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NUCLEAR POWER

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MFN 058-81

March 31, 1981

M. Silberberg, Chief
Experimental Advance Safety Technology
Research Branch
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Silberberg:

SUBJECT: ADDITIONAL COMMENTS ON DRAFT OF NUREG-0772

Reference: R. H. Buchholz letter to M. Silberberg, "Comments on Draft of NUREG-0772," March 17, 1981

This letter provides additional General Electric Company comments on the draft of NUREG-0772, "Technical Bases for Estimating Fission Product Behavior During LWR Accidents." The comments herein are intended to supplement the observations provided in the reference letter and the input provided by the GE representatives at the meeting of the Peer Review Group March 17 and 18, 1981, in Washington, DC.

As noted in the reference letter, General Electric considers the draft report to be a useful aid to focus on important areas regarding fission product behavior from reactor accidents. It is our expectation that a clear, complete, and technically accurate report addressing these important areas could provide a uniformly accepted basis for all future accident consequence evaluations, which in turn will be the cornerstone for important regulatory decisions. However, the draft report, as it is currently written, is incomplete and does not present technically supportable conclusions. GE considers that the report should not be issued or sent to the Commission without significant modifications to correct what we believe are misrepresentations of LWR fission product retention capability. In light of the importance of the report, the requisite changes should be made, and additional peer review completed, before the report can be considered to reasonably represent the state of the art.

As expressed in our initial comments in the reference letter, in our input in the Peer Review meeting, and in the attached supplementary technical comments, NUREG-0772 and its companion document on regulatory impact must properly evaluate LWR design and system capability. From our review of the draft report and participation in the Peer Review, it

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was evident that the Boiling Water Reactor (BWR) system and containment capabilities for fission product retention and attenuation were incorrectly treated. The following principal areas of concern are inadequately addressed by the report. Additional specific detailed comments have been provided in the attachment to this letter.

1. The analyses supporting conclusions regarding BWR accident sequences make assumptions on core coolability, plant conditions, and containment failure modes which are in conflict with the most recent BWR probabilistic risk assessment studies. Throughout the Peer Review, it was evident that there is a pressing need to clarify and examine the assumptions and analytical models employed in the evaluations of the BWR accident sequences to determine their technical adequacy.

2. The conclusion of a best estimate iodine attenuation factor for the risk dominant accidents does not consider the available pool scrubbing data presented in the attachment to the reference letter. Furthermore, it appears that unnecessarily conservative interpretations of the attenuation data have been made in the conclusion of the report that are not substantiated in the report and appendices. Using decontamination factors supportable by current technical data, the report conclusions will change, and accident consequences will be orders of magnitude lower than represented. This is in direct disagreement with a principal conclusion of the draft report.

3. As previously noted in the reference letter, the BWR transport pathways in the containment were not adequately considered. The BWR geometry and containment internal design must be reevaluated in assessing the attenuation capability. GE has recently made presentations to the NRC Staff and the ACRS illustrating the BWR release pathways and quantifying the expected significant attenuation capability.

With regard to Item 2 above, GE strongly recommends that NUREG-0772 establish realistic or best estimate values of fission product attenuation factors as opposed to conservative estimates. The realistic values should be utilized in analyses to properly characterize risk in assessing fission product transport and release resulting from postulated accidents. The risks established using realistic best estimate inputs are appropriate to assess plant performance to support the various rulemaking efforts currently under consideration by the NRC (including Degraded Core, Minimum Engineered Safety Features, Siting, etc.).

In summary, NUREG-0772 must be modified to properly consider the LWR systems and accident sequences to properly assess fission product behavior. GE is eager to initiate a technical liaison with the National Laboratory contractors involved in the accident sequence evaluations to provide consultation on BWR system capabilities to correct the deficiencies in the analytical support of the report. These meetings should be held immediately to provide substantive technical inputs for incorporation into the final version of NUREG-0772. In addition, General Electric will prepare for April submittal a detailed documented review of all pool scrubbing tests and data referred to in the attachment to the reference letter for consideration in the final version of NUREG-0772.

It is recommended that the next draft of NUREG-0772 be issued only after additional peer review. This would provide the necessary technical exchange to address all the problems of the draft report and insure a high quality final document. Any draft not addressing all areas receiving peer criticism should be clearly characterized as preliminary, with significant technical uncertainties under review to avoid distribution of misleading information. This same review process should be applied to the companion document of NUREG-0772 on regulatory impact.

General Electric would be pleased to provide further details on the information contained herein, in addition to supporting future reviews. Specific questions may be addressed to Mr. K. W. Holtzclaw (408) 925-2506 or Mr. J. M. Smith (408) 925-5110 of my staff.

Very truly yours,

S. J. Stark for R. H. Buchholz

R. H. Buchholz, Manager
BWR Systems Licensing

RHB:sem/1127-29

Attachment

GE COMMENTS ON NUREG-0772 DRAFT

The following technical comments have been developed by General Electric following a detail review of NUREG-0772 and participation in the peer review meeting. The comments have been divided into two categorgies with each comment referencing applicable pages in the draft of NUREG-0772 dated March 6, 1981. The comments presented in Category A identify specific technical concerns with NUREG-0772 and provide GE's basis for concluding that the draft document underestimates the fission product retension capability of the BWR. Category B comments identify areas of NUREG-0772 where clarification or revision of the draft text is considered necessary.

Category A

1. Pg. i - The draft concludes that the assumed form of iodine does not have a major influence on the estimated iodine release to the environment for the risk dominant accidents. This conclusion appears to be based on the results of Chapter 7 wherein it is assumed that containment failure has occurred or complete bypass of the containment has occurred, such as the TMLB' sequence. This sequence is not applicable to a BWR and the report does not identify any sequences for the MK III BWR which result in bypassing the suppression pool. The report needs to address differences in containment and reactor designs before arriving at general statements. While one could assume that containment failure resulted in failure of the suppression pool or drywell, these assumptions are only valid if a structural design analysis shows that to be the case. One could also assume that the scrubbing efficiency of the suppression pool is independent of the chemical form entering the pool. However, this assumption is not supported by the data in the report which shows iodide more effectively scrubbed than iodine

2. Pg. ii - The statement is made that "the results of this study do not support the contention that the predicted consequences for the risk dominant accidents have been overpredicted by orders of magnitude in past studies. For example, the analysis in this report indicates that the

"best estimate" (underline added) attenuation factor for iodine is between 2 and 10 for the risk dominant accidents..." It appears that in a number of areas a conservative rather than a best estimate interpretation of the data has been chosen. For example, a partition factor of 100 was the minimum value reported compared to a possible partition factor of 10^5 (see pg. 15). A decontamination factor (DF) of 1-10 was employed for the suppression pool. Appendix E would suggest a minimum DF of 30 (for 2 micron - 4 gm/cc particles, 1 cm bubbles, 250^0 F saturated pool and a 15 second transient time) and a maximum value of infinity for 40 micron particles or iodine vapor entrapped in 1 cm bubbles with a rise time of 10 seconds. Based on this data the 2-10 estimate is overly conservative for the BWR sequences.

3. Pg. 16 - The statement is made that "for the most severe accidents analyzed for the BWR suppression containment" the attenuation factor applicable is 4. It would appear that this conclusion is based on the assumption of zero removal credit by the suppression pool, or bypassing the pool by either drywell failure or suppression pool failure. Relative to zero removal credit by the suppression pool, it would appear in the transcript of the Peer Review (pg. 259) that a "violently" boiling pool was assumed.

   GE has not identified any accident sequences where the pool would be "violently" boiling and result in a zero pool decontamination factor during or after the period of fission product release from the core. In those sequences where containment failure precedes core melt (and the pool is saturated), containment depressurization has already taken place. The pool is relatively "quiet" when the small bubbles of non-condensing steam rises through it and significant scrubbing of particulates and iodine is expected. In those cases where significant fission product release has occurred prior to containment failure, the pool is not in a violently boiling state and therefore provides an effective barrier to fission product migration. Therefore, even assuming violent boiling occurs after containment failure, only a small fraction of the liquid is released due to boiling, and hence only a small fraction fo the contianed activity is released.

Relative to the posulated containment/drywell failure modes, it is necessary that careful consideration be given to design features of the particular containments. For example, while one may postulate, for very low probability events, failure of the free standing shell of the Mark III containment due to overpressurization, the drywell and pool would in all probability remain intact. Since all fission products escaping the RPV would still have to be passed through the suppression pool for this failure mode, the fission product retention would remain very high.

4. Pg. 17 - The statement is made that "scrubbing of particulate iodine would be less efficient in sequences involving limited core damage than for more severe sequences. In the severe accident sequences scrubbing efficiency would be comparable or better than has been predicted for elemental iodine." It is difficult to understand how this conclusion can be reached when only 1 scrubbing test has been referenced. Scrubbing of particulates is also dependent upon the wetting and solubility characteristics of the scrubbed particle as well as the bubble size, residence time in the pool and bubble media, i.e. steam, air, CO_2, etc. The text does not provide sufficient data to allow an independent assessment of the validity of the report conclusion. It is therefore recommended that the rationale and the applicability of the conclusions be included in the report.

5. Pg. 5.25 - The calculated partition coefficients shown in Figure 5.5 are not consistent with the experimental data reported in the literature (Ref. 2 and 3 see attached figures). At least a factor of 10 - 100 larger should be expected at lower iodine concentrations. It is also important to emphasize that, as given on page 5.26, "the calculated partition coefficients in this paper have assumed an initial iodine source of molecular iodine, I_2, dissolved in water and reacted with water to produce the equilibruim concentrations of iodine species. It should be obvious that solutions where the only iodine species is iodine, I^-, will have essentially infinite partition coefficients." (See comment B6 for application of partition coefficients in pool scrubbing calculation).

6. Pg. 5.27 - On pg. 15 the statement is made that methyl iodide is judged to be less than 0.1%, however, on pages 5.27 and C.26 it is recommended that a value of 0.03% be assumed. However, this value is based on the conversion of I_2. Also on page C.26 it is noted that TMI resulted in only a few thousandths of 1% conversion. Based upon the information included in the report and recognizing that the expected chemical form of iodine is iodide not I_2 a best estimate conversion factor would be 0.005%. The report needs to arrive at a recommended best estimate value not a lower bound value. Also, consistency with the data in the total report is required as well as consideration of containment designs, accident scenarios and fission product scrubbing barriers such as the BWR suppression pool.

7. Pg. 7.23 - It would appear that the assumptions of containment failure in the region of the suppression pool or negligible retention in a boiling pool where used in arriving at the conclusions on pages i and ii. i.e. the assumed chemical form of iodine is unimportant in risk dominant accidents and the best estimate attenuation factor for iodine is between 2 and 10. As pointed out in the previous comments, the assumption of suppression pool failure is not valid for all BWR containment designs and the assumption of DF in a boiling pool is not justified for any containment design. Therefore it is GE's opinion that the chemical form of iodine is important for all accident sequences.

8. Pg. 8.6(a)- It is noted that the AE accident sequence involves failure of the primary containment due to overpressure with leakage through the annulus into the reactor building. It should be noted that prior to postulated containment failure significant fission product scrubbing by the subcooled suppression pool will occur, thus limiting the potential radiological consequences of this event.

(b)-It is noted that the TWc sequence resulted in containment failure in 54 hours and results in a "high temperature" of 592°C as indicated in Table 2. It is assumed that Table 8.2 is meant instead of Table 2; however, there is only a TW or a TC sequence identified not a TWc sequence. The time of containment failure is 1.5 hours and the "peak atm. temperature" is 592°C for the TC sequence and 45 hours and 409°C for the TW sequence.

It is not clear if these temperatures are "seen" by the drywell or wetwell, as implied on pg. 8.6, or are temperatures which exist within a very small volume of gas within the drywell. It is also not clear how these values have been used in assessing the effectiveness of ESF systems in general and the pressure suppression system in particular.

(c)- It is stated that the MK III containment does not include the annulus or the SGTS features of the MK I containment. It should be noted that essentially all MK III containments have both a primary containment and secondary containment structure. Leakage is from the primary to secondary containment with secondary containment being treated by the SGTS.

9. Pg. C.11 - Chemistry of Iodine (a) - The chemistry of iodine has been fairly well examined in terms of thermodynamics. It is reasonable to assume the kinetics of the reactions are generally very fast at higher temperatures, but in many cases, the concentration of the reaction product is determined by the availability of the reactants and the necessary conditions involved in the reaction. For example, the oxidation of I^- by O_2 (eq. C.5.11)

$$2\ I^- + 1/2\ O_2 + 2\ H^+ \longrightarrow I_2 + H_2O$$

is thermodyamically possible, but the reaction would occur only in acidic solutions and under the influence of light.

It is obvious that inside the RPV this reaction would not proceed because the water is basic due to the Cs^+ ions, and the oxygen content should be very minimal due to the presence of H_2. Therefore, $\sim$ 20 Kg of iodine released within the RPV as I^- should stay as I^-.

(b)- The document fails to mention the important reaction of iodine speciies with the reactor material. With the excellent reducing nature of metals. at high temperature, Zr, and Fe in the core and steam separator/dryer should provide a powerful reducing medium for iodine. The reactions expected to occur include:

$$I_2\ (\text{or } I) + Zr \longrightarrow Zr\ I_2\ (\text{or } Zr\ I_3)$$

$$I_2\ (\text{or } I \text{ or } HI) + Fe \longrightarrow Fe\ I_3\ (+ H_2)$$

The products of these reactions Zr I_2, Zr I_3, or Fe I_3 are very stable, non-volatile (Ref. 1), and therefore should not be transported out of the RPV.

CATEGORY β

1. Pg. 4.22 - The ordinate is identified as fraction/min., however, for I, Xe and Kr the maximum value is ∼9 which is ∼9 times greater than can be physica achieved, i.e., maximum possible fraction is 1.0. It is not clear i. ..h.s error is also included in the calculated time dependent release rates or is just an error on the graph.

2. Pg. 4.26 - It is noted that between 510 Kg (1100 lbs) and 1600 Kg (3500 lbs) of material would become airborne as a result of the postulated core/ concrete interaction and that the resultant spherical particles would be 2 micron in mean aerodynamic diameter. It is difficult to understand how such a large mass release (1/2 ton - 1 1/2 tons) can result in such a small particle size. It is not clear if the initial particle size of the volatilized material is 2 microns and it remains as 2 microns, or the particles rapidly agglomerate into large particles resulting in rapid settling leaving only a small airborne mass of 2 micron particles.

   Considering a drywell volume of 5000 m^3, as noted on pg. 7.9 and based upon the above mass release, one would calculate a potential airborne concentration in excess of 100 gm/m^3. On pg. 7.10 it is noted that the QUICK code would predict particle sizes between 40 μm and 300 μm for an airborne concentration of 200 g/m^3. Further, the code predicts that within 30 secs, 1/2 of the particles are ≥ 100 microns and in 1 minute 98-99% are ≥ 100 microns. (Peer review transcript pg. 236) The use of a particle size of 2 microns in NUREG 0772 is inconsistent with this data.

3. Pg. 4.30 - The statement is made on pg. 13, 4.30 and implied on pg. B.3 that the release of noble gases, cesium and iodine from the core is essentially complete in 18 minutes. This statement can only be valid for a given core geometry, power density, fuel design, etc. The appropriate qualifying words need to be included in the document which explain the applicability of these values.

4. Pg. 7.2 - Reference is made to the model in Appendix E which mathematically treats vapor and particulate transport from a rising bubble. However, it does not appear that the results of the model calculations are included on pg. 7.16. On pg. 7.16 a pool DF between 1 and 10 is presented, however, the Appendix E model would predict a DF between 12 and infinity. Such inconsistencies should be resolved.

5. Pg. 8.14 - It is implied that if the inboard MSIV fails to close,that the MSIV leakage control system (MSIVLCS) is incapable of performing its function. It should noted that the MSIVLCS will perform its intended function whether the inboard MSIV is open or closed. If the inboard MSIV fails open or has unacceptable leakage characteristics the inboard MSIVLCS will be isolated and a suction will be taken downstream of the outboard MSIV.

6. Pg. E.4 Pool Scrubbing

a) Equation E-9 describes the scrubbing factors (SF) for iodine vapor in a water pool. It is not clear what the relationship is between K_2, the overall mass transfer coefficient for vapor transport, and the iodine partition coefficient. Obviously it is inconsistent to suggest that in the most likely conditions the iodine species in the vapor phase would be CsI or HI, and use a minimum partition coefficient for I_2 of 100 in the calculation using Eq. E-9. The SF should be much larger if the appropriate value (∿ infinity) for the partition coefficient for CsI or HI is used.

b) It is also important to point out that a key parameter in gas bubble scrubbing is the solubility or chemical reaction of the species in water. For the pool scrubbing process for CsI particles (Pg. E.13), it is wrong to assume CsI particles are inert particles and treat them as such. CsI is a very soluble species,and either as a vapor or a particle readily dissolves in water. The model equation (E-30) may require modification if the above mentioned property of CsI is not properly considered in the model.

References

1. T. M. Besmann and T. B. Lindermer, "Chemical Thermodynamics of the System Cs-U-Zr-H-I-O in the Light Water Reactor Fuel-Cladding Gap" Nucl. Tech. 40 297 (1978).

2. U. S. AEC Draft Regulatory Guides "For Implementation of Numerical Guide for Design Objectives and Limiting Conditions for Operation to meet the Criterion "As Low as Practicable" for Radioactive Material in Light-Water-Cooled Nuclear Power Reactors" Docket-RM-50-2 (February 1974).

3. C. C. Lin, "Volatilty of Iodine in Dilute Aqueous Solutions," Accepted for publication in J. Inorg. Nucl. Chem. (1981).

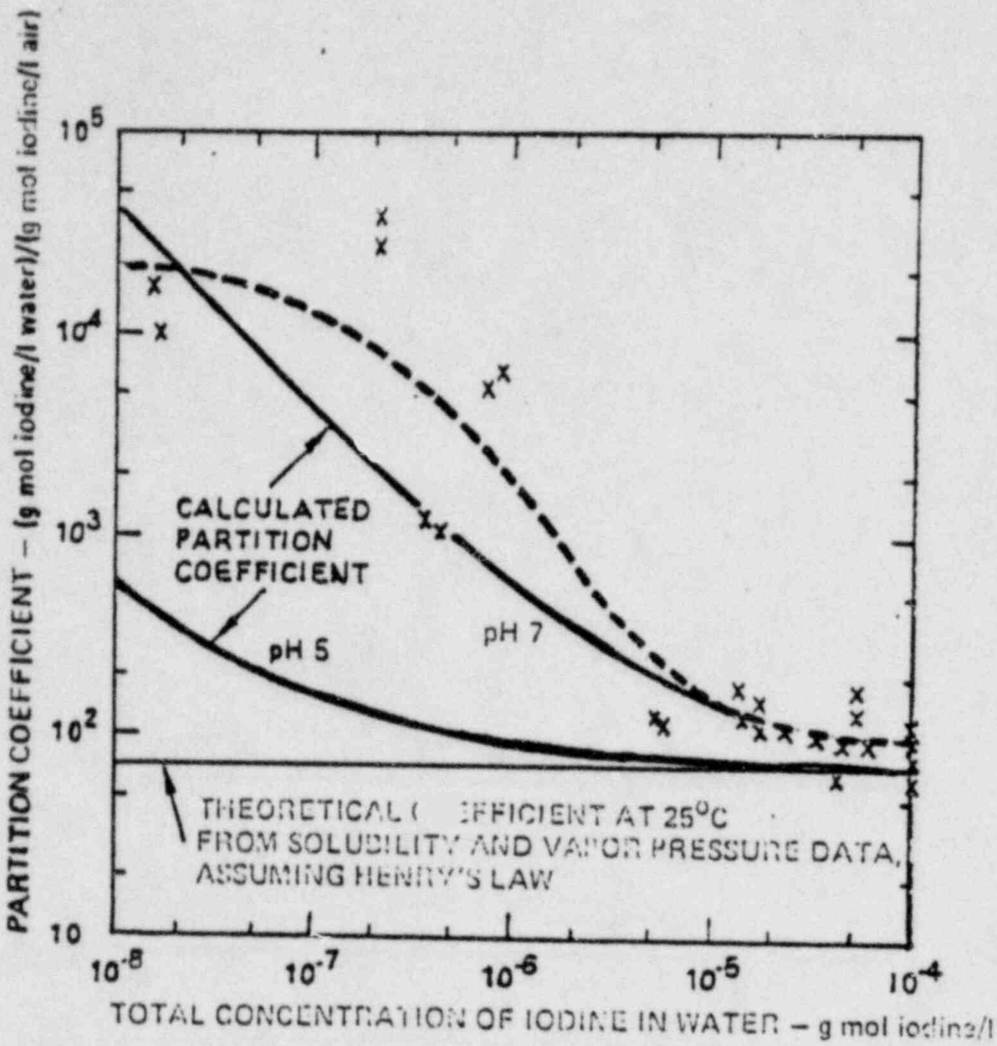
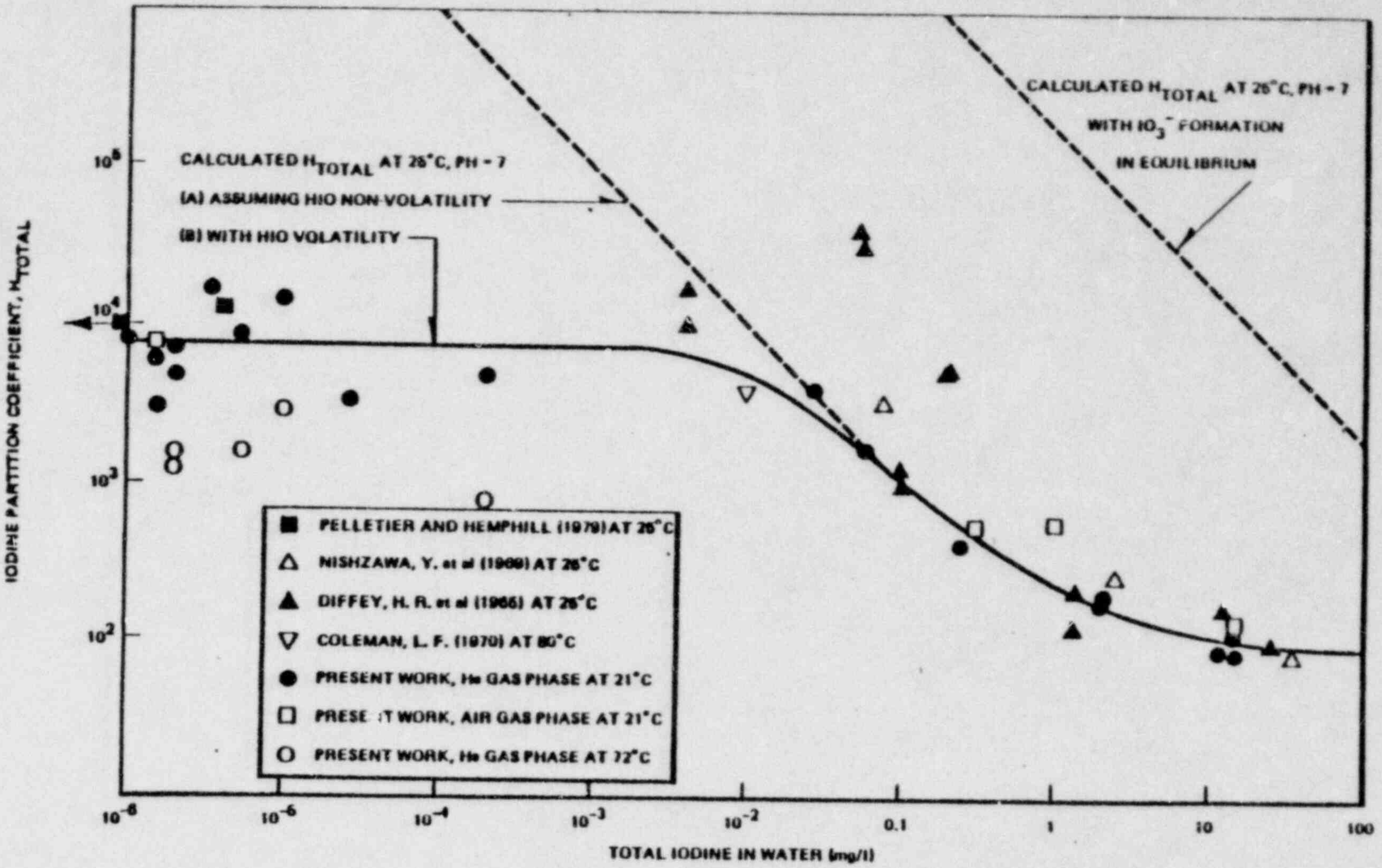


FIGURE B-2

EFFECT OF IODINE CONCENTRATION ON THE EQUILIBRIUM COEFFICIENT FOR IODINE AT 25°C

(Ref. 2)

Docket RM-50-2
Draft Regulatory Guides
Feb. 20, 1974 U.S. AEC



(Ref. 3) Accepted for publication in J. Inorg. Nucl. Chem. (1981)
(C. C. Lin, General Electric Company)

Figure 2. Partition of Iodine between Water and Gas Phase