



UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

DEC 30 1982

MEMORANDUM FOR: D. Eisenhut, Director, Division of Licensing
FROM: R. Mattson, Director, Division of Systems Integration
P. Vollmer, Director, Division of Engineering
SUBJECT: PROPOSED POSITION RE: RECOMBINER CAPABILITY

In your memorandum of October 28, 1982, you requested our views on how to proceed on the subject issue. As you know we have wrestled with the issue over the past several months and have had some difficulty in developing a staff position with adequate supporting data. We have found the requirement for a recombiner capability to be strongly dependent on the post-LOCA radiolysis rate. That is, high radiolysis rates mean the recombiner capability is required and low radiolysis rates mean it is not required. Based on the radiolysis information available, on a case-by-case basis, we can consider modest departures from the conservative prescriptions in Regulatory Guide 1.7. Specifically, in regard to the case presented by the Mark I Owners Group, we find that a defensible basis can be developed for not requiring the recombiner capability in plants with the Mark I containment.

Both the Mark I Owners Group and the staff have undertaken a substantial program to re-examine the expected yield of hydrogen and oxygen from radiolysis during design basis accidents. Our findings to date indicate that the source terms for radiolysis may be reduced substantially from those prescribed in Regulatory Guide 1.7 if there is assurance that: 1) bulk boiling of the reactor coolant will stop after about 12 hours following onset of the accident; and 2) less than about 3 percent of the total iodine inventory in the core is transferred to the reactor coolant.

NRC policy to date relative to design basis accidents is that uncontrolled hydrogen burning in the containment during design basis accidents is unacceptable. However, for degraded core accidents, we have found the controlled burning of hydrogen to be acceptable. We have also required substantial measures of conservatism in the design of engineered safety features to mitigate the consequences of design basis accidents. From these perspectives: 1) if we require consideration of multiple equipment failures, then boiling in the upper portion of the core following a recirculation line break will continue for some 50-60 hours or longer instead of the 12 hours assumed in the licensees'

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analyses; 2) if we require consideration of low probability accident sequences, then substantial fractions of the iodine inventory relative to the one percent assumed by the licensees will be released to the coolant; 3) if we require the containment atmosphere to remain non-flammable for an indefinite period following onset of the accident, then even small ^{131}I -values for radiolysis relative to those in Regulatory Guide 1.7 will eventually (6 months or more) produce combustible mixtures in the containment. Thus, if the Mark I containments did not already have safety grade systems for combustible gas control as prescribed in the original 10 CFR 50.44, we would continue our practice of requiring conservatism in the design of engineered safety features, and recommend that the licensees' requests for a less conservative treatment of the radiolysis source term be denied and that the recombiner capability be required.

However, we need to also consider the background leading to the requirement for the recombiner capability and some cost-benefit matters. The adverse public reaction to the planned post-accident venting at TMI-2 was the reason that led the staff to develop the requirement for a recombiner capability at those facilities that rely on purging as the primary means for hydrogen control. It is important to note that the motivation was the public perception of risk and not our assessment of the actual risk. The intent was that the existing safety grade purging system will continue to be available and acceptable, whether or not the recombiner capability is provided as called for in the revised 10 CFR 50.44. The recombiner capability was intended solely to provide public health officials with the option of not venting in order to avoid the public hysteria associated with the controlled venting of Kr-85 long after the TMI-2 accident.

During development of the recombiner capability rule, the staff thought the cost to each licensee would be small, about \$100,000. The staff received no comments to indicate this cost figure to be inappropriate. The Mark I Owners have since estimated the cost to range between 2 and 4 million dollars per unit, or about \$60 million for the approximately 20 BWR units affected by the rule. We have reviewed the basis for their estimate and find it reasonable.

The basic thrust of the licensees' argument is that the Mark I containments never needed a recombiner or a purge system in the first place. They assert that the licensing basis prescription for analyzing radiolysis which has been used by the staff and the industry over the past decade is far too conservative. This has been the prescription that has caused safety grade recombiners, purge/repressurization systems, and related mixing systems to be installed in most of the existing operating plants.

In the judgment of DSI and DE, there is sufficient new technical information and cost information to justify reconsideration of the requirement for recombiner capability in inerted BWRs that rely on a purge/repressurization system as the primary means of hydrogen control. This new information indicates that radiolysis is a dominant source of hydrogen and oxygen for only a few of the possible accident scenarios.

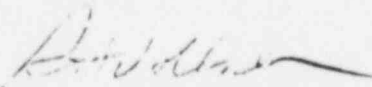
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That is, without bulk boiling, the radiolysis rates will be substantially less than the prescription given in Regulatory Guide 1.7, except for those low probability scenarios where a substantial fraction of the iodine inventory is released to the reactor coolant and the amount of metal water reaction is relatively small, i.e., less than one percent. Moreover, the cost of providing the recombiner capability appears to be as much as 30 times that considered by the Commission when the rule was promulgated. Accordingly, since the likelihood of having to purge the Mark I containment for hydrogen control is more remote than previously considered and since the cost of providing the recombiner capability is some 30 times higher than previously considered, we recommend that the staff request that the Commission exempt the Mark I owners from the requirement for the recombiner capability.

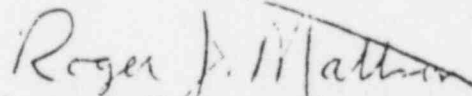
In conjunction with the above recommended exemption, those Mark I/PWR licensees who choose not to provide the recombiner capability should be required to utilize either nitrogen or recycled containment air for its instrument air systems located inside containment. In addition, the Technical Specifications should be reviewed to assure that the LCO value for oxygen concentration is the 4.0% value assumed in the licensees' analyses. These were among the fundamental assumptions relied on by the Mark I Owners Group in concluding that an initially inert containment would remain inert following onset of a design basis accident.

During our briefing of the Commission on the overall subject of hydrogen control during severe accidents on November 19, 1982, DSI informed the Commission of these preliminary findings and of our intent to return to the Commission in a few weeks with the implementation recommendations.

The enclosed discussion paper provides a lot of good background information which you may find useful.



Richard H. Vollmer, Director
Division of Engineering



Roger J. Mattson, Director
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Enclosure:
As stated

PROPOSED NRR POSITION ON RECOMBINER
CAPABILITY FOR MARK I/BWRs

I. INTRODUCTION

The recently issued rule requiring a "Recombiner capability" at certain LWR plants has evolved into a substantive regulatory issue requiring NRR management attention. The relevant background information, definition of the problem, and alternative staff positions are provided below.

II. BACKGROUND

Regulatory requirements on hydrogen control for design basis accidents were first prescribed in Criterion 41 of the General Design Criteria, (Appendix A, 10 CFR 50). Safety Guide 7 contained some of the early guidance on implementation. These early documents were based on a staff objective of having all LWR containments provided with a capability for safely accommodating the hydrogen releases from a postulated accident involving metal-water reaction in 5% of the cladding material plus the hydrogen releases from radiolysis and corrosion. This amount of metal-water reaction was then recognized to be conservatively high for design basis purposes in view of the small fractions of 1% that were being calculated in ECCS analyses. Corresponding measures of conservatism were introduced in the staff's recommended G-value of 0.50 for radiolysis rates.

With the introduction of the Mark III containment design by General Electric in the early to mid-1970's, and in view of The Appeal Board ruling on the Vermont Yankee case, the staff re-examined the recommended design basis values for metal water reaction and radiolysis rates. The results of this re-examination were codified as 10 CFR 50.44 and in Revision 2 to Regulatory Guide 1.7 in late 1978. However, only the metal-water reaction rates, which were reduced from 5% to as low as 1% depending on the results of the ECCS analysis, were put in the rule. The radiolysis rate G-values were not changed from the original values in Safety Guide 7 but were not made a part of the rule. This was the result of the intense controversy over the metal-water reaction assumption. Similar controversy did not then exist in regard to the radiolysis G-value.

Hydrogen control measures need to be evaluated for both short term and long term capability. The short term phase is nominally the first day following onset of the accident where the dominant source of hydrogen is the postulated amount of metal-water reaction. Since its release to the containment is prompt relative to the capability of any recombiner system, the containment net free volume is relied on with the help of a mixing system to assure that the hydrogen (or oxygen for inerted containments) concentrations remain below the lower flammability limits.

The long term phase extends for the duration of the accident where radiolysis of water and corrosion of various materials such as aluminum and galvanized metal and off-gassing from zinc-based paints are the dominant sources of hydrogen. Recently licensed PWR and BWR plants have been required to furnish redundant, safety grade recombiner systems to safely accommodate the long term requirements for hydrogen control. The older plants that were "grandfathered" by the original 10 CFR 50.44 were permitted to rely on purge/repressurization systems in lieu of recombiner systems to satisfy the long term requirements. These systems were called either the CAD (containment atmosphere dilution) system or the ACAD system depending on whether the diluent used in the repressurization system is nitrogen or air. Under certain prescribed conditions, a plain purge system was permitted for the grandfathered plants.

The TMI-2 accident in March 1979 involved metal-water reactions estimated to be between 40 and 50% of the cladding. There was some measure of controversy as to the amount of radiolysis that occurred during the course of the accident. It appears that in this accident sequence, the large amount of hydrogen produced by the metal water reaction and the maintenance of a high system pressure contributed to a relatively high concentration of hydrogen in solution with the coolant. Without substantial bulk-boiling and the associated prompt stripping of radiolysis gases, high concentrations of hydrogen promote a strong back-reaction so that net radiolysis can be negligible.

We note that the actual amount of radiolysis yields during the TMI-2 accident have not been determined. Moreover, other design basis accident sequences could involve: (1) negligible hydrogen concentrations in solution with the

coolant; (2) substantial iodine concentrations in the coolant; and (3) a prolonged phase of bulk boiling in parts of the core. However, the likelihood for these accident sequences is recognized as being small. (See Enclosure 1 for a more detailed discussion on accident sequences.)

This means that regardless of the actual amount of net radiolysis during the TMI-2 accident, and unless the provisions of Regulation Guide 1.7 are satisfied, there exists a need to consider a variety of accident sequences in determining the appropriate G-values for the radiolysis source term for the design basis of hydrogen control systems.

We have examined the licensees' estimates of the expected iodine release from the fuel for a number of accident scenarios. Based upon that examination, we conclude that the radiolysis rates would be substantial for accidents in which the extent of metal-water reaction is limited (i.e., less than 5 percent). For these conditions, the fraction of iodine normally residing in the fuel-cladding gap will be released during the accident, if cladding rupture occurs. Subsequent heating of the fuel would result in additional releases of iodine, but this additional amount would be limited for events with low levels of metal-water reaction.

We have independently calculated the iodine fraction residing in the fuel-cladding gap of the principal fuel designs now in the Millstone-2 core. Our calculations indicated that, for the high linear power levels permitted by the plant's Technical Specifications (particularly, sustained high power levels), a substantial fraction (40%-60%) of the total iodine inventory in a fuel rod may reside in the gap. Should only a small number of the high power rods rupture during an accident (as is predicted by the ECCS performance evaluation), the iodine released could cause substantial increases in the radiolysis rates. Our own calculations indicate that the resulting gas mixture in the containment would reach the lower flammability limits defined by the licensees.

There are a number of significant conservatisms employed in these calculations, including the use of "permitted" rather than "expected" power levels. If expected power levels are used, the calculated fraction of iodine in the gap

is much lower and a larger number of fuel rods must perforate during the accident to yield high iodine concentrations in the coolant. Since these iodine concentrations also approach the limiting levels described by the licensee, flammability cannot be categorically ruled out, as had been hoped, but achieving the flammability conditions appears unlikely because of the conservative nature of the calculations. (See Enclosure 2 and 3 for more detailed discussions of iodine releases and the associated radiolysis G-values.)

In its final report, NUREG-0585, the TMI-2 Lessons Learned Task Force recommended that the "Recombiner capability" matter be made a part of the rulemaking proceeding. A proposed rule incorporating this recommendation was published in the Federal Register (45FR65466) on October 2, 1980. A final rule published in the Federal Register (46FR58484), made the "Recombiner capability" a requirement for all LWR plants that rely on purge/repressurization systems as the primary means for hydrogen control. This capability has to be installed by the end of the first scheduled outage beginning after July 5, 1982. (See Enclosure 4 for the upcoming shutdowns at the affected BWR and PWR plants.)

Some BWR licensees claim that our proposed rule (45FR65466) was ambiguous and appeared not to have had any impact on inerted Mark I containments. These licensees have petitions pending before an Appeals Court seeking relief from the now effective rule. The parties have agreed to delay any action on the petitions pending completion of the staff's review of certain reports filed by the BWR Owners Group and by the Millstone I licensee.

In the reports filed by the BWR Owners Group and by the Millstone I licensee, the licensees assert that the Mark I containments can maintain a non-flammable mixture in the containment without having to purge the containment and without using a recombiner. This assertion is fully dependent on the staff's willingness to accept radiolysis G-values that are substantially lower than those recommended in Regulatory Guide 1.7, Revision 2.

III. PROBLEM DEFINITION

The NRC's objective is to assure that all LWR plants can maintain non-flammable conditions in the containment atmosphere following onset of design basis accidents, without having to purge the containment. The owners of BWR plants with Mark I containments have asserted that even without purging, their containments are able to prevent the development of flammable mixtures, provided they are not required to use the very conservative radiolysis G-values of Regulatory Guide 1.7.

Staff analyses indicate that a one-decade reduction in the RG 1.7 G-value may be sufficient to assure non-flammable mixtures in the Mark I containment. (See Enclosure 5 for the supporting analyses). However, analyses with reasonably conservative assumptions for iodine and hydrogen concentrations in solution yield radiolysis G-values that are very close to those of RG 1.7. Applicable data do not exist to support the reduction in radiolysis G-values required to substantiate the case made by the Mark I Owners Group. Data are insufficient for both the amount of iodines that are absorbed in the cooling water and the effects on G-value of various concentrations of iodine and hydrogen. Some two to four years may be needed to obtain the requisite data without a guarantee that the new data would substantiate the case.

IV. ALTERNATIVE STAFF POSITIONS

Four possible staff positions are considered below. They include:

- (1) denial of the relief requested by the Millstone I licensee and the BWR Owners Group;
- (2) deferral of staff conclusion pending completion of certain experiments;
- (3) approval of the requested relief - licensees' bases;
- and (4) approval of the requested relief - staff's bases.

A discussion of these alternatives is provided below.

A. DENIAL OF THE REQUESTED RELIEF

1. Position

The staff could find the proposed use of radiolysis G-values which are substantially smaller than that recommended in Regulatory Guide 1.7

(Revision 2) to be unjustified and unacceptable. This means that long term control of hydrogen concentrations in containment would require the use of either recombiners or purge/repressurization systems as detailed in 10 CFR 50.44. Accordingly, if purge/repressurization systems are relied on as the primary means for hydrogen control, than a recombiner capability (non-redundant) should be required.

2. Implications

The position is consistent with past agency policies of requiring the use of conservative analysis methods and assumptions for evaluating the consequences of design basis accidents. Specifically, it means

- a) Consideration of a double-ended break of the recirculation line in BWR's such that only 2/3 of fueled core can be kept flooded with water. Bulk boiling in the upper foot or so of the core can be expected to persist for 50 to 75 hours following onset of the accident. Radiolysis G-values will be near RG 1.7 value for this duration regardless of H₂ concentration. We note that this scenario requires a double failure assumption, i.e., failure of both core spray trains.
- b) Use of the "TID Source Terms" for determining contaminant concentrations in the coolant, i.e., 50% of the core iodine inventory should be assumed to be in the water. Even if this were reduced to 5 or 10%, the results will be comparable.
- c) The primary system and the containment are at one atmosphere pressure; i.e., the maximum hydrogen partial pressure should be assumed to be the value for the lower flammability limit or about 0.04 atmosphere. This will minimize the hydrogen in the coolant so that the recombination or back reaction will be negligible. The diluent effect will also be minimal.

If the above detailed conservative assumptions are made, the appropriate design basis for radiolysis G-value will be the RG 1.7 value or 0.50.

The owners of Mark I BWR's will have to each incur an expense of between 2 to 4 million dollars (These are the Owners Group estimates, which we believe are justifiable.) to provide the required recombiner capability. Most of the owners will also have to be granted a temporary exemption from the revised 10 CFR 50.44 because they will be unable to meet the required installation schedule.

A number of the Mark I BWR owners will likely reactivate their petitions now pending before an Appeals Court with the objective of overturning the regulation that calls for installation of a recombiner capability.

B. DEFERRAL OF STAFF CONCLUSION

1. Position

The staff could find that a temporary deferral of from two to four years in implementing the "Recombiner capability" rule at Mark I BWR's is warranted and temporary exemptions to this effect could be granted upon request. This deferral will permit the Mark I owners and the NRC to conduct certain tests to measure the amount of iodine released from the fuel to the coolant following the onset of various design basis accidents and to determine the effects of various contaminant and hydrogen concentrations on radiolysis G-values. The results of these tests, might show that Mark I BWR's need not rely on purge/repressurization systems for hydrogen control and therefore, need not be provided with a "Recombiner capability". However, if this option is chosen by a licensee, then we should require the licensee to convert the instrument air system to a nitrogen system, and they have proposed.

2. Implications

This position would permit the operation of around 20 Mark I BWR's for several more years without the "Recombiner capability" now required by the revised 10 CFR 50.44. If an accident were to occur during this period and the radiolysis effects became significant, the containment may have to be purged to prevent the combustion of hydrogen in containment. In this event, the offsite doses could be on the order of 10 CFR 100 guideline values for the more severe design basis accidents. Licensees of the affected PWR plants will likely request the same relief.

If a degraded core accident involving substantial amounts of metal-water reaction were to occur, the hydrogen will serve as a strong suppressant for radiolysis and as an effective diluent to reduce the relative concentration of the oxygen that existed in the containment prior to onset of the accident.

The petition of some of the licensees now pending before an Appeals Court will likely remain on-hold pending completion of research and decision making during the deferral period.

The estimated 2 to 4 million dollars of expense per Mark I BWR plant need not be incurred pending completion of the deferral period and may not have to be incurred at all if the test results are favorable to the licensees' bases.

C. APPROVAL OF THE REQUESTED RELIEF - LICENSEES' BASES

1. Position

The staff could find the proposed use of radiolysis G-values that are substantially lower than the recommendations in Regulatory Guide 1.7 (Revision 2) to be warranted and acceptable. Since with the use of these reduced G-values, the Mark I BWR's need not rely on a purge/repressurization system as the primary means for hydrogen control, we could conclude that a recombiner capability is not required for Mark I BWR plants.

2. Implications

This position constitutes a substantial "de-ratchet" in staff requirements for hydrogen control. Prior to its implementation the staff will most likely have to obtain endorsements from the CRGR, the ACRS, and the Commission. These endorsements may be difficult to obtain because the requisite reductions in radiolysis G-values are based on analyses rather than experimental data. Moreover, the analyses have to rely on non-conservative assumptions dealing with iodine releases to the coolant and the effects of iodines on the radiolysis G-values.

This position would permit the removal of the safety grade and purge/ repressurization systems recombiners now in place at a substantial number of plants, unless we are able to confine its applicability to the recombiner capability rule.

If this position were adopted by the staff, the petition now pending before an Appeals Court will most likely be dropped.

D. APPROVAL OF THE REQUESTED RELIEF - STAFF'S BASES

1. Position

The staff could find that for a large majority of design basis accidents, the Mark I BWR plants would not have to rely on the use of purge/repressurization systems for hydrogen control. This comes about because the radiolysis rates are substantially smaller than those prescribed in Regulatory Guide 1.7 (Revision 2). Moreover, the cost of the recombiner capability for each Mark I BWR is more than a decade higher than that considered when the rule was promulgated. In view of these circumstances, the staff concludes that the licensees for Mark I BWR plants should be granted exemptions from the "Recombiner capability" requirement of revised 10 CFR 50.44.

2. Implications

This position would leave intact the original requirements of 10 CFR 50.44 for hydrogen control during design basis accidents. It would grant the relief requested by the BWR Owners Group in that they would not be required to furnish the recombiner capability as called for in revised 10 CFR 50.44. If this position were adopted, the petition now pending before an Appeals Court will most likely be dropped.

The position would also mean that for a small fraction of design basis accidents, the containment would have to be purged at some time following onset of the accident to assure that the containment atmosphere remains nonflammable. The off site doses would, of course, remain within the guidelines of 10 CFR Part 100.

V. RECOMMENDED POSITION

We recommend that NRR adopt the last of the four alternative positions and grant by the issuance of exemptions the relief requested by the owners of Mark I BWR plants from the requirements of revised 10 CFR 50.44. We would have to process permanent exemptions for the licensees of about 20 BWR plants.

The recommended alternative is the best alternative because it keeps in place the hydrogen control requirements of the original rule and is consistent with the long standing NRC policy of requiring substantial measures of conservatism in the design of those systems needed to accommodate the entire spectrum of design basis accidents.

The recommended alternative is based on the staff's recognition that:

- (1) There are no significant safety benefits associated with the requirement for the recombiner capability. It was a requirement designed to deal with the problem of the public's reaction to containment purging following an accident, even when the dose consequences are small.
- (2) The costs for the recombiner capability are more than a decade higher than the \$100,000 per unit considered at the time the rule was promulgated.

Therefore, for the Mark I BWR plants, since the benefits do not appear to warrant the costs, we conclude that an exemption from the requirements should be granted.

Proponents of the approval alternative (licensee bases) argue that we should have learned from the TMI-2 accident that radiolysis is a negligible source of combustible gases when there is no bulk boiling and when hydrogen gas is dissolved in the coolant. We would argue that there are other design basis accident scenarios where these pre-conditions do not exist. Moreover, we have learned from the TMI-2 accident that the original hydrogen source term prescriptions for metal-water reaction in 10 CFR 50.44 were not conservative

enough. We, therefore, believe it would be a mistake, in the absence of definitive and applicable experimental data, to take the more drastic action of reducing the radiolysis G-values recommended in Regulatory Guide 1.7.

The deferral alternative is attractive because it would keep the petition now pending before an Appeals Court on hold. It would also defer the nominal 60 million dollar total expense associated with providing the recombiner capability at about 20 operating BWR plants. However, the likelihood that convincing data could be obtained in the next two to three years showing that, in fact, radiolysis G-values should be reduced substantially (by as much as a decade) from those recommended in Regulatory Guide 1.7 is remote.

Regarding the petition pending before an Appeals Court, the risk to the staff of losing the technical substance of the case should be small. If the Court did not sustain the Commission's rule, then the worst that should happen is a recycling of the rulemaking proceeding, resulting in a delay similar to the deferral option discussed above.

Accordingly, based on the above considerations, we recommend that NRR adopt the fourth alternative as detailed above, involving the approval of the requested relief by the issuance of specific exemptions from the requirements for the recombiner capability.