

January 16, 1998

Mr. Oliver D. Kingsley, President
Nuclear Generation Group
Commonwealth Edison Company
Executive Towers West III
1400 Opus Place, Suite 500
Downers Grove, IL 60515

SUBJECT: EXEMPTION FROM REQUIREMENTS OF 10 CFR 50.60 — BYRON, UNITS 1 AND 2, AND BRAIDWOOD, UNITS 1 AND 2 (TAC NOS. M98344, M98345, M98346, AND M98347)

Dear Mr. Kingsley:

The Commission has issued the enclosed exemption from the requirements of 10 CFR 50.60, "Acceptance Criteria for Fracture Prevention for Lightwater Nuclear Power Reactors for Normal Operation," related to Commonwealth Edison Company's request of April 3, 1997, as supplemented on June 19, 1997. This exemption permits the use of the safety margins recommended in the 1996 Addenda to the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code), Section XI, Appendix G, in lieu of the safety margins required by 10 CFR Part 50, Appendix G. 10 CFR Part 50, Appendix G, requires the use of methodologies at least as conservative as limits obtained by conforming to the methodology in the ASME Code, Section XI, Appendix G. 10 CFR 50.55a requires that any reference to the ASME Code refers to addenda through the 1988 Addenda and editions through the 1989 Edition of the Code, unless otherwise noted. Also enclosed is the safety evaluation containing the basis and conclusions for granting this exemption.

A copy of the exemption has been forwarded to the Office of the Federal Register for publication.

Sincerely,

ORIGINAL SIGNED BY:

George F. Dick, Jr., Senior Project Manager
Project Directorate III-2
Division of Reactor Projects - III/IV
Office of Nuclear Reactor Regulation

Docket Nos. STN 50-454, STN 50-455
STN 50-456, STN 50-457

Enclosures:

- 1. Exemption
- 2. Safety Evaluation

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security, and is, otherwise, in the public interest. Therefore, the Commission hereby grants an exemption from the requirements of 10 CFR 50.60 so that the P-T limits may be determined using the 1996 Addenda to the ASME Code, Section XI, Appendix G, and the LTOP system setpoint may be determined so that system pressure does not exceed 110 percent of the P-T limits.

Pursuant to 10 CFR 51.32, the Commission has determined that the granting of this exemption will not have a significant effect on the quality of the human environment (63 FR 2268).

This exemption is effective upon issuance.

FOR THE NUCLEAR REGULATORY COMMISSION

Original signed by Frank Miraglia
 Samuel J. Collins

Frank J. Miraglia, Acting Director
 Office of Nuclear Reactor Regulation

Dated at Rockville, Maryland,
 this 16 day of January, 1998.

*concurrence provided by memo dated 7/9/97; no major revisions
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security, and is, otherwise, in the public interest. Therefore, the Commission hereby grants an exemption from the requirements of 10 CFR 50.60 so that the P-T limits may be determined using the 1996 Addenda to the ASME Code, Section XI, Appendix G, and the LTOP system setpoint may be determined so that system pressure does not exceed 110 percent of the P-T limits.

Pursuant to 10 CFR 51.32, the Commission has determined that the granting of this exemption will not have a significant effect on the quality of the human environment (63 FR).

This exemption is effective upon issuance.

FOR THE NUCLEAR REGULATORY COMMISSION

Samuel J. Collins, Director
Office of Nuclear Reactor Regulation

Dated at Rockville, Maryland,
this day of

*concurrence provided by memo dated 7/9/97; no major revisions
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Accordingly, the Commission has determined that, pursuant to 10 CFR 50.12(a), an exemption is authorized by law, will not endanger life or property or common defense and security, and is, otherwise, in the public interest. Therefore, the Commission hereby grants an exemption from the requirements of 10 CFR 50.60 such that the P-T limits may be determined using the 1996 Addenda to the ASME Code, Section XI, Appendix G, and the LTOP system setpoint may be determined such that system pressure does not exceed 110 percent of the P-T limits.

Pursuant to 10 CFR 51.32, the Commission has determined that the granting of this exemption will not have a significant effect on the quality of the human environment (FR).

This exemption is effective upon issuance.

FOR THE NUCLEAR REGULATORY COMMISSION

Samuel J. Collins, Director
Office of Nuclear Reactor Regulation

Dated at Rockville, Maryland,
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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

January 16, 1998

Mr. Oliver D. Kingsley, President
Nuclear Generation Group
Commonwealth Edison Company
Executive Towers West III
1400 Opus Place, Suite 500
Downers Grove, IL 60515

SUBJECT: EXEMPTION FROM REQUIREMENTS OF 10 CFR 50.60 — BYRON, UNITS 1
AND 2, AND BRAIDWOOD, UNITS 1 AND 2 (TAC NOS. M98344, M98345,
M98346, AND M98347)

Dear Mr. Kingsley:

The Commission has issued the enclosed exemption from the requirements of 10 CFR 50.60, "Acceptance Criteria for Fracture Prevention for Lightwater Nuclear Power Reactors for Normal Operation," related to Commonwealth Edison Company's request of April 3, 1997, as supplemented on June 19, 1997. This exemption permits the use of the safety margins recommended in the 1996 Addenda to the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code), Section XI, Appendix G, in lieu of the safety margins required by 10 CFR Part 50, Appendix G. 10 CFR Part 50, Appendix G, requires the use of methodologies at least as conservative as limits obtained by conforming to the methodology in the ASME Code, Section XI, Appendix G. 10 CFR 50.55a requires that any reference to the ASME Code refers to addenda through the 1988 Addenda and editions through the 1989 Edition of the Code, unless otherwise noted. Also enclosed is the safety evaluation containing the basis and conclusions for granting this exemption.

A copy of the exemption has been forwarded to the Office of the Federal Register for publication.

Sincerely,

George F. Dick, Jr., Senior Project Manager
Project Directorate III-2
Division of Reactor Projects - III/IV
Office of Nuclear Reactor Regulation

Docket Nos. STN 50-454, STN 50-455
STN 50-456, STN 50-457

Enclosures:

1. Exemption
2. Safety Evaluation

cc w/encls: See next page

O. Kingsley
Commonwealth Edison Company

cc:

Mr. William P. Poirier, Director
Westinghouse Electric Corporation
Energy Systems Business Unit
Post Office Box 355, Bay 236 W.
Pittsburgh, Pennsylvania 15230

Joseph Gallo
Gallo & Ross
1250 Eye St., N.W., Suite 302
Washington, DC 20005

Michael I. Miller, Esquire
Sidley and Austin
One First National Plaza
Chicago, Illinois 60603

Howard A. Learner
Environmental law and Policy
Center of the Midwest
203 N. LaSalle St. Suite 1390
Chicago, Illinois 60601

U.S. Nuclear Regulatory Commission
Byron Resident Inspectors Office
4448 N. German Church Road
Byron, Illinois 61010-9750

Regional Administrator, Region III
U.S. Nuclear Regulatory Commission
801 Warrenville Road
Lisle, Illinois 60532-4351

Ms. Lorraine Creek
RR 1, Box 182
Manteno, Illinois 60950

Chairman, Ogle County Board
Post Office Box 357
Oregon, Illinois 61061

Mrs. Phillip B. Johnson
1907 Stratford Lane
Rockford, Illinois 61107

George L. Edgar
Morgan, Lewis and Bochius
1800 M Street, N.W.
Washington, DC 20036

Byron/Braidwood Stations

Attorney General
500 S. Second Street
Springfield, Illinois 62701

Illinois Department of Nuclear Safety
Office of Nuclear Facility Safety
1035 Outer Park Drive
Springfield, Illinois 62704

Commonwealth Edison Company
Byron Station Manager
4450 N. German Church Road
Byron, Illinois 61010-9794

Commonwealth Edison Company
Site Vice President - Byron
4450 N. German Church Road
Byron, Illinois 61010-9794

U.S. Nuclear Regulatory Commission
Braidwood Resident Inspectors Office
RR 1, Box 79
Braceville, Illinois 60407

Mr. Ron Stephens
Illinois Emergency Services
and Disaster Agency
110 E. Adams Street
Springfield, Illinois 62706

Chairman
Will County Board of Supervisors
Will County Board Courthouse
Joliet, Illinois 60434

Commonwealth Edison Company
Braidwood Station Manager
RR 1, Box 84
Braceville, Illinois 60407

Ms. Bridget Little Rorem
Appleseed Coordinator
117 N. Linden Street
Essex, Illinois 60935

Document Control Desk-Licensing
Commonwealth Edison Company
1400 Opus Place, Suite 400
Downers Grove, Illinois 60515

**O. Kingsley
Commonwealth Edison Company**

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Byron/Braidwood Stations

**Commonwealth Edison Company
Site Vice President - Braidwood
RR 1, Box 84
Braceville, IL 60407**

**Mr. Michael J. Wallace
Nuclear Services Senior Vice President
Commonwealth Edison Company
Executive Towers West III
1400 Opus Place, Suite 900
Downers Grove, IL 60515**

**Mr. Gene H. Stanley
PWR's Vice President
Commonwealth Edison Company
Executive Towers West III
1400 Opus Place, Suite 900
Downers Grove, IL 60515**

**Mr. Steve Perry
BWR's Vice President
Commonwealth Edison Company
Executive Towers West III
1400 Opus Place, Suite 900
Downers Grove, IL 60515**

**Mr. Dennis Farrar
Regulatory Services Manager
Commonwealth Edison Company
Executive Towers West III
1400 Opus Place, Suite 500
Downers Grove, IL 60515**

**Ms. Irene Johnson, Licensing Director
Nuclear Regulatory Services
Commonwealth Edison Company
Executive Towers West III
1400 Opus Place, Suite 500
Downers Grove, IL 60515**

**Commonwealth Edison Company
Reg. Assurance Supervisor - Braidwood
RR 1, Box 79
Braceville, Illinois 60407**

**Commonwealth Edison Company
Reg. Assurance Supervisor - Byron
4450 N. German Church Road
Byron, Illinois 61010-9794**

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

In the Matter of)	
)	
COMMONWEALTH EDISON COMPANY)	
)	
(Byron Station, Units 1 and 2))	Docket Nos. STN 50-454, STN 50-455
)	
(Braidwood Station, Units 1 and 2))	Docket Nos. STN 50-456, STN 50-457

EXEMPTION

I.

Commonwealth Edison Company (ComEd, the licensee) is the holder of Facility Operating License Nos. NPF-37, NPF-66, NPF-72, and NPF-77, which authorize operation of Byron Station, Units 1 and 2, and Braidwood Station, Units 1 and 2, respectively. The licenses provide, among other things, that the licensee is subject to all rules, regulations, and orders of the Commission now or hereafter in effect.

The Byron facility consists of two pressurized-water reactors located at the licensee's site in Ogle County, Illinois. The Braidwood facility consists of two pressurized-water reactors located at the licensee's site in Will County, Illinois.

II.

In its letter dated April 3, 1997, as supplemented on June 19, 1997, ComEd requested an exemption from the Commission's regulations. Title 10 of the Code of Federal Regulations, Part 50, Section 60 (10 CFR 50.60), "Acceptance Criteria for Fracture Prevention Measures for Lightwater Nuclear Power Reactors for Normal Operation," states that all lightwater nuclear power reactors must meet the fracture toughness and material surveillance program

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requirements for the reactor coolant pressure boundary as stated in Appendices G and H to 10 CFR Part 50. Appendix G to 10 CFR Part 50 defines pressure-temperature (P-T) limits during any condition of normal operation, including anticipated operational occurrences and system hydrostatic tests to which the pressure boundary may be subjected over its service lifetime, and specifies that these P-T limits must be at least as conservative as the limits obtained by conforming to the methods of analysis and the margins of safety of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code), Section XI, Appendix G. 10 CFR 50.55a requires that any reference to ASME Code Section XI in 10 CFR Part 50 refers to addenda through the 1988 Addenda and editions through the 1989 Edition of the Code unless otherwise noted. It is specified in 10 CFR 50.60(b) that alternatives to the requirements described in Appendices G and H to 10 CFR Part 50 may be used when an exemption is granted by the Commission under 10 CFR 50.12.

To mitigate low-temperature overpressure transients that would produce pressure excursions exceeding the required limits while the reactor is operating at low temperatures, the licensee installed a low-temperature overpressure protection (LTOP) system. The system includes pressure-relieving devices called power-operated relief valves (PORVs). The PORVs are set at a pressure low enough so that if an LTOP transient occurred, the mitigation system would prevent the pressure in the reactor vessel from exceeding the required limits. To prevent the PORVs from lifting as a result of normal operating pressure surges, some margin is needed between the PORV setpoint and the normal operating pressure. In addition, when instrument uncertainty is considered, the operating window between the PORV setpoint and the minimum pressure required for reactor coolant pump seals is small and presents difficulties for plant operation.

The licensee has requested the use of the 1996 Addenda to the ASME Code, Section XI, Appendix G, which allows the use of lower stress intensity factors for determining the applied stress intensity from pressure and thermal stresses, and allows use of an LTOP system setpoint so that system pressure does not exceed 110 percent of the P-T limits. The 1996 Addenda to the ASME Code, Section XI, Appendix G, is consistent with guidelines developed by the ASME Working Group on Operating Plant Criteria to define pressure limits during LTOP events that avoid certain unnecessary operational restrictions, provide adequate margins against failure of the reactor pressure vessel, and reduce the potential for unnecessary activation of pressure-relieving devices used for LTOP. ASME Code, Section XI, Appendix G, 1996 Addenda, has been approved by the ASME Code Committee.

III.

Pursuant to 10 CFR 50.12, the Commission may, upon application by any interested entity or upon its own initiative, grant exemptions from the requirements of 10 CFR Part 50 when (1) the exemptions are authorized by law, will not present an undue risk to public health and safety, and are consistent with the common defense and security; and (2) when special circumstances are present. Special circumstances are present whenever, according to 10 CFR 50.12(a)(2)(ii), "Application of the regulation in the particular circumstances would not serve the underlying purpose of the rule or is not necessary to achieve the underlying purpose of the rule...."

The underlying purpose of 10 CFR 50.60 and 10 CFR Part 50 Appendix G is to establish fracture toughness requirements for ferritic materials of pressure-retaining components of the reactor coolant pressure boundary to provide adequate margins of safety during any condition of normal operation, including anticipated operational occurrences, to which the pressure boundary may be subjected over its service lifetime. Section IV.A.2 of Appendix G to 10 CFR Part 50,

requires that the reactor vessel be operated with P-T limits at least as conservative as those obtained by following the methods of analysis and the required margins of safety of Appendix G of Section XI of the ASME Code. 10 CFR 50.55a requires that any reference to ASME Code Section XI in 10 CFR Part 50, Appendix G, refers to addenda through the 1988 Addenda and editions through the 1989 Edition of the ASME Code, unless otherwise noted.

Appendix G of the ASME Code requires that the P-T limits be calculated: (a) using a safety factor of two on the principal membrane (pressure) stresses, (b) assuming a flaw at the surface with a depth of one-quarter of the vessel wall thickness ($\frac{1}{4} T$) and a length of six (6) times its depth, and (c) using a conservative fracture toughness curve that is based on the lower bound of static, dynamic, and crack arrest fracture toughness tests on material similar to the reactor vessel material.

For determining the P-T limits, the licensee proposed to use the safety margins based on the 1996 Addenda to the ASME Code in lieu of the 1989 Edition. When compared to the 1989 Edition of the ASME Code, the 1996 Addenda permits the use of a lower stress intensity factor for determining the applied stress intensity from pressure and thermal stresses. This results in a slight reduction in the applied stress intensity and a corresponding shift in the allowable pressure at a given temperature in the non-conservative direction; however, this difference is minor when compared to the explicit conservatisms incorporated into Appendix G, and the changes in the stress intensity factor are supported by the work performed for NRC and for others by J. A. Keeney and T. L. Dickson at Oak Ridge National Laboratory (ORNL).

For determining the LTOP system setpoint, the licensee proposed to use safety margins based on the 1996 Addenda to the ASME Code. The 1996 Addenda allows determination of the setpoint for mitigating LTOP events so that the maximum pressure in the vessel would not exceed 110 percent of the P-T limits that are determined using the 1996 methodology. This

results in a safety factor of 1.8 on the principal membrane stresses. All other factors, including assumed flaw size and fracture toughness, remain the same. Although this methodology would reduce the safety factor on the principal membrane stresses, the proposed criteria will provide adequate margins of safety for the reactor vessel during LTOP transients and, thus, will satisfy the underlying purpose of 10 CFR 50.60 for fracture toughness requirements. Further, by relieving the operational restrictions, the potential for undesirable lifting of the PORV would be reduced, thereby improving plant safety.

It should be noted that the provision to set the PORV setpoint so that system pressure remains below 110 percent of the P-T limits has already been incorporated into the Byron and Braidwood licensing basis. This provision was approved by an exemption to 10 CFR 50.60 granted to Byron, Units 1 and 2, on November 29, 1996, to Braidwood, Unit 1 on July 13, 1995, and to Braidwood, Unit 2 on December 12, 1997, to allow the use of ASME Code Case N-514. Therefore, although it represents a change from the 1989 Edition of the ASME Code, it is not a change to the current licensing basis for the facilities.

IV.

For the foregoing reasons, the NRC staff has concluded that ComEd's proposed use of the alternate methodology in determining the acceptable setpoint for LTOP events will not present an undue risk to public health and safety and is consistent with the common defense and security. The NRC staff has determined that there are special circumstances present, as specified in 10 CFR 50.12(a)(2), in that 10 CFR 50.60 need not be applied in order to achieve the underlying purpose of this regulation, which is to provide adequate fracture toughness of the reactor pressure boundary.

Accordingly, the Commission has determined that, pursuant to 10 CFR 50.12(a), an exemption is authorized by law, will not endanger life or property or common defense and

security, and is, otherwise, in the public interest. Therefore, the Commission hereby grants an exemption from the requirements of 10 CFR 50.60 so that the P-T limits may be determined using the 1996 Addenda to the ASME Code, Section XI, Appendix G, and the LTOP system setpoint may be determined so that system pressure does not exceed 110 percent of the P-T limits.

Pursuant to 10 CFR 51.32, the Commission has determined that the granting of this exemption will not have a significant effect on the quality of the human environment (63 FR 2268).

This exemption is effective upon issuance.

FOR THE NUCLEAR REGULATORY COMMISSION



Frank J. Miraglia, Acting Director
Office of Nuclear Reactor Regulation

Dated at Rockville, Maryland,
this 16 day of January, 1998.



UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION
RELATED TO EXEMPTION FROM REQUIREMENTS OF 10 CFR 50.60
COMMONWEALTH EDISON COMPANY
BYRON STATION, UNITS 1 AND 2, AND BRAIDWOOD STATION, UNITS 1 AND 2
DOCKET NOS. STN 50-454, STN 50-455, STN 50-456 AND STN 50-457

1.0 INTRODUCTION

By letter dated April 3, 1997, as supplemented by letter dated June 19, 1997, Commonwealth Edison Company (ComEd), the licensee for Byron Station, Units 1 and 2, and Braidwood Station, Units 1 and 2, requested that the NRC exempt these units from the application of the 1989 Edition of the American Society for Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code), Section XI, Appendix G (1989 methodology) as required by Title 10 of the Code of Federal Regulations, Part 50 (10 CFR Part 50) Section 55a, Section 60, and Appendix G. As an alternative, ComEd proposed to use the version of ASME Code, Section XI, Appendix G, found in the 1996 Addenda to the ASME Code (1996 methodology). When compared to the 1989 methodology, the 1996 methodology would permit ComEd to use lower stress intensity factors for determining the applied stress intensity from pressure and thermal stresses and to set the low-temperature overpressure protection (LTOP) system pressure setpoint so that system pressure does not exceed 110 percent of that required by the pressure-temperature (P-T) limits.

2.0 LICENSEE'S DETERMINATION

The NRC has established requirements in 10 CFR Part 50 to protect the integrity of the reactor coolant system pressure boundary. As one of the requirements, 10 CFR Part 50, Appendix G, requires that P-T limits be established for reactor pressure vessels (RPVs) during normal operation and vessel hydrostatic testing. In particular, 10 CFR Part 50, Appendix G, Section IV.2.b., requires that these limits must be "at least as conservative as limits obtained by following the methods of analysis and the margins of safety of Appendix G of Section XI of the ASME Code." 10 CFR 50.55a requires that any reference to the ASME Code, Section XI, in 10 CFR Part 50, Appendix G, refers to the 1989 Edition of the Code unless otherwise noted. 10 CFR 50.60, which broadly addresses the establishment of criteria for fracture prevention, states that "proposed alternatives to the described requirements in Appendices G and H of this part or portions thereof may be used when an exemption is granted by the Commission under §50.12." Therefore, ComEd determined that application of the 1996 methodology in lieu of the 1989 methodology approved by the staff in the regulations would require an exemption.

In ComEd's initial letter, this exemption was requested under the special circumstances given in 10 CFR 50.12(a)(2)(iii). The provisions of this section state that an exemption may be granted when "compliance (with the regulation) would result in undue hardship or other costs that are significantly in excess of those contemplated when the regulation was adopted, or that are

ENCLOSURE 2

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significantly in excess of those incurred by others similarly situated...." ComEd contended that application of the 1989 methodology would result in undue hardship because of a narrowing of the operational window between the vessel P-T limits or LTOP system setpoint and the minimum reactor coolant system pressure required by reactor coolant pump operation. The NRC staff, although noting that this reduction in operational flexibility was real, did not concur that such a reduction constitutes an undue hardship for these particular facilities. The staff based this finding on the fact that the RPV materials for these units exhibit a relatively low nil-ductility reference temperature (RT_{NDT}) value through end-of-license when compared with other "similarly situated" licensees. A higher RT_{NDT} value results in more restrictive vessel P-T limits. Also, no attempt was made in the initial submittal to quantify whether the costs were "significantly in excess of those contemplated when the regulation was adopted...."

By letter dated June 19, 1997, ComEd amended its application to cite 10 CFR 50.12(a)(2)(ii) as the special circumstance for requesting this exemption. 10 CFR 50.12(a)(2)(ii) states that special circumstances are present whenever "application of the regulation in the particular circumstances...is not necessary to achieve the underlying purpose of the rule." ComEd explained that "the 1996 Addenda....solutions better characterize the conditions for irradiated vessels in the low temperature region where the thermal stresses and allowable pressure are low." ComEd also noted that conservatism incorporated into ASME Code Section XI, Appendix G, include: (1) the 6:1 aspect ratio one-quarter of the vessel wall thickness flaw, (2) a factor of 2 on the membrane stress intensity factor, (3) the determination of material toughness from a reference curve based on dynamic and crack arrest data, and (4) margins on the materials' adjusted reference temperature based on Regulatory Guide 1.99, Revision 2, remain intact in the 1996 methodology. Therefore, ComEd concluded that application of the 1996 methodology would also meet the underlying intent of the regulations—namely, to protect the integrity of the RPV from nonductile failure.

3.0 STAFF EVALUATION

Initially, the staff examined the regulatory bases for ComEd's exemption request. The staff agreed with ComEd's determination that an exemption from 10 CFR Part 50, Appendix G, would be required for applying the 1996 methodology, since it would likely produce results less conservative than the 1989 methodology. Further, the staff examined ComEd's rationale to support the exemption request and the staff concurred that an examination of this alternative method should demonstrate that application of the 1996 methodology would also meet the underlying intent of the regulations. Therefore, requesting the exemption under the special circumstances of 10 CFR 50.12(a)(2)(ii) was appropriate. The staff then examined the 1996 methodology and the bases for the changes made in the ASME Code to confirm whether or not its application would meet the underlying intent of the regulations.

To begin, the staff compared critical features of the 1989 and 1996 methodologies—using parameter values that were expected to be approximately correct for the Byron and Braidwood RPVs—in order to examine the magnitude of the changes to be expected by use of the 1996 methodology. The staff intends to review the application of the 1996 methodology in detail when ComEd submits it as part of an update of the facilities' P-T limits. The differences in the two methodologies are apparent in the determination of the stress intensity factor multiplier, M_m , the formulations for determining the contribution of the thermal stress intensity term, K_{tt} , from the cooldown rate or temperature gradient, and the provision for setting the LTOP system pressure setpoint so that system pressure does not exceed 110 percent of the pressure required by the P-T limit curves. However, this provision on the LTOP system pressure setpoint was previously

approved for Byron and Braidwood through the NRC's approval of ComEd's use of ASME Code Case N-514. Therefore, although it represents a change from the 1989 methodology, it is not a change from the current licensing basis for the facilities and will not be addressed further in this safety evaluation.

The staff first examined the effect of the difference in the way the methodologies determine the stress intensity factor multiplier, M_m . For a typical-to-conservative applied stress-to-yield stress ratio of 0.7 and a vessel wall thickness of 8.5 inches (typical of the Byron and Braidwood vessels), Figure G-2214-1 in the 1989 Code gave a value of $M_m = 2.87$; the calculational methods of the 1996 Addenda gave $M_m = 2.70$. This change would result in approximately a 6 percent reduction in the applied stress intensity and a corresponding shift in the allowable pressure at a given temperature in the non-conservative direction. The staff has concluded that this difference is minor when compared to the explicit conservatisms incorporated into Appendix G of the ASME Code, Section XI, (as listed in Section 2.0 of this SE) and that the changes in the M_m factor are supported by the work performed by J.A. Keeney and T.L. Dickson at Oak Ridge National Laboratory (ORNL) for the NRC (Reference 1), A. Zahoor (Reference 2), and I.S. Raju and J.C. Newman (Reference 3).

The staff then examined the changes to the determination of K_{tt} incorporated into the 1996 methodology. The staff limited its examination of this issue to cooldown transients, in which significant tensile thermal stresses can be developed on the inside diameter of the RPV. As noted in Standard Review Plan Section 5.3.2, "Pressure-Temperature Limits," the staff has approved the use of the information and methodology from Welding Research Council (WRC) Bulletin 175 for the evaluation of applied thermal stress intensities due to various cooldown rates. The staff determined in this review that within the uncertainties in using the graphs from WRC Bulletin 175, the functional form given for K_{tt} in G-2214.3(a) for the cooldown transient is an equivalent methodology.

The staff also accepts that the additional methodology for the heatup transient K_{tt} and the alternate methodology making use of the detailed thermal stress distribution given in G-2214.3(b) are supported by the work of J.A. Keeney and T.L. Dickson for the NRC (Reference 1), A. Zahoor (Reference 2), and I.S. Raju and J.C. Newman (Reference 3). The staff, therefore, concludes that the methodology given in the 1996 Addenda is acceptable for determining K_{tt} . However, the staff must still review and approve details regarding the application of the 1996 methodology (for example, the method chosen for determining thermal stresses as an input to the G-2214.3(b) procedure, if used). These details will be reviewed along with the updated P-T limits or with the Pressure-Temperature Limits Report (PTLR) that incorporates the 1996 methodology into the facilities' licensing basis.

4.0 CONCLUSION

The staff, having been involved in the consensus body development of the 1996 Addenda to Section XI of the ASME Code and having reviewed the major changes between the 1989 Section XI, Appendix G, and 1996 Section XI, Appendix G, methodologies for this review, concludes that the use of the 1996 methodology would meet the underlying intent of 10 CFR 50.60 and 10 CFR Part 50, Appendix G, and is, therefore, acceptable. The staff accepts that the explicit conservatism incorporated within the 1996 Addenda to the ASME Code, Section XI, Appendix G methodology will ensure that the RPV for which this methodology is used will be protected from non-ductile failure. The staff further concludes that, since application of the 1989 methodology poses no undue hardship for Byron and Braidwood, special circumstances as defined in 10 CFR

50.12(a)(2)(ii) exist. The staff has reviewed ComEd's request and approves the use of the 1996 methodology in lieu of the 1989 methodology currently required in 10 CFR 50.60 at Byron and Braidwood.

Principal Contributor: M. Mitchell

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5.0 REFERENCES

1. J.A. Keeney and T.L. Dickson, "Stress-Intensity-Factor Influence Coefficients for Axially Oriented Semielliptical Inner-Surface Flaws in Clad Pressure Vessels ($R/t=10$)," ORNL/NRC/LTR-93/33, Revision 1, September 30, 1995.
2. A. Zahoor, Ductile Fracture Handbook, Volume 3, published jointly by EPRI (NP-6301-D) and Novatech (N14-3), January 1991.
3. I.S. Raju and J.C. Newman, Jr., "Stress Intensity Factors for Internal and External Surface Cracks in Cylindrical Vessels," Journal of Pressure Vessel Technology, Volume 104, pp 283-288, November 1982.