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BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
NORTHEAST NUCLEAR ENERGY COMPANY, *et. al.*	)	Docket No. 50-336 OLA (Spent Fuel Pool Design)
	)	
(Millstone Nuclear Power Station, Unit 2)	)	

CCMN's SUPPLEMENTAL RESPONSE TO NRC STAFF, AND NNECO, INTERROGATORIES AND REQUEST FOR PRODUCTION OF DOCUMENTS.

CCMN'S RESPONSE TO THE ORDERS OF MARCH 15 AND 25, 1993 BY THE ATOMIC SAFETY AND LICENSING BOARD.

By letters dated February 11 and March 9, 1993 CCMN answered all but #5, #6(b), and #7 of NRC December 9, 1992 interrogatories.

NRC's questions #5,6(b) and #7 were to have been answered by Dr. Kaku in NNECO's oral deposition of him in New York on February 22. Counsel for NNECO had to cancel on that day and the March 22 reschedule date was unsuitable for NRC counsel. Dr. Kaku mailed his responses to NNECO's interrogatories on March 31, 1993 to the ASLB, NRC and NNECO. His response to NNECO should encompass NRC questions #5, 6(b) and in part #7 though they were not specifically addressed by number.

In NRC's 2nd motion to compel discovery, NRC perceived deficiencies in CCMN response to questions #2,#3, #5, #6, #7.

We expect Dr. Kaku's response to NNECO's interrogatories (attached) to address NRC's questions #5,#6(b), and #7.

#2(b): To clarify CCMN's response of March 9th, Mary Ellen Marucci will testify on information made available to her or to CCMN through NRC, NNECO and others that show inconsistencies and contradictions in practice and regulation. By this method she expects to show now certain processes used by NRC and NNECO to assure safe pool conditions are arbitrary, inconsistent, contradictory, or otherwise unreliable.

#3: We could not obtain from NU or CE the names of people who worked directly on the criticality calculations for Millstone 2 pool. A person, whom we will not name at this time because of the meaninglessness of the current practice of whistleblower protection laws, has told us that much more degradation was observed than was expected by Northeast Utilities or the NRC when

the boxes were pulled for inspection from the Millstone 2 pool. He indicated that this information is known to the NRC and NU, and should be available. If that is so and the information is released to CCMN through discovery we have no need to rely upon his testimony. The treatment of whistleblowers by NNECO and NRC has put a chill on those with concerns within the industry. We cannot expect under the current climate to depend on concerned workers speaking out. Therefore it is imperative that an open information policy at these nuclear "power" plants and from within the NRC exist.

NNECO and NRC requests to compel CCMN to answer discovery, NRC request to strike CCMN responses, and ASLB order of March 15 to compel CCMN to respond and on March 25 refusing to accept CCMN's March 9th response to NRC, has the appearance of forcing CCMN to comply while at the same time rejecting CCMN's responses. CCMN has to the best of its ability and limited resources made an honest attempt to respond to all requests. NNECO's General Requests have not been answered in the format requested but the information required by NNECO G-1 through G-7 is in the response and supplemental responses submitted on February 11, March 9th, March 31, and April 3. CCMN does not have access to top law firms or a staff of attorneys as does NNECO, but is doing the best it can to comply with the demands made of it.

NNECO's Specific requests have been more than adequately responded to by Dr. Kaku in his March 31st declaration.

These actions by NRC and NNECO counsel and the ASLB make it seem impossible to get a public hearing without lawyers to assist through the legalese.

Should CCMN interpret these actions to be based on a presumption that the other parties believe CCMN to know something that it is not sharing? Maybe it is assumed that CCMN has not answered correctly NRC and NNECO requests because information is not being brought forward that they believe CCMN has in its possession? Is it possible that NRC, NNECO and ASLB think CCMN intends to spring something unknown on the parties if and when this pool design gets a public hearing?

If it hasn't been apparent from the beginning, let it become so now: CCMN's concerns are with the over-optimism and lack of oversight in methods used to prevent supercriticality and other potential spent fuel pool disasters. CCMN found indications of such optimism and lack of oversight in documents produced by NRC and NNECO prior to December 1992, and has found at least one more instance in the material recently acquired through discovery. NU's intention to place spent fuel under blocks that had been required by license specifications to be empty blocked areas so the space would act as neutron flux traps (assuming that the space contained borated water.) No mention was made that NU

would seek a license amendment to begin this procedure or how k_{eff} would be maintained at or below the mandated level.

Inconsistencies and contradictions were found in the documents provided to us by NRC and NNECO prior to December 1992. Because of our seriously limited resources, including volunteer time, we have not finished reviewing material made available to us since then, but are aware of at least one new instance of an arbitrary and contradictory practice. This practice is referenced in the previous paragraph. Information that CCMN believed was not available to the ASLB was sent on February 11,1993 and on March 9th to all parties.

Below are listed some of the inconsistencies we were aware of before December 1992 which will be addressed by Mary Ellen Marucci and Michio Kaku.

I: Safety vs Cost

Northeast Utilities claims to put safety first, yet refuses to place neutron flux monitors in its Millstone 2 pool because it lacks an assured method of reclaiming the cost from the ratepayers and therefore the cost, whatever it is, is too much. Source: NU July 15, 1992 meeting.

II: Highly Radioactive Spent Fuel Placement

Millstone 1 places freshly downloaded spent fuel in area of pool that does not contain Boraflex in order to reduce the radiation damage to the boraflex, and Millstone 2 does not, even after miscalculations placed Millstone 2 out of compliance with K_{eff} safety standards.
See Amendment #158 and Millstone 1 operating report, and CE 2-14-92 letter.

III: Circulation of Pool Coolant Water

a. Pumps are not upgraded when the pool capacity is increased 10 fold. See License amendments issued in 1986 & 1988.

b. Former emergency cooling procedures are allowed to be considered supplemental to meet the increased pool cooling needs under certain anticipated normal conditions with increased use.

c. In refueling and other movement into and/or through pool, the NRC requires the PRACTICE of maintaining a specific level of boron in the circulating water, yet continues to state that boron in coolant water is not used in the <u>CRITICALITY ANALYSIS</u> to insure Keff remains below .95.

d. We have been told the PRACTICE at Millstone 2 pool is to ALWAYS maintain boron in the circulating water. Why? The NRC

has refused to tell us what the actual practice is for boron concentration in the Millstone 2 pool, and just quotes their technical specifications. Why are there requirements to have boron since no credit is given for it to maintain a theoretical K_{eff} below .95. Would exceeding plant specifications for boron levels indicate an Industry distrust for the theoretical basis for K_{eff}? How much, how often, when, and why are boron levels above requirements? Were these elevated levels related to situations that made NNECO unsure of what K_{eff} really was in that pool?
See Millstone 2 specifications for fuel movement in pool; NRC response and objections to CCMN question # 4 of 1-12-93.

IV: Boraflex Reliability

The manufacturer only guarantees the material to operate as described for five years, yet Boraflex has been installed to prevent criticality at Millstone 2 for the total period that pool will be in use which has yet to be determined. The boraflex has been in use at Millstone since 1986 (about 7 years), and was showing deterioration as early as 1990.
See E.J. Mroczka letters to U.S.N.R.C. dated August 7, October 1, 1990.

V: K_{eff} Calculations

Considering the problems associated with forming a reliable guesstimate of how much reactive and radioactive material the pool can hold, why have the NRC and NNECO used configurations that require accuracy within a few percent, or suffer us a supercriticality in a pool containing over 1 billion curies.

Since NNECO is allowed under NRC license to put more than a billion curies of radioactive materials in such proximity as to risk supercriticality, which, if such risk were realized, would have disastrous effects for thousands of years on all of the Northeast, we think it fair and just that a Public hearing be held where these questions can be publicly addressed. <u>The public needs to know</u> why the NRC considers this pool configuration safe enough not to have warranted a public hearing prior to allowing it to operate under the contested license change. The public also needs to know how the NRC and NNECO arrived at their decisions on spent fuel storage at Millstone 2 and how reliable these decisions are.

Our discovery requests seek information on what assumptions are relied upon to keep the spent fuel pool in a sub-critical state and if these assumptions can be relied upon to adequately resemble reality. Under the current NRC license this pool can eventually contain close to 2 billion curies. It is absolutely necessary to all of the people of the Northeastern United

States that it be maintained safely.

Some areas in which NRC and NNECO have denied CCMN's informational requests are: fuel consolidation and its effect on K_{eff}; actual radiation exposure and its effect on Millstone 2 Boraflex boxes; codes that enable us to verify NNECO and NRC K_{eff} results; actual boron use in circulating water. The information we seek is to help us assess if NNECO and NRC are and/or were overly optimistic and undervigilent.

We should not need to hire lawyers and private investigators familiar with industrial espionage techniques, nor should we pay to receive information that is not published by NRC or NNECO but is available to them and used by them to base their regulations and practices, nor should we need to raise funds equal to those raised by the utilities in protecting their dividend cows to protect our health and safety. We should not have to continue to pay rates and taxes that give NNECO and NRC funds over which we have no control and then have them deny us of our right to information, consent, and equal protection under the law.

It is our understanding that both NNECO and NRC counsel discovery requests of December 1992 were served on CCMN to discover what CCMN knew prior to December 18 and December 9th. CCMN has responded in good faith and has honestly answered these requests.

Because of limitations of resources including time, money, access to services, and good communications these responses may not have been as timely as hoped for or intended. In fact this paper will not contain Dr. Kaku's response when faxed, and will not be faxed until after 5 PM on April 5th because of unanticipated equipment problems. Service by mail will not be before April 5th because of delays in receiving Dr. Kaku's fax and unavailability of Saturday afternoon postal service.

Dr. Kaku's March 31st response, along with this supplement to CCMN's March 9th response, completes our discovery response to NRC, NNECO, and ASLB compelling orders of March 15 and 25, 1993.

Please inform us when CCMN can appeal NRC and NNECO partial responses and objections to CCMN's discovery requests.

April 3, 1993

Mary Ellen Marucci

Mary Ellen Marucci
Coordinator CCMN, Inc.

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the matter of

Northeast Utilities (Millstone Nuclear Station Unit 2)

Docket Number 50-336-OLA

Folder Number DPR-65

ASLB Panel 92-665-02-OLA (Spent Fuel Pool Design)

Declaration of Dr. Michio Kaku

I will attempt to answer questions that have been addressed to me concerning my deposition of Aug. 23, 1992.

1. S-1

In preparation of my deposition, I read:

a) Amendment 158

b) Docket 50-336 B12563 letter from NU to NRC, dated Aug. 11, 1987

c) Letter from Asea Brown Boveri, CE, dated Feb. 28, 1992, to NRC - LD-92-034

d) NRC Info Notice 92-21, dated March 24, 1992, from Charles Rossi

2. S-2

My knowledge of the degradation of the Boraflex boxes comes from this material.

3. S-3

The number 16% in my deposition is in error, as was pointed out.

4. S-4

Because of the unexpected degradation of the Boraflex boxes, the utility has tried to model the degradation by assuming a random distribution of gaps. However, this

is questionable, since it omits the possibility of the concentrations of gaps. I raise this only as a possibility, since no one has taken the time or effort to perform a detailed examination of the Boraflex boxes. Neither I, nor the utility, knows whether a concentration of gaps is present, but this issue is important since it can cause a local nonuniformity within the neutron distribution function $\phi(x, y, z, t)$. Since the purpose of the Boraflex boxes is to absorb neutrons, and since a potential concentration of gaps in these boxes could cause a local rise in $\phi(x, y, z, t)$, it is possible that the calculation of k_{eff} does not adequately describe the actual neutron population within the spent fuel pond. This has important consequences, since a local peaking of $\phi(x, y, z, t)$ can cause the neutron population to rise in that area and hence generate heat and further degradation. This would cause the spent fuel pond to be unstable, which is a situation that is to be avoided at all cost. In other words, even if an average k_{eff} seems to be below the NRC requirements, a local singularity within the neutron distribution can cause local heating, further degradation, and possible boiling.

Until a detailed physical examination is performed, neither I nor the utility knows the state of Boraflex degradation, so calculations of k_{eff} performed by the utility are pure fiction.

Errors of even a few percent that may appear in the calculation for k_{eff} due to these and other uncertainties are significant because of the following reasons:

a) Because of a lack of a permanent Federal repository for commercial nuclear waste, the NRC has unwisely allowed for large compactification and consolidation of spent fuel rods, far beyond their original design specifications. The present-day specifications for spent fuel pools have almost no relationship to the original specifications.

b) As a result, the fission product inventory of a spent fuel pool can now exceed well over a billion curies, which I find high regrettable. This is potentially enough radiation to contaminate most of the State of Connecticut, causing hundreds of billions of dollars in property damage, should a large fraction of the inventory be dispersed into

the environment. Also, it is unfortunate that the re-arrangement of fuel, as specified under Amendment 158 for Region B, will increase this fission product inventory even further. The key question that we shall address, therefore, is whether there are sufficient uncertainties within Amendment 158 to warrant a serious examination of this beyond design basis accident.

c) The fact that these spent fuel pools are allowed to operate with k_{eff} at .95, where 1.0 represents criticality, is highly regrettable, reflecting expediency rather than solid concern for the health and safety of the public. Given that a spent fuel pool is operating so close to criticality, the question of whether a fraction of the fission product inventory can escape into the environment is no longer an academic question.

d) Since the spent fuel pool is now being allowed to operate discomfortingly close to criticality, with a fission product inventory large enough to destroy most of Connecticut, it becomes crucial that we allow for extra layers of assurance and safety in our calculation. However, the sloppy and rather cavalier attitude of the utility does not inspire confidence or give them the appearance of an organization walking the extra mile to guarantee the safety of the public. In fact, just the opposite is true. The fact that the utility has resisted so strenuously any effort to provide these extra layers of assurances in its calculations is a cause of public concern.

e) We are left, therefore, with only one layer of assurance. When reduced to its essence, we have only one "guarantee" that a catastrophic accident involving up to a billion curies of radiation cannot happen, and this is the KENO codes of Amendment 158. However, as I hope to show, the KENO codes are themselves riddled with hidden, unwarranted assumptions. These assumptions, in turn, may create biases and errors of a few percent. This may seem small, but only a few percent error is needed to push the spent fuel pond to criticality.

In the following, we will address the uncertainties within the KENO calculation of Amendment 158 that arise both due to physical uncertainties (Boraflex degradation,

lack of adequate benchmarking, increasing the fission product inventory within Region B) as well as theoretical uncertainties (hidden assumptions within Monte Carlo calculations).

5. S-5

In 1987, there was an alert sent to nuclear power plants because of the unexpected degradation found at Quad Cities Unit 1 and Point Beach. Shrinkages of 3-4% were found, which I consider to be a large amount. This unexpected problem surfaced because the intense radiation found in the spent fuel pool caused shrinkage within the polymer matrix holding together the boron carbide making up the Boraflex boxes.

As I mentioned earlier, no one, neither I nor the utility, knows the precise degradation occurring in the spent fuel pond, and therefore no one knows whether the assumptions of Amendment 158 are valid or not. My point is that the utility should be honest about this and clearly state that it is indulging in pure speculation about the state of the Boraflex boxes. This is important because only a few percent uncertainty within the calculation of k_{eff} can push the spent fuel pool beyond the .95 limit.

6. S-6

I am referring to the calculations first performed by CE and later revised by the NITWAL-KENO-5a calculation, as described in Amendment 158.

The latter study is a standard Monte Carlo calculation, the kind studied in most graduate courses on neutron transport theory. It is a standard integro-differential equation using a random number generator.

Only recently has a brief summary of KENO been made available to me by the utility. I made a request to have the KENO codes sent to me directly so that I can run them on my VAX computer, but unfortunately the utility has not honored this simple request. This is very regrettable.

7. S-7

The neutron transport method, which is the foundation of all calculations used by the NRC to estimate neutron populations, relies upon several crucial assumptions. Specifically, neutron transport theory works best when the neutron population is relatively dense and smooth, where the cross sections are large, and where the mean free path of the neutrons is much smaller than the characteristic lengths found within the model.

The neutron transport equation is an integro-differential equation. In general, *analytic solutions of this equation are beyond any calculational technique*, i.e. it takes an infinite amount of time to solve this equation, which in itself is only an approximation to reality.

At this point, several approximations and hidden assumptions must be made. Without these approximations and hidden assumptions, as we mentioned, the equations cannot be solved in a finite amount of time.

One assumption is to assume that the neutron population can, in fact, be modeled as a gas, and hence the classical gas equations worked out in the last century by Maxwell and Boltzmann can be used. This is the diffusion method, which forms part of the basis of the first calculation employed by the utility. (But if the mean free path is much larger than the characteristic length, then a neutron diffusion calculation is relatively insensitive to the fine details of the model, and hence provides a poor description of the model. Then the calculation is too crude to provide a valid description of the actual neutron population.)

The second assumption one can make is to assume that a few representative histories of neutrons can simulate the astronomically large number of histories of the actual neutrons in the system. This is the Monte Carlo method, which forms the basis of the second method employed by the utility, mentioned in Amendment 158.

As we have stressed, both of these approximations depend crucially on the earlier assumptions that the neutron population is large, smooth, the mean free path of the

neutrons is much smaller compared to the characteristic lengths found in the model, etc. Unfortunately, these assumptions may be faulty. For example, the Boraflex boxes have thin panels, as thin as .04 inches. However, the mean free path of fast neutrons may exceed several inches. This is one of the reasons why the original CE calculation was faulty, because it had difficulty modeling a thin, highly absorbing medium. (We should point out that the Monte Carlo calculation, since it is technically independent of the diffusion assumption, is less sensitive to this particular criticism. However, the Monte Carlo calculation itself is subject to several hidden assumptions.)

This is very important, since both the CE calculation and the more recent NITWAL-KENO-5a calculation therefore would have difficulty correctly modeling the specific geometry of the pool. It means that both computer calculations are too clumsy to correctly account for the peculiar geometry of the pool, and hence throws into question the reliability of Amendment 158.

The relationship between the diffusion method and Amendment 158 is therefore twofold: that the unusual geometry of the spent fuel pool resulted in the diffusion approximation introducing errors within the original CE calculation, and that both the diffusion method and the Monte Carlo method of Amendment 158 depend crucially on making large truncations or approximations to the neutron transport equation which, in general, cannot be solved exactly. These approximations, in turn, are not very reliable because of the unusual geometry of the Boraflex boxes.

Thus, the unusual geometry of the Boraflex boxes (with unknown degradation) introduces uncertainties in both the diffusion method and the Monte Carlo method of Amendment 158. Since only a few percent uncertainty can push k_{eff} to 1.0, and since the spent fuel pool has a fission inventory of over a billion curies, this is no longer an academic question.

8. S-8

The point here is that these faulty assumptions invalidate both Fick's law (which

is a restatement of the principle of the diffusion within a gas) and the Monte Carlo method of Amendment 158.

For example, if the neutron population is highly irregular, discontinuous, or non-differentiable, then the gradient of the neutron distribution function $\nabla\phi$ is no longer a reliable quantity, which nullifies the neutron transport equation. This also nullifies Fick's law, which is that the flux is proportional to the gradient function, which is the basis of the diffusion method. Second, it also nullifies the Monte Carlo method, which also assumes that the neutron distribution function is smooth, continuous, differentiable. For example, in the KENO calculation, one had to invert the integro-differential equation by using Green's functions, which only apply for continuous, differentiable functions.

Thus, the relationship between Fick's principle and the KENO method is that they both depend on a smooth gradient of the neutron distribution function and both may be nullified due to the approximations made to the neutron transport equation. Both methods are called into question because of the unusual geometry of the spent fuel pool.

9. S-9

To understand the full scope of the hidden assumptions within the Monte Carlo technique (and to understand how errors of a few percent can easily creep into these calculations) it is useful to review the standard neutron transport equation and the Monte Carlo method. The calculation is based on an integro-differential equation:

$$\frac{1}{v}\frac{\partial\Phi(X,E,\Omega,t)}{\partial t} + \Omega\cdot\nabla\Phi(X,E,\Omega,t) + \Sigma_t(X,E,\Omega,t)\Phi(X,E,\Omega,t) \quad (0.1)$$

$$= S(X,E,\Omega,t) + \int_{E'}\int_{\Omega'}\Sigma_t(X,E'\to E,\Omega'\to\Omega,t) \quad (0.2)$$

$$\times\ \Phi(X,E',\Omega',t)d\Omega' dE' \quad (0.3)$$

where Φ is the neutron flux, X is the position, Ω is the angular direction, Σ_t is the

cross section, Σ_s is the cross section for scattering into energy E, and S is the source term. This equation, as is well-known, is simply a consequence of counting the net neutron loss or gain at a specific point and energy.

The first assumption we make is that the neutron distribution is a smooth, continuous, differentiable function, so that $\nabla\Phi$ is a well-defined concept. However, in general, if the geometry is unusual, then Φ will no longer be smooth, continuous, and differentiable, and the above equation is essentially meaningless. Taking gradients of discontinuous, non-differentiable, non-functions makes no sense as a differentiable equation.

But let us plug on. We then make the dubious assumption that we can find a Green's function which allows us to invert this equation. The trick is to define the Green's function:

$$\frac{1}{\Omega \cdot \nabla + \Sigma_t} \tag{0.4}$$

Under the unusual conditions cited before at length, this function does not really exist at all. The operator cannot be inverted, especially if we have an unusual geometry of Boraflex boxes. For example, we can model the presence of the Boraflex boxes as part of the absorption cross section contained within:

$$\Sigma_t(X, E, \Omega, t) \tag{0.5}$$

If the variations within this absorption cross section function are large but confined to small areas within the spent fuel pool (small compared to the mesh length of the approximation used in the model, or small compared to the over-all geometry), then the inversion of the Green's function becomes unreliable.

The next dubious assumption is that the Green's function exists as a smooth, differentiable function, given by:

$$e^{-T(R)} \tag{0.6}$$

so the solution is given by:

$$\Phi_g(X,\Omega) = \int_0^\infty q_g(X - R\Omega, \Omega) e^{-TR} dR \tag{0.7}$$

where we put all terms which increase the neutron flux into q_g and where:

$$T(R) = \int_0^\infty \Sigma_t(X - R'\Omega) dR' \tag{0.8}$$

Notice that we have piled several dubious assumptions onto other dubious assumptions to arrive at this dubious result. But let us proceed.

It is well known that this equation cannot be solved analytically within a finite amount of time. Therefore, we will make the further dubious assumption that we can discretize the energy spectrum into tiny "groups," so that an infinitely fine-grained spectrum is now chopped up into just 27 pieces. In other words, we are replacing ∞ with 27, labeled by g.

Inserting the discretized Green's function, we find the solution:

$$\Phi_g(X,\Omega) = \int_0^\infty dR e^{-T(R)} \Big\{ \sum_{g'} \frac{1}{k} \int_{\Omega'} v_{g'}(X - R\Omega) \Sigma_{fg'}(X - R\Omega) \tag{0.9}$$

$$\times \quad \chi(X - R\Omega, g' \to g) \Phi_{g'}(X - R\Omega g, \Omega') \frac{d\Omega'}{4\pi} \tag{0.10}$$

$$+ \quad \Sigma_{g'} \int_{\Omega'} \Sigma_{tg'}(X - R\Omega, \Omega') \frac{\Sigma_s(X - R\Omega, g' \to g, \Omega', \Omega)}{\Sigma_{tg}(X - R\Omega)} \Big\} \tag{0.11}$$

(0.12)

where we have made the gross assumption that:

$$\int dE \to \Sigma_g \tag{0.13}$$

that is, we have discretized the energy spectrum into chunks. This equation, even with all its approximations, cannot be solved exactly. Even after truncating the energy

spectrum into large chunks, this equation is still beyond analytic solution. So now we make the final set of assumptions.

First, we can use Fick's law, so that the gradient operator ∇ becomes the Laplacian ∇^2. This gives us a diffusion type equation, which is notorious for being unreliable when there are strong neutron absorbers or when the neutron mean free path is much smaller than the characteristic lengths of the system (as in the Boraflex boxes).

Second, we can make the Monte Carlo assumption, i.e. that a few representative trajectories can adequately describe the behavior of a vast neutron population.

In this way, we see the relationship between the neutron transport equation, the diffusion and Fick's law assumptions, and the assumptions contained within Amendment 158.

9. S-9

Notice that a large amount of assumptions went into the derivation of the final equation used for Monte Carlo simulations. For example, we assumed that the neutron distribution function was a smooth differentiable function which could be modeled by partial differential equations. This, in turn, assumed that the mean free path of the neutron was small and the neutron density fluctuations was small. It also assumed that we could perform integrals over energy. In reality, integrals over the energy cannot be modeled by the Monte Carlo method. Hence, we use the multi-group assumption, i.e. we chop up the energy spectrum.

I do not think that using 27-group energy methods are adequate. For example, small spatial edge effects, due to the unusual geometry of the Boraflex boxes, can create corresponding small deviations in the energy spectrum as well, and hence approximating infinity with 27 may not be a very good assumption. The error in the Monte Carlo calculation can only be reduced if we extend the 27-group method to include N=200 to N=500, which is a closer approximation to infinity.

These uncertainties are not academic, since they could easily create errors in k_{eff},

pushing it beyond the NRC limit. In the first calculation performed by the utility, there was, in fact, a problem with their approximations which nullified the whole result.

The vertical buckling term that I referred in the deposition refers to the first reactivity calculation performed by the utility, which as flawed, as they admit. For example, using the diffusion approximation, we can convert the neutron transport equation into the standard diffusion equation:

$$\frac{1}{v}\frac{\partial\Phi}{\partial t} - D\left\{\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}\right\}\Phi + \Sigma_a\Phi = \nu\Sigma_t\Phi \tag{0.14}$$

For a one dimensional slab reactor, for example, a typical solution can be expanded in terms of eigenfunctions, so that:

$$\Phi = \sum_{n,\text{odd}}\left[\frac{2}{a}\int_{-a/2}^{a/2} dx'\Phi_0(x')\cos B_n x'\right]\exp(-\lambda_n t)\cos B_n x \tag{0.15}$$

Then the geometric buckling term can be solved for:

$$B_1^2 = \left(\frac{\pi}{a}\right) \tag{0.16}$$

The usefulness of buckling terms like these is that they give us an intuitive understanding of the behavior of the neutron population in terms of the cross sections and the geometry. The incorrect handling of the buckling by the utility, however, caused them to incorrectly calculate Φ. The second study, because it integrates the neutron distribution function directly by a Monte Carlo simulation, does not necessarily depend on buckling.

The essential point about Boraflex boxes is that, because of their unusual geometry and unexpected degradation, we cannot assume that the usual neutron reactivity equations apply. If the boxes are degraded further than expected, then all the computer studies in the world cannot model the neutron flux correctly. As is commonly

stated, garbage in, garbage out. Moreover, because of the thin walls of the Boraflex, we cannot assume that the neutron distribution function can be modeled by a smooth differentiable function.

10. S-10

The geometry of the Boraflex boxes is "unusual" for two reasons. First, they have thin, highly absorbing walls, and hence makes a realistic modeling by smooth, continuous functions difficult. Second, their geometries were not benchmarked by actual experimental results.

Because of the biases inherent within Monte Carlo calculations, it is essential to benchmark calculations which accurately describe the system in question. However, no benchmarking of the spent fuel pond with Boraflex boxes was ever done, which calls into question the reliability of the KENO codes. This is serious, because benchmarking is one way of flushing out the hidden assumptions and hidden biases within any Monte Carlo calculation. As the creators of KENO-5a freely admit, there is an inherent mathematical bias within that program which consistently leads to small deviations from the experimental answer. Unfortunately, we do not know the hidden biases within the spent fuel pool in question, because no realistic benchmarking was ever performed for Boraflex boxes. Worse, there has been a tendency within the nuclear industry to cut back on experimental verification of their computer codes, probably for budgetary reasons.

I find this an unacceptable situation. Real fuel rods and absorbers are always better than purely theoretical calculations, but because of what I expect are budgetary reasons, the benchmarking of realistic Boraflex boxes was never performed.

Furthermore, the utility has only given me a rough description of the KENO program, not the codes themselves, therefore it is impossible for me to say how many histories were performed by the utility for the spent fuel pond. However, I would be happy to run the KENO codes myself on my VAX computer in order to calculate how

many histories are needed before a convergence is found. Therefore to fully answer this question, it would be helpful if the utility provides me a complete copy of the KENO code, as we requested several months ago, but was not carried out.

My point is that, if the Boraflex boxes were correctly modeled, an unusually large number of iterations may be necessary (well into the millions) because the convergence of the revised program may be slow. The program that the utility ran to model the spent fuel pond may have converged rather quickly, but that is not my point. Because the utility is using a faulty program, with over-simplified assumptions, its convergence is irrelevant. What is relevant is the convergence of a realistic modeling, involving far more detail than that found in the current KENO code.

There is also a fine theoretical point to be made. As any one who has ever used Monte Carlo techniques knows, a calculation is only as good as its initial "guess." If the initial input boundary conditions are grossly incorrect, then the system might faithfully and reliable converge to the wrong answer. Even though a convergence was found for an enormous number of iterations, the convergence may be to the wrong answer. This convergence problem is often found in minimization programs.

Let us say that we wish to find the minimum of a function of N variables. The standard search or relaxation method is to make a first "guess" and then let the system make a series of iterations, each time getting closer to the answer. The problem with this is that, in N dimensional hyper space, there may be many peaks and valleys. The first "guess" may have started on the wrong mountain, and then faithfully and incorrectly iterated its way down the hill into the incorrect valley, while the correct valley may lie just around the next mountain. The point is that any Monte Carlo or any relaxation program is only as good as its first guess or initial conditions, and the program may therefore converge nicely to the incorrect answer.

This is yet another hidden assumption within the Monte Carlo technique.

11. S-11

There are a number of hidden assumptions in neutron reactivity calculations which introduce errors, some of which we mentioned before. The fact that the utility does not recognize the well-known limitations of Monte Carlo studies does not reflect well on the utility.

Here is a partial list of hidden assumptions:

a) Any Monte Carlo calculation relies upon random number generators. However, all numerical techniques used in random number generators are actually not random at all. For example, random numbers are usually generated by performing a number of multiplications, divisions, etc. and truncations. However, the very fact that a computer can generate the same sequence of numbers by running the program twice means that the numbers the program generates are not random. (To see this, perform a simple test. Have the creators of KENO-5a execute the program twice. Each time, start with the same initial "guess" and initial conditions. The program will faithfully converge to the same answer on both occasions. But if the program were truly generating random numbers, then the random numbers of each run would be different, and hence should produce slightly different answers. Hence, the program is not truly random, and the Monte Carlo calculation cannot realistically model the behavior of neutrons, which really are random. Now, perform the same test using an experimental apparatus, with fuel rods and absorbers. Let the system approach equilibrium on two runs. We see that the system will approach equilibrium slightly differently on each run, because, in reality, the collisions of neutrons are truly random, unlike the fake neutrons of KENO-5a.)

This is not an academic question. This, in fact, has introduced errors in calculations using Monte Carlo calculations done by the intelligence services, as reported in the New York Times and other publications in the past month or so. The fact that the random number generator used in the Monte Carlo calculations used in KENO are reproducible means that they are not random, and hence cannot reliably model

the behavior of neutrons, which are indeed random.

This, in turn, will introduce a bias in the KENO study.

b) As we mentioned earlier, the approximations to the neutron transport equations are flawed because of hidden assumptions and because of the unusual geometry of the Boraflex boxes, calling into question the validity of Amendment 158. The neutron transport equations themselves are suspect. This not only affects the usual neutron diffusion method and Fick's law, but the Monte Carlo method as well. In fact, it invalidates most of the methodology of the Monte Carlo method, and can easily introduce errors of a few percent (which are all that is necessary to push the spent fuel pool into violation of NRC regulations).

c) The Monte Carlo method assumed that we can approximate the actual neutron flux with a smooth, continuous, differentiable function $\phi(x, y, z, t)$, while in actuality the real distribution of neutrons is discrete, discontinuous, and non-differentiable. Hence the Green's function method used in the previous equation is invalid.

d) Monte Carlo calculations are not well-suited for unusual geometries, such as those found with thin-wall, highly absorbing Boraflex boxes. Monte Carlo calculations are better suited for simple geometries, geometries with a large degree of symmetry, and geometries which do not vary much. The point is that the Boraflex boxes have thin, highly absorbing walls and have non-symmetrical geometries, which are difficult to model by any computer program.

e) There is a bias in the Monte Carlo studies themselves. By comparing the calculation with the actual neutron reactivity found in certain configurations, we find a consistent bias in the computer program. This has been confirmed by benchmarking. Unfortunately, this benchmarking was never performed for the configuration in question.

f) The convergence of a Monte Carlo calculation is only as good as the initial guess. A bad guess will yield a convergence around an incorrect result. However, how

we guess is a subjective, personal matter, and hence full of potential problems.

g) The Monte Carlo method itself is based on a gross assumption, i.e. that the behavior of a few representative neutrons can accurately describe the behavior of a vast population of neutrons.

In summary, these and other assumptions call into question the safety of the spent fuel pool. Moreover, it calls into question the utility's inability to either acknowledge their importance or provide any quantitative means of estimating their importance. The utility is deluding itself into believing that Monte Carlo calculations are somehow perfect.

This is important because of the compaction that is taking place nationally at every reactor site. Because spent fuel is backing up at all spent fuel ponds, this means that spent fuel ponds normally meant for a small fraction of the core are now approaching one billion curies in the fission product inventory. I do not consider this an acceptable situation. Because k_{eff} is allowed to reach .95, this means that the slightest accident or miscalculation could conceivably push the spent fuel pond into criticality.

Normally, small errors in the neutron reactivity need not be cause for alarm. In fact, I would not normally be concerned with tiny errors in neutron reactivity. We must, of course, live in a world of uncertainties, because most of the difficult equations in life are unsolvable.

However, the difference is that we are now dealing with an unprecedented situation: spent fuel ponds with enormous radioactive inventories that are being pushed very close to criticality. I do not consider this an acceptable situation. The fact that the re-arrangement of fuel within Region B, allowed under Amendment 158, will increase the fission product inventory even further is also cause for concern. Worse, the fact that the utility does not see the possible errors inherent in computer studies shows a callous lack of regard for the real world, which often proves to be richer in

possibilities and the unexpected than any barren computer calculation.

I am not saying that it is impossible to perform a "reliable" simulation of the neutron distribution function. I saying that the KENO program, as currently formulated, is overly-simplified and is not an honest calculation. Because so much rests upon having an honest calculation, I would consider a "reliable" to be one that:

a) is benchmarked using realistic modeling of the Boraflex boxes, not benchmarked by overly-simplified geometries with no direct relevance to the problem at hand.

b) depends on reliable, experimentally determined physical input parameters, i.e. one experimentally measures the precise degradation within the Boraflex boxes, rather than speculation.

c) uses multi-group equations where N is in the hundreds.

d) tries to numerically calculate the errors introduced by the various assumptions, especially in the presence of the unusual geometry of the Boraflex boxes. This is the most difficult problem, because it means that lattice or discrete approximations must be reduced even further.

e) is available to the public, so that it can be independently run and checkec by concerned individuals for potential flaws.

f) In the final analysis, a realistic calculation should not have any bias detectable by realistic benchmarking greater than $\Delta k_{\mathrm{eff}} = .01$.

Unless these factors are included in an honest calculation, Amendment 158 is fundamentally flawed, and one cannot rule out the possibility of a beyond design basis catastrophe at a spent fuel pool.

M Kaku 3/29/93

CERTIFICATION OF SERVICE

I hereby certify that copies of the foregoing CCMN's SUPPLEMENTAL RESPONSE TO NRC, NNECO, and ASLB have been served by first class U.S. Mail on all the following persons, EXCEPT for those marked with an * who were served by priority mail.

Those marked with ** were sent Dr. Kaku's Response to NNECO under separate cover on March 31, 1993.

A request was made to fax the ASLB. This fax will be sent after 6 PM on Monday, APRIL 5, 1993, since it was uncertain if the ASLB fax would be operational on the weekend after 5 PM Friday, and to all others whose address is followed by a fax number.

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April 5, 1993

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