August 12, 2005

Mr. Joseph M. Solymossy
Site Vice President
Prairie Island Nuclear Generating Plant
Nuclear Management Company, LLC
1717 Wakonade Drive East
Welch, MN 55089

SUBJECT: PRAIRIE ISLAND NUCLEAR GENERATING PLANT, UNITS 1 AND 2 - ISSUANCE OF AMENDMENTS RE: (TAC NOS. MC4245 AND MC4246)

Dear Mr. Solymossy:

The Commission has issued the enclosed Amendment No. 171 to Facility Operating License No. DPR-42 and Amendment No. 161 to Facility Operating License No. DPR-60 for the Prairie Island Nuclear Generating Plant, Units 1 and 2, respectively. The amendments consist of changes to the Technical Specifications in response to your application dated September 1, 2004, as supplemented by letter dated May 17, 2005.

The amendments approve the use of Generation of Thermal-Hydraulic Information for Containment Version 7.1 patch 1 (GOTHIC 7), for licensing analyses for the Prairie Island Nuclear Generating Plants to (1) evaluate the short-term peak pressure and temperature response of the containment atmosphere to large pipe breaks in high energy piping systems — the design-basis loss-of-coolant accident (LOCA) and the design-basis main steamline break, and (2) to evaluate the long-term containment response following a design-basis LOCA.

A copy of our related safety evaluation is also enclosed. The Notice of Issuance will be included in the Commission's biweekly *Federal Register* notice.

Sincerely,

/RA/

Mahesh L. Chawla, Project Manager, Section 1
Project Directorate III
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket Nos. 50-282 and 50-306

Enclosures:
1. Amendment No. 171 to DPR-42
2. Amendment No. 161 to DPR-60
3. Safety Evaluation

cc w/encls: See next page

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HNieh	THarris	ACRS	

ADAMS ACCESSION NOs.: ML052000046
ML052000047 (Package) ADAMS ACCESSION NO.: ML05 (TS)

OFFICE	PDIII-1/PM	PDIII-1/LA	SPSB/SC	OGC	PDIII-1/SC
NAME	MChawla	THarris	RDennig	BPoole	LRaghavan
DATE	07/25/05	07/22/05	07/26/05	08/10/05	08/12/05

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NUCLEAR MANAGEMENT COMPANY, LLC

DOCKET NO. 50-282

PRAIRIE ISLAND NUCLEAR GENERATING PLANT, UNIT 1

AMENDMENT TO FACILITY OPERATING LICENSE

Amendment No. 171
License No. DPR-42

1. The Nuclear Regulatory Commission (the Commission) has found that:

   A. The application for amendment by Nuclear Management Company, LLC (the licensee), dated September 1, 2004, as supplemented by letter dated May 17, 2005, complies with the standards and requirements of the Atomic Energy Act of 1954, as amended (the Act), and the Commission's rules and regulations set forth in 10 CFR Chapter I;

   B. The facility will operate in conformity with the application, the provisions of the Act, and the rules and regulations of the Commission;

   C. There is reasonable assurance (i) that the activities authorized by this amendment can be conducted without endangering the health and safety of the public, and (ii) that such activities will be conducted in compliance with the Commission's regulations;

   D. The issuance of this amendment will not be inimical to the common defense and security or to the health and safety of the public; and

   E. The issuance of this amendment is in accordance with 10 CFR Part 51 of the Commission's regulations and all applicable requirements have been satisfied.

2. Accordingly, by Amendment No. 171, Facility Operating License No. DPR-42 is hereby amended to authorize the licensee’s use of an upgraded computer code for design-basis accident containment integrity analyses called Generation of Thermal-Hydraulic Information for Containment Version 7.1 patch 1 (GOTHIC 7). The amendment is applicable only to Prairie Island for application to containment integrity and environmental qualification calculations. The authorization is granted, as set forth and evaluated in the associated safety evaluation by the Commission’s Office of Nuclear Reactor Regulation dated August 12, 2005.

   The licensee shall update the Updated Safety Analysis Report to reflect this change, as authorized by this amendment, and in accordance with 10 CFR 50.71(e).

3. This license amendment is effective as of its date of its issuance and shall be implemented within 30 days.

FOR THE NUCLEAR REGULATORY COMMISSION

/RA/

L. Raghavan, Chief, Section 1
Project Directorate III
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Date of Issuance: August 12, 2005

NUCLEAR MANAGEMENT COMPANY, LLC

DOCKET NO. 50-306

PRAIRIE ISLAND NUCLEAR GENERATING PLANT, UNIT 2

AMENDMENT TO FACILITY OPERATING LICENSE

Amendment No. 161
License No. DPR-60

1. The Nuclear Regulatory Commission (the Commission) has found that:

   A. The application for amendment by Nuclear Management Company, LLC (the licensee), dated September 1, 2004, as supplemented by letter dated May 17, 2005, complies with the standards and requirements of the Atomic Energy Act of 1954, as amended (the Act), and the Commission's rules and regulations set forth in 10 CFR Chapter I;

   B. The facility will operate in conformity with the application, the provisions of the Act, and the rules and regulations of the Commission;

   C. There is reasonable assurance (i) that the activities authorized by this amendment can be conducted without endangering the health and safety of the public, and (ii) that such activities will be conducted in compliance with the Commission's regulations;

   D. The issuance of this amendment will not be inimical to the common defense and security or to the health and safety of the public; and

   E. The issuance of this amendment is in accordance with 10 CFR Part 51 of the Commission's regulations and all applicable requirements have been satisfied.

2. Accordingly, by Amendment No. 161, Facility Operating License No. DPR-60 is hereby amended to authorize the licensee’s use of an upgraded computer code for design-basis accident containment integrity analyses called Generation of Thermal-Hydraulic Information for Containment Version 7.1 patch 1 (GOTHIC 7). The amendment is applicable only to Prairie Island for application to containment integrity and environmental qualification calculations. The authorization is granted, as set forth and evaluated in the associated safety evaluation by the Commission’s Office of Nuclear Reactor Regulation dated August 12, 2005.

   The licensee shall update the Updated Safety Analysis Report to reflect this change, as authorized by this amendment, and in accordance with 10 CFR 50.71(e).

3. This license amendment is effective as of its date of its issuance and shall be implemented within 30 days.

FOR THE NUCLEAR REGULATORY COMMISSION

/RA/

L. Raghavan, Chief, Section 1
Project Directorate III
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Date of Issuance: August 12, 2005

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO AMENDMENT NO. 171 TO FACILITY OPERATING LICENSE NO. DPR-42

AND AMENDMENT NO. 161 TO FACILITY OPERATION LICENSE NO. DPR-60

NUCLEAR MANAGEMENT COMPANY, LLC

PRAIRIE ISLAND NUCLEAR GENERATING PLANT, UNITS 1 AND 2

DOCKET NOS. 50-282 AND 50-306

1.0 INTRODUCTION

By letter dated September 1, 2004, Nuclear Management Company, LLC (NMC or the licensee) submitted Westinghouse report WCAP-16219-P, "Development and Qualification of a GOTHIC [Generation of Thermal-Hydraulic Information for Containment Version 7.1 patch 1 (GOTHIC 7)] Containment Evaluation Model for the Prairie Island Nuclear Generating Plants," dated April 2004. NMC requested Nuclear Regulatory Commission (NRC) review and approval of this report for referencing in licensing actions. NMC provided supplemental material, in response to the NRC staff's request for additional information, by letter dated May 17, 2005, "Supplement to License Amendment Request dated September 1, 2004, Request for Use of GOTHIC 7 In Containment Response Analyses (TAC Nos. MC4245 and MC4246)."

The supplemental letter contained clarifying information and did not change the initial no significant hazards consideration determination and did not expand the scope of the original Federal Register notice.

The Prairie Island Nuclear Generating Plant (PINGP) units are owned by Northern States Power Company (NSP) and operated by NMC. The PINGP units were designed and constructed to comply with NSP's understanding of the intent of the U.S. Atomic Energy Commission general design criteria (GDC) for nuclear power plant construction permits, as proposed on July 10, 1967.

The Westinghouse report describes the GOTHIC 7 computer program models and features to be used to perform licensing analyses of the containment atmospheric pressure and temperature response of the PINGP to a spectrum of high-energy line breaks.

NMC proposes to replace the currently approved CONTEMPT[1] computer program with the Electric Power Research Institute (EPRI) sponsored GOTHIC[2] computer program, developed by Numerical Applications, Inc. (NAI), for licensing analyses.

This safety evaluation addresses the NMC proposal to use GOTHIC 7 for licensing analyses for the PINGP units to (1) evaluate the short-term peak pressure and temperature response of the containment atmosphere to large pipe breaks in high energy piping systems — the design-basis loss-of-coolant accident (LOCA) and the design-basis main steamline break (MSLB), and (2) to evaluate the long-term containment response following a design-basis LOCA.

2.0 REGULATORY EVALUATION

Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, Appendix A, General Design Criteria (GDC) for Nuclear Power Plants, established minimum requirements for the principal design criteria for water-cooled nuclear power plants. However, the AEC Safety Evaluation Report acknowledged the AEC staff assessed the plant, as described in the FSAR, against the Appendix A design criteria and concluded that "the plant design generally conforms to the the intent of these criteria." As such, the NRC staff reviewed NMC's application for compliance with the following Appendix A GDC:

> GDC 16, *Containment design*. "Reactor containment and associated systems shall be provided to establish an essentially leak-tight barrier against the uncontrolled release of radioactivity to the environment and to assure that the containment design conditions important to safety are not exceeded for as long as postulated accident conditions require."
>
> GDC 38, *Containment heat removal*. "A system to remove heat from the reactor containment shall be provided. The system safety function shall be to reduce rapidly, consistent with the functioning of other associated systems, the containment pressure and temperature following any loss-of-coolant accident and maintain them at acceptably low levels. Suitable redundancy in components and features, and suitable interconnections, leak detection, isolation, and containment capabilities shall be provided to assure that for onsite electric power system operation (assuming offsite power is not available) and for offsite electric power system operation (assuming onsite power is not available) the system safety function can be accomplished, assuming a single failure."

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[1] Don W. Hargroves, "CONTEMPT-LT/028 - A Computer Program for Predicting Containment Pressure - Temperature Response to a Loss-Of-Coolant Accident," NUREG/CR-0255, March 1979.

[2] Thomas L. George, et al., "GOTHIC Containment Analysis Package," developed for EPRI, Numerical Applications, Inc. (Generation of Thermal-Hydraulic Information for Containments).

GDC 50, *Containment design basis*. "The reactor containment structure, including access openings, penetrations, and the containment heat removal system shall be designed so that the containment structure and its internal compartments can accommodate, without exceeding the design leakage rate and with sufficient margin, the calculated pressure and temperature conditions resulting from any loss-of-coolant accident. This margin shall reflect consideration of (1) the effects of potential energy sources which have not been included in the determination of the peak conditions, such as energy in steam generators and as required by § 50.44 energy from metal-water and other chemical reactions that may result from degradation but not total failure of emergency core cooling functioning, (2) the limited experience and experimental data available for defining accident phenomena and containment responses, and (3) the conservatism of the calculational model and input parameters."

GDC 4, *Environmental and dynamic effects design bases*. "Structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss-of-coolant accidents. These structures, systems, and components shall be appropriately protected against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids, that may result from equipment failures and from events and conditions outside the nuclear power unit. However, dynamic effects associated with postulated pipe ruptures in nuclear power units may be excluded from the design basis when analyses reviewed and approved by the Commission demonstrate that the probability of fluid system piping rupture is extremely low under conditions consistent with the design basis for the piping."

The NRC staff also used the guidance in Standard Review Plan (SRP), "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants - LWR Edition," NUREG-0800, Section 6.2.1, "Containment Functional Design," Section 6.2.1.1.A, "PWR Dry Containments, Including Subatmospheric Containments," Section 6.2.1.3, "Mass and Energy Release Analysis for Postulated Loss-of-Coolant Accidents," Section 6.2.1.4, "Mass and Energy Release Analysis for Postulated Secondary System Pipe Ruptures," and Section 6.2.2, "Containment Heat Removal Systems," for this review.

The NRC staff has performed similar reviews for the use of GOTHIC 7.0 for Ft. Calhoun[3] and for the use of GOTHIC 7.0 for Kewaunee.[4] The NMC submittal is based on version 7.1. The differences between GOTHIC 7.0 and 7.1 do not pertain to the analyses of the containment response to design-basis accidents (DBAs) as discussed in this safety evaluation report. The later version corrects unrelated coding errors and includes user features to enable the user to apply models consistent with NRC limitations, as, for example, identified during the Kewaunee review.

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[3] ADAMS Accession No. ML033100290, letter from A. B. Wang, USNRC, to R. T. Ridenoure, Omaha Public Power District, "Fort Calhoun Station, Unit No. 1 - Issuance of Amendment (TAC No. MB7496)," dated November 5, 2003.

[4] ADAMS Accession No. ML012490176, letter from J. G. Lamb, USNRC, to M. Reddemann, Nuclear Management Company, LLC, "Kewaunee Nuclear Power Plant - Review for Kewaunee Reload Safety Evaluation Methods Topical Report WPSRSEM-NP, Revision 3 (TAC No. MB0306)," dated September 10, 2001.

3.0 TECHNICAL EVALUATION

GOTHIC 7 is maintained under a 10 CFR Part 50 Appendix B quality assurance program, is widely used in the U.S. and worldwide, and has been extensively verified and validated by NAI, as documented in the GOTHIC 7 Qualification Manual.[5] Closed form analytical solutions, separate effects and full scale tests were used for the verification and validation of the computer program.

Most of the qualification work reported in the qualification manual involved NAI's comparisons of GOTHIC 7 predictions to experimental data. Experimental data were available from a variety of facilities which included small scale to large scale containment volumes. Small facility experiments generally focused on a few selected issues, and are generally referred to as separate effects tests or studies. Large scale tests, some performed at reactor sites, provided additional information for qualification.

The experimental database covered a large range of containment volumes. The small scale containment model facilities included the Battelle-Frankfurt containment model, the light-water reactor aerosol containment experiments, and the containment systems test facility — part of the Hanford Engineering Development Laboratory experiments, each with a containment volume less than 1,000 m^3. The intermediate size containment facilities included International Standard Problem 35, with a containment volume of about 1,500 m^3. The Marviken, Carolinas Virginia Tube Reactor, and Heissdampfreaktor represented large scale containments with volumes of 4,100, 6,400, and 11,300 m^3, respectively.

Therefore, there is reasonable assurance that GOTHIC 7 can be used to represent the containment features of the PINGP units for the short-term response to the DBA LOCA and the DBA MSLB and to address the long-term containment response to a DBA LOCA.

The following GOTHIC 7 modeling features, as they apply to the evaluation of the containment atmospheric pressure and temperature responses to DBAs, were evaluated by the staff using the guidance provided in the SRP.

3.1 Lumped-Parameter Modeling Approximation

The lumped-parameter modeling approximation has been found to be an acceptable approach for the analysis of the containment atmospheric response to a postulated high energy fluid pipe break with a large break area because of the large break jet momentum. The steam and noncondensable components of the containment atmosphere can be considered to be homogeneously mixed and in thermal equilibrium with each other. Thermal and noncondensable gas stratification within a volume need not be considered. This approach has been used in other computer programs used to perform containment analyses, such as CONTEMPT and CONTAIN.[6] GOTHIC 7 comparisons to a large set of experiments using this modeling approach have shown close agreement between the GOTHIC calculation and the experimental data, with the lumped-

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[5] GOTHIC Containment Analysis Package Qualification Report, version 7.2, September 2004, NAI 8907-09 Rev 8.

[6] Murata, K. K. et al., "Code Manual for CONTAIN 2.0: A Computer Code for Nuclear Reactor Containment Analysis," NUREG/CR-6533, USNRC, December 1997.

parameter model generally over-predicting (conservative) the peak pressure and peak temperature responses. The existence of liquid water droplets, from the break (see Section 3.2 of this evaluation) or from the containment sprays (see Section 3.5 of this evaluation), in the containment atmosphere may be included if the treatment of their thermodynamic and mechanical behavior is justified. The PINGP analyses of record (AOR) for the LOCA and the MSLB, calculated with the CONTEMPT code, are based on the lumped-parameter modeling approximation.

Liquid is collected in a pool on the bottom of the containment volume. The pool surface area for interface heat and mass transfer is modeled in GOTHIC 7. The GOTHIC 7 pool surface area input value is the sum of the horizontal floor heat sink areas. Condensation occurs when the containment steam partial pressure is higher than the saturation pressure at the pool surface. Evaporation occurs when the containment steam partial pressure is lower than the saturation pressure at the pool surface. The use of a simple single, lumped-parameter volume is an acceptable approach for the modeling of the PINGP containment design for the evaluation of the containment atmospheric pressure and temperature responses to DBAs, both the large-break LOCA and the MSLB.

3.2 Break Flow

The partitioning of the mass and energy releases into containment, from the break or from spillage from the emergency core cooling system (ECCS), can influence the containment pressure and temperature response. Either a “temperature flash” or “pressure flash” process can be assumed to evaluate the temperature and pressure response. In the “temperature flash” process the water-steam mixture from the break mixes instantaneously with the entire containment vapor region and instantaneously reaches thermal equilibrium, resulting in a conservative containment atmospheric temperature and pressure calculation. In the “pressure flash” process the water-steam mixture from the break comes into thermal equilibrium at the total containment pressure prior to mixing with the entire containment vapor region and the mixture remains in this state long enough for the water to drop out of the atmosphere, resulting in a conservative containment sump temperature calculation. These models were developed to conservatively address uncertainty in the break flow characteristics by bounding the effects of the water-steam mixture on the containment response. The PINGP AOR for the LOCA and the MSLB, calculated with the CONTEMPT code, are based on the “temperature flash” process.

In GOTHIC 7, with separate conservation equations for liquid, vapor and drops, the break flow steam and drops are assumed to be in thermal equilibrium at the source pressure, with the drop characterization based on experimental data. GOTHIC 7 determines the phase separation, into liquid, vapor, and drops, based on fundamental models for interface heat and mass transfer at the containment conditions. Liquid break flow released to the containment evaporates based on the difference in steam partial pressure at the drop surface and in the atmosphere. The droplets can eventually come to thermal equilibrium with the containment atmosphere and fall into the sump. A user specified break drop size (diameter) is used to model the break liquid in the containment atmosphere. The default break drop diameter is assumed to be 100-microns (0.00394 inches), based on guidance provided by the program developer, NAI. (Section 21.5, “Boundary Conditions,” of the GOTHIC 7 User Manual.)

During a DBA LOCA, the water entering the containment from the reactor coolant system (RCS) is at a temperature above the saturation temperature at the containment pressure. The water flashes to steam when it enters the containment, fracturing the water jet into fine droplets. Experimental test data[7] have shown that when superheated water flashes to steam the mean drop diameter is less than 100 microns. The GOTHIC 7 qualification analyses, presented in the GOTHIC code documentation qualification report, were performed using a single drop diameter of 100 microns. These qualification analyses showed that GOTHIC calculations with the 100 micron assumption agreed with, and typically bounded, the measured pressure and temperature response from blowdown tests and measured pressure drops from orifice pressure drop tests. A 100 micron drop has a terminal velocity (rainout velocity) of between one and 2 ft/sec. This is a realistic terminal velocity and allows for the break drops to be in the containment atmosphere for a realistic time period.

For these reasons, the NRC staff finds the GOTHIC 7 break flow model and the use of the default break drop size (diameter), in combination with the conservatively calculated mass and energy release rates, acceptable for PINGP licensing calculations. This break drop size was previously accepted by the staff as part of the Kewaunee review (ADAMS Accession No. ML012490176). The calculated pressure is expected to be less when compared to the “temperature flash” model, which bounds the effect of the liquid in the break flow, however, the containment pressure calculation will still be conservative because of the conservatism used to generate the mass and energy flow rates.

3.3 Heat Transfer Correlations

CONTEMPT assumes the condensation interface is always at saturation when evaluating the interface heat and mass transfer. CONTEMPT uses the Tagami[8] correlation and the Uchida[9] correlation for condensation heat transfer. These correlations can be used in a GOTHIC 7 model. GOTHIC 7 also contains interface heat and mass transfer correlations that are based on an interface temperature calculated from first principles.

The Tagami correlation for direct condensation heat transfer is considered to be appropriate for use during the blowdown portion of a LOCA analysis, consistent with the guidance in SRP 6.2.1.1.A. The Tagami correlation requires the specification of the time to the first peak pressure (known as the blowdown phase peak) and the accumulated energy into containment during this time phase. The NRC staff finds the use of the Tagami correlation acceptable for GOTHIC 7 licensing analyses. The use of the Tagami correlation in GOTHIC 7 was also previously accepted by the staff as part of a Kewaunee license amendment review (ADAMS Accession No. ML012490176) and a Ft. Calhoun license amendment review (ADAMS Accession No. ML033100290).

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[7] "Sprays Formed by Flashing Liquid Jets," by R. Brown and J. L. York, *AICHE Journal*, Vol. 8, #2, May 1962, University of Michigan, Ann Arbor, Michigan.

[8] Tagami, T., *Interim Report on Safety Assessments and Facilities Establishment Project in Japan for Period Ending June 1965 (No. 1)*, unpublished work, 1965.

[9] H. Uchida, A. Oyama, and Y. Toga, "Evaluation of Post-Incident Cooling Systems of Light-Water Power Reactors," *Proc. Third International Conference on the Peaceful Uses of Atomic Energy*, Volume 13, Session 3.9, United Nations, Geneva (1964).

The Uchida correlation for direct steam condensation after the LOCA blowdown period is considered to be appropriate for use after the blowdown portion of a LOCA analysis, consistent with the guidance in SRP 6.2.1.1.A. The use of the Uchida correlation for direct steam condensation for the MSLB is also considered to be appropriate for use, consistent with the guidance in SRP 6.2.1.1.A. The use of the GOTHIC 7 Uchida model was also previously accepted by the staff as part of the Kewaunee and Ft. Calhoun reviews cited above.

In combination with the use of the Uchida correlation, an 8 percent revaporization fraction is currently accepted by the NRC staff, as discussed in NUREG-0588.[10] In response to a staff request for additional information, NMC clarified that the 8 percent revaporation fraction would only be used in combination with the Uchida model. For other correlations, the GOTHIC 7 built-in revaporization model would be used. The staff finds the NMC proposal to account for revaporization, which is only important for MSLB cases with significant containment superheat, acceptable based on the reasons set forth in the staff position in NUREG-0588.

The PINGP AOR for the LOCA and the MSLB, calculated with the CONTEMPT code, are based on the use of the Tagami and Uchida correlations and the 8 percent revaporization fraction.

NMC proposed use of the GOTHIC 7 mist diffusion layer model (MDLM) for direct condensation and the modeling of heat transfer, with the GOTHIC 7 built-in revaporization model, for PINGP licensing analyses as the replacement for Tagami and Uchida correlations, as used in CONTEMPT.

GOTHIC 7, starting with version 7.0, incorporates an MDLM for direct condensation and the modeling of heat transfer. This is described in the GOTHIC 7 Technical Manual.[11] This manual states that the mist diffusion layer model calculates the condensation rate and the sensible heat transfer rate using the heat and mass transfer analogy.

Condensation of steam on a vertical cold containment surface results in a water film which flows down the surface to the containment floor. The presence of air, a non-condensable gas, results in the buildup of an air-rich boundary layer between the water film and the bulk atmosphere. This boundary layer can significantly reduce the condensation rate since the steam must diffuse through this layer to condense on the water film. This air-rich boundary layer also reduces the sensible heat transfer (heat transfer not due to a phase change).

The mist diffusion layer model calculates the condensation rate and sensible heat transfer rate using the heat and mass transfer analogy. Use of the heat and mass transfer analogy is an accepted engineering practice.[12] In addition, the mist diffusion layer model includes the formation of a mist or fog (small liquid droplets) near the cold wall. The presence of this mist has been

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[10] NUREG-0588, Interim Staff Position on Environmental Qualification of Safety - Related Electrical Equipment, dated December 1979.

[11] GOTHIC Containment Analysis Package Technical Manual Version 7.0, NAI 8907-06 Revision 12, Numerical Applications, Inc., July 2001.

[12] Bird, R. B., Stewart, W. E., and Lightfoot, E. N., *Transport Phenomena*, John Wiley and Sons, New York, 1960.

noted by several experimenters and analysts. These include Mori and Hijikata.[13] They proposed heat transfer models to calculate the heat transfer coefficient for condensation on a vertical cold wall for a vapor weight fraction range of 1 to 99 percent in the presence of a non-condensable gas (e.g., air). Their model included the presence of droplets in the boundary layer. The model calculates a heat transfer value which asymptotically approaches free convection at the outer edge of the boundary layer and condensation at the liquid film flowing along the wall. Mori and Hijikata's paper also presented a photograph of a cylinder on whose outer surface condensation was occurring. Droplets can be seen in the boundary layer. Brouwers and Chester and Brouwers[14] also proposed a condensation heat transfer model using film theory which accounted for the presence of droplets in the boundary layer. Steinmeyer[15] describes fog formation and its implications for industrial equipment. Thus, the presence of a mist in the boundary layer of a condensing fluid in the presence of a non-condensable gas is a recognized phenomenon.

GOTHIC 7 employs a "simplified" model which incorporates mist in the calculated heat and mass transfer. The model appeared to be unique among those examined by the staff since it also included the movement of the mist to the bulk atmosphere. In other models, the mist was assumed to be confined to the boundary layer. The movement of the mist to the bulk atmosphere from the boundary layer affects the pressure and temperature in the containment by the additional of liquid to the containment atmosphere. The GOTHIC 7 model empirically determines the fraction of the mist which migrates to the wall. A portion of the remainder migrates to the bulk vapor. Migration of the mist to the bulk atmosphere has no significant effect if the bulk atmosphere is saturated.

During the review of this model, the staff concluded that the model used to calculate condensation on the wall, would be acceptable for licensing analyses without the boundary layer mist formulation, and without the film roughness enhancements see (ADAMS Accession No. ML012490176).

The form of the MDLM approved by the NRC is now referred to as the diffusion layer model (DLM), starting with GOTHIC 7 the original MDLM without the boundary layer mist formulation and without the film roughness enhancements. The NMC proposal to use the DLM model for PINGP licensing analyses is consistent with the staff's previously approved use and is acceptable.

GOTHIC 7 also contains separate "fog" and "mist" models. In response to a staff request for additional information, NMC clarified that this "mist" model is not part of the MDLM/DLM model and proposed to use the GOTHIC 7 default "mist" model (or the "fog" model) for licensing calculations. If the containment atmosphere becomes supersaturated, a mechanism or modeling assumption is needed to condense the excess steam and release the heat of condensation to the

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[13] Yasuo Mori and Kunjo Hijikata, "Free Convective Condensation Heat transfer With Noncondensable Gas on a Vertical Surface," *International Journal of Heat and Mass Transfer*, Vol 16, pp. 2229-2240.

[14] Brouwers, H. J. H. and Chesters, A. K., "Film Models for Transport Phenomena with Fog Formation: The Classical Film Model," *International Journal of Heat and Mass Transfer*," Vol. 35, pp. 1-11; Brouwers, H. J. H., "Film Models for Transport Phenomena with Fog Formation: The Fog Film Model," *International Journal of Heat and Mass Transfer,*" Vol. 35, pp. 13-28.

[15] Steinmeyer, D. E., "Fog Formation in Partial Condensers, *Chemical Engineering Progress*, Volume 68, No. 71, July 1972.

containment atmosphere. The GOTHIC 7 “fog” model or the GOTHIC “mist” model is used to address this situation. The default “mist” model accounts for a deficiency in the “fog” model. NMC does not propose use of the “fog” model, since the default “mist” model is recommended by NAI, the code developer. There is a potential for the containment atmosphere to develop into a supersaturated vapor for the long-term containment response. If this occurs, modeling problems in GOTHIC 7 without the default “mist” model may lead to non-conservative results. Because the default “mist” model in GOTHIC 7 does not impact the peak containment atmospheric pressure or peak containment atmospheric temperature response, when the containment atmosphere is saturated or slightly superheated, and the default “mist” model is intended to address supersaturated conditions late in the accident, the staff finds the NMC proposal to use the default “mist” model acceptable for PINGP licensing analyses.

GOTHIC 7 also includes the Gido-Koestel heat transfer correlation[16] for steam condensation. NMC did not propose use of this correlation for PINGP licensing analysis, consistent with the staff’s evaluation of this correlation during the Kewaunee review (ADAMS Accession No. ML012490176).

GOTHIC 7 provides a variety of heat transfer correlations for applications. Natural and forced convection heat transfer correlations are used to account for heat transfer to the containment passive heat structures (walls, floors, and in-containment structures and equipment). The characteristic length of a structure is used to determine if the conditions are laminar or turbulent for natural convection to obtain the heat transfer coefficient. It is also used to obtain the forced convection heat transfer coefficient. In GOTHIC 7, the characteristic length is the containment hydraulic diameter. Typically, the characteristic length is related to the specific heat structure, for example the length of the wall. The use of the containment hydraulic diameter is acceptable for PINGP licensing analyses because the heat transfer coefficients are either not dependent on the value or decrease with increasing characteristic length — the containment hydraulic diameter is larger than the typical structure’s characteristic length — resulting in a conservative evaluation. The use of natural and forced convection heat transfer, to supplement the direct condensation heat transfer, is consistent with ANSI/ANS-56.4-1983[17] and is acceptable to the staff for PINGP licensing analyses.

Consistent with the American National Standards Institute (ANSI)/American Nuclear Society (ANS)-56.4-1983, GOTHIC 7 also included containment atmosphere (vapor) to containment heat structure radiation heat transfer. The GOTHIC 7 model is based on a grey gas with grey surrounding walls.[18] For LOCA analyses, and for MSLB analyses that do not rely on a break size to ensure a pure steam blowdown, the containment atmosphere is not superheated and the effects of radiation heat transfer will have a negligible impact on the containment pressure calculation. The containment atmosphere will be superheated for MSLB analyses only with the selection of the break size to ensure a pure steam blowdown. In this case, the impact on the containment pressure will be small, on the order of one psi lower. The NMC proposal to use

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[16] Gido, R. G., and Koestel, A., “Containment Condensing Heat Transfer,” Second International Topical Meeting on Nuclear Reactor Thermal Hydraulics,” Santa Barbara, California, January 1983.

[17] ANSI/ANS-56.4-1983, “American National Standard Pressure and Temperature Transient Analysis for Light Water Reactor Containments,” prepared by the American Nuclear Society.

[18] McAdams, W. H., *Heat Transmission*, Third Edition, McGraw-Hill, 1954.

radiation heat transfer is consistent with ANSI/ANS-56.4-1983 and is acceptable to the staff for PINGP licensing analysis.

3.4 Generalized Equipment Models

GOTHIC 7 includes a set of components for operating equipment to model heat transfer in the containment, for example: fan coolers and containment sprays. GOTHIC 7 also includes a set of components for operating equipment to model heat transfer from the containment sump for the long-term containment response evaluation, for example: residual heat removal and component cooling water heat exchanges, and pumps and valves.

3.4.1 Pumps and Fans

The pump and fan model simulates a centrifugal pump or fan. The differences between pumps and fans lie in the unique characteristics of rated conditions and performance curves. These components can affect the flow in any junction except when the junction is connected to a flow boundary condition. There are three basic pump models in GOTHIC 7: (a) the pump performance is defined by user-defined or built-in homologous curve, (b) the pump performance is defined by a user-defined head versus volumetric flow curve, and (c) the flow is specified.

3.4.2 Valves and Doors

The valve and door components are used to model flow path characteristics that may change during the course of a transient.

3.4.3 Heat Exchangers and Fan Coolers

There are two types of heat exchanger models available: (a) a water-to-water heat exchanger, and (b) a fan cooler. The water heat exchanger is distinct from a fan cooler, but both models are based on similar heat exchanger principles. The distinction involves only the heat transfer fluids. For a water heat exchanger the fluid on both the primary and secondary sides is assumed to be water. In GOTHIC 7, water heat exchangers are commonly used to model cooling of sump water before it is pumped into the containment spray system or the reactor ECCS.

The fan cooler model allows heat transfer from the primary side steam/gas mixture to the secondary side coolant water, for example the service water system or the component cooling water system. Steam can be condensed to the extent allowed by heat transfer or to the extent allowed by the amount of steam in the flow which enters the cooler.

3.4.4 Spray Nozzles

The spray nozzle component is used to model containment sprays, ice condenser drain flows into the lower containment, and vessel spray systems. The nozzle model converts liquid flow through a flow path from the continuous liquid phase to the droplet phase. The fraction of the liquid that is converted into droplets and the drop diameter can be specified as functions of time. Liquid is converted to drops only if the flow is directed into the nozzle discharge volume.

3.4.5 Coolers and Heaters

Coolers and heaters are provided to simulate a heat source or sink, with or without a mass source or sink, when the total heat transfer is known. This component may be used to model furnaces (or a reactor core's decay heat), air conditioners, heaters, heat generating equipment or heated vessels. A cooler can also act as a condenser if a positive volumetric flow through the cooler is specified. A condensing cooler will condense as much steam out of the flow as possible, subject to the limits given by the heat removal rate and the available steam in the flow. Heat not used to condense steam is used to cool the steam/gas mixture in the volume. The condensate is deposited in the liquid film in the volume.

By specifying a positive flow rate through a heater, a boiler can be modeled. The boiling rate is limited by the rate of heat addition, the flow rate through the heater and the total available water in the volume. A boiler will boil as much water out of the flow as possible. Additional heat will be used to raise the liquid temperature in the volume. A heater or cooler operates on only one phase in a volume, but there may be as many heaters and coolers in a volume as needed to obtain a required performance; for example, one cooler may operate on the vapor and a second cooler may operate on the liquid.

3.4.6 Volumetric Fans (Annular Fans, Deck Fans, etc.)

Volumetric fans are used to specify the volumetric flow of a steam/gas mixture and droplets through a flow path as a function of time or as a function of the pressure drop across the flow path. The fraction of the volumetric flow that is made up of droplets is determined by the relative drop volume fraction in the volume from which the flow is taken. The droplets and steam/gas mixture are assumed to have equal velocities through the fan. The velocity of the continuous liquid phase in the flow path is set to 0.0 (zero). If there is no vapor in the upstream volume, or if the upstream end of the junction is submerged, the flow through the fan is set to zero.

Heating or cooling of the flow through the fan can be specified as a function of time or as a function of the volumetric flow through the fan. This component may be used in place of a heater or cooler by locating the volumetric fan on a junction for which both ends are connected to the same volume. However, since phase change cannot occur in a junction, the volumetric fan is limited to sensible heating or cooling of the steam/gas mixture passing through the junction. A volumetric fan may also be used to model annular fans in dual containments.

Additional components available in GOTHIC 7, which were not considered during this review include (a) vacuum breakers, (b) hydrogen recombiners (forced and natural convection), (c) ignitors (spark device used to ignite hydrogen burns), and (d) pressure relief valves.

3.4.7 Generalized Equipment Models Summary

NAI used analytic problems for the qualification of GOTHIC 7, including quantitative and qualitative tests that evaluated the performance of individual models. By demonstrating close agreement with the analytic problems, NAI concluded that the basic building blocks of GOTHIC 7 were validated.

GOTHIC 7 is maintained under a 10 CFR Part 50 Appendix B quality assurance program, is widely used in the U.S. and worldwide, and has been extensively verified and validated by NAI. Therefore, there is reasonable assurance that the component models available in GOTHIC 7 can be used to represent the heat removal systems in the PINGP containments and to represent the heat removal systems for the PINGP long-term containment response evaluation.

3.5 Engineered Safety Systems

The two engineered safety systems used in the PINGP containment design for control of the post-accident containment atmosphere are the containment sprays and containment fan coolers.

3.5.1 Containment Spray

The staff finds the modeling of the containment spray system acceptable for PINGP GOTHIC 7 licensing calculations when used to produce a conservative containment calculation through the selection of the modeling parameters, for example: the spray flow rate, spray drop size, and spray efficiency. The methodology used to model the effectiveness of the containment spray (active heat removal mechanisms) is consistent with the guidance in SRP 6.2.1.1.A and 6.2.2.

3.5.2 Containment Fan Coolers

The staff finds the modeling of the containment fan coolers acceptable for PINGP GOTHIC 7 licensing calculations when used to produce a conservative containment calculation through the selection of the modeling parameters, for example: the flow rate, the secondary side temperature, and the heat transfer rate. The methodology used to model the effectiveness of the containment fan coolers (active heat removal mechanisms) is consistent with the guidance in SRP 6.2.1.1.A. and 6.2.2.

3.6 Mass and Energy Releases

The peak pressure and temperature generally occur early in the accident (on the order of a few minutes), during the short-term period for both the LOCA and the MSLB. A full analysis, for the long-term, should be performed long enough to return the containment pressure and temperature to their original values prior to the initiation of the LOCA event. This duration, for a LOCA, may be up to two weeks. The distinction between the short-term and the long-term periods is made with reference to the time at which the safety injection source is switched from the refueling water storage tank to the containment sump, referred to as the recirculation phase for long-term cooling. The short-term analysis is concluded at this time and the long-term analysis continues afterwards for a specified period of time after the occurrence of the DBA.

The model for the long-term containment pressure analysis should have sufficient details to generate the containment pressure and temperature response trend for the specified time period. The modeling details should primarily address two aspects: (1) the break mass and energy transfer rates from the RCS to the containment, and (2) the cooling mechanism for the containment sump. The containment sump is typically cooled by heat exchangers during the recirculation phase to provide sufficient net positive suction head for the safety injection pumps as well as sufficient cooling to remove the stored energy in the RCS metal (sensible heat) and the core decay heat.

The NMC proposed methodology for obtaining the mass and energy releases for use in GOTHIC 7 will be based on previously accepted methods, for example WCAP-10325[19] and WCAP-8822,[20] and will be consistent with the guidance provided in SRP Section 6.2.1.3 for LOCAs and Section 6.2.1.4 for secondary side releases.

The accumulator nitrogen release will be modeled for the LOCA event in the GOTHIC 7 PINGP containment model. This was not considered in the CONTEMPT model for the LOCA event. The staff finds the inclusion of the accumulator nitrogen release into containment acceptable for PINGP licensing analyses because the additional non-condensable gas being added to the containment atmosphere will inhibit the heat transfer, resulting in a conservative pressure evaluation.

3.7 Summary

The NMC proposal for the use of GOTHIC 7 (QA) - September 2003 to perform licensing analyses to (1) evaluate the containment atmospheric peak pressure and temperature response of the PINGP containments to large pipe breaks in high energy piping systems — the design basis LOCA and the design basis MSLB, and (2) to evaluate the long-term containment response following a design-basis LOCA is based on the guidance provided in SRP Sections 6.2.1, 6.2.1.1.A, 6.2.1.3, 6.2.1.4 and 6.2.2, and in ANSI/ANS-56.4-1983. The guidance ensures a conservative evaluation for the peak PINGP containment atmospheric pressure and peak containment atmospheric temperature following a DBA LOCA or MSLB for use in demonstrating conformance with GDCs 4, 16, 38, and 50. Use of the guidance also ensures a conservative evaluation of the PINGP long-term engineered cooling systems used to reduce the containment pressure to acceptably low values for use in demonstrating conformance with GDC 38.

The staff finds the description for the use of GOTHIC 7 (QA) - September 2003 for these PINGP licensing analyses, as presented in Westinghouse report WCAP-16219-P, “Development and Qualification of a GOTHIC Containment Evaluation Model for the Prairie Island Nuclear Generating Plants,” dated April 2004, acceptable for reference in PINGP licensing applications. The mass and energy releases and the initial and boundary conditions used in future PINGP license applications using GOTHIC 7 will be reviewed by the staff to assure that the analyses are performed consistent with the guidance in the SRPs and the description presented in WCAP-16219-P.

4.0 STATE CONSULTATION

In accordance with the Commission's regulations, the Minnesota State official was notified of the proposed issuance of the amendment. The State official had no comments.

5.0 ENVIRONMENTAL CONSIDERATION

The amendment changes the requirements with respect to installation or use of a facility component located within the restricted area as defined in 10 CFR Part 20 or change the

[19] “Westinghouse LOCA Mass and Energy Release Model for Containment Design March 1979 Version,” WCAP-10325-P-A, May 1983.

[20] "Mass and Energy Releases Following a Steam Line Rupture," WCAP-8822 (Proprietary), WCAP-8860 (Nonproprietary), Land, R. E., September 1976.

surveillance requirements. The staff has determined that the amendment involves no significant increase in the amounts, and no significant change in the types, of any effluents that may be released offsite, and that there is no significant increase in individual or cumulative occupational radiation exposure. The Commission has previously issued a proposed finding that the amendment involves no significant hazards consideration and there has been no public comment on such finding (69 FR 57990). Accordingly, the amendment meets the eligibility criteria for categorical exclusion set forth in 10 CFR 51.22(c)(9). Pursuant to 10 CFR 51.22(b), no environmental impact statement or environmental assessment need be prepared in connection with the issuance of the amendment.

6.0 CONCLUSION

The Commission has concluded, based on the considerations discussed above, that: (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) such activities will be conducted in compliance with the Commission's regulations, and (3) the issuance of the amendment will not be inimical to the common defense and security or to the health and safety of the public.

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Date: August 12, 2005