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SUBJECT: Responds to NRC request to submit comment on NMP petition to extend Unit 1 operating period from 10,600 hours to 14,500 hours before insp of core shroud.

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3 December 1998

Darl Hood

Office of Nuclear Reactor Regulation

Nuclear Regulatory Commission

Washington, DC

Dear Mr. Hood,

I attended the public meeting held on 24 September at SUNY-Oswego to discuss the Niagara Mohawk petition to extend the Nine Mile Point One operating period from 10,600 hours to 14,500 hours before inspection of the core shroud. At that meeting I raised several concerns and technical issues pertaining to the core shroud study performed by Niagara Mohawk and to the NRC safety evaluation of Nine Mile Point One. This letter is in response to your request to submit my comments in writing.

I will begin the letter with a discussion of issues of scientific integrity, ethics, and safety analysis. I will conclude with a review of several technical errors I have found in your report, "Safety Evaluation by the Office of Nuclear Reactor Regulation Regarding the Results of the Reinspection of the Core Shroud, Niagara Mohawk Power Corporation, Nine Mile Point Nuclear Station, Unit 1, Docket No. 50-220". 33095

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To provide some context to my comments I would like to begin by relating my educational background. I received both my SB and PhD in physics from MIT. My graduate work was in nuclear structure physics, specifically using electron scattering to probe nucleon-nucleon interactions at high momentum transfer. I graduated in 1993 and am currently a research associate at Syracuse University.

The nuclear power and nuclear regulatory community in the US is a rather small group, and their work is highly charged with political and economic forces. A group of scientists and engineers should in principle adhere to the research goals of principled objectivity and of following the scientific method. But the unfortunate reality is that economic and political pressures can and have influenced the conclusions of scientific studies. This problem is particularly acute in areas such as the medical field where the outcome of a study can translate into large financial or career gains. I believe that the nuclear industry faces similar pressures and that any report issued or supported by that community should be reviewed with intense scrutiny to prevent any bias from coloring the results.

In regard to the recent petition, Niagara Mohawk has based their arguments for an inspection delay on the conclusions of a study performed by General Electric. General Electric built the Nine Mile Point One reactor and they are a manufacturer of reactor fuel rod assemblies. Their clear financial interest demonstrates an obvious conflict of interest. In addition General Electric's record for technical integrity is less than stellar – the most notorious example being the 1989 report that GE was using substandard bolts when manufacturing aircraft engines for the DOD. GE initially denied these reports that were later found to be true. Curiously the news reports were aired on ABC and CBS but were absent from NBC, a subsidiary of GE.

While I do not claim that the report issued by GE includes any biased results, given GE's conflict of interest in this case, I believe that their report should only be utilized by the NRC if a parallel study of equal scope was performed as well.

Secondly, I would like to focus on the difficulty of performing a proper safety analyses. As physicists and engineers we are trained how to calculate probabilities even for very unlikely events. However, your job as a regulatory agency is complicated by the fact that you must weight each possible event by its impact or possible damage to the community. Simply from a mathematical

perspective this is a difficult calculation since you are multiplying a small number (the probability of a rare event, for example the core shroud distorting to the point where it impinges upon the fuel rod assemblies) times a large number (the damage caused if the operator lost control of the reaction). Each of these numbers has an associated error that results in a wide range of possible outcomes. Finally we must define a level of acceptable risk and the method by which that level should be determined.

In the particular case of the core shroud cracking, the NRC faces a difficult task in that the shroud cracking is not a well understood problem. Nor has a full analysis yet been done to determine the associated risk factor as a function of the extent of shroud cracking. This risk factor would of course have to include both the direct impact from the cracking and the more indirect effects when the cracking is combined with other instrument degradation. Finally this risk factor must be compounded by the probable cost of a resulting accident. The limiting cases are trivial: if the shroud is at full structural integrity there is no risk and no cost, and if the shroud has lost its integrity then the risk of it impairing the core operation and inducing a meltdown is high and the cost is enormous. Unfortunately we are now in that uncertain and uncomfortable middle ground. It is your role to perform the study to calculate that risk factor for all reasonable scenarios. This task is admittedly a daunting one. A reasonable person might even be tempted to neglect doing this work by assuming that we are still within the low risk regime. However the costs resulting from an accident are so extreme that we cannot delay in performing this evaluation, nor can we be so cavalier as to assume that this study would be unnecessary. Before such an assessment is complete, we are proceeding either in ignorance or with limited intuition. One might reasonably argue that without knowing the risk involved we should shut down the reactors. However if we do choose to proceed we should do so with extreme caution and by assuming the most conservative model for the cracking. In the particular case being argued at the public meeting, debating over factors of two in the crack growth rate before that growth rate has even been measured, is an unwise and unsafe strategy. Only when the growth rate has been conclusively measured and well modeled should we feel justified and safe in assuming a less conservative value.

Third, I will review issues regarding the use of theoretical versus empirical modeling. A complex system, by which I mean any system where there are several competing dynamics, and

especially when these processes are nonlinear, is extremely difficult to model. Any good scientist can construct a model for a laboratory test where a single effect is measured and all other parameters are kept fixed. However combining several processes into a realistic model requires extensive knowledge about how these various processes interact. And that model, no matter how refined, is worthless unless it explains and predicts the data. At present, despite extraordinary gains in science and engineering, the world is full of complex systems that the scientific community can only model empirically.

My point here is that it is **the data from a complex system** which allows us to test our theoretical models or develop an empirical model. Data from laboratory tests which examine a single factor help us in developing a theoretical model, but taken alone that data does not replace direct measurement on a complex system. In regard to the core shroud at Nine Mile Point One, there have been two measurements done on the core: the measurement of crack length done in the Spring of 1997 and the analysis performed on the two boat samples which was submitted to the NRC in January 1998. This data provides a snapshot of the level of cracking in the core. However, we are interested in knowing the crack growth rate. To determine the crack growth rate requires several measurements of the crack size at various times. We should not assume that the growth rate would be linear. The fundamental data necessary to test our theories about the core shroud cracking does not exist. That data is only obtained by performing repeated measurements of the core shroud crack size over the next several fuel cycles. Without that data our models are only conjectures. With the scant data that currently exists I would, as an experimental physicist, say that we know very little about the core shroud crack growth rate.

At the 24 September meeting a Niagara Mohawk representative made the statement that there are actually two measurements of the crack size since we can take as given that the cracks were of length zero when the shroud was installed. This data is only relevant in establishing an average growth rate over a long time period. The instantaneous growth rate can deviate significantly from the average rate. Moreover since one expects the initial crack growth rate to be nonlinear, then this "initial measurement" of zero crack length, is practically irrelevant. To illustrate this point we consider the data on core shroud cracks at Nine Mile Point 2 (NM2). The NM2 core shroud was inspected in October 1993 and found to have no perceptible cracks. An inspection on 2 June 1998

found cracks ranging from 0.25 – 0.65 inches deep over about 60% of the vertical welds. This data would indicate an average growth rate of $0.6 - 1.6 \times 10^{-5}$ inches/hour for 100 % operating time. The water conductivity was less than 0.20 μS/cm for the whole first 3 cycles. I should note that this average growth rate at the given water conductivity is not very different from the instantaneous growth rates predicted by Niagara Mohawk at this level of water conductivity. Nine Mile Point One (NM1) had water with higher conductivity for much of its operating life and should have thus sustained higher crack growth rates, yet even if its crack growth rate had been as low as the average rate for NM2, the NM1 welds should have cracked through entirely by now. They have not. Therefore the average and instantaneous rates must be different.

My final comment on modeling concerns the Niagara Mohawk conclusions regarding the method of cracking. The NMPC study concludes that the core shroud cracking is basically intergranular stress corrosion cracking (IGSCC). Since I am not a material scientist I will take as given that the boat samples have the fracture pattern indicative of this method of cracking. I will also assume, for now, that we understand that the crack growth rate is primarily a function of the stress intensity in the material and the water chemistry. Given this knowledge it should be possible for NMPC to use their history of water chemistry and current level of cracking to model the stress intensity in the shroud and see if it provides a self-consistent picture. A more in-depth model is truly what is required. Simply quoting crack growth rates does not do justice to the complexity of the problem. For example, let us assume a crack growth rate of 2.2×10^{-5} inches/hour which is the value cited in the NMPC report. The crack depth along vertical weld 9 (V9) has been measured to be 82% of the wall thickness or 1.23 inches. At the assumed growth rate that crack should have formed in 6.4 years. That crack, which extends for at least 70 inches along the weld, should have grown to this length in 363 years. These numbers are seemingly ridiculous because the model for crack growth is a great deal more complex than a simple linear rate calculation. One has to model the nonlinear processes of crack formation and crack growth when the material ligature is small compared to the crack dimensions. To truly prove that they understand the problem, NMPC should make a predictive model that can match several crack size measurements over a range of time. Without a realistic model and with such scant data, I believe it prudent in the near future to assume the NRC's upper bound crack growth rate of 5×10^{-5} inches/hour. In addition a more

detailed model should be required within the next few years to assess the associated risk factor of the core shroud cracking and to determine when the shroud's structural integrity is likely fall below the ASME standards.

I would like to conclude my letter by focusing on the NRC report entitled "Safety Evaluation by the Office of Nuclear Reactor Regulation Regarding the Results of the Reinspection of the Core Shroud, Niagara Mohawk Power Corporation, Nine Mile Point Nuclear Station, Unit 1, Docket No. 50-220". This report contained several basic math or conceptual errors which left me seriously questioning the technical ability of the authors of the study. Let me focus on a few of the errors.

- Page 5, final paragraph: The report discusses how the systematic error is calculated for the measurement of the crack length. The crack length is measured by determining the position of each end of the crack using a detector. The detector is positioned using a delivery system. Let us declare, a, the position of the detector according to the delivery system, and, b, the position of the crack end as measured by the detector. In this case the crack length is given by $l=(a_1+b_1)-(a_2+b_2)$ where the subscripts refer to the measurements for a given end of the crack. In this case the resulting error in the length is given by $\sigma_l=\sqrt{2\left(\sigma_a^2+\sigma_b^2\right)}$ where σ_a and σ_b are the errors in a and b respectively. Using the errors cited in the report, $\sigma_a=1.106$ and $\sigma_b=0.364$ inches, yields a length error $\sigma_l=1.647$ inches which is about half the figure given in the report. The author assumed that $\sigma_l=2\left(\sigma_a+\sigma_b\right)$ which is incorrect.
- Page 6, first paragraph: The EVT (enhanced visual test) error is given at 1.2 inches. I will assume that this error was calculated correctly although I am left wondering if it does not suffer from the mistake noted on page 5. Nonetheless, while the error is first listed as being the error in the length, in the next sentence the author then calculates the total measurement uncertainty as 2.4 inches. I will assume that the author means for the first error to be the error in determining the end of the crack. In this case the crack length error is $\sigma_l=1.7$ inches. In any case $\sigma_l\neq 2.4$ inches. The author then makes the egregious mistake of adding the error to the value of the measured crack length. Values and errors are two entirely separate types of objects

that obey completely different mathematics. For those unfamiliar with the basics of error analysis let me recommend that you read *Data Reduction and Error Analysis for the Physical Sciences* by P. R. Bevington. This book teaches the well founded and proven method for propagating errors through a calculation. When one simply adds the error to the value, as was done in your report, then that value is wrong and all further calculations done using the value are wrong as well. And, even though the error may have been added to the crack length to yield an upper bound, that does not imply that all further calculations done using this length value will yield the most conservative value (i.e. consider the crack growth rate in this case, or any case where errors are not constant for all data).

- Page 6, Section 3.3, Paragraph 4: The authors note that NMPC was unable to detect welds V5 and V6 using their current detection methods. They also point out that the tie rod repair loses its effectiveness if these welds are completely cracked and welds H2 and H3 are completely cracked. I find it surprising that this point is passes over so lightly. One of the two major points that the NRC report addresses is the failed tie rod repair. If these welds are significantly cracked then the tie rods lose thermal preload. In addition since the ring segment is mounted normal to the direction of tie rod stress, these welds will be stressed due to the torque from the tie rods and will thus be subjected to higher crack growth rates. NMPC should model how the stress from the tie rods will effect crack growth rates in the vertical welds. The authors conclude this discussion by stating that inspections reveal that the cracks in weld H3 were not extensive enough to inhibit safe operation. However the report on the weld inspection, given in Appendix C, showed that weld H3 was not inspected (or the results were not listed in the report).

- Page 8, Paragraph 2: The author is discussing the crack growth data from the Brunswick BWR and comparing the crack size measured using UT during two successive refueling outages. The author notes "that there was no change in length or depth" which is a meaningless statement in the context of a measurement where the error in the detector reading is twice as large as the expected signal. Let me explain. If we assume a typical fuel cycle of 14,000 hours and a crack growth rate of 5×10^{-5} inches/hour, then we might expect a crack length increase of about 0.7

inches. However as noted above the length error is $\sigma_l = 1.647$ inches for the method used by NMPC. I will assume that the method used for the Brunswick measurement was of similar accuracy to the method used by NMPC (if not then questions arise as to why NMPC would use a less accurate method). Since the error is large compared to the expected signal one MUST cite the error to understand the measurement. Even if the exact same length and depth were measured the crack may still have grown. In fact by assuming the values for the length error and the fuel cycle duration the error in crack growth rate would be 16.64×10^{-5} inches/hour or 3.3 times the NRC limit of 5×10^{-5} inches/hour.

- Page 8, Paragraph 2: "At NMP1, no field data on crack growth are available for vertical welds. Of the horizontal welds, field data are available only for the H8 weld." This fact alone should be the cause of great concern to the NRC for without data from the system in question we can not truly say we understand the system. Gathering more data on NMP1 core shroud crack size should be of paramount importance to both the NRC and NMPC.

- Page 8 Paragraph 2: The single measurement on crack growth rate was performed on weld H8. The depth of the crack measured during the 14th fueling outage was less than that measured during the 13th fueling outage. NMPC drew no conclusions about this data and the NRC simply went along with the industry's erroneous thinking. Once again the NRC neglected the importance of the relevant error analysis in this case. When the measurement errors were considered was the data within the error. If not then how different was the measurement in terms of the error (e.g. 1σ? 2σ?) If there was a large deviation then the NRC should be concerned that the detector error being reported by the NMPC is too small. Conversely if the data was within the error then the data should not be disregarded for it is useful data which implies a range of possible growth rates. One is always left to wonder when data is disregarded whether such exclusion is done justly or whether it is excluded because it does not conform to the experimenter's preformed conclusions. The NRC need to be especially watchful of such tainted science when dealing with scientists who may be under pressure to achieve a conclusion which benefits their employer.

- Page 11, last paragraph: The allowable vertical weld flaw size is being modeled assuming that the horizontal welds are cracked through wall. The last sentence reads, "Typically, the allowable crack sizes are large and approach or exceed the length of the weld itself." What exactly does it mean when the allowable crack size is larger than the weld itself? If the model truly allows for such unphysical results then the relevance of the results of that model should be seriously questioned.

- Page 13, Section 4.2.4: This section discusses the NRC staff's independent calculation for the largest acceptable axial flaw. According to the authors the NRC performed a calculation for the bounding final crack length and found it to be slightly larger than would be allowed assuming both LEFM failure mechanism and the ASME criteria. Since the authors do not cite any numerical results the reader has no way of assessing the validity of their conclusions. Nevertheless the NRC notes that NMPC also obtained a similar result when they performed their calculation assuming that the cracks were through wall and that the horizontal welds were fully cracked. The authors then noted that a more detailed NMPC calculation, which included the additional strength from partially cracked welds, was within the ASME safety standards. They then jump to the conclusion that if they performed a similarly more detailed calculation that their results would also fall within the safety requirements. The authors *may* be right, but it is the responsibility of the NRC to *do* these calculations and not speculate what the results *might* be. It is the NRC's job to perform the necessary safety calculations to ensure that the public's safety is being protected.

- Page 14, Section 4.3.1: There is a math error in calculating the crack area. It states that a crack has an area of 3 square inches for a 0.003 inch wide and 90 inch long crack. Assuming the crack to be 0.003 inches wide, the correct area is 0.27 square inches. The leakage rates should be reduced by a similar factor although this will not effect the conclusions drawn in this section of the report.

- Page 17, Section 5.2.1: In this section the authors review the condition of the tie rod assembly which had been in place for a single fuel cycle. A great deal of interest is placed on the tie rod at

270° which had vibrated loose and was thus not providing the full design tension. Indeed the updated design was intended to remedy this defect. However I was alarmed to learn that the clasp at 90° had snapped and that part of the clasp was thrown over to 330°. In any engineering design, one expects that the hardware will be designed to withstand stresses at least double the maximum expected stress. I would assume that in a nuclear reactor the safety margin should be even higher. Why then did that clasp snap? Was the material of poor quality? Was the calculated stress too low? How did this flaw get past the initial NRC review? These are serious questions which are not addressed and leaves one in doubt concerning the design's revision.

- Page 17, Section 5.2.5: NMPC reported that the tie rod at 270° had loosened because the base of the rod was not correctly seated in the tie rod anchor on the apron of the core shroud. As part of the design revision they recommended a new installation procedure which, they said, would insure that the rods were properly seated. However two paragraphs later the NRC notes that upon inspection after installation NMPC found that the tie rod middle support at 90° and 166° was no longer in contact with the RPV. They attributed this loss of contact to "movement of the lower support assembly up the cone toward the shroud." It is just such movement that the new installation procedure was supposed to eliminate. This description suggests that the new design does not correct for the loosening problem.

I am deeply concerned in reviewing your report that you have not implemented enough oversight to prevent conflict of interest from tainting your technical conclusions. I am also disturbed at the numerous errors in basic experimental analysis that exist in your report. If you have made such frequent mistakes in the most basic error calculations, what then should I reasonably assume about your more complex calculations? And how should I feel about your competence in your role as the public agency charged with performing technical oversight of the nation's nuclear industry? If this oversight is compromised, then would not reactor safety and the

public health both be at risk? I await your response and do sincerely hope that you will demonstrate that my conclusions regarding your competence and the associated risk to public health are in error.

Sincerely,

Dr. Steven Penn

Cc: David Lockbaum, Union of Concerned Scientists