POLICY ISSUE
(Information)

April 22, 1994 SECY-94-110

FOR: The Commissioners

FROM: James M. Taylor
Executive Director for Operations

SUBJECT: CLOSEOUT AND STATUS OF THE PIUS PREAPPLICATION REVIEW

PURPOSE:

To provide the Commission with a closeout report on the staff's preapplication review of the Process Inherent Ultimate Safety (PIUS) reactor design.

BACKGROUND:

In the staff requirements memorandum (SRM) dated June 9, 1993, regarding SECY-93-104, "Program Analysis and Recommendations Concerning the Nuclear Regulatory Commission (NRC) Reviews of the Advanced Reactors (PRISM, MHTGR, and PIUS) and CANDU 3 Designs," the Commission directed the staff to:

> ...document the results of ABB-CE's preapplication review activities conducted to date and terminate all other activities until an application is submitted by ABB-CE.

The staff had been involved with the PIUS preapplication review since June 1991 using limited resources to coordinate review efforts that were carried out under contract with various national laboratories. The PIUS review was fourth in priority behind the other advanced reactors and CANDU 3 which had

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NOTE: TO BE MADE PUBLICLY AVAILABLE IN 10 WORKING DAYS FROM THE DATE OF THIS PAPER identifiable schedule milestones and defined work products. Only a limited portion of the PIUS preapplication review was ever completed. In July 1993, Asea Brown Boveri - Combustion Engineering (ABB-CE) was notified of the Commission's intention to close out the PIUS preapplication review until an application for design certification was received.

DISCUSSION:

The PIUS reactor is a 640-MWe advanced pressurized-water reactor (PWR) design, by Asea Brown Boveri (ABB) Atom, that takes advantage of the physical laws of nature to accomplish control and safety functions usually performed by mechanical means. The PIUS design consists of a vertical pipe, called a reactor module, which contains the reactor core and is submerged in a large pool of highly borated water. The pool of borated water is provided to shut down the reactor and to cool the core by natural circulation while the reactor is shut down. The reactor module is open to the borated pool at the bottom and also at the top of the reactor module. At these two openings, density locks, consisting of a number of open tubes, are provided.

Under normal operating conditions, reactor water in the primary loop flows up through the core, out of the top of the reactor module to the steam generators, and is pumped back into the bottom of the reactor module, bypassing both the top and bottom density locks. There is no physical flow barrier in the density locks between the primary loop and the borated pool; however, the difference in density between the primary loop reactor water and the cooler borated pool water provides a relatively stationary boundary.

Under certain transient conditions, the density difference is overcome and the borated water flows into the core and shuts down the reactor. A natural circulation flow path is then established from the borated pool through the lower density lock, up through the core, and back into the borated pool through the upper density lock for long-term shutdown cooling. Unlike most reactors, the PIUS does not require mechanical control rods for regulating reactivity. Reactivity is controlled by the boron concentration and temperature of the reactor water in the primary loop.

The temperature of the reactor pool during shutdown is maintained passively via eight pool heat exchangers connected to eight natural circulating loops. Pool heat is dissipated through four natural draft cooling towers situated on top of the reactor building. Additionally, the core can be cooled for approximately 7 days solely by evaporation from the large reactor pool of borated water—approximately 3,000 m^3 of water.

In October 1989, ABB Atom asked the NRC to review its Preliminary Safety Information Document (PSID) for licensability of the PIUS reactor. The review was requested in accordance with the NRC Advanced Reactor Policy Statement (51 FR 24643). The PSID was submitted in May 1990. The staff began its review in June 1991. The technical review of the PIUS centered around contracts issued by the Office of Nuclear Reactor Regulation (NRR) and Office of Nuclear Regulatory Research (RES) with the national laboratories. These contracts were for core neutronics, thermal hydraulics, systems analyses, severe accidents, and materials evaluations.

There were four major work efforts associated with the PIUS preapplication; these work efforts were: (1) SECY-93-092, "Issues Pertaining to the Advanced Reactor (PRISM, MHTGR, and PIUS) and CANDU 3 Designs and Their Relationship to Current Regulatory Requirements"; (2) NUREG/CR-6111, "Integrated Systems Analysis of the PIUS Reactor"; (3) Draft NUREG/CR, "PIUS Core Performance Analysis"; and (4) a series of letter reports and symposium papers dealing with the TRAC Code modeling of the transient analyses of the PIUS reactor design and with a thermal-hydraulic assessment of the ATLE test loop in order to benchmark TRAC. The ATLE test loop is a scale model of the SECURE district heating reactor designed by Asea Atom. The ATLE test loop was built to verify the computational methods and to demonstrate the self-protective thermal-hydraulics of the SECURE/PIUS type of reactor. ABB used the ATLE test loop to benchmark RIGEL, the code used for analyzing PIUS. The TRAC analysis was done under RES contracts with Los Alamos National Laboratory (LANL).

POLICY ISSUES:

On April 8, 1993, the staff issued SECY-93-092 to the Commission, requesting guidance in those areas in which the staff proposed to depart from the current regulatory requirements in the preapplication reviews of the advanced reactors and CANDU 3 designs. The policy issues pertaining to PIUS are accident evaluation, source term, containment performance, emergency planning, reactivity control, operator staffing, residual heat removal, and control room and remote shutdown area design. With the exception of the issue regarding the electrical qualification of the control room, the Commission agreed with the staff that certain deviations from the regulations could be considered for the advanced designs. For the PIUS design, the most significant policy issue was to decide if the NRC should accept a reactivity control system that has no control rods. The Commission and the Advisory Committee on Reactor Safeguards agreed with the staff that such a system should not necessarily disqualify a reactor design. A design without control rods may be acceptable, but the preapplicant must submit sufficient information to justify that the system without control rod produces an equivalent level of safety in reactor control and protection as does a traditional system that has rods.

INTEGRATED SYSTEMS ANALYSIS:

Brookhaven National Laboratory (BNL) prepared NUREG/CR-6111 (BNL-NUREG-52393), "Integrated Systems Analysis of the PIUS Reactor," November 1993, for the RES. The systems analysis of the PIUS design consisted of a component level analysis utilizing failure modes, effect and critically analysis techniques and some deterministic analyses, and an integrated systems analysis utilizing hazards and operability analysis techniques. The analyses studied potential event sequences ranging from anticipated operational occurrences to severe accidents; systems that are important to safety for mitigation of severe accidents; and key operator actions for mitigation of accidents. A noteworthy observation from the study was the lack of diversity and redundancy in the passive scram system. However, as noted in the study, the design continued to evolve and redundancy and diversity were designed into the scram system. A number of PIUS design changes were made while this work was in progress and are not included in the systems analysis. Also, the staff expects that the PIUS design will continue to evolve until ABB-CE submits a design certification application. Even considering that the design will change, NUREG/CR-6111 should give the staff a general understanding of how the design will behave.

PIUS CORE PERFORMANCE ANALYSIS:

BNL evaluated the fuel burnup dependent power distribution and scram reactivity of the PIUS design for the Office of Nuclear Reactor Regulation (NRR). This work is described in a draft NUREG/CR report (presently unnumbered) titled "PIUS Core Performance Analysis," dated February 1994. The program was initiated to develop methods and models for producing core performance analyses, and to carry out specific evaluations to confirm acceptable safety margins of the PIUS design. The report documents the initial analyses and includes (1) the development of a coupled neutronics/thermal-hydraulics model of the PIUS core, (2) evaluation of the core's cycle-dependent power distribution peaking, (3) evaluation of the PIUS feedback coefficients, and (4) analysis of the scram reactivity characteristics.

PIUS TRANSIENT ANALYSIS AND THE THERMAL HYDRAULIC ASSESSMENT OF PIUS:

The PIUS transient analysis was performed for RES and included an understanding of ABB's analytical methods, an assessment of the experimental data base, the development of a core region input deck, and the development of a working plant system model. The LANL effort led to the development of the following five symposium papers and one data base assessment report: (1) LA-UR-93-4206, "Loss of Offsite Power Transients in the Updated PIUS 600 Advanced Reactor Design"; (2) LA-UR-93-4282, "Small-Break Loss-of-Coolant Accidents in the Updated PIUS 600 Advanced Reactor Design"; (3) LA-UR-93-4358, "One-Dimensional TRAC Calculations of Main Steam Line Break Events for the PIUS 600 Advanced Reactor Design"; (4) LA-UR-93-4456, "Reactor Scram Events in the Updated PIUS 600 Advanced Reactor Design"; (5) LA-UR-93-4460, "Large-Break Loss-of-Coolant Accidents in the Updated PIUS 600 Advanced Reactor Design"; and (6) LA-UR-93-3564, "Assessment of the PIUS Physics and the Thermal-Hydraulic Experimental Data Base."

The thermal-hydraulic assessment of PIUS was documented in one report—LA-UR-93-4133, "TRAC Calculations of a Pump-Trip Scram and Partial Loss-of-Heat Sink for the ATLE Test Facility."

The reports from LANL provide an assessment of the inherent passive capabilities of the PIUS design to cope with upset conditions. These documents will be an excellent resource for future staff activities if the PIUS design is submitted for design certification.

Other efforts were started in anticipation of a design certification and canceled due to a lack of resources. These included data base and materials assessments, severe accident analysis with MELCOR, and preliminary work on source term development. Information on the terminated contracts as well as additional information related to the works identified above can be found in the PIUS Project File Number 680 and in the archived RES Project File.

This paper concludes the staff efforts on the PIUS design preapplication review. In keeping with the Commission's directive, no further staff resources will be expended on the PIUS design until the staff receives notification of a pending design certification application from ABB-CE.

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