The Honorable Said Abdel-khalik
Chairman
Advisory Committee on Reactor Safeguards
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

April 8, 2010

Subject: Concern with Industry Standards in Licensed Operator Training

Dear Chairman Abdel-khalik:

Enclosed please find three sets of documents:

- Explanation of my concern for Licensed Operator Training Standards (fundamentals)
- Record of correspondence between myself and NRC concerning NRC GFE question P415
- Professional resume for myself (Kenneth W. Norris)

After reading my stated issues in the first document and reviewing the my attempt to correct just one question in the NRC's GFE bank which is seriously flawed (and documented in NRC correspondence as admittedly flawed, yet subsequently used on a recent GFE) I believe you will understand my frustration and concerns, not just with the NRC GFE bank and testing process, but with the developing cultural changes taking place industry wide. I included my resume to provide you with insight for my perspective.

I request that you consider the recommendations at the end of the first document along with any others that you may see appropriate to address the issues identified. My intent is not to become a "whistleblower" but rather to convey serious concerns to those who are in the highest positions of responsibility for the regulation and oversight of this industry. As a nuclear professional, I am not in the habit of raising concerns without providing recommendations for correcting those issues that I identify, and so my first enclosure includes such recommendations. While matriculating at the University of Michigan in the late 1970s, I was fortunate to be taught Reactor Safety by then ACRS chairman William Kerr. It is my experience with him, and my attendance at an ACRS meeting in Chicago (as an observer) that led me to consider sending you this correspondence. I ask that you use this information to query the appropriate NRC personnel to at least initiate appropriate organizational dialogue to address these issues. I sent a similar cover letter with the same enclosure to the NRC Chairman.

Please feel free to contact me regarding any further details of my experience with these issues.

Most Respectfully,

Kenneth W. Norris

[redacted]

The Concern for Licensed Operator Training Standards

As a career nuclear professional with over 30 years of combined civilian and naval nuclear experience (**see attached resume**), I am concerned that the civilian nuclear industry has significantly lowered its standards for fundamental scientific understanding of nuclear power plant operations in licensed operator training programs. While I philosophically support the concept of an openly competitive market place, the recent paradigm shift from regulated monopolies to competing energy companies affects more than the quarterly earnings of these companies. I am asking that the Nuclear Regulatory Commission and the Institute of Nuclear Power Operations recognize their role in affecting the culture of this industry as a whole, and that they act to prevent the devaluation of technical understanding that can lead to major consequences. One only need read the following excerpt from the Columbia (space shuttle) Accident Investigation Board, August 2003 (from the Report Synopsis) to recognize that shifts in management and incentives have the ability to degrade technical decision making:

> We considered it unlikely that the accident was a random event; rather, it was likely related in some degree to NASA's budgets, history, and program culture, as well as to the politics, compromises, and changing priorities of the democratic process. We are convinced that the management practices overseeing the Space Shuttle Program were as much a cause of the accident as the foam that struck the left wing.

Recalling a past INPO president who compared the energy that is at the finger tips of a reactor operator to that of a space shuttle in order to impress upon operators the serious nature of their role should give us some pause.

Accompanying the inherent pressures for efficiency in an open marketplace, utility managers, from the top down, have challenged a variety of practices that existed in the previous paradigm to eliminate those that do not benefit the company economically. This practice is understandable and appropriate, to a degree. Implementation of this practice includes scrutiny of intangible items, such as operator knowledge and understanding.

Simultaneously, the industry has shifted focus to improving procedures to provide standardized methods of performance for planned tasks, and to a focus on human performance practices to prevent errors. These tend to focus on "form" rather than substantive understanding (although this is technically listed among such practices, e.g. INPOs SER 03-5 list of operator fundamentals). The statement, "by standardizing procedures, creating procedures for as many conceivable tasks as possible, raising the quality of procedural detail and ensuring 100% operator adherence to procedures, future events will always be prevented," seems to best capture the philosophical core of today's nuclear industry. This position ignores some very significant facts.

The first fact is that the writers and revisers of operating procedures are typically plant operators themselves. The second is that the vast majority of licensed operators and procedure writers in the industry were hired in the 1970s or early 1980s and will likely soon retire from the industry. They will take with them a vast range of knowledge and experience that their replacements will lack. If those replacements do not possess the same level of scientific/technical understanding of plant operation as their predecessors, what will prevent them from eventually revising procedures to seemingly more efficient processes that miss very fundamental scientifically based sequences or prohibitions? The emphasis on rule-based operation in the current industry has the potential to become the Achilles Heel because the procedure writer needs a knowledge base that is beyond the bare minimum necessary to implement existing procedures. Combined with the reduction in fundamental scientific rigor in licensed operator fundamentals programs, it has the potential for disaster.

Given a competitive economic environment, companies gradually reduce the resource investment in production to a minimum. Governing entities (such as NRC and INPO) need to recognize this and establish mitigating incentives/rules that prevent companies from cutting where they shouldn't. Across this industry, nuclear plants have reduced their target for fundamental knowledge of nuclear science to that which is necessary to successfully pass the NRCs GFE. A secondary goal is to convey operator understanding. If the NRCs GFE actually provided a rigorous evaluation of such principles, and if it had been maintained relevant and accurate for current nuclear plant operations, this might be acceptable. My personal conclusion regarding this bank of approximately 1500 multiple choice questions that is open to the public is that it does not meet such criteria.

There is probably no person who can be credited more than Admiral Hyman G. Rickover for the development of our nuclear technology, even as it now exists. In his testimony before the Subcommittee on Energy Research and Production of the Committed on Science and Technology, US House of Representatives, May 24, 1979 I found the following quotes relevant to this discussion:

"Properly running a sophisticated technical program requires a fundamental understanding of and commitment to the technical aspects of the job and a willingness to pay infinite attention to technical details"

"If you ignore those details and attempt to rely on management techniques or gimmicks you will surely end up with a system that is unmanageable"

"The examinations given must be tough, and must be approved by a competent person in authority"

In my career I have considered the NRCs GFE bank as a minimal standard for government acceptance of an operator's knowledge, but I personally never looked at it as the sole goal of fundamentals training. For the vast majority of nuclear plants, that is now the case. While performing as an operations instructor I have done my best to adhere to the true spirit of a systematic approach to training by incorporating revisions to fundamentals materials based on industry and plant operating experience (OPEX), changes to procedures and operator tools (such as current curve book data), updates to plant equipment, and of course, any new forms of questions that appear in the NRC GFE bank. All of these changes are incorporated with the review and approval of the governing curriculum review committee. This method has resulted in a living fundamentals program that retains direct relevance to the job of the operator, and as a secondary goal, has resulted in a 100% success rate on the NRC GFE for my station since the NRC began this method of evaluation.

In contrast, I find the NRCs exam bank has become obsolete and in a number of cases, erroneous. For example, I sent the NRC a challenge to GFE question P415, regarding source range nuclear instrumentation response to core and vessel voiding, based on documented work performed at Argonne National Lab and NSAC and subsequently included in the 1991 Westinghouse Mitigating Core Damage materials. I sent highlighted copies of the key pages along with an explanation of the challenge to the NRC on May 9, 2006.

The NRC response on May 26, 2006 indicated that their problems were based on the 1983 Westinghouse materials and that they had not yet obtained a copy of the new version. The NRC acknowledged the validity of the challenge, but stated that a final determination would not be made until updated reference material was obtained. I have continued to brief our students on this problem, and the others that address the same issue in the bank, to ensure that students understand the real expected source range response in such situations, but also that if they see this problem on an exam to provide the NRC with its outdated answer.

One would expect that the question would not be used on a GFE by the NRC after admitting its obsolescence. Contrary to that expectation, this exact question (P415) was used by the NRC on the June 2008 GFE which was administered to our ILT class. The question appeared as question number 5 on form A of the June 2008 PWR GFE. All of my students provided the NRC with the correct (albeit outdated) answer because they did precisely as they were taught during fundamentals training.

As of February 2010 this question (and the other faulty questions on the same topic) reside in the NRCs GFE bank. There are at least three other questions in the NRC bank that focus on the same issue (question numbers **P1312, P1612, and P1811**) that should not be used until properly reviewed and updated. It is my position that questions P1312 and P1811 are faulty and need to be removed/replaced (similar to P415). In my challenge to the NRC, I provided four legitimate substitute questions to facilitate ease of correction. The NRC has not incorporated these into the bank, nor has it removed the erroneous question P415. Documentation of the correspondence between myself and the NRC, including the technical bases for my challenge, are all included as attachments to this correspondence.

These are not isolated problems that are faulty or obsolete. NRC includes several questions that relate to the critical boron concentration for a PWR over core life. The curves provided in the problems represent PWR core behavior for core designs in the

1980s. Critical boron curves that represent modern cores (used since the 1990s) show a rise in boron concentration shortly after the compensating drop that accounts for initial Xenon-135 build-up. This is related to the use of more sophisticated forms of burnable poisons (integral fuel burnable absorber or IFBA). This also affects trends in shutdown margin for a reactor operating at 100% power in the first third of a fuel cycle (affecting the accuracy of other NRC exam bank questions).

Within the industry, significant reactivity events should be used as a basis for the creation of new questions, however I see no evidence of this in the bank. For example, the Feb. 21, 1997 Zion Unit 1 event resulted from a combination of factors, one of which was a culture that did not value technical understanding of reactor behavior. While multiple factors contributed to this event, the operators' actions revealed a lack of understanding of (or at least a lack of consideration for) subcritical reactor behavior, in addition to basic reactivity calculations. Other industry reactivity events have resulted from the lack of understanding or consideration for the depletion of Boron-10 in the reactor coolant system over the fuel cycle. This affected an estimated critical condition calculation at one plant when a primary loop was drained and refilled in support of a forced outage and the plant staff failed to recognize the effect.

Both of these events (as well as others) merit the creation of related GFE questions that would leverage the industry to pay attention to such issues (and therefore help ensure the reduction in repeat events). I see no evidence of this by the NRC. Other technical accuracy issues exist in the bank that misrepresent actual reactor behavior and could easily be corrected. For example, the data typically provided by the NRC for inverse count rate ratio problems (also commonly known as 1/M plots) for reactor startups (e.g. NRC GFE question P969) assumes completely linear relationship between rod position and rod worth. This is not the case and problems closer to a real response, therefore better testing operator understanding, are not that difficult to create using the same format.

In addition to this exam bank losing relevance with passing time, there are serious issues with question construction. One would expect that in using multiple choice questions, wherein the examinee is presented with four choices, that the three incorrect choices (known as distractors) would not include identical wrong information, thus allowing the examinee to rule out all three distractors based on one piece of information. There are several questions in the NRC bank that fall into this category (examples include questions P2647, P364 and P1950).

In summary, the following issues exist:

- Industry focus on rule-based operation has resulted in a cultural shift that no longer values understanding of the fundamental scientific principles underlying plant operation. Combined with the mass exodus of experienced nuclear industry workers to retirement, this will set the stage for eventual repeat events (some resulting from procedure revisions based on inadequate knowledge level of the writer, and an operator who implements it without the knowledge base to challenge the procedure, and in fact, is discouraged from such challenge).

- o The nuclear industry has defaulted to the NRC GFE as the sole basis for a standard of understanding the scientific principles related to nuclear power plant operation. This is a result of the open market place for electricity.
- o The NRC GFE bank of questions has become obsolete and is gradually losing relevance to modern nuclear plant operation.

To address these issues, I recommend the following actions:

- o As a part of Operations Accreditation Team Visits (ATVs) conducted by INPO, nuclear plant fundamentals programs should be reviewed for the following:
    - To determine if the plant's fundamentals program is simply targeted at the NRC GFE. One of the key indicators or symptoms of this philosophy is a fundamentals program exam bank comprised of only NRC GFE questions. In addition to the bank, the teams should review exams from recent classes to determine the scope of testing at these facilities.
    - To determine how the plant's fundamentals program incorporates industry and individual plant operating experience as a basis for topics presented and directly relates the theoretical discussion to actual operation.
    - To identify specific examples where the plant's fundamentals program covers plant specific deviations from the generic assumptions of the NRC GFE.
    - To review how training programs connect the theoretical discussions and presentations to actual plant application. For example, plants should integrate use the plant specific shutdown margin procedures and integrate the use of the specific curve book data into the theoretical discussion on this topic.
- o INPO should review and revise its existing ACAD concerning initial license training to establish new criteria that drive plants toward a goal of solid operator understanding of plant operation rather than a minimal government standard for one NRC GFE.
- o The NRC should initiate the following efforts to improve the quality, accuracy and relevance of the NRC GFE bank and related exams:
    - Conduct a thorough technical review of the entire bank. Questions that are technically in error should be removed as soon as they are identified.
    - Conduct a thorough review of each question for proper construction.
    - Remove questions that are of no discriminating value and have therefore not been used on an exam for more than ten years.
    - Identify select industry representatives that the NRC determines to be among the top experts in the fundamentals area to form an advisory committee with specific exam bank review functions and authority. The individuals involved should have a bachelors of science in a technical field and considerable experience with plant operations or training, or both. The purpose of this committee is to prevent the NRC GFE bank from ever again drifting towards obsolescence.

The Concern for Licensed Operator Training Standards

Early in my civilian nuclear career I worked with several others in my company to create the first team training for control room operators. For a variety of reasons we looked to the airline industry as an example for dealing with technical decision making as a control room team. On January 15, 2009 Captain Chesley Burnett "Sully" Sullenberger III successfully ditched US Airways Flight 1549 in the Hudson River saving everyone on board when all of his plane's engines failed due to an encounter with a flock of birds. The situation was not encompassed by the emergency procedures but the pilot's expertise, experience and initiative resulted in success. Ten or fifteen years from now, when a nuclear plant experiences a situation that is not specifically covered by the emergency procedures, or even worse, includes emergency procedure direction that is erroneous, will we have a "Sully" Sullenberger in the control room?

Norris, Kenneth W.

From: Ivan Kingsley [ikingsley@sonalysts.com]
Sent: Friday, May 26, 2006 3:20 PM
To: Norris, Kenneth W.
Cc: gmu@nrc.gov
Subject: Response to query on NRC GFE question P415

Mr. Norris,

Thank you for the query and supporting documentation you submitted regarding NRC GFE question P415, which examines the response of excore nuclear instrumentation to homogeneous core voiding. Your disagreement with the posted answer to P415 is clearly supported by the documentation you submitted from a Westinghouse Mitigating Core Damage (MCD) reference manual dated 1991. The documentation we used to develop the question was a Westinghouse MCD reference manual dated 1983. Upon review it was confirmed that our documentation supports the posted answer. Thus, there is a contradiction between these reference manuals from Westinghouse. Consequently, we are in the process of acquiring the latest editions of the MCD reference manual and other reference manuals. Unfortunately, a final determination on your concern cannot be made until the updated reference manuals are received. We will contact you once we have made our final determination.

Ivan Kingsley

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George M. Usova
U.S. Nuclear Regulatory Commission
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Washington, D.C. 20555

May 9, 2006

Dear Dr. Usova:

Thank you for your prompt reply allowing me to submit this request in a timely fashion. The following question appears in the NRC GFE (PWR) bank:

TOPIC:	191002
KNOWLEDGE:	K1.17 [3.3/3.5]
QID:	P415

A plant has experienced a loss of coolant accident with degraded safety injection flow. Core voiding is homogeneous and is currently 20%.

Which one of the following describes excore source/startup range neutron level indication as homogeneous core voiding increases from 20% to 100% of the core? (Assume the neutron detectors are located adjacent to the bottom portion of the core.)

A. Decreases continuously
B. Decreases, then increases
C. Increases continuously
D. Increases, then decreases

ANSWER: D

Key aspects of the question involve the following:

- Location of the excore detectors
- Assumption of homogeneous voiding from 20% to 100%

Enclosed please find a copy of selected pages from the relevant reference material published by the Westinghouse Owners Group (Mitigating Core Damage WOGMCD.3.1, Westinghouse Electric Corp. Copyright 1991) with key information highlighted.

<u>Concerning Location of the Excore Detectors</u>:

Pages 1-35 and 1-36 of the enclosure state that detector sensitivity to the effects of homogeneous voiding is reduced when the detector is located above or below the midplane. This concept is stated in a general manner and includes no clarifying remarks concerning an alteration in the overall trend (direction) in response being affected by the location. As such, one would expect the magnitude of change in detector response with increasing homogeneous voiding to be reduced by the axial position (other than midplane) but not necessarily the overall trend.

Concerning Overall Trend/Response of Excore Detectors to Homogeneous Voiding:

Pages 1-33 and 1-38 clearly state that analyses performed (based on the references in Figure 3-1.11 and 3-1.12 it appears that one was performed at Argonne National Lab and the other by NSAC) following the TMI-2 accident showed a resulting increase in detector response up to about 80 percent homogeneous voiding and then either a leveling off (Figure 3-1.11) or continuous increase (Figure 3-1.12). No analysis is cited that demonstrated an increase followed by a decrease in detector response. In fact, the reference material provided shows an upward trend in detector response followed by a downward trend in detector response for *heterogeneous* voiding and *detector location at midplane*, but this is not the condition presented in the stem of the question.

Based on the information cited and associated analysis results, I do not see where answer D to the referenced question can be supported as being correct. If you have additional analyses that has superceded the referenced analyses and supports answer D, I would greatly appreciate it if you would provide the reference (or at least a means of obtaining a copy). Otherwise, I request that the question be revised. Below are a some versions that I see as possible replacements:

TOPIC:	191002
KNOWLEDGE:	K1.17 [3.3/3.5]
QID:	P415

A plant has experienced a loss of coolant accident with degraded safety injection flow. Core voiding is homogeneous and is currently 20%.

Which one of the following describes excore source/startup range neutron level indication as homogeneous core voiding increases from 20% to 100% of the core? (Assume the neutron detectors are located adjacent to the bottom portion of the core.)

A. Decreases continuously
B. Decreases, then increases
C. Increases then levels off
D. Increases, then decreases

ANSWER: C

TOPIC: 191002
KNOWLEDGE: K1.17 [3.3/3.5]
QID: P415

A plant has experienced a loss of coolant accident with degraded safety injection flow. Core voiding is homogeneous and is currently 20%.

Which one of the following describes excore source/startup range neutron level indication as homogeneous core voiding increases from 20% to 100% of the core? (Assume the neutron detectors are located adjacent to the bottom portion of the core.)

A. Decreases continuously
B. Decreases, then increases
C. Increases continuously
D. Increases, then decreases

ANSWER: C

TOPIC: 191002
KNOWLEDGE: K1.17 [3.3/3.5]
QID: P415

A plant has experienced a loss of coolant accident with degraded safety injection flow. Core voiding is heterogeneous and is currently 20%.

Which one of the following describes excore source/startup range neutron level indication as heterogeneous core voiding increases from 20% to 100% of the core? (Assume the neutron detectors are located adjacent to the bottom portion of the core.)

A. Decreases continuously
B. Decreases, then increases
C. Increases continuously
D. Increases, then decreases

ANSWER: D

Again, I appreciate your consideration in this matter and look forward to your reply,

Sincerely,

Ken Norris
Braidwood Operations Training

ratio and, thereby, in determining the excore detector response to homogeneous voiding. As voiding reduces the density of the fluid in the downcomer, there is less attenuation of neutron flux in the downcomer, and the transmission ratio increases.

In fact, as the homogeneous void fraction in the core region increases from 0 to 100 percent, the transmission ratio increases by several orders of magnitude (from four to six orders of magnitude, depending upon the core model and method of calculation used). The increase in transmission ratio causes the excore detector response to increase with homogeneous voiding.

Similarities and Variations in Analysis Results

The results of all excore detector response analyses performed following the TMI-2 accident were consistent in the following respect: For homogeneous void fractions of up to about 80 percent, detector response increases (that is, the count rate goes up) continuously.

For homogeneous void fractions in excess of about 80 percent, the detector response results reported in various analyses are not entirely consistent. Some analyses show detector response leveling off at a void fraction of about 80 percent (fig. 3-1.11). Others show detector response continuously increasing for higher void fractions, all the way up to 100 percent voids (fig. 3-1.12).

In all of the analyses, increases in detector response are attributed to increases in the transmission ratio, which in turn are attributed to decreases in downcomer fluid density. The differences in results for homogeneous void fractions greater than 80 percent voids can be attributed to the following differences in the analyses:

- Calculated effects of voiding on k_{eff}
- Calculated effects of voiding on core source strength

All analyses show k_{eff} decreasing as voiding increases. However, some show k_{eff} decreasing more than others, especially at very high void fractions. Similarly, all analyses show core source strength decreasing as voiding increases.

However, some show source strength decreasing more than others.

The analyses showing detector response leveling off at very high void fractions are based on comparatively low values for k_{eff} and source strength at high void fractions. In these analyses, the reduction in core neutron population that occurs at very high void fractions counterbalances the increased transmission ratio. Although the neutron leakage probability increases with voiding, there are fewer neutrons available to leak. So the detector response levels off.

The analyses showing detector response continuing to increase at very high void fractions are based on comparatively high values for k_{eff} and source strength at high void fractions. In these analyses, the increasing transmission ratio combined with less of a decline in the neutron population results in a steadily increasing detector count rate.

INTERPRETING DETECTOR RESPONSE TO HOMOGENEOUS VOIDING

The fact that an excore neutron detector responds to homogeneous voiding in the core region leads to the question of whether the detector response can be used as an indication of void fraction. The excore detector response following reactor shutdown under normal conditions is known. Can the detector response to accident conditions be compared to the normal response in order to obtain a quantification of the void fraction?

Assessing the Correlation of Detector Response to Void Fraction

To assess the feasibility of establishing a correlation between detector response and void fraction, three factors should be considered. Before considering these factors, it is worth noting that the RVLIS dynamic range provides direct indication of relative coolant void fraction when at least one RCP is running. Therefore, looking at excore detector response to gage the void fraction need be considered only as a nonpreferred alternative to RVLIS.

Variations in Void Fraction

The first factor to consider is that the assumption of homogeneous voiding (that is, a uniform void fraction throughout the core and downcomer) is only a reasonable approximation of the conditions likely to prevail during an accident in which one or more RCPs continue to run. The void fraction will vary within the core. Voiding will occur initially and to a greater extent in the hotter regions of the core. Additionally, the coolant enthalpy rise across the core will promote voiding in the top of the core.

Thus, the assumption of homogeneous voiding yields only a first-order estimate of the actual detector response to voiding during forced circulation. Because voiding is not perfectly homogeneous, it is not feasible to establish a well-defined, consistent, repeatable correlation between a given count rate and a specific void fraction. Nor is it feasible to establish such a correlation between any particular void fraction and a given ratio of accident count rate to normal count rate.

Location of Voiding

Second, although excore detector response is sensitive to the location of voiding, the response cannot be used to infer the location of voiding. In fact for voiding in some locations, the detector may not respond at all. For cases in which the detector does respond, the response does not provide any definite information about the location of voiding or about possible variations in the void fraction axially or radially within the core. The most that can be said is that the detector will be more responsive to voiding in the downcomer than to voiding in the core.

If voiding is localized in the central region of the core or if the void fraction is higher there than in the rest of the core, then the effects of voiding will be shielded from the excore detector by the coolant in the unvoided or less voided periphery of the core. That is, for localized voiding in the center of the core, the excore detector will not respond.

If the downcomer is not voided, the detector will not see the effects of any voiding that does occur within the core. Given the potential for subcooled fluid to flow into the downcomer during safety injection and/or forced circulation, the shielding effect of the downcomer is quite significant.

Detector Axial Position

Third, the axial position of the excore detector influences its sensitivity to homogeneous voiding. Detectors axially positioned at the horizontal midplane of the core are more sensitive to the effects of homogeneous voiding than are detectors located above or below the midplane. This is because the horizontal midplane is the optimum axial position for a detector to see neutrons from all parts of the core.

A detector positioned above or below the midplane sees relatively little neutron flux from the opposite axial end (top or bottom) of the core. This means that source range detectors axially centered on the bottom core quarter plane are not well placed for sensitivity to homogeneous voiding.

Because of all the factors just discussed, a given excore detector response (for example, a ratio of the actual to the expected count rate from a source range detector) cannot be correlated precisely or even roughly to any particular homogeneous void fraction.

Anticipating and Evaluating the Detector Response to Voiding

Previously it was stated that the fact of detector response to voiding leads to the question of whether detector response can serve as an indication of void fraction. That question has been answered in the negative for all of the reasons just discussed. Additionally, provided that the dynamic range of RVLIS is operable, there should be no need to look at excore detector response as an index of relative void fraction. So now the questions become, "Of what use is the excore detector response to homogeneous voiding? What is its value, importance?"

Expected Response

First of all, it is important for operators to understand that increases in the void fraction will increase neutron leakage from the core and that the excore detector is expected to respond with an increasing count rate if the void fraction becomes large enough. The magnitude of the detector response depends upon the extent and location of the voiding and upon the sensitivity of the detector to the effects of voiding. Detector sensitivity to voiding depends primarily upon the axial position of the detector, with the horizontal midplane of the core being the optimum position.

If the operators do not understand this, they can become needlessly preoccupied by concerns about a return to reactor criticality and unnecessarily distracted from concentrating on more valid and urgent concerns.

Determining Cause of Response

Second, it is important for operators and other personnel to make some determination of whether the detector is responding to increased void fraction or to increased core reactivity. This determination cannot be made solely on the basis of the detector response; other parameters must be considered. Additionally, it is not a determination that can be made categorically, with absolute certainty. At best, the accumulated evidence obtained from a variety of parameters will provide strong corroboration that voiding is the cause of the detector response, not positive reactivity.

Strong corroboration that voiding is the cause of the detector response is provided when all of the following conditions are present:

- RVLIS dynamic range indicates that voiding is occurring.
- RCS pressure and temperature (subcooled margin) indicate that the RCS has reached saturation conditions.
- Analysis results of reactor coolant samples are consistent with the existence of an adequate soluble boron concentration in the core region.
- RCS temperature trend does not indicate excessive cooldown.
- Rod position instruments indicate that all RCCAs are fully inserted.

If core exit thermocouple temperatures indicate that the core coolant is subcooled or if the RVLIS dynamic range indication is nominal for the number of RCPs running, then abnormally high excore detector count rates must be evaluated further.

If RCCAs are not all fully inserted and/or if boron concentration is low, then abnormally high count rates may be indicative of reduced shutdown margin. In such a case, the reactivity effects of coolant temperature changes must be carefully considered before cooling down the RCS.

Another possible cause for abnormally high detector count rates is relocation of fuel to the downcomer. The section on recriticality contains an explanation of how this could come about. For now it is enough to say that such relocation requires fuel damage and an accident history that is consistent with relocation.

Response above the SR

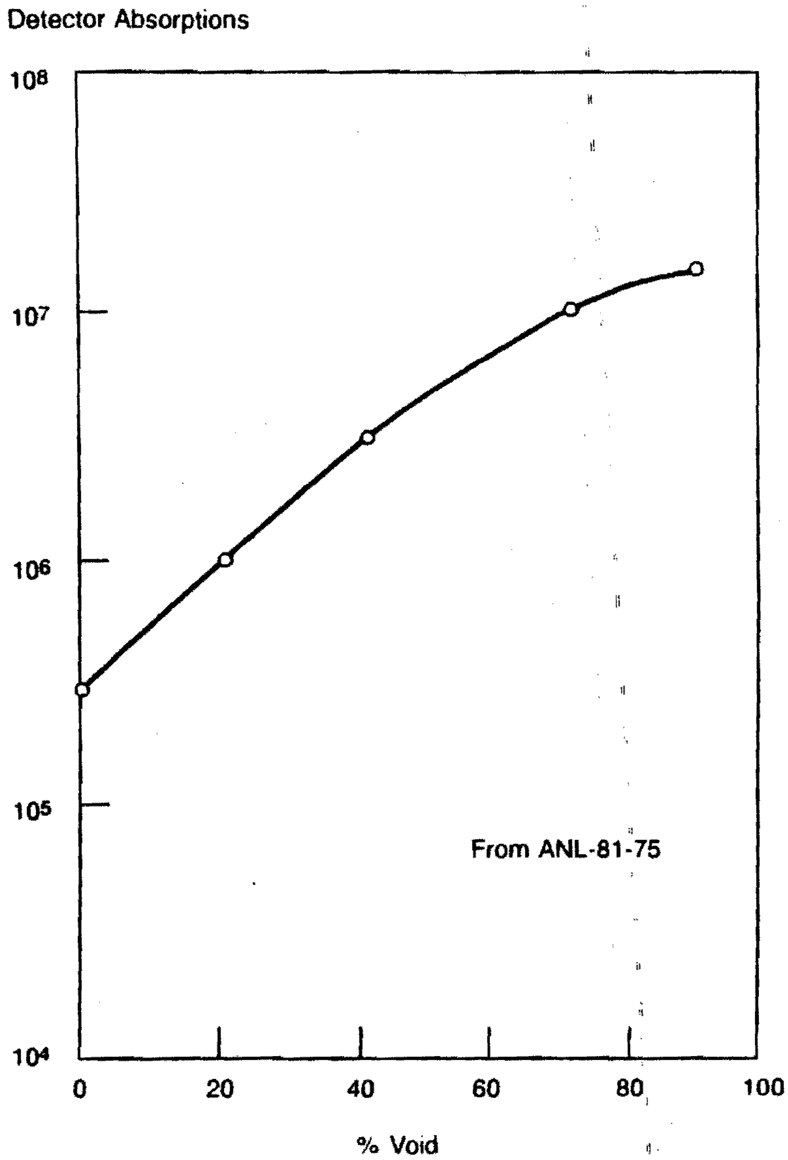
Third, it is important for operators and other personnel to understand that even a very high homogeneous void fraction approaching 100 percent cannot escalate the count rate beyond a certain point. If the count rate does increase above this limit, then the increase cannot be attributed entirely to voiding.

Reactivity effects such as boron dilution or cooldown may be responsible, at least in part, for the high count rate. Alternatively, the high count rate may be caused by fuel that relocated to the downcomer, provided that such relocation is consistent with the accident history.

Previously, it was pointed out that the results of excore detector response analyses performed following the accident at TMI-2 were not entirely consistent, especially for very high homogeneous void fractions in excess of about 80 percent. Some analyses show detector response leveling off at a void fraction of about 80 percent. Based on these analyses, homogeneous voiding can account for a maximum increase in the count rate of a factor of about 40.

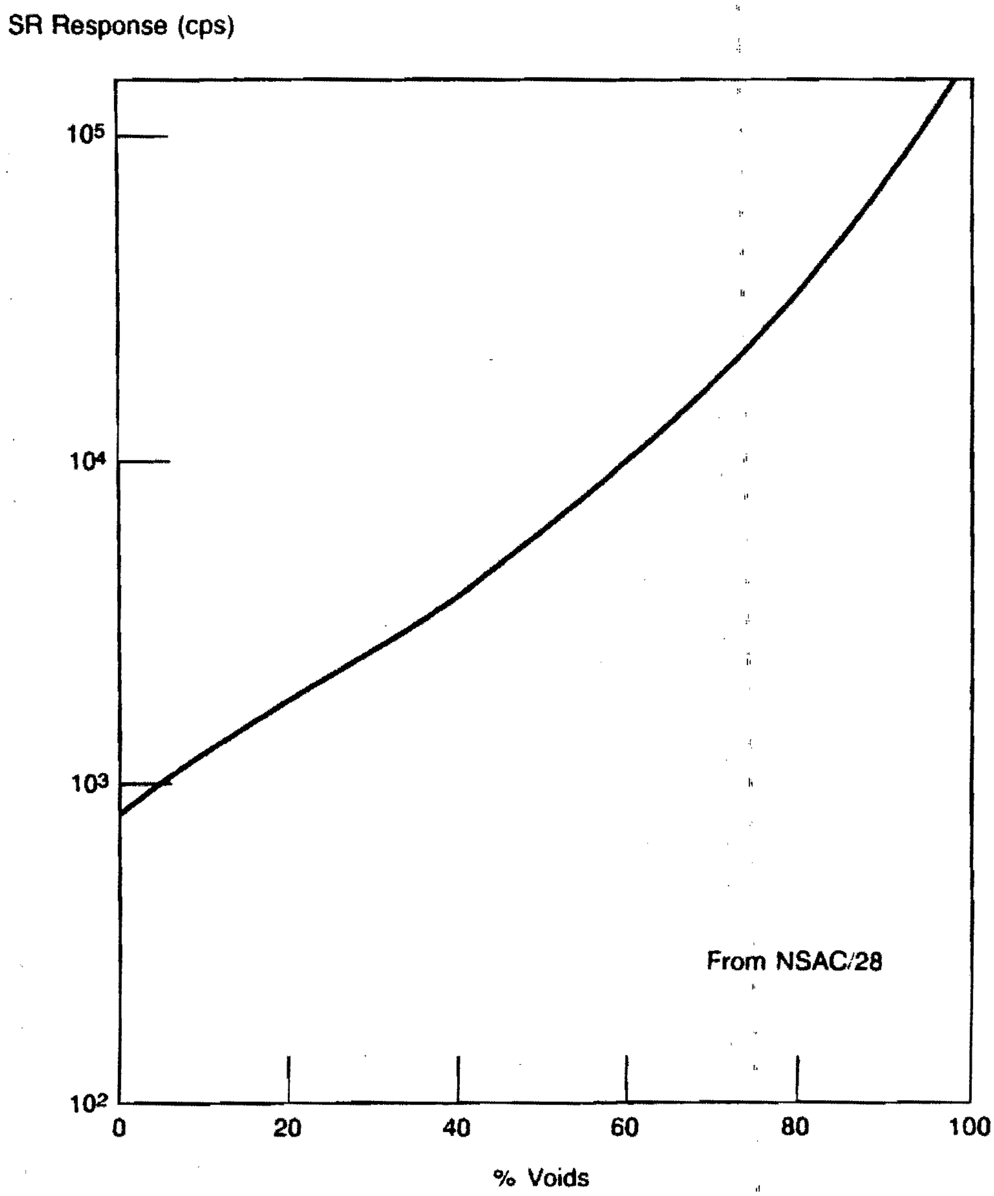
Other analyses show detector response continuously increasing for higher void fractions all the way up to 100 percent voids. Based on these analyses, homogeneous voiding can account for a maximum increase in the count rate of a factor of about 200.

FIGURE 3-1.11
DETECTOR ABSORPTIONS VS VOID FRACTION



37890 X7

FIGURE 3-1.12
SR RESPONSE TO HOMOGENEOUS VOIDING



37890 X8

axial position of the excore detector, the detector can become exposed to the neutron shine from the uncovered core region.

EXCORE DETECTOR RESPONSE TO CORE UNCOVERY

The excore detector response to core uncovery (heterogeneous voiding and no RCP) is shown in figure 3-1.15, which is based on data obtained from NSAC/28, "Interpretation of TMI-2 Instrument Data." Figure 3-1.15 shows the count rate response (in cps) for a source range detector axially positioned at the horizontal midplane of the core. The abscissa is labeled with two levels, one for the core and one for the downcomer.

Analysis Assumptions

The data reported in NSAC/28 regarding core uncovery are the results of neutron transport calculations that were performed using the DOT-IV computer code, which is a two-dimensional, discrete ordinates transport code. Again, several independent studies produced similar and consistent results, which are typified by the results reported in NSAC/28.

The assumptions made in NSAC/28 to analyze excore detector response to core uncovery are as follows:

- **Heterogeneous voiding, no forced circulation**
- **Source range detector axially positioned on the horizontal midplane**
- Downcomer level lower than core mixture level over most of the core height
- Average coolant temperature of 500°F
- Soluble boron concentration of 1030 ppm
- Time after reactor shutdown is two hours

Close inspection of the level labels on the abscissa of figure 3-1.15 shows that the height difference between the core and the downcomer columns appears to gradually diminish as the reactor vessel liquid inventory boils off. By the time the last few feet of the core uncover, the two columns appear to be the same height. The height difference between the two columns appears to diminish in these results because of simplifying assumptions made in one of the voiding and void distribution models used in the NSAC/28 study.

In an actual accident involving core uncovery, the density difference between the core and downcomer would diminish, provided that the void fraction in the downcomer progressively increases. As the liquid inventory of the entire RCS is depleted, the void fraction in the downcomer is likely to go up.

Analysis Results: Influence of Downcomer Level

The count rate response to core uncovery shown in figure 3-1.15 can be explained in the following way. As the top half of the core uncovers, the detector response increases by two orders of magnitude. Because downcomer water level is less than core mixture level, the detector is able to "see" the uncovered core region well before the mixture level in the core falls to the horizontal midplane.

Thus, most of the detector response is obtained as the top 4 feet of the core uncover (from 12 feet down to 8 feet). In fact, because of the unshielding effect created by the depressed liquid level in the downcomer, much of the detector response is obtained before any of the core uncovers.

The predominant effect of downcomer liquid level (or of downcomer fluid density) on excore detector response, as compared to the effect of core mixture level or mixture density, is shown by the following count rate behavior. When the core is still completely covered (mixture level at 12 feet) but the downcomer water level is at 9.87 feet, the count rate increases by a factor of 20 (from about 100 to about 2000 cps). The combination of a highly voided downcomer and a fully covered core, although less likely to occur, would produce similar results.

Analysis Results: Influence of k_{eff} and Source Strength

Because of the lack of moderator, the uncovered region becomes a source of neutron shine from fission that is sustained by thermal neutrons from the flooded region. The detector count rate is driven by the neutron shine from the uncovered region of the core streaming through the empty portion of the downcomer. As the bottom half of the core is uncovered, the detector count rate levels off and then decreases. This count rate behavior is caused by a drop in k_{eff} and by a reduction in the core source strength.

Even though k_{eff} in the uncovered core region is very low, the value of k_{eff} for the overall core remains high as long as most of the core remains covered. Table 3.1.1, in addition to showing the same data represented graphically in figure 3-1.15, also shows the effect of core uncovery on k_{eff} for the overall core. These are the data reported in NSAC/28 for excore detector response to core uncovery (heterogeneous voiding and no RCPs).

When the core first starts to uncover, k_{eff} drops some but then stabilizes as the top half of the core is uncovered. Then, as the bottom half of the core is uncovered, k_{eff} resumes its decline at a steeper and steeper rate.

The flooded region of the core is the source of thermal neutrons for the uncovered region. As the flooded region becomes progressively smaller, so does the deuterium photo-neutron contribution to the core source strength. When the bottom half of the core starts to uncover, the combined effects of reduced source strength and lower k_{eff} begin to offset some of the effect of increased leakage on the excore detector response. Thus, the count rate levels off and decreases somewhat. However, it remains far above the value expected for normal conditions following a reactor shutdown.

Boron Concentration, k_{eff}, and Detector Response

The analysis of excore detector response in NSAC/28 also examined the combined effects of core coolant level and boron concentration on k_{eff}. Table 3.1.2 shows the results. For any given level of coolant in the core, increasing the boron concentration causes k_{eff} to drop. k_{eff} falls because the thermal utilization factor goes down. The thermal utilization factor decreases because of increased neutron competition from the higher soluble boron concentration in the core.

For any given initial boron concentration, decreasing the coolant level in the core causes k_{eff} to decrease. As the liquid level in the core decreases because of boil-off, the boron concentration increases above its initial value. Because very little boron is carried off by the steam, which is almost pure water vapor, the boiling process concentrates the soluble boron in the core. Again, k_{eff} decreases because thermal utilization goes down.

The impact of boron concentration on excore detector response during core uncovery is shown in figure 3-1.16. At higher boron concentrations, the detector response is suppressed, although it maintains the same general shape.

INTERPRETING DETECTOR RESPONSE TO CORE UNCOVERY

The fact that an excore neutron detector responds to core uncovery leads to the question of whether the detector response can be used as an indication of the coolant level in the core. The excore detector response following reactor shutdown under normal conditions is known. Can the detector response to accident conditions be compared to the normal response in order to obtain an indication of the extent of core uncovery?

Assessing the Correlation of Detector Response to Uncovery

To assess the feasibility of establishing a correlation between detector response and core uncovery, three factors should be considered. Before considering these factors, it is worth noting that the RVLIS static range provides direct indication of reactor vessel water level when none of the RCPs is running. Therefore, looking at excore detector response to gage the core water level need be considered only as a nonpreferred alternative to RVLIS.

Ambiguous Interpretation

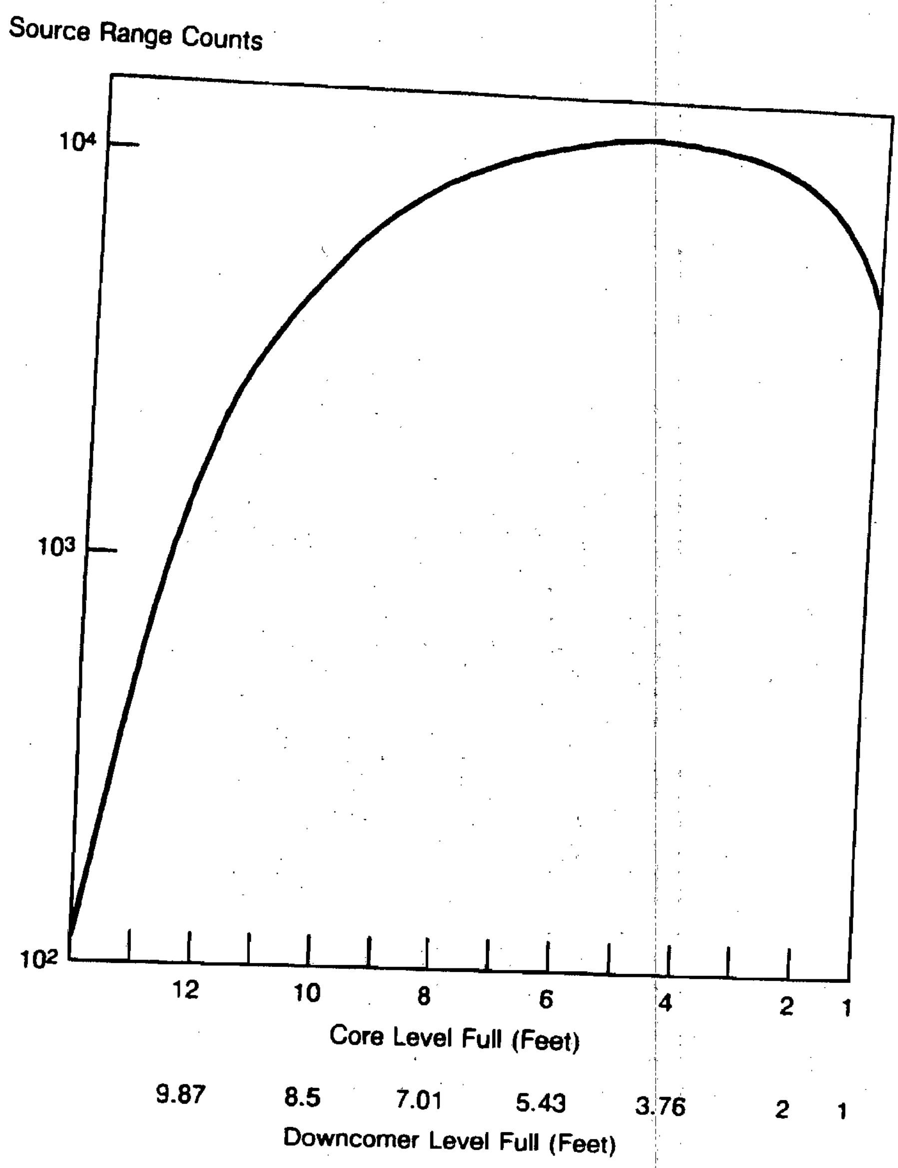
The first factor to consider is that detector response initially increases with core uncovery and then decreases somewhat with continued uncovery. Within a certain range of core water level, which in the NSAC/28 results shown in figure 3-1.15 is from about 10 feet down to about 1 foot, an increase in count rate could be caused by either an increase or a decrease in water level.

Similarly, a decrease in count rate could be caused by either a decrease or an increase in water level. Put another

Assumes heterogeneous voiding

FIGURE 3-1.15

SR DETECTOR RESPONSE VS CORE AND DOWNCOMER LEVEL



37890x11

Norris, Kenneth W.

From: George Usova [GMU@nrc.gov]
Sent: Tuesday, May 09, 2006 12:48 PM
To: Norris, Kenneth W.
Cc: Neil O'Keefe
Subject: Re: Submittal of GFE question request for review

Thank you, Mr. Norris, for your concern over a GFE question. Please identify the question, state your reason(s) for its error, and forward related support materials to the following address:

George M. Usova
U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
OWFN - MS: 6F2
Washington, D.C. 20555

Respectfully,

George M. Usova

>>> <kenneth.norris@exeloncorp.com> 05/09/06 10:31 AM >>>
Dear Dr. Usova:

I am an Exelon Operations instructor at Braidwood Station and the primary instructor for our Fundamentals (Theory) phase of instruction. While reviewing questions in the NRC GFE bank I identified a question that I believe to be in error and would like to submit my request and accompanying explanation. The material is not currently in electronic form (although if you would prefer we could scan the pages and e-mail). Would you please reply with your mail drop information to facilitate efficient delivery of the materials to you.

Thank you in advance and best regards,

Ken Norris

TOPIC: 191002
KNOWLEDGE: K1.16 [2.3/2.7]
QID: P2911 (B2611)

Reed switches are being used in an electrical measuring circuit to monitor the position of a control rod in a reactor. The reed switches are mounted in a column above the reactor vessel such that the control rod drive shaft passes by individual reed switches as the control rod is withdrawn.

Which one of the following describes the action that causes the electrical output of the reed switch circuit to change as the control rod is withdrawn?

A. An ac coil on the control rod drive shaft induces a voltage into each reed switch as the drive shaft passes by.

B. A metal tab on the control rod drive shaft mechanically closes each reed switch as the drive shaft passes by.

C. The primary and secondary coils of each reed switch attain maximum magnetic coupling as the drive shaft passes by.

D. A permanent magnet on the control rod drive shaft attracts the movable contact arm of each reed switch as the drive shaft passes by.

ANSWER: D.

TOPIC: 191002
KNOWLEDGE: K1.17 [3.3/3.5]
QID: P415

A plant has experienced a loss of coolant accident with degraded safety injection flow. Core voiding is homogeneous and is currently 20%.

Which one of the following describes excore source/startup range neutron level indication as homogeneous core voiding increases from 20% to 100% of the core? (Assume the neutron detectors are located adjacent to the bottom portion of the core.)

A. Decreases continuously

B. Decreases, then increases

C. Increases continuously

D. Increases, then decreases

ANSWER: D.

Bad Question

KENNETH W. NORRIS

[redacted]

PROFESSIONAL SUMMARY:

October 1999 to Present: **Exelon Nuclear**

LICENSED OPERATOR INSTRUCTOR: BRAIDWOOD STATION

October 1999 TO PRESENT

- ILT Fundamentals Lead Instructor: Ensured continuous improvement/maintenance of training materials and program design
- Lead Instructor various simulator phases for six different ILT classes
- Project coordinator/manager for on-line work (Station Air Compressor, RH Pump and System, Six Year Diesel Generator Overhaul) and Containment Sump Projects (three consecutive refueling outages)
- Wrote Accreditation Self-Evaluation Report for Braidwood Station in 2003 and 2007
- Shift Technical Advisor Program Lead Instructor
- As Lead instructor for various ILT phases prepared and conducted various Curriculum Review Committee Meetings
- Performed various corrective action program assessments (Common Cause Analysis, Benchmarking, Check-In Assessment)
- Continue to maintain active SRO certification

May 1998 to August 1999: **AEP**

LICENSED OPERATOR INSTRUCTOR: D.C. COOK

MAY 1998 TO August 1999

- Developed new training and qualification process for OJQ (TPE) of Operators at D.C. Cook (Program subsequently recognized as an industry strength by INPO)
- Implemented new OJT training and process at D.C. Cook as an extension of revising OJQ (TPE)
- Project Manager for Lesson Plan Upgrade Project (LPUP) for Systems Training of Licensed Operators
- Maintained active SRO certification

1984 to April 1998: **COM ED**

LICENSED OPERATOR INSTRUCTOR: ZION STATION

SEPTEMBER 1994 TO APRIL 1998

- Completed SRO Certification Reactivation (for ZION STATION) May 1995
- Taught Simulator phase of Engineering Certification Pilot (Summer 1995) results contributing to re-accreditation by INPO
- Prepared PRA/On-Line Maintenance Training for Licensed Operators and Upper Management.
- Developed detailed training on Zion Improved Technical Specifications for Licensed Operators, Engineers and others, including creation of 185 question exam bank.
- Taught ILT class 96-01 (100% pass rate on NRC license exams)
- Qualified Severe Accident Management Guideline Evaluator (1997)

KENNETH W. NORRIS

[redacted]

MODIFICATION DESIGN ENGINEER: ZION STATION

NOVEMBER 1991 TO SEPTEMBER 1994

- After taking over several modifications from other engineers, re-scoped to continue to meet design requirements while significantly reducing cost to Zion Station and Com Ed (total savings over $ 1,000,000)
- Team Leader on several Modifications/Exempt Changes to Zion Station
- Met all Design Deliverable Due Dates
- Created the License Amendment Library in Mod Design Engineering to ensure all SERs available to Engineers (as required per 50.59 reviews)
- Responded to/Resolved numerous Station Commitments all within due dates.
- Resolved variety of design bases issues that arose from development of Zion Technical Specification Improvement Program
- Independently created and distributed QE Engineering Procedure Index to facilitate use by all Modification Design Engineers (all stations)
- Trained fellow Modification Design Engineers on Safety Analysis and LER processing

LICENSED OPERATOR INSTRUCTOR: BRAIDWOOD STATION (PTC)

SEPTEMBER 1986 TO NOVEMBER 1991

- Fundamentals Lead Instructor ensured continuous improvement/maintenance of training materials
- Developed/Maintained SCRE/STA training materials and administrative controls (ACMI) to ensure high quality training and continued INPO accreditation.
- Conducted License Training in all areas.
- Extensively re-wrote numerous texts/lesson plans to improve quality of presentation in various areas of operations training.
- Successfully attained INPO initial accreditation of SCRE/STA Training
- Completed Westinghouse SRO Certification (July 1987)

ENGINEERING GROUP INSTRUCTOR: BRAIDWOOD STATION (PTC)

SEPTEMBER 1984 TO AUGUST 1986

- Developed CECo SCRE/STA Training Standard
- Successfully piloted SCRE/STA Training for Byron, Braidwood and La Salle Stations in preparation for initial INPO accreditation
- Transitioned SCRE/STA program to Licensed Operator Training with personal move to Licensed Operator Training
- Completed Basic and Advanced Instructor Courses
- INPO Accreditation Peer Evaluator (1986)

UNITED STATES NAVAL OFFICER (NUCLEAR SUBMARINE FORCE)

JUNE 1980 TO SEPTEMBER 1984

- Qualified Engineering Officer of the Watch/Engineering Duty Officer on USS Alexander Hamilton (SSBN 617): responsible for supervision of nuclear propulsion plant operations and maintenance control on shift, both operating and shutdown.
- Division Officer: Trained, supervised, evaluated, counseled, wrote fitness reports , and administered different divisions of 10-12 personnel.
- Completed Training and Qualifications at Naval Nuclear Power School (Orlando Florida) and Naval Nuclear Prototype S7G in Ballston Spa NY.

KENNETH W. NORRIS

[redacted]

EDUCATION

1980 Bachelor of Science in Nuclear Engineering from University of Michigan, Ann Arbor MI

1976 Graduate, North Canton Hoover High School, North Canton, Ohio