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U.S. Nuclear Regulatory Commission
Document Control Desk
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Perry Nuclear Power Plant
Docket No. 50-440
Plant - Specific Hydrogen
Control Final Analysis

Gentlemen:

The purpose of this letter is to provide the final resolution of the hydrogen control issue, as cited in 10 CFR 50.44, for the Perry Nuclear Power Plant (PNPP). The following discussion and the attachment hereto provide background information and a summary of the PNPP Hydrogen Control Final Analysis.

In October of 1980, the Nuclear Regulatory Commission (NRC) published a proposed hydrogen control rule. The final version of the rule was issued on January 25, 1985, by amending the hydrogen control requirements of 10 CFR 50.44. Section (c)(3)(vi)(A) of 10 CFR 50.44 requires that each boiling water reactor (BWR) licensee with a Mark III containment submit an analysis that provides an evaluation of the consequences of releasing large amounts of hydrogen into the primary containment during a postulated degraded core accident. The analysis is required to address recovery from the degraded condition, utilize scenarios that are accepted by the NRC, support the design of the hydrogen control system, demonstrate that the containment structural integrity will be maintained, and assure that systems and equipment necessary to establish and maintain safe shutdown will be capable of performing their function if exposed to the environmental conditions created by the burning of hydrogen.

The Hydrogen Control Owners Group (HCOG) was formed in May 1981 by the utility owners of General Electric (GE) BWR/6 nuclear steam supply systems with Mark III containments (which includes PNPP) to deal collectively with issues related to hydrogen control during recoverable degraded core hydrogen generation events. The HCOG has completed a significant amount of testing and analysis to demonstrate compliance with 10 CFR 50.44. A distributed system of glow plug

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igniters was selected as the optimum design for hydrogen control at PNPP, and a system of this design was installed at PNPP. The Hydrogen Control System (HCS) igniter system preliminary analysis, which included the igniter system design criteria, method of operation and testing criteria, was provided in letters PY-CEI/NRR-0199 L, dated March 1, 1985, and PY-CEI/NRR-0220 L, dated March 21, 1985. The NRC provided the results of its review of the preliminary analysis in the Safety Evaluation Report, Supplement 6 (SSER-6), NUREG-0887, April 1985. These results concluded that 1) the containment ultimate capacity would not be challenged, and 2) equipment required for safe shutdown and containment integrity would survive the thermal environment created by the burning of hydrogen generated during degraded core accidents. The Atomic Safety and Licensing Board (ASLB) agreed with the findings of the NRC staff, but required that, prior to granting PNPP operation in excess of five percent of rated power, 1) further confirmatory analysis of the pressure survivability of equipment not so qualified or with narrow qualification margins must be made, and 2) written procedures for operation of the hydrogen igniter system must be available. The resolution of these items was cited in letters PY-CEI/NRR-0502 L, dated July 17, 1986, and PY-CEI/NRR-0504 L, dated August 6, 1986, respectively, as documented in SSER-10, issued September 1986. In addition, the Atomic Safety and Licensing Appeals Board (ALAB-[illegible]1, dated July 25, 1986), while accepting the ASLB decision, required that the NRC ensure that the final PNPP HCS analysis include 1) a more detailed review of containment heat removal capability, and 2) a further consideration of the potential for and effects of the release of combustible gases from heated cable insulation. These issues have been addressed in the PNPP Hydrogen Control Final Analysis Report.

The HCOG Hydrogen Control Program culminated in the design and construction of a large (1/4-scale) test facility and the performance of plant-specific testing to define the hydrogen combustion phenomena and attendant effects for a Mark III containment. The postulated accident simulated at the facility was a recoverable degraded core accident leading to a hydrogen release equivalent to a 75% metal-water reaction of the active fuel rod cladding.

The Hydrogen Control Final Analysis Report for PNPP provides an evaluation of the consequences of hydrogen released from a recoverable degraded core accident, including the recovery period, using a postulated accident sequence accepted by the NRC. The analysis supports the design of the hydrogen control system installed at PNPP, shows that containment structural integrity is maintained, and demonstrates survivability of systems and components necessary to establish and maintain safe shutdown and containment integrity. The PNPP final hydrogen control analysis meets or exceeds the requirements specified in 10 CFR 50.44.

The final analysis was also conducted in accordance with the requirements in the NRC Safety Evaluation Report (SER), dated August 6, 1990, accepting the HCOG topical report, HGN-112-NP, "Generic Hydrogen Control Information for BWR6

Mark III Containments". The SER was supplemented on June 26, 1993, and the supplement was corrected for errata on September 16, 1993. The accepted topical report, HGN-112-NP-A, was transmitted to the NRC by the HCOG on September 24, 1993. That transmittal, as cited in letter PY-CEI/NRR-1322 L, dated February 28, 1991, initiated the commitment to transmit, within 6 months, the PNPP Hydrogen Control Final Analysis Report to the NRC staff. By NRC letter dated August 4, 1993 (PY-NRR/CEI-0647 L, R.J. Stransky to R.A. Stratman, TAC No. M60340), PNPP was informed that the NRC need only be advised of the completion date of the PNPP Hydrogen Control Final Analysis Report, as well as any significant findings and conclusions of the analysis, in lieu of transmitting the Final Analysis Report to the NRC. The NRC is hereby advised that the PNPP Hydrogen Control Final Analysis Report was completed on December 17, 1993, and an attachment to this letter provides a summary of the significant findings and conclusions of the Final Analysis Report. The Report is available at PNPP for NRC staff review.

If you have questions or require additional information, please contact Henry Hegrat - Regulatory Affairs at (216) 280-5606.

Very truly yours,

Robert A. Stratman

RAS/rmc

Attachment

cc: NRC Project Manager
NRC Resident Inspector Office
NRC Region III

SUMMARY OF PERRY NUCLEAR POWER PLANT
PLANT-SPECIFIC
HYDROGEN CONTROL FINAL ANALYSIS

I. INTRODUCTION

A. Background

The hydrogen control program for the Perry Nuclear Power Plant (PNPP), Unit 1 was initiated in early 1980, following the accident at Three Mile Island Unit 2 in March 1979. In May of 1981, the utility owners of General Electric BWR/6 nuclear steam supply systems with Mark III containments (which includes PNPP) formed the Hydrogen Control Owners Group (HCOG). The primary purpose of HCOG was to collectively address the technical and licensing issues associated with hydrogen control.

In July 1981, the HCOG began an integrated program which provided guidance for member utilities' hydrogen control programs while completing generic work that could be shared by the entire group. In order to define the various hydrogen control issues, the HCOG developed program plan documents which outlined specific tasks and actions required for their resolution. The Hydrogen Control Program Plan Documents were submitted to the NRC staff by the HCOG. The work associated with these tasks has been completed.

B. Licensing Topical Report and Safety Evaluations

In February of 1987, the HCOG issued a Topical Report (HGN-112-NP) to the NRC staff which summarized the tasks of the Hydrogen Control Program and documented the closure mechanisms and attendant references for the many subtasks delineated by the Hydrogen Control Program Plan. On August 6, 1990, the NRC staff issued a Generic Safety Evaluation Report (SER), which documented their review of the HCOG generic program regarding the Mark III Containment Hydrogen Control Program. The evaluation focused on the assessment of the completed generic testing and analyses performed by the HCOG in support of the plant unique analysis. The HCOG submitted two additional documents in April of 1991 to address several SER concerns. The NRC staff's evaluation of those concerns indicated that the HCOG's intended disposition was consistent and compatible with 10 CFR 50.44. A Supplemental SER (SSER) was issued in June of 1993 providing final closure of the outstanding NRC issues.

On September 24, 1993, the HCOG issued Accepted Topical Report HGN-112-NP-A, "Generic Hydrogen Control Information for BWR6 Mark III Containments", to meet a requirement of the NRC SER and to update the previously submitted Topical Report for the generic program tasks. Issuance of the Accepted Topical Report by the HCOG initiated the commitment (letter PY-CEI/NRR-1322 L, dated February 28, 1991) to transmit the PNPP plant-specific Final Analysis Report to the NRC. However, in accordance with the NRC letter dated August 4, 1993 (PY-NRR/CEI-0647 L, R.J. Stransky to R.A. Stratman, TAC No. M60340), the NRC is hereby advised that the PNPP Hydrogen Control Final Analysis Report was completed on December 17, 1993, and a summary of the significant findings and conclusions of the Final Analysis Report is included herein. The Report is available at PNPP for NRC staff review. The PNPP hydrogen control program has addressed the pertinent plant-specific activities outlined in HGN-112-NP-A.

II. SIGNIFICANT HYDROGEN CONTROL PROGRAM FINDINGS

A. Selection, Design, and Installation of Hydrogen Control System

Several hydrogen control concerns were evaluated by the HCOG. From a performance, functional, safety, and testing perspective, it was concluded that a distributed hydrogen ignition system provided the optimum design. The system consists of thermal glow plug igniter assemblies located uniformly throughout the containment and drywell. There are 102 igniter assemblies in the PNPP system, which is designed such that no single active or passive failure will prevent acceptable system performance. The system is powered from redundant, separate Class 1E power sources. The vulnerability to interruption of power to the hydrogen igniters has been further evaluated for PNPP as part of the Individual Plant Examination (IPE) effort, as required by the Generic SER and by Generic Letter 88-20, Supplement 3. The IPE for PNPP, submitted to NRC by letter PY-CEI/NRR-1517 L dated July 15, 1992, has concluded "...Station Blackout sequences result in the loss of the igniters. However, as the total contribution to core damage from Station Blackout sequences is only 9% and the contribution to containment structure failure as a result of hydrogen burns is less than 5 percent, the addition of a backup power supply would not significantly impact the source term release given the other contributions to containment failure..."

B. Definition of Accident Scenarios Appropriate for Recoverable Degraded Core Accidents

The selection of accident scenarios addressed by the HCOG program was initially delineated in HGN-006, dated September 9, 1982, and subsequently clarified in HGN-052, dated August 1, 1985. The latest versions of NUREG-1150 indicate that short term station blackout sequences, i.e., TBU, represent the dominant contributors to the Mark III containment core damage probability, though the core damage probability is quite low. The HCOG reviewed the TBU sequences and, based on information contained in NUREG/CR-4550 and 4551, identified the TBU sequences which provide a recoverable core configuration and are therefore appropriate for hydrogen control evaluations under 10 CFR 50.44. To render a TBU sequence recoverable as specified by 10 CFR 50.44, timely power restoration and timely reflood must be assumed. With these considerations as stipulations for the TBU sequences, the TBU sequences are encompassed by the HCOG hydrogen generation event (HGE) scenarios and the attendant analysis developed during the Hydrogen Control Program. Furthermore, the reflood timing and the reflood flow rates have been selected via comprehensive sensitivity analyses to produce a conservative calculation of the total hydrogen production and establish a conservative hydrogen generation profile, consistent with staff comments in the SER regarding the BWR Core Heatup Code (BWRCHUC). HCOG's position with regard to the HGE scenarios was accepted in the SSER.

C. **Completion of the 1/4-Scale Test Program**

The 1/4-Scale Test Facility was a large scale test vessel which provided detailed data on the thermal environments that would result from diffusive combustion in Mark III containments. Plant-specific testing in the PNPP configuration ensured that the 1/4 scale results are directly applicable to and accurately model PNPP. In addition, a significant amount of instrumentation was provided to generate a comprehensive data set for mapping temperatures at full scale. The results of the PNPP production tests were detailed in HGN-130, dated March 4, 1988. A keynote conclusion of the 1/4-scale testing was that the Mark III containment distributed system of glow plug igniters is a very effective means of controlling hydrogen combustion. The data compiled for PNPP provided an excellent representation of the environmental conditions that would exist during a conservatively developed postulated HGE which meets the intent of 10 CFR 50.44.

D. **Equipment Survivability Analysis**

The SER requires each licensee to provide plant-specific information concerning plant unique design features that are relevant to the essential equipment selection. The PNPP Equipment Survivability List adheres closely to the generic selection criteria. Terminal blocks and junction boxes were not specifically listed, but these components have been considered in the electrical cable survivability analysis. The thermal response of a variety of equipment has been evaluated using the HEATING-6 computer code in conjunction with the 1/4-scale test data. The PNPP Equipment Survivability Analysis Report describes the evaluations in detail.

Locations of equipment essential for hydrogen control have been evaluated to ascertain the local thermal environments. Equipment located in limiting thermal environments, as determined from 1/4-scale data, was evaluated using the HEATING-6 code. Massive equipment such as motor-operated valve components exhibited calculated peak critical component temperatures which were considerably less than the equipment qualification temperature. Less massive equipment such as pressure transmitters exhibited higher peak calculated temperatures but still less than the qualification temperature. A few small cables had peak calculated temperatures which exceeded the qualification temperature. The results of various industry cable tests were examined in this context. These tests indicated the cables could survive high temperatures for short durations. Based on the information available, it was judged that short term excursions above the qualification temperatures (i.e., 10 to 15 minutes) would not be expected to cause cable failures. Based on the extensive program of testing and analysis by the HCOG and on the plant-specific results, it is concluded that all essential equipment for hydrogen control in the PNPP containment and drywell would survive the postulated hydrogen generation event. The analysis thus indicated that no plant modifications are necessary to ensure equipment survivability.

E. **Generic and Plant-Specific Emergency Procedures for Hydrogen Control**

The PNPP plant-specific implementation of the HCOG Generic Combustible Gas Control Emergency Procedure Guideline (CGC EPG) is contained in the hydrogen control procedure PEI-M51/56. Procedure PEI-M51/56 has been developed in a consistent manner with the generic guidance while taking into account the plant-specific design features of PNPP.

In accordance with the CGC EPG, the PNPP hydrogen igniters are actuated if reactor vessel water level either drops to Level 1 or cannot be determined and both the primary containment and drywell hydrogen concentrations are below the Hydrogen Deflagration Overpressure Limit (HDOL). The igniters are also actuated if primary containment or drywell hydrogen concentration reaches 0.5%, provided the primary containment or drywell HDOL is not exceeded. It is intended that once turned on, the igniters be continuously operated thereafter until containment and drywell concentration can be maintained below 0.5% and reactor vessel water level is restored and maintained above Level 1. In the extremely unlikely event that the HDOL was exceeded and containment hydrogen concentration could not be restored and maintained below the HDOL, PEI-M51/56 directs that the containment be vented until the concentration is within the HDOL.

As cited above, the PNPP hydrogen control procedures are consistent with the CGC EPG, which has been reviewed and accepted by the NRC, while taking into account the plant-specific design features of PNPP.

III. **Conclusions Regarding Conformance with 10 CFR 50.44**

Section 8 of the SER requires that each licensee document its overall conclusions with respect to the Hydrogen Control Rule. This PNPP Hydrogen Control Summary Report summarizes the major aspects of both the HCOG generic and PNPP plant-specific hydrogen control programs. The intent of these programs has been to achieve compliance with the Hydrogen Control Rule.

Section (c)(3)(iv)(A) of 10 CFR 50.44 requires that "Each licensee...with a Mark III type of containment...shall provide its nuclear power reactor with a hydrogen control system justified by a suitable program of experiment and analysis." Relative to conformance at PNPP, the following can be concluded:

1) The Hydrogen Control System (HCS) installed at PNPP meets the requirements of 10 CFR 50.44. Plant-specific testing in the 1/4-Scale Test Facility has demonstrated the viability and effectiveness of the HCS itself and of the concepts of deliberate ignition and controlled combustion.

2) Hydrogen generation events for 10 CFR 50.44 evaluations have been adequately addressed during the HCOG generic hydrogen control program and attendant PNPP plant-specific efforts. ATWS

and SBO scenarios have received considerable attention in this regard. The HCOG HGE scenario has resulted in a conservative hydrogen release history for hydrogen combustion testing and analysis. The HCOG scenario encompasses a recoverable TBU short-term station blackout sequence.

3) The ultimate capacity of the PNPP containment used in the hydrogen control analysis is 56 psig. Based on the PNPP 1/4-scale test results and peak pressures calculated in the HCOG generic CLASIX-3 Analysis Program, the PNPP containment would maintain its structural integrity during a recoverable degraded core HGE. The PNPP drywell structure is stronger than the containment and would also maintain structural integrity.

4) Based on the analysis reported in the PNPP Equipment Survivability Analysis Report and in the HCOG generic work on this subject, the drywell and containment equipment essential for hydrogen control are capable of surviving a recoverable degraded core HGE. Hence, safe plant shutdown and maintenance of containment integrity can be established and maintained. No plant or equipment modifications are required to ensure that the essential systems function as required.

Overall, it is considered that PNPP conforms to the requirements of 10 CFR 50.44. Emergency procedures are in effect for hydrogen control, and the design of the key mitigative hydrogen control systems is supported by extensive analysis and testing.

In conclusion, issues specified in the PNPP SER and ALAB-841, the requirements of 10 CFR 50.44 and the requirements in the Generic SER have been addressed by the PNPP hydrogen control final analysis. This analysis has provided, by reference or inclusion, an evaluation of the consequences of hydrogen released from a degraded core accident leading to 75% metal-water reaction, including the recovery period, using a postulated accident accepted by the NRC. The analysis supports the design of the HCS, shows that the containment structural integrity is maintained, and demonstrates survivability of systems and components necessary to establish and maintain safe shutdown and containment integrity.