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November 20, 1985

Mr. Denwood F. Ross, Deputy Director
Office of Nuclear Regulatory Research
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Mr. Ross:

I enclose herewith my comments on the document, "Reassessment of the Technical Bases for Estimating Source Terms," NUREG-0956. These comments are divided into two sections; first, those that I think are of major or general concern, and, second, page by page comments organized by chapter, page, and paragraph.

The U.S. members of the (now dissolved) ANS Special Committee on Source Terms have been advised of the extension of the comment period and have been urged to submit their personal comments.

It is my opinion that the document is not satisfactory as it now exists, and I presume to offer an idea for its revision and/or the writing of NUREG-1150. If the intent is to create a document representing the point of view of (and acceptance by) the technical community of specialists in severe accident analyses (as opposed to a document representing only the NRC point of view), the technical community must be asked to share in the preparation of such an assessment of the state of knowledge. IDCOR and EPRI come to mind at once as organizations that could provide such assistance. The assistance could be very early review of drafts of chapters, or even in the writing of chapters. In the long run, a document so prepared would have a much quicker and wider acceptance, and a better understanding by all parties.

Sincerely yours,

W. R. Stratton

William R. Stratton

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REVIEW OF NUREG-0956

Points of Major Concern

1. The title of the document is "Reassessment of the Technical Bases for Estimating Source Terms." A review, then, can ask how well the document satisfies the reassessment function, and how closely it adheres to the goal as defined by the title.

2. The current evaluation of severe accidents and consequent source terms is a multi-organization, world-wide effort. The diversity of effort provides a great deal of assurance that significant physical and chemical phenomena will not be missed. The review process during technical meetings, for example, is no different from review of reports of a new scientific discovery. The criticisms are very often sharp, and result in an improved, more technically defensible position. The technical work produced by IDCOR, SWEC, EPRI, ORNL, NYPA, the FRG, French, etc., as well as BMI, has been reviewed in this manner and should be a part of the "Reassessment of the Technical Bases for Estimating Source Terms."

This is not the case. These several studies have not been considered, and NUREG-0956 can be regarded only as a statement of NRC's position relative to the evaluation of source terms. It is not an assessment of the knowledge of the technical community. The title should be changed, or the reassessment should include results of the entire technical community.

3. The stated intent is to produce "best estimate" evaluations of source terms. The evaluations of source terms described in BMI-2104 (on which NUREG-0956 is based) are indeed better than the estimates in WASH-1400 or the arbitrary conditions in TID-14844, but cannot be described as "best estimates." For example, the containment failures incorporated into the BMI work are described as a parametric study and "are not meant to characterize the expected, or most likely, containment behavior." (See page 4-28, third paragraph.) However, relative to containment behavior, a best estimate is attainable if the results of the containment working groups are factored into the BMI analyses. Is this step now underway?

4. The matter of uncertainties is emphasized, but the subject is confused throughout the document. An uncertainty of a factor of 10 up or down is very important for a source term that is, for example, 0.05 of core inventory, but it is unimportant if the reference value is 0.0005 times core inventory of the element in question. The QUEST study is referred to as an uncertainty study, but is admitted to be a sensitivity study on pages 3-29 and 6-4. Both uncertainty and sensitivity studies are important, but the difference must be kept clear.

5. The American Nuclear Society is a professional society. It is not a part of an industrial group, as stated on page xix, first paragraph.

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6. A comparison of BMI-2104 calculated source terms to those calculated by other groups (IDCOR, SWEC, EPRI, NYPA, ORNL) shows a disturbing and consistent difference: The BMI results are higher, sometimes by significant amounts. Given the serious responsibilities that the NRC has, these differences must be explained and understood. A major effort must be mounted to obtain agreement on physical and chemical assumptions, mathematical approximations, computational formulations, etc. Clearly, the same physics, chemistry, and mathematics should give the same result independent of the computer or programmer. This matter is of the utmost importance. Design of plant, safety features, formulation of rules, regulations, safety guides, etc., depend on resolution of the source term matter. The BMI code suite cannot be accepted until resolution of results is obtained.

7. There is no indication of when or at what point the program, experimental and analytical, planned for the future will come to a satisfactory conclusion. Some measure of what source term or terms is good enough must be found. A deminimis criterion or criteria are badly needed, both for consequences and for probability.

8. The history discussed in Chapter 2 is incomplete. The first study of importance was WASH-3, in 1950. The ACRS first proposed the assumptions in TID-14844 in 1960, and the investigations of the past half-dozen years were stimulated by the accident at Three Mile Island.

9. The document overemphasizes the dangers of generalization of source term results. A great deal is possible; e.g., many PWR accident sequences in large, dry containments are functionally similar and can be so compared. Furthermore, accidents can be grouped as to initiating event (e.g., large break, small break, etc.). If the worst case (e.g. S_2B) is acceptable, all other S_2 sequences in which something works will be less severe. The whole problem is difficult enough without making it worse.

10. The risk appraisal presented in Chapter 6 and Appendix D is of questionable value. It is not necessary for a "Reassessment of the Technical Bases for Estimating Source Terms." The appraisal uses source term results from BMI-2104, which are admitted to be a parametric study of containment integrity. Hence, the appraisal has an air of unreality about it.

If a risk appraisal is to be performed, a closer comparison to WASH-1400 would be helpful. To be precise, a direct comparison to accident categories in WASH-1400 (Tables V 3-14, V 3-16, and Table V 2-1) should be made. For example, have PWR-1 and BWR-1 really disappeared?

Further, the large body of modern calculations, with a small number of exceptions, shows no early fatalities. Therefore, this measure of the severity of an accident is best dropped and person-rem, or some related variable, should be adopted as a supplement to (and ultimate replacement of) WASH-1400.

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11. Finally, the implication is given throughout that the BMI code suite is complete, correct, adequately reviewed, and accepted. It is, indeed, a very large step forward from WASH-1400, TID-14844, and safety guildes 1.3 and 1.4, but is not regarded as complete, correct, adequately reviewed, or accepted. The very large differences between NRC and the technical community must be resolved.

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COMMENTS ON NUREG-0956

(The format followed is to note the page and paragraph for each chapter, followed by comments)

Executive Summary:

1. xvii,1; The intent to use improved analytical methods in WASH-1400 and to reassess the assumptions in TID-14844 is laudable, and should be encouraged.

2. xvii,2; An additional, independent validation study and uncertainty analysis should be performed. The existing "uncertainty" analyses is better described as a sensitivity study.

3. xvii,3; The absence of BWR Mk-II in the NRC effort is notable. This has been completed outside the NRC funded program.

4. xvii,4; The peer review by the panel of 14 scientists was never completed for the final draft BMI-2104.

5. xix,1; The American Nuclear Society is a professional society; it is not a part of an"industry group."

6. xix,2; Because the newer evaluations (including others than NRC-BMI) show no early fatalities for essentially all sequences, a better measure of consequence is person-rem with some estimate of distribution of dose.

   A reference to the 1986 publication should be given.

7. xix,5 (conclusion 2); The matter of containment strength and non-importance of steam spike and steam explosion should be mentioned.

8. xix,6 (conclusion 4); The implication is given that the code suite is complete and the review is complete and satisfactory. This is not the case.

9.xx,Table ES.1, #6; The "mechanistic" treatment of core-concrete interaction may be questionable It has not been subjected to peer review except cursorily by the APS.

10.xxi,Table ES.2; An indication of relative importance to calculated source terms is necessary. An uncertainty may be large, but unimportant because the reference value is very small.

An additional uncertainty is the time of leak or failure of containment. This is not mentioned.

11.xxii, conclusion 7; The correct description of the fission product chemistry is of equal or greater importance than the correct evaluation of containment strength.

12.xxii, conclusion 8; Much generality is possible, e.g. many PWRs in large dry containments are functionally similar and will respond similarly to accidents. Some few sequences are design dependent, but complications need not be invented.

13.xxii, conclusion 9; The new evaluations of source terms that are much smaller than those in WASH-1400 dominate, overwhelmingly, those very few that are comparable. The iodine factor is essentially eliminated; early containment failure is unlikely. The conclusion is incorrect.

14.xxii, conclusion 10; This is a complete puzzle because the containment response is part of source term evaluation.

15.xxiii, conclusion 11; This conclusion is unnecessarily negative.

16.xxiii, d (Continuing Research); A major point missed is the need for an overall, peer review of BMI-2104 and the assumptions and boundary conditions that are imposed upon the source term calculations.

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17.xxiii, Recommendation 1; Correct; even with inadequacies and errors, this would be a major step forward.

18.xxiii, Recommendations 2 and 3; The implication is given that the NRC "Source Term Code Package" is complete, correct, and undisputed. This is not true and far from correct.

19.xxiv, References; Reference should be given to the ANS Source Term Study, the IDCOR program, the several SWEC reports, the work sponsored by the PASNY, etc.

Chapter 1:

1.1-1,2; "Setting priorities" implies the existence of a deminimis criterion (or criteria). This is largely ignored but is very important.

2.1-2,5: The most important of the Source Term evaluations assume that no active mechanical or electrical equipment operates. Hence, operability of active components is irrelevant unless needed for public health and safety. This is not the case.

3.1-3,5; The NRC studies relating to containment capability (Containment Loads and Containment Performance Working Groups) should be issued for review and undergo a peer review by a designated group of international experts.

4.1-3,6; Groups other than BMI and IDCOR are involved. SWEC, ORNL, EPRI, NYPA, ANS, foreign groups should be acknowledged. The effort is international.

5.1-4,2; BMI-2104 is not the most recent quantification. The process is world-wide and continuous. BMI-2104 has been criticized as incomplete, inaccurate, and wrong in places.

6.1-4,4; The peer review of BMI-2104 was not comprehensive. It was and is not complete. Some parts have not been reviewed at all.

Chapter 2:

1.2-1, 1,2,3; The brief history is incomplete. The first estimates of release of radioactive materials in an accident is found in WASH-3 (1950). This document set the pattern.

The Geneva Conference in 1955 and the Windscale accident in 1957 are important for their influence.

Prior to the publication of TID-14844 in 1962, the ACRS issued a letter in 1960 recommending essentially the same assumptions.

The stimulus for NUREG-0772 was external to the NRC staff.

2.2-1,3,; The real shortcomings in WASH-1400 were not recognized until after the accident at TMI-2. The early criticisms were in the probability estimates and did not affect significantly the estimates of risk. The errors in consequences, however, are very significant.

3.2-4,1; The iodine was required to behave much like a noble gas in its airborne and leakage behavior.

The later writing of Safety Guides should be mentioned. The significant change was that, given the initiator (e.g. a pipe rupture), the iodine and noble gases would be "immediately" dispersed throughout the containment.

4.2-5,4; Mention of plutonium is a red herring. PuO_2 is extremely refractory, dense, and to make and keep it airborne would be most unlikely.

5.2-7,1; "Some amount of volatile species of iodine" begs for a quantification.

6.2-7,3; "The Reactor Safety Study (with all its weaknesses)" is an unnecessary and incorrect chop. The RSS was and is an extraordinary study.

7. The world-wide investigation of source terms derived from the TMI-2 accident, the Kemeny Commission investigations, and the letters in 1980 from three national laboratories and one industry laboratory that pointed out where NRC rules, regulations, and guides were in error relative to iodine behavior. The R&D effort did not originate in the NRC.

8.2-10,6; The phrase, "cover other initiating events as an envelope," is a very useful generalization. The same philosophy was used in the ANS Source Term Study. NUREG-0956 ignores this possibility for generalization.

9.2-11,5; The inclusion of "accident sequences of very low frequency" begs the questions: how low and how low is low enough to be ignored.

10. The NRC-Sandia "uncertainty" study may be, in fact, a sensitivity study. The NRC needs additional advice in this regard.

11.2-14,2; The review of BMI-2104 was not thorough and is not complete. Some parts have not been reviewed at all.

Chapter 3:

1.3-15,1; Most fission products are not radioactive or were of short half-life and have decayed to a stable state.

2.3-15,5; The uncertainty in ORIGEN is unduly pessimistic. The users of ORIGEN should be consulted and quoted.

3.3-22,2; A deposition velocity of 0 for CsI is surely an error that must be corrected.

4.3-22,4; Experiments on resuspension of deposited aerosols have been performed by Fauske and Assoc. These should be mentioned.

5.3-23,7; An independent peer review of the Vanessa code has not been started. This, and related physical phenomena, should be completed before NUREG-0956 is revised.

6.3-29,4; The importance of an uncertainty (a factor of 100 is mentioned) depends on the base case estimate. This is not quoted.

7.3-30, Table 3.2; Coding symbols are quoted. These are useless to the reader. The 6th and 7th items in the table are, essentially, nonsense statements.

8.3-32, 6 and 7; If containment sprays are operating, the source term is very small.

9.3-32,11,12, & 13; If the suppression pool is effective, the source term is extremely small and a large uncertainty is unimportant.

10.3-33,4; The iodine was treated as a noble gas; chemistry was ignored.

11.3-33,6; "Some elemental iodine" begs for quantification.

12.3-35,3; The fate of tellurium atoms when they decay to nascent iodine is ignored. It would be chemically fixed in place.

13.3-35,4; Vanessa has not been reviewed. It may or may not represent "a major advance in the accuracy of source term analyses." The statement is defensive.

14.3-38, Table 3.5; A major uncertainty not mentioned is the set of assumptions made by the user of the code.

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15.3-40,3; Deposition on ice should be no different than deposition on other surfaces, depending on temperature and wetness.

Chapter 4:

1.4-1,1; A summary of all calculations should be included to allow the reader to judge the results and conclusions.

2.4-1,2; A large amount of generality is possible and should be noted; i.e. for source term considerations, there is no difference between a factor of ~~10^{3}~~ 10^{-3} and ~~10^{5}~~ 10^{-5}.

3.4-1,3; The Mark II containment is different and must be analyzed by NRC-BMI. This has been done by SWEC, with surprising results.

4.4-5, V Sequence; The effectiveness of the safeguards building was not included in the calculation. The "submerged V-sequence" variation appears to be ignored.

In general, it appears to be the case that the retention capability of buildings exterior to the containment is ignored.

5.4-10,2; The containment failure mode was "selected in the March code." Apparently, the risk analyses in this document (0956) are based upon arbitrary assumptions relative to containment failure, ignoring the work of the two containment working groups.

6.4-10,4; The implication is that all 1.5 metric tons are radioactive. This is not the case and should be clarified. The 10 billion curie number is unimportant because of very rapid radioactive decay.

7.4-22, Table 4.10 and 4-23, Table 4.11; The release numbers quoted in the tables are to the containment volume, not outside containment. This is not clear from text or table. Curies should also be tabulated.

8.4-32,4 & 5; Calculations other than those by BMI are acknowledged here. The very large number that have been completed by others is ignored. This is a major failing of the analyses in this document.

9.4-35, 3 &4; The containment failures are postulated. This should be stated.

10.4-40, Table 4.13; The containment failure modes and times are arbitrary. This should be stated.

11.4-45,3; The release fraction of 0.5% of I needs more justification before it can be accepted. A review is necessary.

12.4-45,5; The BMI-2104 results discussed derive from arbitrary assumptions r.e. containment failure and neglect of auxiliary buildings.

13.4-46,1; The QUEST study is admitted, elsewhere, to be a sensitivity study. Therefore, it should not be used to estimate uncertainties in risk.

Chapter 5:

1.5-3; Major factors identified by the peer review group included better accounting of water and the effectiveness of auxiliary buildings. It is not clear that either of these recommendations was followed adequately.

2.5-6,2; The NRC uncertainty study was a sensitivity study, as admitted elsewhere in this document. An independent uncertainty study is needed.

3.5-8,7; Results for all investigations (at about July, 1984) are presented in the ANS Source Term Study. It is not clear that this enormous body of information is used at all. The neglect is a major failing of this analysis.

Chapter 6:

1.6-1,4; Probabilities are those of WASH-1400; thus, apparently steam explosion phenomena must be included in the analysis. This is completely incorrect and ignores the general conclusion that steam explosions of magnitude sufficient to cause containment to fail can be ignored.

2.6-2,3; The analyses for the CCDF plots apparently use the BMI-2104 calculations in which the containment failure modes are admitted to be parametric. Thus, no credence can be given to these analyses.

3.6-2,5; Because of low source terms, the use of early fatalities is no longer a good measure of an accident, and the use of latent fatalities is questionable. Some other measure of dose must be used.

4.6-4,6; The QUEST study is admitted to be a sensitivity study.

5.6-7,3; Retention of fission products in the reactor building has been calculated by IDCOR. These and other studies should be a part of this analysis and that planned for NUREG-1150.

Chapter 7:

1. The experimental program that is described is large, and apparently covers the matters of major interest.

However, the relative importance is not obvious, nor is any evaluation offered as to what knowledge is sufficient for regulatory purposes. I.e., what release fraction for each isotope is low enough that it can be ignored. This implies that a deminimis criterion or criteria must be developed. This should be addressed in conjunction with an experimental program to keep it within reasonable bounds.

From another point of view, it is apparent that NRC-BMI source term results are consistently different from those of other investigators. In order to evaluate the necessity of experiments, agreement as to the state of knowledge must be reached. A large and intensive effort to resolve differences must be started and continued until agreement is reached.

Chapter 8:

1.8-1,1; The peer review of BMI-2104 is not complete as stated. The complete suite and some parts have not been discussed.

2.8-1, Conclusion 1; The BMI-2104 suite of codes is a significant advance over methods used in WASH-1400, but is scarcely complete or a best estimate. Review and improvement is needed.

3.8-1, Conclusion 2; A major deficiency in past work was the neglect of deposition in auxiliary buildings. This has not been corrected adequately in BMI-2104.

4.8-1, Conclusion 3; The relative importance of uncertainties is ignored. Many are minor and will have only a small effect on source terms when fully resolved.

5.8-2, Conclusion 4; Again, a complete review (and implied acceptance and agreement) is claimed. This is not true. The "uncertainty study" is admitted to be a sensitivity study.

6.8-2, Conclusion 5; The statement is confused; the "purpose of the analysis" invariably is to obtain the best, most realistic estimate of problem at hand.

7.8-3, Conclusion 7; For many sequences, chemistry is of equal or greater importance. The high solubility of cesium and iodine salts can limit releases independent of containment integrity. Further, even a leaky containment can plug with aerosols, but not with gases.

8.8-4, Conclusion 9; The conclusion is contradicted by the discussion, where it is admitted that analyses are incomplete. The conclusion does not note that the overwhelming number of analyses show large reductions from WASH-1400.

9.8-5, Conclusion 10; This conclusion is irresponsible, because the containment failure modes used in the BMI-2104 analyses are admitted to be an arbitrary parametric study. See page 4-28, paragraph 2. The risk values, therefore, are without merit.

10.8-5, Conclusion 11; The conclusion is contradicted by the discussion.

11.8-6, Recommendation 1; This is correct; the new methods should be used while improvements are continuing.

12.8-7, Recommendation 2; The "Source Term Code Package" has not been reviewed, is believed to be incomplete, and may have errors.

13.8-7, Recommendation 3; The Source Term Code Package cannot give a "best-estimate" source term estimate if the many qualifications earlier in this document are to be believed. Review is necessary.

Appendix B:

1.B-15,2,3,& 4; The assumption is made that operation of sprays and fan coolers in the containment will lead to conditions that allow a massive hydrogen explosion to occur that will cause failure of containment. This is nonsense, is contradicted by discussions elsewhere in 0956, and contains hidden assumptions about the postulated accident, metal-water reactions, hydrogen ignition, and strength of containment.

Appendix C:

1.C.1-3,1; The group of "expert analysts" apparently did not have any containment design and construction experts. The work should be reviewed by experts in design and construction.

2.C.1-4, Standard Problems; The choice of challenges is complete enough to provide a basis for analysis.

3.C.1-7,2; The steam-spike-induced failure is judged to be "of very low probability." Given the analyses, why not zero probability?

4.C.1-8,1; Failure is estimated at 16 hours for the Zion containment. Other analysts predict much longer times, suggesting that review of the working group would be advisable.

5.C.1-9,1; Again, why not a zero probability?

6.C.1-10,1 and C.1-11,1; The matter of batteries for ~~ignitions~~ igniters in the ice condenser containments is mentioned. Can this be regarded as a passive safeguard? Clearly, it is not in BMI-2104.

7.C.1-11,2 and C.1-12,3; The postulated early failure for Mk-I and Mk-II containments should be analyzed further for leak rate and deposition in the surrounding reactor building.

8.C.1-14,2; The short review of the postulated "direct heating" sequence shows very clearly that extreme assumptions are required, and that depressurization might occur prior to vessel failure or even fuel melting. A more intensive study is needed.

9.C.2-3, Executive Summary of the Containment Performance Working Group (CPWG); Generally, this group has completed a very useful study. The results should be reviewed by a group of individuals who are

active in the design and construction of containment buildings. Further interaction can modify estimates made for the most likely failure and reasonable extremes.

These data must then be fed into the BMI analyses to product better estimates of source terms.