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RS-03-149

August 15, 2003

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Byron Station, Unit 1
Facility Operating License No. NPF-37
NRC Docket No. STN 50-454

Subject: Byron Station, Unit 1 Licensed Thermal Power Limit Verification

References:

(1) Letter from J. A. Zwolinski (U.S. NRC) to J. L. Skolds (Exelon Generation Company, LLC), "Licensed Thermal Power – Byron Station, Unit 1," dated January 22, 2003

(2) Letter from K. R. Jury (Exelon Generation Company, LLC) to the U.S. NRC, "Byron Station, Unit 1, Licensed Thermal Power Limit Verification," dated February 5, 2003

(3) Letter from G. F. Dick (U.S. NRC) to J. L. Skolds (Exelon Generation Company, LLC), "Licensed Thermal Power, Byron Station, Unit 1 – Request for Additional Information," dated July 8, 2003

In Reference 1, the NRC notified Exelon Generation Company, LLC (EGC) that due to a number of plant performance indications and observations, the NRC is concerned that Byron Station, Unit 1 may be operating above its licensed thermal power level. In this letter, the NRC requested that EGC provide assurance that Byron Station, Unit 1 is operating within its licensed thermal power limit. EGC provided the requested information to the NRC in Reference 2.

During the review of Reference 2, the NRC determined that additional information would be needed to fully resolve the issue of whether Byron Station, Unit 1 is operating above its licensed thermal power limit. Subsequently, the NRC issued a request for additional information in Reference 3. The requested information is provided in Attachment 1 to this letter.

As described in the response to Question 2.3 of Attachment 1, EGC will conduct additional testing and validation of the accuracy of feedwater flow as measured by the ultrasonic flow

meters. The goal of the testing is to confirm that Byron Station, Unit 1 is operating within its licensed thermal power limit.

Should you have any questions related to this letter, please contact J. A. Bauer at (630) 657-2801.

Respectfully,

Kenneth A. Ainger for

Keith R. Jury
Director – Licensing, West

Attachment 1: Response to Request for Additional Information, Byron Station, Unit 1, Licensed Thermal Power Limit Verification

Attachment 1

Response to Request for Additional Information

Byron Station, Unit 1
Licensed Thermal Power Limit Verification

In a letter from G. F. Dick (U.S. NRC) to J. L. Skolds (Exelon Generation Company, LLC), "Licensed Thermal Power, Byron Station, Unit 1 – Request for Additional Information," dated July 8, 2003, the NRC requested that Exelon Generation Company, LLC (EGC) provide a response to the below questions.

1. *Questions specific to the licensee's February 5, 2003, submittal*

1.1 *On Page 2 and on Page 5, the licensee identified participation by other than on-site personnel in such activities as detailed review of the installation and re-evaluation of the installation uncertainty calculations of the ultrasonic flow meters (UFMs). Please provide the basis for concluding, "that the equipment was performing within specification."*

Response to Question 1.1

Westinghouse Electric Company, LLC (i.e., Westinghouse) and Advanced Measurement Analysis Group (AMAG) personnel were engaged in the Spring of 2002 to review the installation and system performance of the UFMs at Byron Station, Unit 1. The evaluation included the following activities:

- Performed additional pipe wall thickness, outside diameter and spacing between the transducer measurements in Unit 1. It was verified that there were no significant differences compared to the original setup values for Byron Station, Unit 1.

- The transducer characteristics were checked in Byron Station, Unit 1 using the crossflow standard receive signal strength indicator and tone-burst procedures. The results indicated that the transducers on Byron Station, Unit 1 were performing as expected.

- All cables in Byron Station, Unit 1 were tested (i.e., ohmic-resistance and capacitance measurements). All tests were acceptable and no problems were identified with the cables.

- The Byron Station, Unit 1 signal conditioning unit (SCU) and multiplexer were checked by performing the UFM standard internal test signal commissioning test for the SCU and the UFM standard multiplexer function test procedures. The SCU and multiplexer test results satisfied the acceptance criteria in the testing procedures.

- The installed UFM software (version M3.0.2) is the same in both Byron Station, Unit 1 and 2 computers. The software was checked and compared with the latest version of the UFM software (version M3.5.0). The results of the measurements were identical using the upgraded UFM software. These results verified that the

installed software was performing correctly.

- After completing the UFM component checks, a comparison measurement was performed between the main feedwater common header and the four feedwater loops of Byron Station, Unit 1. A UFM bracket was installed on the common feedwater header in a long run downstream of a single elbow (i.e., standard UFM installation). The results of this installation and comparison to the individual feedwater loops verified the four loops are being accurately measured within the UFM uncertainties.

- A test was also performed to compare the common feedwater header UFM reading to the plant flow indications (i.e., venturi and tempering lines). The ratio of the common feedwater header UFM reading to the sum of the venturis in all four loops plus the tempering lines was calculated for two different configurations with and without the tempering lines secured. Both ratios were very close which indicated that the tempering lines flow was being accurately reported by plant instrumentation.

- The standard UFM hardware tests were performed on the electronics used for the common feedwater header flow measurement. All tests were acceptable.

- For Byron Station, Unit 1, the isometric drawings for the four feedwater loops and the common feedwater header piping were reviewed and the piping was walked down. No significant issues were identified with respect to piping geometry.

- Based on the previously calculated correction factors (CFs) for Byron Station, Unit 1, changes in the calculated CFs were identified which were not experienced in UFM installations at other power plants. A modified UFM configuration file was prepared and installed for the Byron Station, Unit 1 feedwater loops, (e.g. frequencies were modified to re-tune the system for optimal performance). New sets of plant data were collected using the modified configuration file. All the collected data satisfied the acceptance standards for rejection rate and standard deviation conditions.

- A flow oscillation of up to 3% was observed in Byron Station, Unit 1 in several loops. The cause was determined to be the feedwater regulating valve characteristics on each of the four loops for Unit 1 at Byron Station. The UFM system was re-tuned to re-optimize system parameters to accommodate the observed flow oscillations. It was recommended that this issue be monitored with a long continuous run of data collection to determine if there is any correlation between the observed changes in calculated CF and this flow oscillation. This activity has commenced and is further described in the response to Question 2.3.

Based on the above evaluations, it was concluded that the UFM software and equipment were performing properly, within specifications.

1.2 *On Page 9, the licensee identified a Mwe evaluation and toward the end of the letter, discussed other parameters associated with the plant secondary side. Please provide a description of observations and conclusions obtained during those or any other evaluations, including any items that may be consistent with a thermal power level being greater than 100 percent. Include any observations relative to the turbine/generator performance, including but not limited to the overall conversion efficiency of the turbine generator with the assumption that the plant is operating at 100 percent thermal power.*

Response to Question 1.2

Prior to and during the Byron Station UFM installation, concerns were raised regarding implementation of the UFM CFs. Due to these concerns, a number of evaluations were conducted, some focusing on the plant secondary side performance while others focused on UFM installation and performance. The evaluations which focused on the plant secondary side performance and instrumentation identified that the majority of secondary side parameter values were above the values predicted by the thermal models at full power; however, on an individual parameter basis, the values remained within the thermal model and instrumentation uncertainty ranges. No specific conclusions regarding the higher than expected readings were drawn from these evaluations. The multiple evaluations addressing UFM installation and performance concluded that the UFM instrumentation was properly installed and feedwater flow was accurately measured.

The UFM evaluation was undertaken with the UFM vendor and EGC personnel to determine whether the Byron Station, Unit 1 results were caused by measurement errors in the original installation, by some unknown problem with the hardware, or by computer problems. The SCU was checked to ensure that it was within standard calibration and self-test performance parameters. The frequencies were checked to ensure that the best possible signal-to-noise ratios and data capture rate were achieved. A side-by-side installation on Byron Station, Unit 1 Loop D was performed that demonstrated a diverse computer/SCU/MUX/bracket/transducer combination yielded the same results. Apart from this activity, the station studied the instrumentation accuracies and the uncertainty calculation and determined that the implementation was acceptable. The operating experience of other "UFM plants" was researched and no unexplained problems were identified; i.e., the Byron expected increase (in percent) was slightly above the industry average, but well within the range of industry experience. Reviews of vendor data from hydraulic laboratory testing performed for their topical report confirmed that the velocity profile CF was predictable. Additional testing on a straight pipe at Alden Labs provided agreement with the weigh tank within the vendor promoted UFM accuracy. The existing Braidwood Station procedure for calculating and applying the CF was reviewed and determined to be acceptable for use at Byron Station. The original Byron Station testing was done with no insulation over the bracket (i.e., analyzed in the design calculation), while Braidwood Station testing was done with insulation on (i.e., analyzed in both stations design calculations), so an additional Byron Station test was

performed with insulation and minimal differences in the test measurements were noted.

It is also noted that the previous submittal (i.e., letter from Keith R. Jury (Exelon Generation Company, LLC) to NRC, "Byron Station, Unit 1, Licensed Thermal Power Limit Verification," dated February 5, 2003) discussed a unit generation evaluation and a comparison of plant data to the design heat balance. The MWe evaluation was a Byron Station, Unit 1 to Braidwood Station, Unit 1 comparison of test data collected and corrected using American Society of Mechanical Engineers (ASME) PTC-6A, "Appendix A to PTC 6, the Test Code for Steam Turbines," methodology. The result of this comparison is that Byron Station, Unit 1 produces 16.0 MWe more electricity than Braidwood Station, Unit 1. The comparison of plant data to the design heat balance was only performed for Byron Station, Unit 1. The results of this data indicated that many of the plant parameters were higher than the values specified in the design heat balance. Since the MWe evaluation is a comparison between units, and the plant data to design heat balance comparison was only performed on Byron Station, Unit 1, no direct comparison or conclusion can be made between the two types of evaluations.

Equipment reliability issues were reviewed by the turbine/generator vendor as part of the power uprate project and determined to not be an issue. All cases studied provided at least 2% flow margin, although some cases required hardware changes. Key secondary indications were addressed as noted in Byron Station Design Engineering Report 001-00, Revision 2-20-00. PEPSE models for both Byron and Braidwood Stations were independently verified, as well as the models used to predict the expected conditions after implementation. The models were unable to resolve the plant discrepancies.

Following the power uprate project, the different plant behaviors with regard to ability to achieve full thermal power were noted, and a condition report was initiated in the corrective action program to review the situation. The preliminary review determined that the Byron and Braidwood units had been operating at the same power output until the implementation of the UFM, and then changed with Byron Station producing a higher output for the same input. Based on this and fuel burnup as measured by reactor coolant system boron concentration, the reviewers suspected that the plant was operating at a power level higher than indicated but were not able to identify the cause or quantify the amount, and recommended a more in-depth investigation. The results of this further investigation were reported previously in Reference 2, Attachment 1, Item D(1), page 4 last paragraph, and Item 3, pages 10-12 with respect to UFM equipment and CF calculation; and fuel burnup, respectively.

Following a review of 2002 industry operating data (i.e., yearly data from MWth and MWe collected from Platts Nucleonics Week) presented at the 2002 EPRI P2EP conference (i.e., the nuclear thermal performance engineer's conference), it was observed that Byron Station, Unit 1 had the third best gross uncorrected heat rate in the country, (and best for a four-loop Westinghouse Nuclear Steam Supply System

(NSSS) Westinghouse turbine), at 9587 Btu/KWhr. Additional testing is being conducted on Byron Station, Unit 1 as discussed in Question 2.3.

In conclusion, based on the above noted inputs and evaluations, specifically the Byron Station Design Engineering Report 001-00, Revision 2-20-00, Byron Station decided to implement the UFM CFs. Report 001-00 concluded that the ultrasonic flow measurement technology has been proven to be more accurate than conventional venturi measurement devices. The accuracy gains are attributable to the undetectable prompt and gradual fouling of conventional venturis and inherent inaccuracies in the ability to predict scale up from low Reynolds numbers (as tested) to the high Reynolds numbers (from actual temperature and flows) when using ASME nozzle scale up, for conventional venturis.

2. <u>*Questions related to the feedwater flow meters*</u>

2.1 *Included in topical reports Westinghouse has submitted affirming the accuracy of the AMAG CrossFlow ultrasonic flowmeter at a number of nuclear power plants, are comparisons of feedwater flow readings from the UFM with simultaneous readings from the installed venturi-based FW flow meters. Westinghouse notes that the FW venturis tend to defoul upon return to power following an outage, and that the UFM accuracy can, therefore, be confirmed immediately following start-up.*

Please provide all available data showing simultaneous readings or correction factor computations for the venturis and the UFMs upon return to power or at other times when the venturis were known to be clean. Please provide the data, showing the degree of correlation between the two types of flowmeters. If such data do not exist, please provide the staff with information regarding how the data will be obtained. If simultaneous measurements are proposed, the venturi delta-P instruments should be calibrated before taking data, or supplemented with laboratory-grade devices. Please include uncertainty evaluations for the data measurement and acquisition equipment for both the existing data and new data.

Response to Question 2.1

The overall accuracy of the UFM technology is documented in NRC approved topical report CENPD-397-P-A, Revision 01, "Improved Flow Measurement Accuracy Using CROSSFLOW Ultrasonic Flow Measurement Technology", dated May 2000. Most of the collective accuracy assessment includes field data that was obtained during the plant specific installation process (e.g. cross-sectional flow area of a specific pipe). The balance of the accuracy assessment was the estimated uncertainty associated with the velocity profile flow coefficient. As documented in the topical report, the flow coefficient was calculated from classic fluid dynamics equations and presented as a function of Reynolds number. This calculated curve was further validated over a full range of Reynolds numbers with a collection of both laboratory and plant test measurement data. Plant data at a high Reynolds number (Re = 25,000,000) was

obtained by comparing the UFM data to highly accurate ASME flow nozzles that had been recently calibrated and re-installed. This data was collected during plant startup before the onset of significant fouling.

It has not been a past Byron Station practice to collect and analyze UFM data following a refueling outage when laboratory grade instrumentation of known calibration was installed and functioning. Therefore this comprehensive pedigree of plant specific data for Byron Station does not currently exist. At the end of each outage, as the plant reaches 90% or greater power, a reactor coolant system flow measurement (i.e., a precision calorimetric) is performed. This flow measurement procedure utilizes instrumentation that is calibrated within the previous seven days. Prior to the test, at least two of the four feedwater flow meter venturis are visually inspected and if fouling is found all four venturis are cleaned. Following the precision calorimetric, the units ramp to full power and the UFM CF test is performed using normal plant instrumentation. This instrumentation is within its normal calibration cycle of once per operating cycle, but is not recalibrated during the refueling outage since the calibration is performed on line. This on line calibration means that it could be up to nearly a full operating cycle since the instrumentation was last calibrated. The results of CF testing at Byron Station and Braidwood Station are as follows:

Comparison of UFM CF Initial Implementation and Post-First Refueling Outage (RFO)				
Event	Byron 1	Byron 2	Braidwood 1	Braidwood 2
Initial Implementation	0.983175	0.98305	0.993241	0.99415675
Post-First RFO	0.984475	0.985975	0.9977785	0.994596

In addition, the assumption that the venturis and ultrasonic meters should be in close agreement under these conditions is not necessarily true. It is true that venturis may defoul during a power reduction, but it should not be assumed the fouling is always complete. In addition, other mechanisms can contribute to accurate venturi performance such as instrument drift, initial calibration issues, cracked sensing tubes, etc.

Industry data does exist that validates the accuracy of the UFM technology (i.e., specifically the flow profile CF) during plant operating conditions at high Reynolds numbers. This data, which is presented in Figure 4-3 of Topical Report CENPD-397-P-A, provides documented evidence of the meter's accuracy. In each of the comparisons, the facility had verified either prior to or following the test, that the venturis and supporting instrumentation were properly calibrated at the time of the test.

EGC does not currently have plans to change calibration practices or add special laboratory grade instrumentation for venturi differential pressure, feedwater temperature or feedwater pressure instrumentation for the purposes of CF data gathering. EGC is verifying the accuracy of the UFM application at Byron Station as described in the response to Question 2.3.

2.2 *Please provide a complete description of the methodology used to calculate the correction factors. Include the behavior as a function of power.*

Response to Question 2.2

The venturi CF is calculated by taking the ratio of an average of several hours of UFM readings and dividing it by an average of the corresponding venturi readings for the same time period for a manual venturi calibration. Thus, when the venturi readings are multiplied by the CF, the corrected venturi will be in close agreement with the UFM meter.

For the Byron Station, a CF is calculated at least once every nine months for each of the four venturis for each unit, as controlled by the station surveillance program. The revised CFs are then entered into the plant computer, where they are used to correct the venturi flows that are used in the calorimetric.

Normally, the CF is expected to remain fairly constant as power is increased. This expectation is based on the assumption that the UFM meter and the venturi measurements are linear with respect to changes in flow. However, based on a limited amount of data, there are indications that the venturi responses may not be linear, but are changing as the flow is increased. EGC is currently in the process of continually monitoring both the UFM and venturi outputs on Byron Station, Unit 1. Hence, as this data is collected during flow changes, it will be possible to obtain a clearer understanding of the Byron Station, Unit 1 flow instrumentation and the associated flow measurement characteristics.

2.3 *Fluctuations in the CF for Byron appear to be greater than at other plants. It was recommended by Westinghouse to run continuous UFM monitoring for a period of six months to possibly identify the root cause of the fluctuations. Please describe how the CF fluctuations at Byron compared with the CF fluctuations at Braidwood, and how indicated power is affected by the level of CF fluctuation. Describe actions that have been taken in response to the Westinghouse recommendation and what was found to be the root cause of this condition. Discuss the status of corrective actions to resolve this condition, and how the CF fluctuations currently compare between the Byron and Braidwood units.*

Response to Question 2.3

The normal small fluctuations (i.e., variations around a mean value) in the Byron Station and Braidwood Station units' CFs, which are defined in the response to Question 2.2, were observed following the power uprates. However, a shift (i.e., a change in the mean value) in the CFs were observed prior to the uprate. Therefore, EGC has implemented a test program with the intent of determining the root cause of these shifts. The fluctuations in CF are expected to be within the limits for variable fluctuations accounted for in the Westinghouse uncertainty calculation. This fluctuation criterion was met for the last cycle, and the impression about "other plants"

is not substantiated. Continuous UFM monitoring is currently being done at Byron Station, Unit 1 with approximately two and one half months of data gathered to date. Preliminary vendor data analysis shows the CF to be stable (i.e., no shift in CF and well within expected CF fluctuation limits for this period). With an expected gap for the fall 2003 refueling outage, the data gathering will end in December 2003. The root cause is still under investigation; therefore, no corrective actions have been taken to date.

The CF fluctuations at Byron Station, Unit 1 are similar to those experienced at Braidwood Station, Unit 1 when comparing post uprate data (i.e., ±.002, within the limits of the Westinghouse uncertainty calculation). For Byron Station, Unit 2 and Braidwood Station, Unit 2, post uprate CF fluctuations are ±.001 and ±.0008 respectively. The Byron Station, Unit 1 CF decreases over time and generally increases following a trip or refueling outage. The same may be concluded from the Braidwood Station data.

Current Testing Plans

EGC has initiated a project to identify the reasons for the megawatt-electric differences between Byron and Braidwood Stations. The project is designed to investigate long term trends of specific plant performance parameters. Trending of these parameters have historically been recommended, based on industry experience, to determine whether an overpower condition exists. The project also calls for the review the calculational methodologies and will use an additional UFM meter to check both the venturi flow sum and the existing UFM flow sum on Byron Station, Unit 1 and Braidwood Station, Unit 1. Current plans include using this added meter with the existing meters on coastdown for the upcoming Byron Station, Unit 1 refueling outage in the Fall 2003, to observe the effect of changing power on CF. The data gathered will be evaluated and a report prepared. The report will be independently reviewed by a third party.

The current schedule for the project has the data gathering on Byron Station, Unit 1 occurring through the fourth quarter of 2003, including the coastdown and startup data from the Fall 2003 outage. The completion of the six month continuous run data on Byron Station, Unit 1 will be completed by late December 2003. The data will be analyzed in the fourth quarter 2003, the report drafted and reviewed, and the independent review completed in the first quarter of 2004. Corrective actions will be initiated as appropriate.

3. *Question related to the quality of the calorimetric calculations*

Provide information for Byron and Braidwood Stations regarding the methodology of the plants' calorimetric calculations, as well as calibration and uncertainty information for the instrumentation that is used as input to the calorimetric calculation. Include any changes in this information as a result of implementing the power uprate for the units and implementing the UFM for feedwater flow measurement.

Response to Question 3

General Calorimetric Methodology

Calorimetric power level (pre-UFM; for both Braidwood Station and Byron Station) was determined by a calculated steam generator heat balance using the secondary system energy flows into and out of the steam generators in the following general format:

Calorimetric = (Steam Flow * Steam Energy) +
    (Blowdown Flow * Blowdown Energy) –
    (Feedwater Flow Venturi * Feedwater Energy) –
    RCS Incidental Energy Flows
With Measurements of:
    Feedwater Flow, Temperature, Pressure
    Blowdown Flow
    Steam Pressure, Quality
With Calculated Constants for:
    RCS Incidental Energy Flows
Where:
    Steam Flow = Feedwater Flow Venturi – Blowdown Flow

To accommodate a feedwater flow venturi calibration, a new UFM CF was introduced as follows (i.e., post-UFM; for both Braidwood Station and Byron Station):

    Feedwater Flow Correction = Feedwater Flow Venturi * UFM Correction
    Calorimetric = (Steam Flow * Steam Energy) +
    (Blowdown Flow * Blowdown Energy) –
    (Feedwater Flow Correction * Feedwater Energy) –
    RCS Incidental Energy Flows
    Also:
        Steam Flow = Feedwater Flow Correction – Blowdown Flow
        (other parameters as noted above)

Detailed Calorimetric Methodology – Pre UFM Implementation

The calorimetric methodology is explained in detail below. As a high level view, the methodology was the same between stations prior to UFM implementation and the methodology is the same between stations after UFM implementation.

Prior to implementation of the UFM for feedwater flow measurement, the methodology for the plants' calorimetric calculations was contained in the unitized software requirements specification, BD05035, Revision 1.0.6, dated January 21, 1997, that automated the unitized operating surveillance procedures for the "Calorimetric Calculation Daily Surveillance." A prerequisite for this surveillance is that plant conditions, over a five minute time period, are stable. The stable plant parameters include reactor power level, steam generator levels, steam generator pressures, no rod motion, feedwater flow, feedwater temperature, and blowdown flow. Steam enthalpies were determined from saturated liquid and vapor tables using average steam pressure for each loop. Feedwater enthalpy is determined from the compressed liquid steam table using feedwater temperature and pressure. Steam enthalpy is corrected for steam quality using steam quality based on the latest moisture carryover test data.

Feedwater mass flows were determined based on the product of the venturi tap specific feedwater flow constant (i.e., two taps per venturi), the tap specific thermal expansion factor, and the square root of the nozzle differential pressure divided by the specific volume of the feedwater using the compressed liquid steam table for feedwater temperature and steam generator pressure taken at the blowdown tap per loop. The average feedwater flow in kilopounds per hour on a loop basis is the sum of the tap specific flows divided by 2000. Blowdown flows are measured at both the upper and lower taps in gallons per minute (gpm) summed and converted to kilopounds per hour by multiplying the summed flow by 0.00802 (i.e., 60 minute/hr divided by 7.4805 gallons/ft^3 divided by 1000 units/kilo unit) divided by the specific volume of blowdown using the saturated liquid steam table with the average steam generator pressure at the blowdown taps for each loop. Part of the feedwater flow does not go through the venturis, but rather goes through the tempering line for each steam generator. Tempering line flows in kilopounds per hour were calculated on a per-loop basis from the product of the flow indication in gpm from the tempering flow controller and 0.00802, divided by the specific volume of the feedwater, previously determined. The net feedwater flow per loop is the sum of the venturi average flow and the tempering line flow.

Loop thermal power in British Thermal Units / hour (BTU/hr) was computed as net feedwater flow minus blowdown flow multiplied by steam enthalpy plus blowdown flow multiplied by steam generator liquid enthalpy minus net feedwater flow multiplied by feedwater enthalpy minus 13652000 (i.e., the reactor coolant pump heat input and ambient loss term). All four loops are summed to get the "sum loop power". Percent power is calculated as the sum loop power multiplied by 100 divided by 11.6417E+09 BTU/hr. The calculation is performed using 10-minute averages (i.e., based on the

latest 10 one-minute averages), 60 minute averages (i.e., based on the latest six ten-minute averages) and eight-hour averages (i.e., based on the 48 latest 10-minute averages). The methodology noted above is also reflected in the "Hand Calculated Calorimetric Surveillance" procedures.

Detailed Calorimetric Methodology – Post UFM Implementation

The above noted document (i.e., software requirements specification, BD05035, Revision 1.0.6) was revised in April 1999 as a general revision (i.e., Revision 2.0) to accommodate the use of feedwater UFM and improve readability. The document was revised to, "Requirements Specification, SE0001." All input points were collected into Appendix A of SE0001. The prerequisites for the calorimetric daily surveillance were as previously noted, with the exception of blowdown flow, and were collected into Appendix B of SE0001. Blowdown flow stability was revised from ±1.0% to ±10.0% based on an existing evaluation that ±10% was acceptable for use in the calorimetric package. The calorimetric calculation was collected into Appendix C of SE0001. Changes were made to the software specification to enter constants in addressable cells rather than as constant numbers in the calculation (e.g., steam quality, which may change at the next moisture carryover test, became an addressable cell), to minimize the number of formal software changes needed in the future. The addressable locations are also identified in Appendix C of SE0001. The venturi thermal expansion factor was revised to match the ASME fluid meters curve over the region of interest per Byron Station setpoint scaling change request (SSCR) 98-021. Venturi flow was changed to be the same as previously calculated for each tap multiplied by the loop UFM flow multiplier constant divided by the square root of the feedwater venturi delta-pressure (DP) transmitter full scale constants. This latter term was added as derived in the post-UFM version of the "Calorimetric Calculation Techniques and Sensitivity Factors for Byron/ Braidwood Calorimetric" discussed below. The last term of the reactor thermal power per steam generator was revised to be the reactor coolant pump and miscellaneous heat multiplied by the conversion factor from BTU to MWH divided by 1000 (i.e., conversion of units to kilo units). Total reactor power in megawatts is the sum of the individual steam generator thermal powers in kilowatts, divided by 1000 kilowatts/megawatt. Percent reactor power is the sum of the steam generator thermal powers multiplied by 100 multiplied by the conversion factor from BTU to MWH divided by 1000 (kilo to mega units). Data uses the same averages as before. As before, the methodology noted above is also reflected in the "Hand Calculated Calorimetric Surveillance" procedures which are used when the computer is unavailable.

Calorimetric Sensitivity/Accuracy

The methodology described above and the sensitivities of the calculation methodology was documented before UFM implementation in calculations, NED-0-MSD-8, Revision 0, “Sensitivity factors for Byron/ Braidwood Power Calorimetric,” and NED-0-MSD-10, Revision 1, “Byron/Braidwood Power Calorimetric.” Calculation NED-0-MSD-10 was superseded and the contents included in calculation NED-0-MSD-8, Revision 1, “Calorimetric Calculation Techniques and Sensitivity Factors for Byron/ Braidwood Calorimetric.” Note that these calculations apply to both units at both sites.

Calculation CN-FSE-99-151, Revision 0, is the current calculation of record for the Byron/Braidwood net heat Input. This calculation was put in place for the power uprate project. Net heat input is 16.65 megawatts-thermal (MWt) for Byron Unit 1, 16.53 MWt for Byron Unit 2, 15.03 MWt for Braidwood Unit 1, and 15.91 MWt for Braidwood Unit 2. Prior to uprate, these values were 16.6 MWt/unit.

The calorimetric accuracy was calculated before UFM implementation in calculation NED-1-EIC-0233, Revision 0, “Daily Power Calorimetric Accuracy Calculation.” This calculation evaluates the channel error associated with the Byron/Braidwood daily power calorimetric under normal operating conditions. Included in the loop evaluation are the feedwater flow transmitters, the feedwater temperature elements, the tempering line flow transmitters, the blowdown flow indicating transmitters, and the steam pressure transmitters. Flow elements are analyzed per the methodology of ASME PTC 6 Report – 1985; and the methodology used for the calculation was that presented in Commonwealth Edison Standard, TID-E/I&C-20, “Basis for Analysis of Instrument Channel Setpoint Error and Instrument Loop Accuracy,” Revision 0; and TID-E/I&C-10, “Analysis of Instrument Channel Setpoint Error and Instrument Loop Accuracy,” Revision 0.

Post-UFM implementation, the calorimetric accuracy was calculated in calculation NED-1-EIC-0233, Revision 1, “Daily Power Calorimetric Accuracy Calculation.” The methodology used was revised to incorporate the methodology of NES-EIC-20.04, Revision 0, ”Analysis of Instrument Channel Setpoint Error and Loop Accuracy.” Further, the calculation incorporated current station procedures and evaluated feedwater flow and total reactor thermal power accuracy to address possible use of a UFM device to adjust computer venturi feedwater flow readings. In addition to the instruments listed in the pre-UFM calculation, feedwater flow elements, flow indicators, and flow differential control stations were listed for feedwater flow in the calculation. Similarly, tempering line flow elements and flow control stations were listed in the calculation. For blowdown flow, the flow elements and some additional flow indicating transmitters and flow indicators were also listed. For steam pressure, some additional pressure indicators were listed. The total error 2σ confidence level for calorimetric uncertainty for Byron Station is ±1.72% for venturis and ±1.56% for the UFM. For Braidwood Station, the corresponding values are ±1.79% and ±1.63%,

respectively. Calculation NED-1-EIC-0233, Revision 1, lists the surveillances and plant procedures that were impacted.

As a result of the power uprate, no changes to the feedwater flow portion of the on line calorimetric or uncertainty calculation were required. Westinghouse provided new unit specific constants for RCP net heat input (i.e., a minor change), and new constants for steam generator quality (i.e., moisture carryover) were implemented based on post power uprate test results (i.e., a minimal change). The changes are as follows:

a. Unit 1 S/G Quality – no post power uprate testing, no change

b. Unit 2 S/G Quality – pre-power uprate: 0.9992; post-power uprate: 0.9988

c. Unit 1 RCP Net Heat – pre-power uprate: 4.15 MWt/SG; post-power uprate: 4.1625 MWt/SG

d. Unit 2 RCP Net Heat – pre-power uprate: 4.15 MWt/SG; post-power uprate: 4.1325 MWt/SG

The uncertainty calculations, methodology, and software specifications are thus demonstrated to be the same between the Byron Station and Braidwood Station units before and after UFM implementation. Minor changes were made as noted above to the calorimetric as a result of the power uprate.

4. <u>Questions related to other secondary side equipment</u>

4.1 Describe and explain any changes in the turbine efficiencies at Byron prior to and following UFM implementation. Provide the same type of information for Braidwood. Also describe and explain any differences in turbine efficiencies between the Byron and Braidwood units prior to and following UFM implementation.

Response to Question 4.1

Turbine design efficiencies prior to the power uprate (and prior to UFM implementation and after UFM implementation) are given in Westinghouse report, "Thermal Performance Data for 13A4931 Commonwealth Edison Byron Units 1&2 - Braidwood Units 1&2." The design efficiencies are the same for all four units.

Following power uprate, the Byron Unit 1 and Braidwood Unit 1 turbine design efficiencies are given in "Thermal Performance Data for Commonwealth Edison Byron Unit 1 - Braidwood Unit 1" Siemens Westinghouse Power Corporation S.O. 13A4931 - 13A5011. The design efficiencies are the same for both units.

Following the power uprate, the Byron Station, Unit 2 and Braidwood Station, Unit 2 turbine design efficiencies are given in "Thermal Performance Data for Commonwealth Edison Byron Unit 2 - Braidwood Unit 2," Siemens Westinghouse Power Corporation S.O. 13A4941 -13A5021. The design efficiencies are the same for both units.

<u>Heatrate Data</u>

The following table documents the changes in heatrate and UFM CF for each of the Units:

Unit	Heatrate			
	Before UFM Implementation	After UFM Implementation	Change in Heatrate (%)	Change in Feedwater Flow Due to UFM (%)
Byron U-1	10,044	9,875	1.68	-1.68
Byron U-2	10,053	9,872	1.80	-1.70
Braidwood U-1	10,059	10,008	0.51	-0.68
Braidwood U-2	10,225	10,160	0.64	-0.58

From this table, it can be seen that there is a strong correlation between the change in heatrate and the change in indicated feedwater flow using the UFM. Hence, it is concluded that the change in heatrate was essentially due to the change in feedwater flow and not due to any changes in turbine efficiency.

The corrected gross heatrates mentioned above were generated from daily average reactor power, gross generation, and circulating water inlet temperature. The reactor power and gross output was converted to unit heatrate and was then corrected to design circulating water inlet temperatures of 90°F using a heatrate correction curve. No other corrections were made for the above data.

4.2 *Describe and explain any differences in the turbine governor and throttle valves between the Byron and Braidwood units. Were these valves originally purchased as identical valves for Byron and Braidwood?*

Response to Question 4.2

The high pressure turbine throttle and governor valves were originally purchased as identical equipment. Currently, as valves are replaced during refueling outages for preventive maintenance, the refurbished valves could end up in any valve location at any Byron Station or Braidwood Station unit. There are no design differences in the turbine governor and throttle valves between stations.

4.3 *Were any modifications made to the turbine governor or throttle valves (or to the turbines) prior to, in conjunction with, or subsequent to power uprate?*

Response to Question 4.3

There were no modifications to any Byron Station or Braidwood Station main turbine governor or throttle valves prior to, in conjunction with or subsequent to power uprate. The Unit 1 high pressure (HP) and low pressure (LP) turbines and Unit 2 LP turbines at Byron and Braidwood Stations are unchanged from original design. The Unit 2 HP turbines were modified in conjunction with power uprate the same way at both Byron and Braidwood Stations.

Both Unit 2 turbines at Byron and Braidwood Stations had blade stages removed from the high pressure section. This modification was necessary since the Unit 2 steam generators were of an older design and delivered a lower steam pressure to the turbine. Removing blades reduced the resistance to steam flow and enabled these units to pass steam at a rate corresponding to the uprated 100% power level. All turbine elements at Byron and Braidwood Stations were structurally enhanced to improve their life at the higher uprate steam flows. All turbines at Byron and Braidwood Stations received identical modifications.

The documentation of the impact to thermal efficiency is noted in the response to Question 4.1, above.