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Quality Application to Space Nuclear Power (SP-100)

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APPLICATION OF QUALITY AND RELIABILITY ASSURANCE TO THE HANFORD GROUND ENGINEERING SYSTEM TEST SITE

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ABSTRACT

Westinghouse Hanford Company (WHC) was selected by DOE as the preferred site to install and conduct operational, performance, and reliability tests on the ground-based prototype of the space reactor. These tests will be conducted with the reactor in a large vacuum chamber to simulate the space environment. A containment vessel system from the decommissioned Plutonium Recycle Test Reactor will house the chamber and provide appropriate safeguards. The reactor will generate 2.5-MW thermal energy from uranium nitride fuel clad in a Nb - 1% Zr alloy and will use lithium as the primary coolant.

The SP-100 Program is sponsored by three agencies: Department of Energy, Department of Defense, and NASA. The Ground Engineering System (GES) phase of the SP-100 is administered by DOE-HQ through DOE-SAN with ANSI/ASME NQA-1[1] forming the basis for the Quality Assurance Requirements. All participants in the GES program, which includes seven Federal Laboratories and several private contractors, will develop programs to implement the GES Quality and Reliability Assurance Program Plan (Q&RAP).

WHC developed a sub-tier Q&RAP for our activities based on existing procedures (as we do for all our projects). Our laboratory is committed to and has been implementing NQA-1 since 1979. We were the first laboratory to do so, we believe. As a result, we have in place control procedures that satisfy the 18 NQA-1 criteria. These are familiar to and understood by the performing personnel at WHC. The narrative for each criterion is a simple description of the selected methodology. Our Q&RAP is, then, a road map to the implementing procedures.

INTRODUCTION

The commitment to investigate Space Nuclear Power began in the early fifties, peaked in the mid-sixties, dropped very low in the mid-seventies, and is experiencing a revival during the eighties.[2] Although many concepts and programs were explored earlier, there are currently two types of nuclear power: radioisotope thermoelectric generators (RTG) and fission reactors.[3] RTGs use the heat source plutonium-238 to generate electricity by solid-state conversion and hence are passive. Although highly reliable and durable, RTGs are typically limited to low power (1 kWe). The use of fission reactors as the primary power source will extend power levels into the 10-1000 kilowatt range.

The Program began in 1983 with three sponsoring agencies: Department of Energy, Department of Defense, and NASA. Participating Federal laboratories include: Westinghouse Hanford Company, Los Alamos National Laboratory, Oak Ridge National Laboratory, Lewis Research Center, Argonne National Laboratory, Energy Technology Engineering Center, and Jet Propulsion Laboratory. The involved private contractors include General Electric as the systems developer with Westinghouse Electric Corporation and Thermoelectron as subcontractors. DOE-HQ will administer the program and has selected for the Quality Assurance standard ANSI/ASME NQA-1 to form the basis of the Quality Assurance requirements. DOE San Francisco field office (DOE-SAN) has the lead on QA and prepared the GES Quality and Reliability Assurance Program Plan (Q&RAP) for all the participants to implement.

Considerable progress has been made by several of the participants. WHC's role is to provide a surface-located test facility to simulate a space environment. We will receive the fuel assemblies, assemble the components, install the reactor in the vacuum chamber, ensure adequate safety and safeguards, and conduct tests on this prototype.

THE REACTOR

The reactor will be designed and provided by General Electric. Currently, the design is in the preliminary stage; but the fuel is expected to be uranium nitride and the cladding will likely be an alloy of niobium with 1% zirconium. No moderators are anticipated. One concept places the fuel elements in a cylindrical array, with hemi-cylindrical drums covering the outside elements. Absorbers on the drums serve as control elements and are rotated inward to reduce power and vice versa. Lithium will be the heat transport fluid. The reactor is targeted at the relatively high operating temperature of 1350K. It is expected to operate for a nominal seven-year life. Overall, the reactor weight is about 525 kg.[4] The unit is expected to be launched in a subcritical frozen lithium condition.

The ground-based reactor is intended to be as prototypical as possible, but there are major differences in design considerations, including gravity and safety/safeguard requirements. Fuels, materials, and operating parameters except for zero gravity can be simulated. However, ground-based safety requirements are different from those in space and include an emergency heat removal system. The ground unit may also take advantage of a "free surface" and natural convection derived from gravity. Currently the design power for the ground unit is 2.5 MWt.

THE MISSION

The mission at Westinghouse Hanford Company is to conduct ground tests of the prototype reactor. The three major tasks involved are: 1) prepare a safe and environmentally sound facility; 2) design, fabricate, and install the control system, vacuum test chamber, and heat removal system for the reactor; 3) conduct operational performance and reliability tests of the reactor.

To simulate the space environment we will install the reactor in a vacuum chamber with a capacity to maintain a very high vacuum during reactor operation. The reactor control system will be designed and built to applicable requirements.

The heat removal system will use lithium as the primary coolant, sodium as the secondary coolant, and an intermediate heat exchanger. Waste heat will be dumped to the ambient air.

THE STATUS

For the first task selected, the former Plutonium Recycle Test Reactor (PRTR) facility was chosen as the Test Site. This facility was decommissioned in 1969, and the fuel and pressure tubes were removed. For the GES Test Site three large cells adjacent to the PRTR were selected to house the reactor and auxiliary systems.

When selected, these cells contained piping, heat exchangers, and other equipment not removed during PRTR decommissioning. WHC prepared an Equipment Removal Plan, including a Readiness Review for removing the equipment. Overall about 36,000 ft^3 of electrical conduit and wiring, compressors, heat exchangers, pumps, and support structures were handled, transported, and buried. Although radioactive levels were low, all material was treated as radioactive; and the workers were suited and masked. No personnel contamination occurred. QA provided surveillance of the removal, handling, and shipping operations; and only one nonconforming condition was noted in an NCR. This was for one heat exchanger that contained some residual liquid (contrary to the records). The liquid turned out to be water and was uncontaminated. QA also served on the Readiness Review Board, reviewed the Equipment Removal Plan, and participated in the NCR disposition.

The second task (the design of equipment) is in the preliminary stage. QA support is for program definition and review of the designs. One preparation activity is further along. Certain equipment built earlier and intended for use in the Fast Flux Test Facility was transferred to the GES Test Site. These units contain ASME Boiler & Pressure Vessel Code[5] Section III hardware capable of liquid metal service. The equipment was disassembled in accordance with ASME travelers; and the components, including valves, were handled in such a way as to preserve their Code pedigree. QA participated in planning the disassembly, approved the travelers, and verified that the storage facility complied with Code requirements. We participated in the disposition of the three NCRs generated, provided surveillance of the removed hardware and the storage area, and maintained the contract with the Authorized Nuclear Inspector.

The third task, operational testing, is in the early planning stages; and methods of operation and test control will be patterned on those developed and used at the highly successful FFTF. The content of the tests will be discussed and agreed to by several of the participants over the next few years. Each test will be conducted according to an approved Test Plan.

THE QUALITY AND RELIABILITY ASSURANCE PLAN (Q&RAP)

Following selection of the preferred GES Test Site at WHC, one of the first activities was the preparation of a Q&RAP. This was led by Quality Engineering with input from the Project. The intention was that the completed Plan become "owned" by the Project since it is the Project personnel who operate and manage according to the Plan. WHC's method of Q&RAP preparation, particularly for the QA portion, is to select among existing manuals and standard practices those procedures that satisfy the 18 criteria of NQA-1 plus the supplemental requirements identified by the GES Q&RAP. We arrived at this method by 17 years of evolution and improvements. When Westinghouse arrived at Hanford in 1970, a QA system was developed in accordance with the RDT Standard[6] F 2-2 required at that time. This became a mature fully developed system to support the Liquid Metal Reactor Program, particularly the FFTF. In 1979 when ANSI/ASME NQA-1 became the preferred standard, WHC converted and formatted the QA system according to the 18 criteria. We were the first major laboratory to do so. In addition to the FFTF, several other relatively large projects were underway at WHC. Each project developed its own control manual including a Quality Assurance Program Plan (QAPP) and procedures for the 18 criteria. In general, the procedures were similar to those for the FFTF. During 1985 a Quality Task Team was assembled to "standardize" the procedures, and in 1986 a standard engineering practices manual was adopted laboratory-wide.

At the time GES started at WHC, there were two QA manuals. The main quality assurance manual covered all work except for ASME Code-related activities. The second manual covered the Code. Both were needed by GES since the Coded status of the system is to be maintained. Several other control procedures and manuals were also laboratory-wide; including Procurement, NDE, Welding (special process), Receiving Inspection, Cleanliness Control, Technical Review Board, etc. We feel that this "standardization" brings several benefits including: 1) everyone becomes familiar with the procedures and may work on several projects more productively, and 2) control manuals for new projects can be rapidly assembled by combining individual procedures from the top-level standard manuals. WHC achieved both these advantages for the GES Test Site. From essentially the time of award of contract we were able to commence productive work in all needed areas. We could do this because a Quality Assurance Program Index (QAPI) was easily and rapidly assembled, agreed upon by all disciplines, and approved by the Project Manager and the responsible QA Manager; and work was undertaken in a controlled and disciplined fashion. The QAPI was simply a listing of the controlling procedures selected from the "library" of WHC manuals. Next a QAPP was generated. The principal author was the Quality Engineer, but all WHC Project Management staff offered input, reviewed, concurred, and became owners and implementors of the completed document. The WHC Q&RAP describes how we meet the requirements of the DOE Q&QA Program Plan. We do not simply restate the requirements of the higher tier documents.

Our procedures for performing reliability analyses and reliability assurance are not currently as mature and standardized as those for Quality Assurance. The responsibility for achieving a reliable design and system rests, of course, with Engineering. Quality Engineering will provide reliability assurance, but we may perform Fault Tree Analyses (FTA) and/or Failure Mode Effects Analyses as agreed to with Engineering. For our overchecks we do not intend to simply repeat the analyses performed by Engineering nor vice versa. A separate Reliability Plan is being prepared that is expected to eventually be incorporated with the Q&RAP. This was consistent with our schedule in that reliability procedures were needed only for our conceptual design activities and not for the equipment removal at the PRTP facility.

One of the main purposes of the WHC Q&RAP is to assist the WHC Project in achieving the necessary quality and reliability. We have a long history of successful application of quality and reliability plans. We believe we have produced a "living" and useful document - a tool that is beneficial to our Project.

CONCLUSION

WHC has a long history of excellent quality and reliability planning and performance. We have applied our existing system effectively to the GES Test Site activities and have moved expeditiously to support the Project.

REFERENCES:

(1) ANSI/ASME Standard NQA-1, "Quality Assurance Program Requirements for Nuclear Facilities."

(2) Dix, G. P. and Voss, S. S. "The Pied Piper - A Historical Overview of the U.S. Space Power Reactor Program," Space Nuclear Power Systems, 1984.

(3) Chipman, G. L. Jr. "Space Nuclear Power Programs - Present and Future," ibid.

(4) Katucki, R. et al. "Evolution of System Concepts for a 100 kWe Class Space Nuclear Power System," ibid.

(5) ASME Boiler and Pressure Vessel Code.

(6) RDT Standard F 2-2, "Quality Assurance Program Requirements," currently NE Standard F 2-2.