June 10, 1980

MEMORANDUM FOR: D. F. Ross, Director
Division of Systems Integration
Office of Nuclear Reactor Regulation

FROM: R. M. Bernero, Director
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Office of Nuclear Regulatory Research

SUBJECT: VALUE OF INERTING TO OVERALL RISK REDUCTION

Attached is a summary of the PAS views on inerting. The attached paper is based on a presentation on this subject before an ACRS Subcommittee on October 3, 1979. Further amplification is available if needed by reference to that ACRS transcript.

Original Signed By:
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Enclosure: Views of the PAS
On The Matter of Inerted
Containment Atmosphere

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VIEWS OF THE PAS ON THE MATTER

OF

INERTED CONTAINMENT ATMOSPHERE

This report is intended to summarize the views of the Probabilistic Analysis Staff (PAS) on the potential value of inerting containment for reducing overall accident risks. The PAS views on this matter were presented on October 3, 1979, to the ACRS Subcommittee on TMI-2. The Chairman, Dr. David Okrent, had requested PAS views in connection with ACRS deliberations on "lessons learned" from TMI-2. A copy of the PAS viewgraphs presented at the October 3 meeting is enclosed for information and these are briefly addressed herein.

Background for PAS views:

The PAS views on inerting derive largely from risk-based studies that have considered a spectrum of accident scenarios in several PWR and BWR designs. These studies have included the following kinds of LWR designs:

- o A "dry" subatmospheric, reinforced concrete containment - PWR
- o A Mark I vapor suppression containment (steel shell) - BWR
- o A "dry" pre-stressed, concrete containment - PWR
- o An Ice Condenser containment (steel shell) - PWR

Results from these studies have indicated that in order to have high risk, the core must experience a meltdown accident - but that not all meltdown accidents would involve high public risk. That is, if risk is to be measured by the likelihood of significant public health impacts such as acute and latent cancer fatalities. As illustrated by viewgraphs #3, #4, #5, and #6, these studies have revealed that there are a number of pathways that can lead to meltdown and to containment failure. The health impacts generally are largest when:

1. an energetic failure of containment occurs in the presence of a large source of fisson product gases in the containment atmosphere or,
2. When the containment and its systems are essentially by-passed with the discharge of fission product gases (as with Event V - an interfacing system LOCA).

The risk-based studies have revealed that those containments of smaller size (e.g., Mark I, II) and those of lower design pressure (e.g., ice condenser) tend to be more closely coupled (or sensitive) to the effects of a degraded core accident. In other words, given a meltdown scenario, in a small containment, the outcomes in terms of health impacts (or release magnitude) tend to be clustered together more than for the larger, dry containment designs. As illustrated in viewgraph #6, the PWR dry containment design can have a wider spectrum of possible outcomes than does the smaller vapor suppression containment design. Table 1 (Enclosure 1) provides further insight on the spectrum of potential outcomes for the larger PWR containment design. This table was derived from the Reactor Safety Study [1] and it illustrates various core degradations and meltdowns that might occur in the presence of degraded containment leak integrity (the loss of containment leak integrity is the main safety threat postulated to result from a burn or explosion of hydrogen). The main point to be seen from Table 1 is that the presence of containment sprays has order of magnitude value in reducing

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[1] Subatmospheric containment design

the release of the halogens even with loss of containment leak integrity. Since halogens have a major role in the potential health impacts to the public, the presence of sprays has risk reduction value. Also illustrated by the shading in Table 1 is the approximate pathway of the TMI-2 accident which was terminated somewhat short of being a core meltdown. The fission product retention processes involved in terminating the TMI-2 accident, that is; isolating the LOCA and repressurizing the coolant system; the automatic initiation of sprays by the hydrogen burn, the presence of a reasonably good containment leakage integrity, and the absence of any significant driving force for leakage subsequent to the hydrogen burn; are all factors that contributed to a very small magnitude of halogen release from TMI-2.

It is, however, the accident at TMI-2 that once more gives rise to the long-standing issue of whether or not to inert the containment atmosphere against hydrogen; in particular, for the smaller BWR Mark I and II vapor suppression designs and the PWR ice condenser containment designs.

The PAS Views on Inerting

The principal views of the PAS are that:

1. The use of an inerted containment has small value in terms of reducing the overall accident risks to the public;
2. Reducing the probability of occurrence (or mitigating the release outcome) of those accident sequences presently dominating the overall risks would have equal or greater value than inerting; and

3. The individual occupational risks presented by plant operation with an inerted continment atmosphere may be considerably larger and outweigh the small value gained in overall accident risk reduction which is applicable to this same individual.

These above views are believed to be particularly appropriate for the BWR Mark I and II containments for which inerting is the present issue.

Viewgraph #11 illustrates some of the principal reasons for the above PAS views on the BWR Mark I, II, containment inerting question. Results from risk-based studies of a BWR #4, Mark I design, have indicated that the overall risk would be dominated by several transient inititiated accidents that involve (1) failure to shutdown the power of the core and (2) the failure to remove shutdown decay heat from the core and containment following its isolation. For these accidents, containment failure by steam overpressure precedes any damage or meltdown of the reactor core, i.e., the core experiences damage only after a major loss of containment leak integrity has occurred. The loss of the containment atmosphere prior to core damage being incurred would seem to make the overall risk reduction value of an inert atmosphere a rather moot issue. For such sequences, greater overall risk reduction value would be achieved by either reducing the probability of the core damage sequences or possibly by further mitigating the potential magnitude of release accompanying these sequences (e.g., use of ~~an~~ automatically activated sprays).

If, on the other hand, one chooses to ignore these risk dominant sequences and to limit the possible accident scenarios to only those for which containment integrity is initially present when the core undergoes some as yet unspecified, but terminated, degree of damage, then inerting can be viewed as having value in reducing the possible threat to containment leak integrity from a hydrogen burn or explosion. This threat to containment leak integrity applies however, to any containment design.[2] The issues seem to be (1) which design appears more sensitive to some postulated quantity of hydrogen or clad-reaction in the unspecified, terminated core accident and (2) whether or not this design is judged to be too sensitive relative to all the rest.

A number of calculations (and some experiments) regarding hydrogen sources and hydrogen evolution to containment have been performed over the past decade or more. Over these many years, there appears to have been little disagreement that for certain parameters of importance (e.g., % clad reaction, containment design and/or failure pressure and the containment free volume), the sensitivity of various designs to hydrogen would rank about as follows:

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[2] The technical bases underlying paragraph 50.44 of 10CFR50 specified that all containments should be inerted and that this would be the case unless (1) calculations tied to the legally required Appendix K ECCS modeling were submitted and (2) the results gave acceptably low hydrogen concentration in containment when a factor of 5 margin was applied to the Appendix K result. The PAS is unaware of any changes in these existing rules that would now exclude the BWR, Mark I and II designs and their ability to meet these rules.

CONTAINMENTS	CONTAINMENT SPRAY MITIGATION
1. BWR-Mark I and II	o These designs generally depend on ECCS to drive the sprays and a human decision on whether or not to manually activate sprays.
2. BWR Mark III and PWR Ice Condenser	o Generally these designs have automated containment sprays that could yield order of magnitude benefit in reducing halogen release, assuming a hydrogen burn leads to loss of containment leak integrity.
3. Subatmospheric and Intermediate size dry containments	
4. Large dry containments	

The above sensitivity ranking to hydrogen seemingly implies a higher urgency for resolution for the BWR Mark I and II containments given the post TMI-2 climate. It is not clear to PAS however, that such an urgency does prevail given the existence of nearly an order of magnitude more operating experience for the BWR design than in fact did exist for those PWR designs like TMI-2. To have such urgency for inerting the BWR containment not only denies the available risk-based perspectives, it also presupposes that the the same likelihood of a TMI-2 type of accident exists in the BWR designs. Experience alone already denies this latter supposition. If one assumes that the overall nuclear industry has benefited by applications of the TMI-2 lesson learned and that the likelihood of a degraded core has been further reduced as a result, then it seems logical that the urgency to inert the MARK I and II containment is even less now than it was prior to TMI-2; notwithstanding the long known sensitivity of the smaller containments to hydrogen.

In contrast to the Mark I and II containments, the risk-based studies on a PWR ice condenser containment suggest that an overall risk reduction factor of roughly 4 might exists if the containment were to be inerted. (See viewgraphs #9 and #10). However, these same studies suggested that relatively straight-forward ways existed to achieve at least an equivalent improvement (with minimal impacts) by reducing the probability of the risk dominant sequences. It is also our present understanding that some of these improvements have already been factored into the design and/or planned operations for the Sequoyah and the Floating Nuclear Plants. Inerting would, of course, still yield some additional value for reducing the overall accident risks in an ice condenser design.

Presently, no PWR ice condenser containment design uses or is required to use an inert containment atmosphere although risk based studies would suggest a higher value for inerting an ice condensor relative to the Mark I and II containment.

In summary, the PAS view is that inerting has small value in terms of overall accident risk reduction and it is believed that other means exist that could have equal or greater value. If an urgency presently exists for inerting the Mark I and II containments, the bases are not found in any risk-based studies of which the PAS is aware. It should also be said that the PAS can presently offer no overwhelming argument against an inerting decision except for those views described above.

TABLE 1

ILLUSTRATION OF A SPECTRUM OF DEGRADATIONS IN THE REACTOR CORE, IN CONTAINMENT ENGINEERED SAFETY FEATURES, AND IN CONTAINMENT LEAK INTEGRITY.

TMI-2 → DEGRADED CORE ACCIDENT

Core Halogen Inventory →

- o Increasing Public Health Risks
- o Increasing Degradation of Installed Engineered Safety Features

ACCIDENT SEQUENCE DESIGNATION (REACTOR SAFETY STUDY)	PREDICTED FRACTION OF CORE HALOGENS AIRBORE TO CONTAINMENT	PREDICTEL FRACTION OF CORE HALOGENS RELEASED FROM CONTAINMENT TO ATMOSPHERE (To ∼ 30 Days Post Accident)	SCENARIO DESCRIPTIONS AND COMMENTS
A (Degraded Clad, No Melt Down)	≲ 0.02	∼ 1X 10^{-7}	o LOCA ≳ 6" diameter o 100% Clad Perforation o Sprays Operate o NaOH in Sprays o Containment Leakage ∼ 1%/day
Aδ (Degraded Clad, No melt Down)	≲ 0.02	∼ 1 X 10^{-4}	o Same as above except containment leakage via ∼4" diameter equivalent hole
DEGRADED CORE ACCIDENT			
ADε, AHε (Melt Down)	∼ 100%	∼ 2 X 10^{-5} Leakage Until Time Base Mat Penetrates ∼ 5 X 10^{-4} Including Base Mat Penetration	o LOCA ≳ 6" diameter o ECCS Fails in Either Injection (D) or Recirc Phase (H) o Sprays Operate o NaOH in Sprays o Core Melts Down o Containment Leakage ∼ 1%/day until base mat is penetrated
ADδ, AHδ (Melt Down)	∼ 100%	∼ 8 X 10^{-3}	o Same as AD, AH above, except containment leak integrity is lost (∼ 4" diameter equivalent hole)
AHIδ (Melt Down)	∼100%	∼ 4 X 10^{-2}	o Same as AHδ above except NaOH is not introduced into spray system.
ADFδ (Melt Down)	∼ 100%	∼ 5 X 10^{-2}	o Same as ADδ above except containment heat removal (recirc sprays) fails, quench sprays + NaOH operate until water is exhausted from RWST
ACDδ, ACDGIδ, (Melt Down)	∼100%	∼ 9 X 10^{-2}	o Same as ADδ above except quench sprays, NaOH and the system conveying heat from containment fail. The recirculation sprays operate to spray borated water in containment.
AHFδ, (Melt Down)	∼ 100%	∼ 3 X 10^{-1}	o Same as AHδ above where core melt down occurs due to failure of ECCS in recirc phase - except containment spray and heat removal are failed.
Releases From Risk Dominant Sequences Shown in WASH-1400 (Release Category #2) (Melt Down)	∼ 100%	∼ 7 X 10^{-1}	o Includes transients, Event V, Scenarios where all ESFs (Engineered Safety Features) are inoperable. Containment can energetically fail due to steam overpressures unless precluded by existence of abnormally high containment leakage rates (e.g., ≳ 4" diameter openings)

TABLE 1: TMI-2 vs. Some RSS Accident Sequence Outcomes