either training and/or cask certification over the last several years. These incidents are increasing in frequency and are a cause for concern.

D) Options

- The equipment can stay at TREAT until that location is untenable based on the use of the building for transient testing or NHS use.
- Another building can be found at the INL-CFA/INTEC area that is underutilized and the equipment moved to that structure.
- A commercial building can be found in Idaho Falls for lease to house the equipment.
- A new outdoor storage location can be identified and outfitted with the appropriate power required by the RTGTS. The engineering development laboratory (MFC-772) can be re-configured to accommodate the operation of a single 9904 cask at a time for annual certification and training, although the storage of the RTGTS and 9904 casks would still be an outstanding issue.
- A building can be built at the INL for housing the RTGTS and the 9904 casks and possibly the unfueled convertors (see next section).

E) Discussion

The maintenance needs for the RTGTS have been carefully evaluated versus common industrial practices, please see attachment A (TEV-859, “Evaluate the RTGTS Preventive Maintenance Schedule”, and it has been found that a more thorough monthly/quarterly maintenance/operational schedule could be used in place of the current weekly/monthly maintenance schedules. This would allow for consideration of placement of the units in a building that is not located on the MFC campus (where our manpower resources for maintenance are located) without a substantial increase in the effort costs on an annual basis. The annual costs would be approximately **$25 K** for the rent of the facility with an upfront set-up cost of approximately **$100 K** to outfit the facility with the appropriate power receptacles and associated equipment and the exhaust lines to facilitate operation of the diesel generators indoors. The operating costs would be essentially the same as the current storage location at TREAT for the INL personnel providing the recommendations of the attached TEV-859 are implemented (more rigorous monthly/quarterly checks in place of weekly maintenance). The switch from the weekly/monthly/quarterly/annual maintenance schedule to a monthly/quarterly/annual schedule would save enough costs to balance out the 45 minute travel (each way) that the maintenance crew would incur by using a non-MFC storage location for the RTGTS.

It may be necessary to provide for a separate facility to perform training and annual certification of the 9904 package. It would be ideal if the storage facility to be leased for the RTGTS were outfitted with the appropriate 5-ton overhead crane with the required hook-to-floor distance of 15 feet, but this is not a certainty. Modifications to the current configuration of the EDL on the second floor would allow for this facility to be used for this operation. This effort would involve removal of several deck plates of the existing second floor and installation of additional railing and movement of a set of stairs. This configuration has been used for the facility in the past, so it is not an unknown; although the equipment in the facility was different at that time. It is estimated that the re-configuration effort would cost approximately $**20 K** and take approximately three months from start to finish to accomplish with the finished capability being sufficient to handle a single cask at a time for training or annual certification. The modifications would be done so that they are non-permanent in nature and would impact operations for approximately 1 month a year.

Establishing a new outdoor parking area would involve ground preparations (grading and paving) and electrical receptacles (220 V/3 phase, 100 A per phase). The cost for this is likely to be **$50-100 K** based on previous experience.

An alternative to outfitting the EDL to perform training and annual certification of the 9904 packages would be to lease a building with sufficient vertical space and purchase a rolling gantry type crane similar to that which Savannah River Site purchased for the Hanford drum project which was very suitable for disassembly for the 9904 operations conducted there. The cost would be in the **$ 100 K** range and it would be positioned in the leased facility, but belong to the INL.

The most promising alternative based on our current knowledge would be the utilization of one of the six buildings located at the INTEC campus of the INL that were recently transferred from the clean-up contractor CH2MHill Washington Group International(CWI) to the INL. Buildings 1634 and 653 are both currently unoccupied and have been previously operated as hazard category II nuclear facilities but have been down graded to non-nuclear facilities with the concurrence of the radiation safety organization. Our need would be to use one of them as a non-radiological facility. Both would require some modifications but 1634 appears to have the most attractive features from an RPS program perspective. It is approximately 40’ x 80’ and is equipped with environmental controls (AC/heat) and a restroom. It is also tall enough to accommodate the disassembly of the 9904 cask system for training and annual certification. It is also equipped with a certified 10-ton bridge crane and a relative abundance of power (single and three phase). The facility has a single-wide garage door that is high enough to accommodate the RTGTS ingress/egress. Modifications that are necessary include: 1) removal of a 12 inch high, gently sloping interior ramp from the garage door down to the main floor, 2) addition of a second garage door to allow “straight in positioning” of the RTGTS units, 3) addition of a trunk ventilation system and blower to allow for running the diesels inside the structure, and 4) general access to the facility by removal of an adjacent building (currently planned as part of CWI’s contract). It is reasonable to explore the placement of the MHW generator manifold in this structure as well as part of a conceptual floor layout plan. The costs associated with the INTEC alternative is not fully developed but is probably in the **$100-300 K** range for the initial modifications based on discussions with the engineer that supported the construction of the facility 16 years ago. On-going costs would be very similar to our current costs for maintaining the units at TREAT based on using existing work control practices as discussed earlier (less frequent and more extensive maintenance, but increased personnel travel time). The availability of these structures may change with time as other programs, primarily NHS funded programs, are interested in them as well. I would anticipate that some sort of formalized interest on our part (letter) would be necessary in the next few months, although the modifications could then be done over the next year (FY11).

F) Recommendation

The INL would recommend pursuing ownership of building 1634 at the INTEC campus for RPS Program use. This would provide for indoor storage of the RTGTS and 9904 cask systems and possibly a more dependable future location of storage of the MHW and GPHS-RTG unfueled convertor storage if these systems are to be kept by the Program.

2.0 UNFUELED CONVERTORS

2.1 Description of Systems

There are several unfueled convertors of two types stored on a gas manifold system in the area adjacent to the TREAT reactor. There are six unfueled multi-hundred watt (MHW) convertors (F-1E, E-1, E-2, E-5, F-7, F-13) and a single unfueled GPHS RTG (F-5). These convertors are stored with an inert gas atmosphere over the internals in the case of the MHW convertors and with the GPHS convertor stored inside an airtight shipping container with a cover gas of argon in all cases. Four of the six MHWs are also stored inside airtight shipping containers with two of them being stored without the shipping container. Gas servicing is conducted on a roughly monthly basis and periodic gas taps are conducted for confirmatory analysis of gas composition.

These units are kept for two primary purposes: 1) a possible source of Si-Ge unicouples for the building of future RPS units, such as the GPHS-RTG and 2) the possible refurbishment of the GPHS-RTG (F-5) for future use.

The gas manifold system is meant to tie-in with one of several gas management carts that are part of the RPS program at the INL. Each cart is equipped with a two-cylinder inert gas supply to the manifold.

A) Requirements

-Use of ordinary 110 V power
-Minimal heating/cooling (60-100 F conditions)
-Space of 20’ x 30’ with access available on a monthly basis

B) Current Situation

The MHW and the GPHS-RTG are currently stored in the main building of the TREAT reactor complex. The 6 MHW generators are stored on a stand-alone gas manifold, which ensures their internals are maintained under an inert cover gas to minimize degradation of the Si-Ge unicouples for possible future use, since production of the unicouples is currently discontinued. The GPHS RTG (F-5) is stored in a pressurized container under inert cover gas for similar reasons. The approximate space involved in this activity for the 7 convertors, gas manifold and gas operations cart is 20’ x 30’. The frequency of maintenance operations is every 28 days for pressure checks and gas sampling (when required).

C) Reason/Rationale for Change

The reasons for changing this configuration are explained above in the section on the RTGTS since the convertors are stored within the same building that the RTGTS is stored next to. Competition for the use of the TREAT reactor building will continue to be of concern.

D) Options

- The equipment can stay at TREAT until that position is untenable, if that occurs, based on the use of the building for transient testing or NHS use.
- The unfueled convertors can be disposed of by the excess equipment process or donation to museums. Export control issues may play a factor in this outcome, if pursued.
- Another building can be found at the INL-CFA area that is underutilized and the equipment moved to that structure.
- A commercial building can be found in Idaho Falls for lease to house the equipment.

- A building can be built at the INL for housing the RTGTS and the 9904 casks and possibly the unfueled convertors.

E) Discussion
The storage of these systems should be evaluated as to whether it is still in the best interest of the national program as a starting point.

F) Recommendation
If it is deemed to be in the best interest of the national RPS Program to retain these units; then the INL would recommend moving them to the structure that will house the RTGTS equipment.

3.0 FUELED CONVERTORS

3.1 Description of Systems

The Space and Security Power Systems Facility (SSPSF) is currently storing fueled convertors and/or significant fueled components of convertors for several different types of radioisotope power systems. These include but are not limited to the following as of 2010: 1) Multi-Mission Radioisotope Thermo-electric Generator, 2) Stirling Generators, and 3) heat source for the High Performance Generator Modification-3 (HPG-mod3). This is accomplished in one of four designated SNM storage rooms within SSPSF (Thermo-Vacuum room-111,112, Module Reduction Room-116, Support Room-117). These storage areas are also used for conducting acceptance tests on generators and assist in assembling generators, i.e., they serve a dual purpose for the primary role of the facility, fueling and testing RPSs.

The current storage situation is such that 3 of the 4 rooms have fueled RPS components stored in them. The utmost capacity of storage of a design such as the MMRTG is presently approximately 3-4 total without conflicting with the ability to perform a thermal vacuum power test, for example. This physical logistics statement does not take into consideration the thermal loading in various rooms. Although the air handling equipment was designed with storage of GPHS-RTGs in mind, the thermal loading of the facility should be evaluated.

A) Requirements

- A structure with the appropriate nuclear hazard classification (category II) must be used.
- The appropriate authorization basis must be present for the facility to house Pu-238 heat sources and generators.
- Some consideration for the appropriate monitoring of the convertors must exist which may change from convertor to convertor

- The convertors must have the fire suppression systems removed or rendered inoperable in verifiable fashion.
- A performance category 3 structure.
- The structure must be compatible with an established method of transporting the convertors there (9904 cask or direct transfer on the T-cart or BPCA).
- Appropriate convective cooling means must exist to safeguard the health of the convertors.

B) Current Situation

The current inventory of generators and other generator components (1-MMRTG, 4-SG, 1-Mod 3 heat source and 33 GPHS fuel clads) are stored in the Space and Security Power Systems Facility (SSPSF). They are housed in several of the 4 rooms engineered for long-term storage in SSPSF. The rooms were designed to be secured with locks on 1 foot thick concrete doors. This storage is currently adequate; although the surge capacity beyond this current situation would require the termination of any thermal vacuum power testing since that room is the only one that would remain empty of Pu-238 fueled components. The final examination of the heat sources that exhibit positive ultrasonic test (U-T) indications is conducted using a hood and a linear accelerator positioned within one of the Thermo-vacuum chamber rooms. These examinations could be not be conducted if the room is being used to store RPS units for a large mission such as the outer planets flagship (OPF) mission. It is anticipated that the Advanced Stirling Radioisotope Generator (ASRG) program may require this storage room and that the planned OPF mission would far exceed this current capability. The OPF mission currently calls for 5 or 6 MMRTG units, which SSPSF is unable of storing.

C) Reason/Rationale for change

The capacity of the SSPSF to store RPS convertors and like Pu-238 components will be exceeded.

D) Options

Another existing building on the INL site could be found that could house the fueled convertors and Pu-238 components.

An extension to the existing facility could be added to accommodate storage of the convertors and Pu-238 components. This extension should be approximately 1500-2000 ft^2 in footprint. This would also include adequate space to perform radiography on fuel clads that exhibit positive UT indications during the manufacturing process. This testing was not part of the original design criteria for SSPSF but was accommodated at the request of DOE after the construction was complete (2005). It is part of the allowed activities for SSPSF but could be better accommodated in an extension to the building that was specifically designed to house it with enhanced shielding for enhancing personnel safety.

E) Discussion

The only feasible option to accommodate the anticipated several RTGs (6-7) for the OPF mission, which is planned for approximately 2020, is new construction. The most logical location for this new construction is a location that would allow for leveraging of the existing staff in SSPSF. The requirements for a nuclear facility would drive a certain level of staffing to conduct day-to-day operations and maintenance of the building. A nominal number of additional staffing for a small facility would likely be in the range of 3-5 persons (nuclear facility manager, shift supervisor and a few operators). A building extension to SSPSF or a co-located structure that could be administratively controlled by the operations staff of SSPSF would minimize additional staffing requirements.

The INL could perform a conceptual design for a simple structure to be co-located with SSPSF to perform 2 or 3 basic functions: 1) storage of multiple RPS units, 2) house an area to perform radiography that exhibits enhanced shielding, and as a option 3) loading of the 9904 casks (this requires a high bay and an overhead crane). The conceptual engineering work could be accomplished in FY11 for consideration as an item for the FY13 budget.

There are no current structures that the INL has that meet the basic requirements for storing Pu-238 RPS units (performance category III structure with no active fire suppression system). The new storage vault for SNM being established at the INTEC campus in building 651 will have no ability to handle the 9904 cask and thus would require shipment of units to and from there in the BPCA with SSPSF being used to perform final packaging in a DOT certified container. Shipment to that building would require either closing public roadways (US-20) or the building of a new roadway between the MFC campus and the INTEC campus. Such a roadway has been discussed for many years but no progress has been made. Recent cost estimates have been in the $25 M range.

F) Recommendation

It is the recommendation of the INL that an addition to SSPSF be considered for the storage of fueled convertors for the RPS program.

APPENDIX A

Document ID: TEV-859
Revision ID: 0
Effective Date: 04/08/10

Technical Evaluation

Evaluate the RTGTS Preventive Maintenance Schedule

Idaho National Laboratory

The INL is a U.S. Department of Energy National Laboratory operated by Battelle Energy Alliance.

REVISION LOG

Rev.	Date	Affected Pages	Revision Description
0	04/08/10	All	See eCR 579205. New issue.

CONTENTS

1. PROBLEM STATEMENT

The Radioisotope Thermoelectric Generator Transportation Systems (RTGTS) trailers are currently stored outside, east of building 720 at the Materials and Fuels Complex (MFC). The Space Nuclear Systems & Technology (SNS&T) directorate has been pursuing options for inside (warehouse) storage of the RTGTS trailers. The options include buildings located at other INL complexes as well as potentially leased off-site commercial buildings (locations remote from the MFC where the directorate's personnel and support staff are located). One factor in assessing the feasibility of remote locations is the additional costs associated with travel to the remote location to complete scheduled maintenance on the RTGTS. This technical evaluation evaluates the basis for the current preventive maintenance checks to determine what adjustments to the periodicity are appropriate with inside storage.

2. BACKGROUND

The RTGTS were procured and delivered to DOE in 1996. The RTGTS are enclosed semi-trailers, customized for the transport of the 9904 casks loaded with Radioisotope Power Systems (RPS). The on-board systems include redundant 40 kW diesel generator (DG) sets, redundant chillers for cooling the casks, a HVAC system for conditioning the trailer space, and a data acquisition system for monitoring and recording data from the on-board systems as well as from RPS instrumentation.

Upon receipt of the two RTGTS trailers, preventive maintenance schedules (PMS) were developed based on vendor manuals (References 1 and 2), engineering experience and vendor recommendations. The PMS have also incorporated lesson learned and experience from operation of the RTGTS over the past 14 years. The PMS are currently broken down into weekly, monthly, quarterly and annual checks. Tables 1 through 4 at the end of this evaluation tabulate the weekly, monthly, quarterly, and annual checks and provide the basis for each check.

Most of the OEM documents recommend the maintenance checks based on a time interval or equipment usage, usually in terms of hours of operation. Per the monthly PM documentation, the DGs have approximately 1300 hours of run time total life-to-date. This equates to slightly less than 100 hours of run time per year. Shipments utilizing the RTGTS with its on-board systems (DGs and chillers) operating are infrequent, typically less than one mission every couple of years. In addition, the RTGTS is used occasionally (typically once every couple of years or less) for cask transport only (without use of the on-board systems) to support dry runs and transfer of materials that do not require active cooling during transport.

3. EVALUATION

3.1 Weekly Checks

The weekly PMS includes DG run tests and checks of exterior panels, tires, shore power cables, interior lighting, weather seals, power breakers, chiller piping, smoke and carbon-monoxide detectors. The most significant weekly check is the DG inspection and run test. The run test is currently a no-load run with the DG output breaker open. The Kohler Power Systems Operation Manual for Industrial Generator Sets, TP-5750 (3/95), Section 2, Exercising the Generator Set, states the following:

> "If the generator set is not equipped with an automatic transfer switch or the transfer switch does not have the automatic exercise option, run the generator set **under load** once a week for one hour with an operator present…." (Bold added for emphasis)

The importance and value of weekly DG run tests has been widely discussed in industry and DOE maintenance forums over the past two decades. Based on general DOE site practices (per experience in the DOE EFCOG Backup Power Working Group) during this timeframe (1990s), it was a common practice to specify weekly no-load operability tests of DG sets in emergency, backup or standby power systems. It was subsequently determined that such frequencies, particularly with low load factors, often resulted in undesirable wet stacking of the diesel engines. As a result, most sites deleted weekly no-load test runs. Although NFPA 110, *Emergency and Standby Power Systems*, is not applicable for this application, it provides a benchmark for comparison. It requires that EDGs (systems that are expected to come on-line automatically without any prior notice or opportunity for checking prior to use) in emergency and standby power systems be inspected weekly and exercised under load at least monthly. As another reference point, MFC maintains 12 backup or standby DGs for nuclear facilities and site utilities (i.e. deep well pump power & firewater). All but the DG fire pumps are all exercised on a monthly frequency. This included the two FCF safety class EDGs.

A factor favoring more frequent (i.e. weekly) run tests is to keep the cylinders lubricated, reducing cylinder wear during start up and pressurization of the lubrication system. Another factor favoring more frequent (i.e. weekly) run tests for DG sets in standby or backup service (i.e. no prior notice to when the systems may be automatically placed into service) is to provides a more frequent operability test to confirm that the DG will start when needed without any operator intervention. In contrast, the deployment of the RTGTS and operation of its systems including the DG sets is known well in advance. Final operability checks and inspections can be scheduled and performed prior to deployment. Deployments to ship RPSs that require operation of the RTGTS DGs and chillers are relatively infrequent, typically only once every two to three years.

The local distributor and service representative for Kohler Industrial Power is EC Power Systems in Boise, ID. On 3/22/10, SNS&T (R. Stewart and N. Duckwitz) discussed the RTGTS application of the Kohler 40 kW DG with Mr. R. Ridgway, a service technician with EC Power Systems. He confirmed the validity of the drivers for weekly operability checks, especially for standby and backup service applications as described above. Upon discussing and understanding our specific application, Mr. Ridgway stated that it would be reasonable to reduce the frequency of operability tests and inspections to a monthly frequency, ensuring that the DGs are operated under load to eliminate wet stacking concerns.

In addition to the DG checks and operability tests, the weekly PMS includes checks of exterior panels, tires, shore power cables, interior lighting, weather seals, power breakers, chiller piping, and smoke and carbon-monoxide detectors. With inside storage and the current infrequent use, age deterioration for these items will likely decrease. The vendor manual citation for those checks states the checks should be performed once every two weeks or every 2000 miles. Thus with inside storage, a monthly periodicity for these items is reasonable. Without inside storage, a weekly walk through of the RTGTS should be continued (especially in winter weather) as a minimum to ensure the HVAC system is operating for freeze protection of the chiller systems.

3.2 Monthly Checks

The RTGTS monthly operational checks are listed in Table 2. These checks have been generically grouped as trailer exterior checks; interior checks; operational run tests of the DGs, chillers, and IDAS; and a 20-mile road test/exercise of the trailer. The trailer exterior checks and interior checks overlap most of the weekly checks discussed above and should be continued on a monthly basis. The operational run tests of the DGs are also discussed in the evaluation above for the weekly checks. These checks should be continued as written, ensuring the DGs are loaded with the HVAC and chiller system loads as well as with the chill water

7.5 kW resistance heaters' loads. The operational tests verify proper performance of the DGs, ATSs, chillers and IDAS. Note that the IDAS PMS is currently under evaluation with the upgrading of the system's computer and electronic storage media.

A review of the RTGTS document did not establish a basis for the 20-mile road test/exercise of the trailer other than engineering judgment and operating experience. With the demands on the RTGTS for transfers typically being as infrequent as once every couple of years, it is important that the trailer be exercised periodically to detect any developing problems with the wheel bearings, suspension system or structural components that may have not been readily observable with the visual inspections. Rotation of the axles also relubricates the portion of the wheel bearings that is setting above the axle oil fill line when the trailer is parked. Also it is known that long term storage of ball bearings in a fixed position often leads to false brinelling of the bearing races. Industry literature (Reference 3) states, "Where bearings are oil lubricated and employed in units that may not be in service for extended periods, the equipment should be set in motion periodically in order to spread the lubricant over all bearing surfaces. Intervals of 1 to 3 months should suffice." False brinelling is particularly a concern in "storage" locations with vibration of the support structure due to adjacent traffic or equipment operations. If the storage facility or warehouse is adjacent to an active railroad or heavy haul highway, lubrication at the shorter frequency is appropriate. This should be a consideration for the selection of the storage location. The current outside storage location at TREAT is relatively isolated from such vibration concerns. As such, a quarterly periodicity for the road exercise is appropriate.

3.3 Quarterly Checks

The RTGTS quarterly preventive maintenance checks are listed in Table 3. These checks can be generically grouped as grease lubrication (air ride couple, zerks on the landing gear, and chiller fan), verifying road worthiness (i.e. tightness) of equipment mounts/fasteners, checks on battery chargers, and checks for deterioration of hoses/drains. The road worthiness checks fit well with the recommendation (storage location dependent) to move the 20-mile road test/exercise to a quarterly periodicity. The current quarterly checks are reasonable and appropriate. Other than the addition of the road test, no changes are recommended

3.4 Annual Checks

The RTGTS annual preventive maintenance checks are listed in Table 4. These checks can be generically grouped as operational testing of the custom external alarm panel (connects to the front of the trailer), inspection and maintenance of the UPS, inspection of belly box lighting, drain collection and cooling hose/reel system, trailer DOT inspection, DG maintenance [replacement of DG oil and filters (oil, fuel, and air), test coolant glycol concentration, post maintenance DG operational checks], and check of the refrigerant for the chiller systems.

The OEM manual recommends changing of engine oil and filter every 250 hours of engine operation which is typically about two years of RTGTS operation. Oil degradation is not only affected by DG operation but is also affected through crankcase condensation. Crankcase condensation is a function of ambient humidity, daily temperature swings, and DG storage conditions. The DGs are equipped with block heaters which help in reducing temperature swings within the crankcase. Inside storage will also reduce crankcase condensation. Current predictive maintenance practices for MFC standby and backup DG sets utilize oil sampling and analysis results to establish oil replacement intervals. Oil analysis provides the added benefit of identifying signs of engine wear and degradation (i.e. checks for fuel dilution and wear products) before they result in engine failure. While the current practice of annual oil changes is conservative, it is recommended that the availability and use of oil analysis be explored in the future.

3.5 Other Checks

Maintenance records reveal that the DGs have had some replacement of coolant system parts such as the block heaters and a radiator. Coolant has been replaced during these repairs; however, no record has been located to determine if and when the coolant systems have been flushed. The OEM manual recommends flushing the DG coolant system at 1200 hour/2-year intervals. As noted in the background information, the RTGTS DGs each have approximately 1300 hours of operations life-to-date. Thus a 2-year interval seems excessive considering that the DGs only run about 200 hours over that interval; however, supplemental coolant additives (SCAs) that protect against corrosion of the cylinder walls are depleted with time. To ensure adequate corrosion protection is maintained under extended coolant drain and flush intervals, the coolant can be tested and SCAs may be added. Alternatively, an extended life coolant (e.g. John Deere Cool-Gard or equivalent) which is formulated for a 5 year/5000 hour life can be used and the flush/drain interval established accordingly. It is recommended that all coolant systems be drained and flushed during the next annual and replaced with an extended life coolant. The annual PMS should be revised to require recording the last coolant drain/flush and repeating on a 5 year interval.

The DG engine OEM manual recommends that the valve clearance be checked an adjusted at 1200 hour/2-year intervals. No record has been located to indicate the valve clearance has been checked since the systems were delivered. It is recommended that valve clearance be checked and adjusted if necessary. Findings during the check should be used to establish the appropriate frequency to be included in the RTGTS PMS.

4. CONCLUSION/RECOMMENDATIONS

The DG application for the RTGTS DGs is relatively unique. Deployment of the RTGTS and operation of its systems including the DG sets is known well in advance. Final operability checks and inspections can be scheduled and performed prior to deployment. This is in contrast to DGs in standby, backup or emergency service that provide power on demand upon loss of normal power, typically without the benefit of prior notice. Based on the RTGTS history and use, the following changes to the PMS are recommended:

1. The weekly checks be merged with the monthly PMS and performed monthly. Without inside storage, a weekly walk through of the RTGTS should be continued (especially in winter weather) as a minimum to ensure the HVAC system is operating for freeze protection of the chiller systems.

2. The monthly road test/exercise of each trailer should be extended to a quarterly frequency and merged with the current quarterly PMS.

3. The availability and use of oil analysis for the diesel engines be explored in the future.

4. All diesel engine coolant systems be drained and flushed during the next annual and replaced with an extended life coolant. The annual PMS should be revised to require recording the last coolant drain/flush and repeating on a 5 year interval.

5. The diesel engine valve clearance be checked and adjusted if necessary. Findings during the check should be used to establish the appropriate frequency to be included in the RTGTS PMS.

5. REFERENCE

1. Operations, Maintenance and Service Manual TL4827, Mobilized Systems, INC.

2. Kohler Power Systems Operation Manual TP-5750 (3/95), Industrial Generator Sets, Models 20-2000 kW

3. FAFNIR Bearing Company, “How to Prevent Ball Bearing Failures,”

Table 1 RTGTS Weekly Operational Checks (RPS/HS-MI-37100A)

System (MI Paragraph)	Check	Basis for Current Periodicity
Trailer Exterior (8.1.1)	Body panels for leaks, loose or missing fasteners	(1)
	Tires for proper inflation and obvious damage	(1)(4)
	Shore power cable and connectors for obvious deterioration/damage	(3)
Fuel System & Tanks (8.1.2)	Tanks and plumbing for damage/leakage	(2)
	Fuel level adequate	(2)
Diesel Generators (8.1.3)	Battery connections and restraints secure	(2)
	Controller lamps operational (push test button)	(2)
	Unobstructed cooling air flow	(2)
	Air filter housing installed and undamaged	(2)
	Verify coolant level & check for coolant leaks	(2)
	Verify oil level and check for oil leaks	(2)
	If necessary, drain fuel filter of water and debris and bleed off air	(2)
	Check fan belt condition and tension	(2)
	Check exhaust system, outlet is clear and fitting are tight	(2)

Table 1 RTGTS Weekly Operational Checks (RPS/HS-MI-37100A)		
System (MI Paragraph)	Check	Basis for Current Periodicity
	With output breaker off, start and run diesel for 1 hr; while running check oil pressure & fuel lines for leakage	(2)
Trailer Interior (8.2)	Interior lights operational	(3)
	No tripped breakers	(3)
	Front compartment free of leakage	(1)
	Roof hatch weather seals leak tight	(1)
Air Conditioner/Heater (8.2.1)	Heat operability	(3)
	Cooling operability	(3)
Chillers (8.2.2)	Chiller fluid piping, fittings and hoses for damage or leakage	(3)
Smoke detectors (8.2.3)	Test switch to verify operability	(3)
	Press test button on battery powered detectors to verify operability	(3)
Carbon-monoxide detectors (8.2.4)	Press test button to verify operability	(3)

(1) The RTGTS Operations, Maintenance and Service Manual, Model TL4827, prepared by MSI recommends these checks be performed "2000 miles or 2 weeks

(2) The Kohler Power Systems Operation Manual for Industrial Generator Sets, TP-5750 (3/95), Section 2, *Exercising the Generator Set*, states the following:
"If the generator set is not equipped with an automatic transfer switch or the transfer switch does not have the automatic exercise option, run the generator set **under load** once a week for one hour with an operator present…." (Bold added for emphasis)

(3) Engineering judgment or experience.

(4) The RTGTS Operations, Maintenance and Service Manual, Model TL4827, prepared by MSI recommends these checks be performed as "trip or daily." The checks are also performed prior to use and/or after each use and documented on preuse and/or post use checksheets.

Table 2 RTGTS Monthly Operational Checks (RPS/HS-MI-37100B)

System (MI Paragraph)	Check	Basis for Current Periodicity
Trailer Exterior (8.1.1)	Body panels for leaks, loose or missing fasteners	(1)
	Shore power cable and connectors for obvious deterioration/damage	(3)
Fuel System & Tanks (8.1.2)	Tanks and plumbing for damage/leakage	(2)
	Fuel level adequate	(2)
Brake-system Plumbing (8.1.3)	Tubing and hoses are secured from chaffing, in good condition and no indication of leakage	(4)
	Pull air-dump lanyards to bleed any accumulated moisture	(3)
Tires (8.1.4)	Tires for proper inflation and wear condition	(1)(4)
Wheel Studs (8.1.5)	Wheel stud nuts have not backed off	(4)
Hub Oil Level (8.1.6)	Level in operating range and hub free of oil leakage	(4)
Hubometer (8.1.7)	Record mileage and confirm meter is registering as expected	(3) (4)
Mud Flaps (8.1.8)	Check for aging, wear, damage, cracking and deterioration; Fasteners are tight and flaps are properly secured to trailer	(4)
Kingpin and Pick-up Plate (8.1.9)	Visual check of kingpin and plate for wear and damage	(1)(4)
Frame Outer Rails and Cross Members (8.1.10)	Inspect for damage, loose or missing fasteners, or cracks	(1)

Table 2 RTGTS Monthly Operational Checks (RPS/HS-MI-37100B)

System (MI Paragraph)	Check	Basis for Current Periodicity
Landing Gear (8.1.11)	Check for wear, damage, and loose fasteners	(3)
Retention-Tank (8.1.12)	Check all hoses, connection, and tank for damage or leakage	(1)
	Drain tank as necessary	(3)
Doors, Hinges, Locks and Weather Seals (8.1.13)	Functional check; Check seals for leakage; Adjust striker plate if necessary	(1) (1) (1)
Step Ladder (8.1.14)	Check ladder for damage, cracking, loose or missing fasteners	(3)
Trailer Interior (8.2/8.2.1))	Interior lights operational	(3)
	No tripped breakers	(3)
	Front compartment free of leakage	(1)
	Roof hatch weather seals leak tight	(1)
Air Conditioner/Heater (8.2.2)	Heat operability	(3)
	Cooling operability	(3)
Chillers (8.2.3)	Chiller fluid piping, fittings and hoses for damage or leakage	(3)
Smoke detectors (8.2.4)	Test switch to verify operability	(3)

Table 2 RTGTS Monthly Operational Checks (RPS/HS-MI-37100B)		
System (MI Paragraph)	Check	Basis for Current Periodicity
	Press test button on battery powered detectors to verify operability; Replace batteries after one year use	(3)
Carbon-monoxide detectors (8.2.5)	Press test button to verify operability	(3)
Fail-Safe Louvers (8.2.6)	Verify louvers open on power loss and close when power is restored	(3)
Fire Extinguishers (8.2.7)	Verify gauge is in green range	(3)/NFPA
Electrical Receptacles and GFCIs (8.2.8)	Check for damage and corrosion; test GFCIs	(3)
Diesel Generators Preop Checks (8.3.1)	Battery connections and restraints secure	(2)
	Controller lamps operational (push test button)	(2)
	Unobstructed cooling air flow	(2)
	Air filter housing installed and undamaged	(2)
	Verify coolant level & check for coolant leaks	(2)
	Verify oil level and check for oil leaks	(2)
	If necessary, drain fuel filter of water and debris and bleed off air	(2)
	Check fan belt condition and tension	(2)

Table 2 RTGTS Monthly Operational Checks (RPS/HS-MI-37100B)

System (MI Paragraph)	Check	Basis for Current Periodicity
	Check exhaust system, outlet is clear and fitting are tight	(2)
Exercise ATS and Run DG for 2-Hr Load Test and Op Test chillers (8.3.2)	With output breaker off, start the diesel 1 and load it by switching output breaker on. Record generator output V and freq; Record DG operating temperatures; Monitor engine oil pressure and temp	(2)
	Check chiller mounting hardware for looseness, check coolant level and connections for leaks	(6)(3)
	Check condenser fan belt condition and tightness	(5)
	Check/clean condenser coils and air flow path for obstructions	(5)
	Start/Op run test chiller A; check refrigerant filter drier and refrigerant sight glass clear indicating proper operation	(5)
	Chiller controls to setpoint (40F)	(5)
	Secure chiller A; Switch DGs by securing DG1 and verifying DG2 starts and ATS operates to pick up load; Repeat DG op/run test described above for DG 2 and chiller B	(2)
	Test ATS by securing DG2 and verifying DG1 picks up load; Secure DG1 and reconnect to shore power	(2)
Exercise IDAS (8.4.1)	IDAS Op Test (Will be updated with completion of the system upgrade)	(3)

Table 2 RTGTS Monthly Operational Checks (RPS/HS-MI-37100B)		
System (MI Paragraph)	Check	Basis for Current Periodicity
Exercise PDAS (8.4.2)	Verify PDAS powers up and battery level is greater than 80%	(3)
Trailer Exercise (8.5) Hook-up (8.5.1) Ride-Height Adjustment (8.5.2)	After coupling to tractor, adjust ride-height and verify proper operation	(4)
Air-Ride Coupler (8.5.3)	Check and, if necessary, adjust air-ride coupler gap; Check coupler for any loose or missing fasteners	(4)
Suspension Air-Bags and Piping (8.5.4)	Visually check suspension-bags for wear, damage & inflation; Ensure shock absorbers are not damaged/leaking	(1)(4)
	Ensure welded suspension components are free of cracks; Visually checks bolts for wear/tightness	(3)
	Check air-suspension piping for damage/leakage	(1)(4)
Fifth-Wheel Air System (8.5.5)	Check air piping for damage/leakage	(1)(4)
Exterior Lights and Reflectors (8.5.6)	Check lens and lamps for operation, cracks, deterioration, moisture	(1)(4)
Exercise Trailer (8.5.7)	20-mile road test	(3)

(1) The RTGTS Operations, Maintenance and Service Manual, Model TL4827, prepared by MSI recommends these checks be performed “2000 miles or 2 weeks”. Per the monthly PM documentation, the DGs have approximately 1300 hours of run time total life-to-date. This equates to slightly less than 100 hours of run time per year.

(2) The Kohler Power Systems Operation Manual for Industrial Generator Sets, TP-5750 (3/95), Section 2, *Exercising the Generator Set*, states the following:
"If the generator set is not equipped with an automatic transfer switch or the transfer switch does not have the automatic exercise option, run the generator set **under load** once a week for one hour with an operator present…." (Bold added for emphasis)

(3) Engineering judgment or experience.

(4) The RTGTS Operations, Maintenance and Service Manual, Model TL4827, prepared by MSI recommends these checks be performed as "trip or daily." The checks are also performed prior to use and/or after each use and documented on preuse and/or post use checksheets.

(5) Engineered Environments Inc, Operating, Maintenance, and Service Manual, Model LC25210 Liquid Chiller Unit, recommends these checks be performed monthly.

(6) Engineered Environments Inc, Operating, Maintenance, and Service Manual, Model LC25210 Liquid Chiller Unit, recommends these checks be performed annually.

Table 3 RTGTS Quarterly Preventive Maintenance Checks (RPS/HS-MI-37100C)		
System (MI Paragraph)	Check	Basis for Current Periodicity
Trailer Exterior (8.1.1)		
Air-Ride Coupler (8.1.1)	Grease coupler	(2)(6)
Landing Gear (8.1.2)	Visual check for wear, damage, loose fasteners;	(4)(5)
	Exercise and lubricate as necessary	(3) (4)(6)
Air Conditioner/Heat-Pump Mounting and Condensate Drain (8.1.3)	Check for loose or missing mounting fasteners	(1)
	Check condensate drain for restriction and deterioration	(4)
Trailer Roof (8.1.4)	Check for damage, debris and loose fasteners; Potential leakage points	(1)
Generator mounting (8.1.5)	Check front generator mounts for loose or missing fasteners and vibration mounts; Check exhaust mounting for loose or missing fasteners	(1)
	Check rear generator mounts for loose or missing fasteners and vibration mounts; Check exhaust mounting for loose or missing fasteners; Functionally check two air intake louvers/lubricate as necessary	(4)
Garden Hose and Reel (8.1.6)	Check garden hose and reel hose for deterioration; Check hose reel for loose or missing fasteners and broken welds; Functionally test and lubricate hose reel	(4)(6)

Table 3 RTGTS Quarterly Preventive Maintenance Checks (RPS/HS-MI-37100C)

System (MI Paragraph)	Check	Basis for Current Periodicity
Battery Chargers GEN 1, GEN 2 and Belly box (8.1.7)	Check power and charging cables for deterioration; Check electrical contacts for damage and corrosion and clean if necessary; Check fuse to ensure not failed; Coat battery terminal connections with grease	(4)
Trailer Interior (8.2)		
Interior Panels (8.2.1)	Check for loose or missing fasteners and damage/leaks	(1)
Dock lights (8.2.2)	Check for damage/operability; Check power cables for deterioration	(4)
Chiller Hoses and Fittings (8.2.3)	Check all high-pressure fittings for damage, corrosion or leakage	(4)
IDAS (8.2.4)	Clean cooling fan screen and replace foam air filters as necessary	(4)
Floor Drains (8.2.5)	Functionally test; Verify drain path is unobstructed	(4)
Chiller Fan (8.2.6)	Grease shaft bearing if necessary	(6)

(1) The RTGTS Operations, Maintenance and Service Manual, Model TL4827, prepared by MSI recommends these checks be performed “2000 miles or 2 weeks”.

(2) Tartan Transportation System Maintenance Procedures, Air Ride Coupler – CRK 20 Series recommends coupler lubrication every 10,000 miles or “during the normal maintenance cycle of the trailer.”

(3) Binkley, 1995, Pamplet “Binkley-built….Best by Design,” Model LG 5 and LG6 Landing Gear, recommends lubrication of the landing gear every 12 months.

(4) Engineering judgment or experience.

(5) The RTGTS Operations, Maintenance and Service Manual, Model TL4827, prepared by MSI recommends these checks be performed as “trip or daily.” The checks are also performed prior to use and/or after each use and documented on preuse and/or post use checksheets.

(6) The RTGTS Operations, Maintenance and Service Manual, Model TL4827, prepared by MSI states “lubricate all high pressure fittings” every “2000 miles or 2 weeks”.

Table 4 RTGTS Annual Preventive Maintenance Checks (RPS/HS-MI-37100D)		
System (MI Paragraph)	Check	Basis for Current Periodicity
Trailer Interior (8.2)		
Custom Alarm Panel (8.2.1)	Connect and OpTest Panel (Panel connects to front of trailer next to VIC connection)	(1)
UPS Batteries (8.2.2)	After securing IDAS and NI computer, inspect UPS batteries and cables or tightness, corrosion, cracked insulation, and battery case damage	(1)
	Power up and OpTest UPS	(1)
Chiller System (8.2.3)	Check chill water for proper glycol concentration	(1)
Belly Box Equipment Box (8.2.4)	Check drain collection tank for need of cleaning	(1)
	Unreel and inspect belly box hose	(1)
	Inspect belly box charger and battery	(1)
Trailer Lighting and Receptacles (8.2.5)	Check belly box lighting, trailer lighting, and check trailer receptacles using a circuit tester	(1)
Annual DOT Inspection and Maintenance (8.3)	Annual DOT inspection performed by qualified shop	49 CFR 396
Diesel Generators (8.4)		
Engine Air Filter (8.4.1)	Clean/replace filters; inspect housing and attachment points	(1)(3)
Engine Oil Filter (8.4.2)	Change oil and filter	(2)
Engine Fuel Filter (8.4.3)	Change fuel filter	(3)

Table 4 RTGTS Annual Preventive Maintenance Checks (RPS/HS-MI-37100D)

System (MI Paragraph)	Check	Basis for Current Periodicity
Sample Engine Coolant (8.4.4)	Check glycol concentration	(3)
DG Post Maintenance OpCheck (8.5)		
	Check battery connections, battery restraints, controller lamps, cooling air flow for obstructions, properly reinstalled air filter housing, coolant connections for leaks, coolant level, oil level, drain fuel filters, check fan belts, check exhaust connections	(1)
Refrigerant System Maintenance (8.6)	Performed with support of a refrigerant specialist if needed; Check for damage or excessive wear; check refrigerant levels	(1)

(1) Engineering judgment or experience.

(2) Deere, 1994, Series 300, 3029, 4039, 4045, 6059, and 6068 OEM Diesel Engines Operation and Maintenance Manual, OMRG 18293 Issue H4, recommends this PM be completed every 250 hours of operation.

(3) Deere, 1994, Series 300, 3029, 4039, 4045, 6059, and 6068 OEM Diesel Engines Operation and Maintenance Manual, OMRG 18293 Issue H4, recommends this PM be completed every year or 600 hours of operation.