August 4, 2003

MEMORANDUM TO: Bruce A. Boger, Director
Division of Inspection Program Management
Office of Nuclear Reactor Regulation

/RA/

THRU: Theodore R. Quay, Chief
Emergency Preparedness and Plant Support Branch
Division of Inspection Program Management
Office of Nuclear Reactor Regulation

/RA/

FROM: Richard P. McIntyre, Senior Reactor Engineer
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Office of Nuclear Reactor Regulation

SUBJECT: TRIP REPORT FOR VISIT TO THE FRAMATOME/SIEMENS TECHNICAL CENTERS AT OFFENBACH, KARLSTEIN AND ERLANGEN, GERMANY (SWR-1000)

On June 23-27, 2003, Richard McIntyre, Antony Attard, Muhammed Razzaque and George Thomas of the Office of Nuclear Reactor Regulation (NRR) and James Han, William Krotiuk and Donald Helton of the Office of Nuclear Regulatory Research (RES) participated in meetings at the Framatome Advanced Nuclear Power (FANP) facilities in Offenbach, Karlstein and Erlangen, Germany. The purpose of the visit was to introduce the test facilities to the NRC staff and to provide the opportunity for the staff to review and observe FANP's quality assurance controls at these facilities. Attached is the trip report from this activity.

Project No. 723

Attachments: As stated

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NRC FOREIGN TRIP REPORT

Subject

SWR-1000 Quality Assurance and Test Control visit to Framatome Advanced Nuclear Power (FANP) Test Facilities.

Dates of Travel and Countries/Organization Visited

June 23-27, 2003
Offenbach, Karlstein and Erlangen Technical Centers, Germany

Author, Title, and Agency Affiliation

This report is a compilation of inputs from the following NRC staff:

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Sensitivity

Distributed non-proprietary meeting materials are available to the public (ADAMS Accession # ML 032160142).

Background/Purpose

The SWR-1000 is a Framatome Advanced Nuclear Power (FANP) boiling water reactor design that incorporates passive safety features. FANP requested pre-application discussions with the staff and plans to submit Design Certification application for SWR-1000 sometime after 2005.

Attachment

By letter dated March 27, 2003, FANP invited the NRC staff to visit their test facilities in Germany to obtain timely and specific feedback on test and quality assurance (QA) program controls. This feedback may be used to support design certification activities of the SWR-1000 design so that their application is more complete. This visit also provided an opportunity to review, discuss and observe FANP's quality assurance controls at their test facilities. The visit included a trip to FANP's test facility in Karlstein, Germany, where SWR-1000 vent testing, quencher testing, fuel design critical heat flux testing, and components testing (e.g., spring assisted check valve, control rod drives) have already been performed or will be performed in the future. The visit also included a trip to FANP's test facility in Erlangen, Germany, where external vessel cooling and fast boron injection tests have already been performed or will be performed in the future.

FANP Technical Centers are located at four sites in Europe, two in France at Chalon and Le Creusot and two in Germany at Erlangen and Karlstein. The Technical Centers in Erlangen and Karlstein offer the following range of services and technologies:

- Thermal Hydraulics and Fluid Dynamics
- Radiochemistry, Hot Cells, Analytical Chemistry
- Radiation Metrology, Radiation Protection Services
- Component Engineering and Qualification
- Components and Systems Testing
- Fabrication of Special Components
- Materials Technology, Root Cause Failure Analysis
- Materials Engineering and Testing

<u>Abstract: Summary of Pertinent Points/Issues</u>

During the visit the NRC staff observed that the FANP test facilities personnel were knowledgeable on all technical aspects of testing activities and noted the professionalism exhibited during all interactions with NRC team members. Touring the test facilities further enhanced the team's understanding of the SWR-1000 test program. The staff concluded that the visit was very beneficial in that the knowledge and information gathered would definitely help the staff prepare for the technical reviews of the SWR-1000 design certification application. Mr. Bernhard Brand, who is the director for the Karlstein and Erlangen Technical Centers, commented that Framatome ANP would continue to cooperate with NRC on future SWR-1000 testing activities.

During the quality assurance discussions and reviews, the team identified three areas that FANP will need to evaluate and clarify prior to their submittal of the SWR-1000 design certification application to the NRC. These issues include: (1) the independence of the personnel performing quality assurance activities at the testing facilities from their other technical job functions at the facilities, (2) the FANP control and use of suppliers providing equipment used at the test facilities, and (3) the pedigree of quality of test data from non-FANP test facilities (such as PANDA at the Paul Sherrer Institute (PSI) in Switzerland) that may be used to support SWR-1000 design certification. The staff expects to make future trips to these facilities to verify implementation of the quality program for testing activities when the detailed test schedules are known.

Discussion

During the one week visit, meetings were held at the Siemens/Framatome ANP offices in Offenbach, Karlstein and Erlangen and the team toured the various test facilities at Karlstein and Erlangen. The meetings included Framatome ANP personnel from the corporate office in Lynchburg, VA and also Framatome ANP personnel from the three German locations.

On Monday, June 23, the team met at the FANP/Siemens office in Offenbach. Discussions included an overview of the SWR-1000 design and innovative safety systems and FANP's Quality Assurance (QA) program. The topics included SWR-1000 design history, testing history and the following design features: Emergency Condenser, Containment Cooling Condenser, Passive Pressure Pulse Transmitter, Passive Outflow Reducer, Passive Core Flooding System, Fast Acting Boron Injection System (FABIS) and Scram Tank and Boron Tank with Steam Cushion. Since SWR 1000 is one of the four reactor designs submitted to Finland for consideration, FANP personnel also made a presentation to comparing Finnish nuclear regulatory process and NRC's regulatory process.

On Tuesday, June 24, the team visited the FANP Technical Center in Karlstein. Topics covered were an overview of testing activities at the Karlstein facility and the QA program and process requirements for testing activities at Karlstein. The team also toured the instrumentation calibration laboratory, the Large Valve Test (GAP) facility and observed the quencher used during previous testing. The team also witnessed a critical heat flux (CHF) test at Multifunction Thermal-Hydraulic Test Loop (KATHY).

On Wednesday and Thursday, June 25 and 26, the team visited the FANP Technical Center in Erlangen. Topics covered were an overview of testing activities at Erlangen and the QA program and process requirements for testing activities at Erlangen. The team also toured the external vessel cooling test set up, the fast acting boron injection system (FABIS) test set up, and PKL III test facility (PKL is a German acronym for "primary system", a scaled-down model of a four-loop German PWR).

On Friday, June 27, a closing meeting was held at the Offenbach office. The team provided comments on the testing facilities, the overall testing activities, and the various testing capabilities. The team also provided some specific feedback on FANP's QA process for testing activities, including certain areas that will need to be evaluated for compliance to 10 CFR part 50 Appendix B quality assurance requirements .

The following are the technical areas and testing activities that include discussions and Framatome ANP presentations.

FANP Test Facility Quality Assurance

One of the purposes of the visit was to review and observe FANP's quality assurance controls at the German test facilities. The FANP Technical Center test facilities at Karlstein and Erlangen are implementing a QA program hierarchy that includes, but is not limited to: FANP Corporate Quality Management (QM) Directives; FANP Technical Center Quality Management Manual; Technical Center SWR-1000 test specific Quality Assurance Plans (QAPs); FANP

Corporate QM-Procedures; and Technical Center SWR-1000 Test procedures. This hierarchy quality program is intended to implement numerous international codes, standards and regulations.

Based on the review of the above Framatome ANP quality program documents and the discussions with FANP Corporate and Technical Center personnel, it appears that since 2000, the FANP Technical Center has been implementing a quality program similar to the Framatome ANP Lynchburg, VA, Corporate QA program and this program is structured to satisfy the international codes, standards, and regulations listed below:

- US 10 CFR Part 50, Appendix B Quality Assurance Criteria
- ISO 9001-2000, International Organization for Standardization, Quality Management Systems - Requirements
- IAEA 50-C-QA - 1996 International Atomic Energy Agency Code on the Safety of Nuclear Power Plants: Quality Assurance
- KTA 1401, - June 1996, German Standard, General requirements Regarding Quality Assurance
- ASME NQA-1 - 1983, Quality Assurance Program Requirements for Nuclear Facilities, and
- Ministerial Order of August 10, 1984, French Regulation Relative to the Quality of the Design, Construction, and Operation of Nuclear Facilities.

During the quality assurance discussions and reviews with FANP personnel, the team identified three areas that FANP will need to evaluate and clarify prior to their submittal of the SWR-1000 design certification application. These issues include: (1) the independence of the personnel performing quality assurance activities at the testing facilities from their other technical job functions at the facilities, (2) the FANP control and use of suppliers providing equipment used at the test facilities, and (3) the pedigree of quality of test data from non-FANP test facilities (such as PANDA at the PSI in Switzerland) that may be used to support SWR-1000 design certification.

“**Full size” Vent Pipe Tests**

In the existing Siemens/Framatome BWR design approximately 40, 24-inch diameter vertical vent pipes are mounted nearly equidistant in the whole wetwell pool. In the SWR-1000 design, the number of vent pipes is reduced to 16 and the nominal diameter is enlarged to 28 inches. This change in the design necessitated the test. Tests were conducted for the SWR-1000 between June 11 and August 14, 2002.

Three full-size vent pipe designs were tested in the GAP facility at the Karlstein Technical Center, which consists of a large steam accumulator (125 m^3, as large as a PWR steam generator) connected to a 22-MW steam power station, a tank (15 m^3), quick-opening valves, piping, and a large water pool (970 m^3) for steam condensation. Configuration A was a nearly

horizontal vent with a small downward angle. Configuration B was similar to A except with a long quencher (with holes on the wall) attached to the vent. Configuration C had a vertically downward vent opening.

Based on the pressure fluctuations at the pool bottom, it was found that Configurations A and B were a better design than Configuration C. Although Configuration B has smaller pressure fluctuations than A, it is much more expensive than A. As a result, Configuration A with a nearly horizontal vent opening has been selected for SWR 1000 (to be installed between the drywell and wetwell). These tests were conducted before our visit. A video presentation of a test for each vent pipe design was shown to the team.

“Full-Size” Quencher Tests

Normally , the pool is the wetwell pool and the quenchers are fixed to its bottom with a submergence of > 4.0 meters. For the SWR-1000, a different configuration is used. The quenchers are located in the flooding pool, which is part of the drywell. The new designed quencher has only 2 arms instead of the current 4. This design change and new the configuration necessitated the testing.

A new “full-size” two-arm quencher (compared to 4-arm quenchers in the operating BWRs) was tested at the GAP facility. These tests were conducted for the SWR-1000 on January 28 to 30, 2003. Pressure fluctuations were measured at the quench pool bottom underneath the quencher. A video presentation of the test was shown to the team.

Critical Heat Flux (CHF) Tests

The team witnessed a CHF test for ATRIUM-12 fuel assembly at the KATHY test loop at the Karlstein Technical Center. The KATHY loop for this CHF test consists of a high-pressure BWR test vessel with “full-size” electrically-heated rods to simulate an ATRIUM-12 fuel assembly, a condenser, two high-pressure coolers, and a circulation pump. The CHF test was conducted by increasing the rod power until an increase in rod temperature was observed, indicating CHF occurrence. The power was then reduced to bring the rod temperature back to normal. ATRIUM-12 fuel assemblies will be used in SWR- 1000 design. FANP staff at Karlstein used the RINGS sub-channel code to predict CHF and then verified it by conducting dryout tests. The agreement between the predicted results and the test data was excellent.

External Vessel Cooling Tests

The SWR-1000 design is aimed to control a postulated core melt accident to such an extent that the consequences of a severe accident remain restricted to the plant. As an accident management strategy, water from the Core Flooding Pool can be used to flood the lower drywell and circulate in the gap between the reactor pressure vessel wall and the thermal insulation surrounding the vessel to cool the corium inside the core during a core melt accident. Steam produced on the external surface of the vessel will flow into the drywell, where it is expected to be condensed by the containment cooling condensers. The condensed water will fall back into the Core Flooding Pool.

A 1/10 linear scale model was built at the Erlangen Technical Center to represent the gap volume between a reactor vessel and the insulation surrounding the vessel. The main components are the simulated RPV and the insulation, which is made of transparent panels. The scaled-down reactor vessel has a porous lower head where air is injected from the vessel inside into the gap space outside the vessel. Tests were conducted in this adiabatic air-water model with flow visualization and local void fractions and flow velocities measured.

Based on the test results of the 1/10 scale air-water model, an electrically-heated steel test section (at approximately 1/12 of the lower head surface area) of a “full-size” segment of the SWR-1000 lower head has been constructed including the gap volume between the outside surface of the steel section and the outside insulation. Tests will be conducted to measure the critical heat flux on this electrically-heated section of a “full-size” segment of the vessel lower head.

It should be pointed out that a core melt accident analysis in SWR 1000 was performed under the assumption of a stuck-open SRV and the failure of all active and passive core cooling systems. The MELCOR and IVA codes were used for the analysis.

Fast Boron Injection System Tests

Since Finland requires that the SWR-1000 design must have a Fast Acting Boron Injection System (FABIS) to quickly shut down the reactor should an ATWS occur, boron injection tests have been conducted at the Erlangen Technical Center. An adiabatic test facility with 6 by 4 “full-size” fuel assemblies with a shorter length was built. Two types of tests have been performed in this test facility, dye injection for flow visualization or using a mixture of plastic powder and water to simulate borated water that can be tracked with laser beam. Meanwhile, FANP also performed Computational Fluid Dynamics (CFD) calculations using the PHOENICS code.

In addition, FABIS tests have also been conducted at a small-scale test facility at Lappeenranta University in Finland.

Pipe Insulation Fragmentation Test

A Pipe Insulation Fragmentation test was conducted at the GAP facility by blowing a large jet of steam and two-phase flow at a 90-degree angle onto a large pipe enclosed inside insulation. The purpose of the test was to determine pipe insulation damage for a large-break loss-of-coolant accident (LBLOCA). The insulation was enclosed in a stainless steel jacket. The portion of the insulation facing the jet was blown out with insulation material being fragmented.

Containment Cooling Condenser Tests at PANDA

Performance of the containment cooling condenser was tested at the PSI PANDA test facility in Switzerland. The condenser tubes tested had the same diameter as the SWR-1000 prototype, but at a shorter length (3 meters instead of 4). Finally, the number of condenser tubes was less than a full-size condenser.

Emergency Condenser Tests

The Emergency Condenser was tested at the NOKO test facility (Julich, Germany) with the same diameter and length as the prototype, but with a smaller number of condenser tubes. Two sizes of condenser tubes were tested to determine the maximum heat transfer under design conditions.

Test of the Siphon Between the Drywell and Wetwell

The SWR-1000 does not include vacuum breakers between the drywell and wetwell. Instead, the design uses liquid-filled siphons (loop seals) to account for the pressure difference between the drywell and wetwell. Tests were conducted in a scaled facility to confirm the siphon operation.

Contingent “Full-Size” Test Program

FANP stated that should the FANP SWR-1000 design be selected by Finland for new plant construction, FANP will conduct “full-size” testing for a number of safety systems and components including the Emergency Condenser, Containment Cooling Condenser, Passive Core Flooding System, and Boron Injection Tank.

LOCA Analyses for SWR-1000

FANP uses S-RELAP5 (a Siemens’ version of RELAP5) to analyze transients and LOCAs in SWR-1000. The code models not only reactor vessel phenomena, but also containment phenomena. LOCA analyses have been performed for a feedwater line break, main steam line break, bottom drain line break, and core flooding pool injection line break. Only the results of the feedwater line break were briefly discussed in the meeting. The reactor core remains covered during this accident based on the S-RELAP5 prediction.

Pending Actions/Planned Next Steps for NRC

FANP is expected to make a decision concerning the submittal of an application for design certification to the NRC sometime after Finland’s selection of the reactor design to be used for the TVO-3 PLANT. The SWR-1000 is one of the four reactor designs being considered by Finland. The NRC does not anticipate any staff actions until the decision is finalized.

Points for Commission Consideration/Items of Interest

None

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