Qualification of Special Processes using a Graded Approach for the Light-Weight Radioisotope Heater Unit Metallic Component Production at Oak Ridge National Laboratory

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Oak Ridge National Laboratory (ORNL) Radioisotope Power Systems (RPS) Program has completed the development and qualification of special processes used for the manufacturing of metallic components for the Light Weight Radioisotope Heater Unit (LWRHU) Program. The completion of this task along with previously completed tasks such as formal approval of drawings, specifications and processing procedures, procurement and installation of new manufacturing equipment, and development of a vendor to supply the Pt-30Rh material in a variety of product shapes, etc. completes the reestablishment of manufacturing capability for metallic components and subassemblies for the LWRHU program. The reestablishment of producing graphitic components or production of final assemblies is not discussed in this paper. There has been a twenty-year lapse in the production of metallic components with the last production campaign completed by EG&G Mound Applied Technologies at the DOE Mound Laboratory in 1997. Similarly, the last production of LWRHU assemblies concluded at LANL in 1999. This paper will discuss the process of qualifying special processes in re-establishing LWRHU metallic component production at ORNL to provide for future NASA space exploration science mission needs where LWRHUs are required or provide for increased mission capability.

1. INTRODUCTION

LWRHUs (Figure 1) are radioisotope fueled heat sources designed to help maintain desired temperatures in crucial locations throughout the spacecraft. These heater unit clads are fabricated from Pt-30Rh alloy sheet, foil, and seamless tubing. LWRHU clad subassemblies consist of five piece parts (i.e. Shim, Vent Cap, Frit, Closure Cap, and Clad Body) that are manufactured using various metalworking processes, machining, welding and inspection operations.

Fig. 1. Light Weight Radioisotope Heater Unit.

A Frit fabricated from platinum powder is electron beam welded to a Vent Cap to create a Vent Cap Assembly. A Vent Cap Assembly is electron beam welded to a Clad Body to create a Clad Body Subassembly. Individual components and subassemblies are shown in Figure 2.

Fig. 2 LWRHU individual components and subassemblies.
II. CONTROL OF SPECIAL PROCESSES

The definition of a special process or work activity varies from ASME NQA-1 (Ref. 1), DOE Order 414.1D (Ref. 2), 10CFR Part 830 (Ref. 3) and QAP-X-89-RTG (Quality Assurance Plan [QAP] for ORNL RPS program) (Ref. 4). A special process as defined by ASME NQA-1 is a process highly dependent on the control of the process or the skill of the operator, or both and the specified quality can be readily determined by inspection or test (Ref. 1). In the case of welded metallic components, welding might not be considered a special process since inspection and test methods exist to determine quality. However, NQA-1 Requirement 9, specifically states “processes that control or verify quality, such as those used in welding, heat treating, and nondestructive examination, shall be performed by qualified personnel using qualified procedures in accordance with specified requirements”. Neither DOE Order 414.1D or 10CFR Part 830 defines special processes but does define work and the control of work in a similar manner as NQA-1 does for special processes. These differences may lead to specify certain processes as special processes while other organizations may not consider the same process as a special process.

The ORNL RPS program-specific quality plan complies with the requirement documents above and further states that “processes and associated equipment, tooling, and fixtures with the potential for affecting the quality of item … shall be controlled”. It further provides a nonexclusive list of special processes as welding, heat treating, nondestructive examination, cleaning, bonding, coating, soldering, plating, and hard surfacing.

In reviewing the requirements, the following processes were deemed special processes for the manufacture and assembly of metallic components that required qualification of the processes and required personnel that were specifically trained to be qualified to the requirements of drawings or specifications:

1) Welding;
2) Heat Treating;
3) Sintering;
4) Acid Cleaning;
5) Leak Testing;
6) and Dimensional Inspection.

For the six processes deemed to be special processes, components or materials were processed and then evaluated for compliance to drawings or specifications. The results were compiled and reviewed by the program quality representative. The relevant equipment processing parameters were integrated into production procedures.

Operator training and qualification is an integral part of special processes. In addition to the ORNL RPS QAP, operator training requirements are contained in GPHS-PGD-1 (Ref. 5). This document specifies the training requirements and certifications required for personnel. In the case of welding, it provides a recommended number of components and the evaluation criteria to qualify the process and personnel. It also allows a specific plan to be agreed to between the task manager and quality representative. For the LWRHU program, a specific plan was developed for the number of components to be welded and the acceptance criteria for evaluating the welds.

Two (heat treating and welding) of the six special processes will be further discussed. Heat treating of Pt-30Rh foil is required to prepare it for forming operations. The foil is purchased in a specific cold worked condition and requires recrystallization or annealing to ensure there is sufficient ductility during forming operations. Heat treating studies were conducted on the as-received foil and evaluated by hardness testing and metallographic examination and a qualification report generated (Ref. 6). Heat treating temperature parameters were developed that were approximately 2 ½ times the calibration uncertainty of the control thermocouples for the vacuum furnace. Figures 3 and 4 show the microstructures of the as-received cold worked foil and after the recrystallization heat treatment.

![Fig. 3. Cold worked Pt-30Rh microstructure.](image1)

![Fig. 4. Recrystallized Pt-30Rh microstructure after heat treatment.](image2)
Two electron beam welds are performed to produce subassemblies. The Vent Cap Assembly is produced by welding the Frit within the machined cavity of the Vent Cap. The purpose of this seal weld is to allow the escape of fission gases while preventing the escape of radioisotopes when activated during LWRHU final assembly. The second weld produces the Clad Body Subassembly by a full penetration weld between the Vent Cap Assembly and the Clad Body. For both welds there were no existing part contact tooling or weld positioners (fixtures) to accomplish these welds. A procurement was made following quality protocols of QAP-X-89-RTG with an equipment specification as part of the procurement documentation to the electron beam welder manufacturer. After receipt, the weld positioner was inspected to the inspection criteria agreed to between the task manager and the quality representative. In addition, part contact tooling was designed, inspected, qualified and integrated into production procedures for configuration control. The positioner is capable of controlling movement for either weld after installation of part contact tooling within the electron beam welder. A concept sketch of the weld positioner is shown in Figure 5.

![Rotary Ferris Wheel Fixture, 10 position](Fig. 5. Rotary Ferris Wheel Fixture, 10 position.)

Welding procedures and operator training followed acceptance of the weld positioner culminating in special process qualification of the equipment, process and operators using the specific plan developed for LWRHU. Welded assemblies were successfully evaluated to the plan. Like the other special processes, after the generation of the qualification report, the processing parameters, tooling drawings, etc. were integrated in the production procedures (Ref. 7). Among the multiple evaluation criteria, a metallurgical evaluation was performed for grain structure and weld penetration. Figures 6 and 7 show representative sections of the welds produced during qualification activities.

![Typical Frit to Vent Cap electron beam weld.](Fig. 6. Typical Frit to Vent Cap electron beam weld.)

![Typical Vent Cap Assembly to Clad Body electron beam weld.](Fig. 7. Typical Vent Cap Assembly to Clad Body electron beam weld.)

### III. Graded Approach

Use of a graded approach customizes the quality level to ensure the proper level is maintained without burdening the user with requirements that may not provide value. This approach is an area where NQA-1, 10CFR Part 830, and DOE Order 414.1D all use nearly identical language. There are three general areas where the level of documentation and records may vary.

During basic research, the researcher can often determine the levels of record keeping, process and equipment logs, equipment calibration, and training that are necessary. Planning should be performed to the extent possible, but basic research may lead to varied paths for success. Thus, obtaining preplanned instructions or procedures may not be beneficial. During applied research and development, the quality rigor increases to the controls necessary to reproduce the results of the development work. This generally includes process and equipment logbooks, equipment calibration, certified material reports, generic procedures or work instruction, preliminary drawings, etc. while work is progressing to meet technical standards, specifications or drawing requirements. It is important during this phase of work activities to plan for the quality requirements that will be imposed or
required in production of components so supporting records are generated. Finally, during qualification, production or support activities require full quality rigor where roles and responsibilities are defined. Additionally, full configuration management is applied as well as the independence of the personnel performing inspections or verifications from personnel performing operations.

The ORNL RPS program has implemented, in some special processes, an independent verification of instrument CNC programs or steps deemed critical for successful welding performance.

IV. CONCLUSIONS

The Oak Ridge National Laboratory Radioisotope Power Systems program has completed the reestablishment of producing LWRHU metallic hardware that were last produced in 1997 by EG&G Mound Applied Technologies at the DOE Mound Laboratory. A graded approach to quality management was applied to meet applicable quality requirements in the areas of process development, training, procurement and the qualification of special processes.

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