OCT 17 1988

Note to: J. Bunting

From: K. Chang

Subject: DRAFT CONVO EVALUATION AND ENHANCEMENT PLAN

The subject draft document has been reviewed by members of the Engineering Branch and Geosciences and Systems Performance Branch. Our consolidated comments are enclosed.

We are in general agreement with the Center's recommendation and improvements on CONVO. However, our consolidated comments identify many areas of concern ~~on CONVO~~. Please note that no priorities and schedules have been provided for recommended work.

The main thrust of the recommendation on updating and improving CONVO is toward non-essential improvements such as a faster means of evaluating the models statistically and improved user friendliness. While these things are important, they are overwhelmed by the fact that the submodels that actually explain the physical mechanisms of waste package degradation and especially releases from the EBS are almost completely lacking for the unsaturated tuff environment. In terms of priorities, we would like to see virtually all the budget for the engineered barrier system devoted to studies of models of radionuclide release from the waste packages in the tuff environment. These studies should include the reducing potential of the waste package and cladding material in the oxidizing environment. Work on statistical convergence and user friendly interfaces should only be performed when the basic physical principles are understood. There is a danger in having a computer program that can produce statistical results of the performance of the EBS in advance of any information on the physical behavior of the waste form.

When the Center submits final form ~~of the~~ plan, ~~the~~ priorities and schedules should be included. In performing the recommended work on CONVO, the Center is also responsible to take full advantage of other NRC supported work (e.g., National Bureau of Standard's work on corrosion), and include planning for integration of waste package and far field repository performance evaluation. They should also keep other NRC contractors informed to allow them to understand how results of their work will be used in the Center's plan.

Back in March 1988, Mr. Ken Stephens, a NMSS consultant, made a series of recommendations on CONVO in his final progress report to NRC. Nearly all of those recommendations are still valid for our present CONVO with the exception that work on basalt and salt should not be considered since salt and basalt sites are no longer considered in DOE's plan for high-level waste repository. I have enclosed a copy of Mr. Stephen's recommendations.

Please send the consolidated ~~comments~~ and Mr. Stephens recommendations to the Center for their record and for possible inclusion to the final plan.

Kien C. Chang

Enclosures:
As stated

cc: ~~R. Weller~~
~~J. Pearring~~
D. Brooks
J. Bradbury
J. Buckley
R. Codell
J. Trapp
~~P. Justus~~
P. Brooks

Concur ST
JB

Consolidated Comments on CONVO Evaluation and Enhancement Plan (9188)

Section 1

1. Recommends this section to include discussions on that CONVO will provide a source term for use in the assessment of compliance with the EPA standard. The assessment requires consideration on unanticipated processes and events as well as anticipated processes and events and as such should be incorporated in the code.

2. Page 1, Paragraph 5 and 6.

   We think the "new methods" refer to such things as LHS and FPPA. Is this the case?

Section 2

1. The usefulness of the information presented in Section 2.1 and 2.2 has not been demonstrated. While the information is of historic interest, it appears unappropriate to present information related to the defunct Basalt and Salt Projects, unless the information is also appropriate to the Tuff Project. In that case it should be addressed in Section 2.3.

2. While references have been cited for the various codes identified in Section 2.3, references have not been cited to identify the sources of the other information presented. We recommend that the author reference the various data sources that were researched to obtain the information that is presented related to DOE's current compliance demonstrated effort.

3. The expectation presented in the last sentence of Section 2.6, paragraph 1, is not consistent with the Regulatory Requirements of the NRC. Codes associated with compliance determination need only be "adequate" for the requirement. There is no need for them to be the "best".

4. Information presented in the last paragraph of Section 2.6 appears inadequate to support the conclusions presented. While the capability to link external codes is indeed a consideration, the validity of process modules is at least an equally important element in NRC compliance determination strategy. Recommend this paragraph be deleted and an affirmation regarding the importance and priority of updating the modules be presented.

5. Page 2, first paragraph, third line, the word "emphasize" should be "emphasis."

6 Page 3, fourth paragraph, fourth line, the word "issued" should be "is used."

Section 3

1. Page 5, Section 3.1, Introduction, Paragraph 2.

   It is our understanding that this report is intended to review the CONVO "approach" and to determine if it is adequate for NRC to use to evaluate waste package performance. Paragraph two states that "...CONVO is a viable tool...." This is a rather weak recommendation as to the adequacy of CONVO. We think more needs to be said about why CONVO should be developed and enhanced in Section 3.3 (for example).

2. Page 5, Section 3.2.1, Introduction, Paragraph 1.

   "...CONVO, was developed to demonstrate... a methodology for waste package... performance assessment..." (page 1/¶4). We agree with this characterization. However, on page 5, CONVO is described as coupling two process models, one of which is "..a radionuclide release/transport model that characterizes flow into the host matrix...." CONVO is not intended to characterize "...flow into the host matrix...," rather it is intended to characterize release/source term to the host matrix. It should be made clear that this is a waste package code and deals only with canister/packing/failure/source term, and therefore, only "...transport..." in the waste package (canister/packing).

3. Page 5, Section 3.2.2.

   Include a statement on why standard Monte Carlo is appropriate.

4. Page 7, QFIT2

   As noted under areas such as 3.2.2, the input for this calculation is not well known and is uncertain.

5. Page 7, TEMP

   We are not dealing with a uniform 3-D medium, especially when we are dealing with the earth. How does this affect the output in TEMP?

6. Page 7, TEMP, and QFIT2

   Not sure which it fits under, but heat is a function of air gap and its uniformity due to such things as spalling, geothermal gradient, stress, coupling, etc. I don't think they are all covered.

7. Page 9, Section 3.2.2.2, Corrosion Models, Paragraph 1.

   It is pointed out that the corrosion models used in CONVO "...have inadequacies resulting from both lack of... data and the proper definition of the governing geochemical and environmental conditions...." This appears to be a significant problem that is neither discussed or related to the recommendations for code enhancement.

8. Page 9, Paragraph 1.

   From the description, this is not a response surface. It may be a series of response surfaces.

9. Page 9, Paragraph 3.

   We do not think you can do a simple addition of the geothermal condition, because the temperature is not totally independent of the geothermal conditions. Please discuss this.

10. Page 10, Section 3.2.2.3, Transport Models, Paragraph 1.

    It needs to be made clear that this is transport only within the waste package. Also, CONVO addresses only ...diffusion transport..." and does not consider any geochemistry. Perhaps this is good enough when considering only transport to the edge of the waste package. This needs to be discussed in Section 3.3 (for example).

11. Pages 11, 12 and 13, Section 3.3.1.1, Thermal Models/3.3.1.2, Corrosion Models/3.3.1.3, Transport Models.

    Each of these sections "...summarize assumptions, compatibilities and limitations of... models used in CONVO." However, assumptions/capabilities/limitations are lumped so that you cannot tell one from another. Further, there is no discussion. We would think that this would be key to deciding whether or not CONVO was an approach worth pursuing and developing recommendations.

12. Page 12, (8) under linear model.

    This statement needs more discussion.

13. Pave 12, Section 3.3.1.3, Transport Models.

    Two additions to the lists presented in this section are:

    - Radionuclide (daughter) build up not considered
    - Water/packing chemistry assumed to be constant

    There may be others.

14. Page 13, Paragraph 2, Item (2).

    The word "formsurface" should be "form surface"

15. Page 13, Paragraph 3, Second line.

    "3.2.1" should be "3.3.1"

16. Page 13, Section 3.3.2, Data Limitations, Paragraph 1.

    Items "(1) Rock parameters...," and "...(6) Retardation of ...rock..." are not directly related to CONVO/waste package performance evaluation.

17. Information presented in Seciton 3.3.2 regarding data limitations not appear to be complete. It is not apparent that characterization of the heat source as impacted by emplacement mode has been considered. It is also not apparent that the retardation effects of packing, backfill, and the geologic setting, as effected by thermo-mechanical and thermo-chemical considerations have been considered.

    It is also not apparent that thermal and thermo-mechanical effects on rock mass parameters have adequately been addressed. Recommend more detail be presented in this section to address these items. In addition reference sources for information presented in this section should be cited.

18. Conclusions presented in Section 3.3.3 do not allow the reader to correlate the information presented regarding model capabilities and limitations with the information presented in Sections 3.3.1 and 3.3.2. Recommend this section be expanded to demonstrate the correlations between the information presented in Sections 3.3.1 and 3.3.2 and the conclusions presented in Section 3.3.3.

<u>Section 4</u>

1. Paragraph 4.1.

   <u>All</u> potential emplacement modes should be considered including the long-hole horizontal emplacement mode which DOE has identified in the CDSCP. Recommend this paragraph be expanded to address all potential emplacement modes. In addition, this section does not appear to adequately address "anticipated" and "unanticipated" processes and events.

2. The updated assumptions for corrosion modeling presented in page 15 do not include environmental conditions resulting from potential adverse conditions which have not as yet been ruled out through site characterization activities. Until the results of site characterization efforts demonstrate the absence of potential adverse conditions, all environmental conditions resulting from potential adverse conditions should be considered.

3. The basis for assumptions presented throughout 4.1 are not documented in the text. All considerations which affected the authors' judgments related to the appearance of reasonableness of the assumptions selected should be presented.

4. Page 15, Paragraph 3, Item (2), Second line.

   Replace "and at thereafter" by "and thereafter."

5. Page 15, thermal model.

   We consider the assumptions on stress, spalling, air gap, uniformity of thermal properties, lack of consideration of change in climate and precipitation, faulting etc., are all unrealistic to solving the regulatory concern.

6. Page 15, Corrosion.

   We do not really know how water moves in the unsaturated zone, especially potential nonuniformity, therefore, degree of "wetness" around canister is totally unknown.

7. Page 15, Corrosion.

   (5) is totally unrealistic.

8. Page 18, Bayesian.

   While we agree the use of Bayesian statistics may help determine the correct questions, the use of this method to give the answer is self-defeating. If we do not have the information how are we going to get reasonable assurance in the licensing arena when we say the number calculated down to x number of places was based on a wild guess as to the input parameters? Sophisticated calculations with no basis do not solve the problems. Bayesian statistics have their place, but must be used with extreme caution.

9. Page 19, Figure 3, Table on the left corner.

   Please check numbers 11 and 19 under column "Number of CONVO Runs."

<u>Section 5</u>

1. The level of detail presented in the plan for upgrading/enhancing the capabilities of CONVO code presented in Chapter 5 is insufficient to allow review and comment. We recommend a detailed statement related to the purpose and objectives of the proposed upgrade first be presented. A detailed discussion of the expected utility of the proposed updated CONVO should next be presented. We recommend detail be presented related to

each step proposed in the upgrade along with criteria proposed for measuring success or failure of the work in each step. We also recommend specific evaluation points be identified throughout the plan to provide points for assessment of what has been accomplished, versus what was planned, so that recommendations for proceeding or termination can be provided by the CNWRA to NRC, as appropriate, in a timely manner.

2. Page 24, Figure 4.

   This figure does not show the logic performed by the main driver, e.g., nuclide transport will not happen unless a package has failed because of corrosion. Please include drive logics.

3. Page 25, Section 6.1, Summary.

   Item 2 refers to the "...multiple-barrier concept...." Item 3 makes it clear that in the context of CONVO multiple-barriers means canister and packing. In general, the term multiple-barrier is a much broader concept that includes the geology/geochemistry/hydrology of the site. Therefore, the term multiple-barriers, when used to refer to parts of the waste package needs to be used cautiously.

4. Pages 25-26, Section 6.2, Recommendations.

   - This section suggests that much work needs to be done to get CONVO "up to speed." One area that does not appear to be addressed is uncertainty/precision/accuracy.

   - It is not clear from the assessment of CONVO that this is the way for NRC to go. A question that needs to be asked is whether or not we are ahead of DOE. And, of so, should we be or should we slow down. Another question is whether or not CONVO will be ready for us to use (i.e., 5 years).

   - Section 3.3 needs to be expanded to provide a basis for any "Recommendations...."

<u>Section 6</u>

1. Page 25, Item (5).

   How should the models' needs be improved? What features should existing models have but do not have?

2. Page 26, Item (2).

   This item only addresses priority and ranking of parameters. It should also address sensitivity of failure modes, therefore, priority and ranking of failure modes (e.g., comparison of failures resulting from pitting corrosion with those from stress corrosion cracking).

3. Page 25, Recommendations.

   CONVO may not be sound if it is not representing what needs to be representing, such as the full range of required input parameters and boundary conditions.

Consultant Recommendations
EBS Reliability Assessment - The CONVO Code

INTRODUCTION

In many respects the development of an independent approach to repository performance evaluation is still in an early stage. However, the basic approach has been settled, and much has been accomplished in the implementation of various important aspects of the overall performance assessment in the form of the CONVO code.

A great deal of work has been done in implementing the modular approach, developing Monte Carlo codes for the modules, using the response surface technique to reduce the time required to carry out an analysis, and providing detailed analyses of transport of radionuclides based on well understood mechanisms. Much of this effort was directed toward the evaluation of the basalt repository, although it was recognized that the tuff repository would have to be addressed and that it presented some unique problems.

In addition to the studies implemented in the CONVO code, a large number of other studies have been carried out that are expected to be incorporated into the code. In most of these cases the effort required is substantial, because a new module must be coded and tested for accuracy. In addition, in some cases the available data are sparse or very uncertain and must be evaluated carefully before being used for predictive purposes even in a probabilistic sense.

The specific models used for corrosion in the basalt environment were known to be unsatisfactory and would have to be replaced by models with greater validity. Thus, a substantial effort has been underway to address this issue, specifically to locate, develop, or modify a mechanistic corrosion model that would be applicable to basalt. A similar effort was undertaken for the tuff environment.

Most of these efforts along with many others have received ongoing attention. This has included modification of the CONVO code for ease of use and efficiency, analysis of data needs in a number of areas, consideration of stand-by failure modes, and assessment of the importance of synergistic effects and the possible need to include them in CONVO.

On the basis of these various studies and specific developments, it is possible to assess the present status of the EBS performance assessment methodology as it presently exists in the form of the CONVO code and the various supporting formal and informal reports that have been provided over the past several years. The most important areas for continuing development have been identified.

Although it is not possible to completely separate data needs from methodology and code improvements, modifications, and other issues, the following recommendations address the data needs areas for each of the basic modules within the CONVO code. The issues regarding the structure of CONVO and how it may best be improved, modified, and integrated with repository performance codes are discussed separately. Although the primary emphasis is now on the tuff repository, the basalt medium may be a candidate in the future. Accordingly, some basalt items have been included in the recommendations. Some of the data may already exist in DOE and other reports, but must be reviewed before use.

For the data needs included below, priority is indicated by asterisks: ** = highest priority, * = high priority, none = lowest priority.

DATA NEEDS

Thermal Module

General Data Needs:

(1) Statistical information on fuel burn-up for each LWR type; either mean and standard deviation or burn-up as a function of the fraction of spent fuel inventory.

(2) Cooling time as above.

Tuff Related Data Needs

(1) Thermal conductivity and specific heat as a function of degree of saturation.

** (2) A validated thermal code suitable for use in CONVO that is applicable to the tuff environment. Strictly speaking, this is not a data need, but is included here because it is a very important, and presently missing ingredient.)

Basalt Related Data Needs

(1) Thermal conductivity and specific heat of bentonite packing.

Corrosion Module

General Data Needs:

(1) Zircaloy corrosion in all environments.

* (2) Interaction of corrosion products with groundwater and the impact on spent fuel chemistry.

* (3) Acid contamination from drilling fluids. (Also applies to the transport module.)

(4) Effects of cements and grouts on groundwater chemistry, corrosion, and transport.

Tuff Related Data Needs:

** (1) Radiation effects on intergranular stress corrosion cracking (IGSCC).

(2) Low temperature sensitization of 304L. (Experiments may not be feasible.)

* (3) Corrosion data in simulated tuff environment with temperature programming for copper, copper alloys, and nickel alloys.

a) Identification of surface films and their ability to provide corrosion protection.

b) Identification of corrosion mechanism in copper.

* (4) Sensitization and IGSCC of 304L, 316L, and 825 alloys in tuff environment with and without radiation. (Some work has been done on 304L.)

Basalt Related Data Needs:

(1) Definitive study on general (uniform) corrosion of low-carbon steel in basalt/bentonite groundwater at appropriate temperatures.

(2) Effect of hydrogen adsorption on low-carbon steel strength.

(3) Definitive study on pitting and mechanism identification.

(4) Corrosion rates and mechanisms for copper in basalt.

(5) Effect of organic acids present in bentonite. (Also applies to transport module.)

Transport Module

General Data Needs

** (1) Geochemical analysis of spent fuel and vitrified HLW in tuff and basalt groundwaters.

** (a) Equilibrium species identification and solubilities (tuff).

* (b) Kinetics affecting concentrations and release rates.

(c) Temperature effects on speciation and solubilities (basalt).

(2) Quantitative data on retention coefficients in tuff and basalt.

(3) Analysis of data on surface diffusion.

** (4) A model of transport in unsaturated tuff, i.e., one of the following:

a) A methodologically sound model that is practical for use in CONVO, or

b) A model that provides a bounding estimate of transport in an unsaturated medium, or

c) Application of a saturated-medium model to provide an upper limit on release rates.

(5) Tectonic effects on release rates.

Stand-By Failure Module

General Data Needs

* (1) Tectonic data: Frequency as a function of intensity and distance to epicenter.

* (2) Canister mechanical failure modes and forces required for failure.

(3) Estimates of canister manufacturing flaws and weld closure flaws; i.e.,

a) Lack of proper annealing in seam welds,

b) Incorrect alloy used in welds,

c) Others?

(4) Estimates of probability of occurrence of other rare, external, and discrete events, such as: human intrusion, meteorological changes, ice age, large change in water table level, etc. (There may be conditional links among these events.)

(5) Internal corrosion (especially for glass waste form).

MODIFICATIONS TO CONVO

Numerous modification in the CONVO code will have to be made before it can be used for the evaluation of a given repository. Most of these modifications are repository-specific although it is expected that in a generic sense an overall modification that allows the user to select the type of repository to be evaluated would be desirable. Otherwise, there would have to be separate versions of the code.

The following discussion of modifications in the CONVO code is arranged in the order of the priorities assigned.

Tuff Environment

(1) Thermal Calculations. Thermal calculations are the key to all subsequent calculations. These calculations also provide the concentrations of all radionuclides as a consequence of the decay heat calculations that are imbedded in the selection of a heat source. For tuff these calculation involve convection, radiation, and possibly evaporation of groundwater. At least one thermal code, used as input to the DOE PANDORA code, is represented as capable of this type of analysis, but it has not been reviewed. It is imperative that an appropriate code be selected, reviewed, and used to develop a response surface of temperature for the tuff environment.

(2) Canister Corrosion. The highest priority in this area is to employ the model of IGSCC for 304L stainless steel and the available empirical supporting data to develop a practical approach to predicting sensitization and subsequent IGSCC. The theoretical model of sensitization relies on a large body of experimental data that are often very uncertain. Model predictions must account for these uncertainties, but to do so involves a Monte Carlo calculation in which more than 25 random variables have to be sampled. The number of runs required would be extremely large, far too large for the PC version of CONVO and perhaps too large for an ordinary mainframe.

Clearly, the approach will have to be to reduce this large number of random variables by: (1) judicious use of sensitivity analysis to limit the sampled variables to those having a significant effect on the output, (2) elimination of coupled variables by making approximations such as combining some variables into a single dummy variable and using second order coefficients, and by use of response surface techniques. Several approaches have been identified to assist in this endeavor. These approaches should be studied and an appropriate procedure implemented.

(3) Transport. In the tuff environment, transport may represent the greatest technical challenge that will be faced. It is clear that no relatively straight-forward analytical solution to the transport problem is likely to exist. Various approximations can be envisioned. As an expedient it might be appropriate to use the available influx of groundwater due to precipitation modified by evaporative loss and assume that saturation of this volume would occur as it passed through the repository. Alternatively, an upper limit can be estimated by assuming advective/diffusion limited release in a groundwater saturated medium.

(4) Spent Fuel Dissolution and Groundwater Geochemistry. The present model assumes that for each radionuclide, a single radiochemical species occurs and that it is present at its saturation limit. This

is an over-simplification of the real situation. A superior approach, which should be implemented, is to use the results of a geochemical simulation to develop a response surface of the concentration vs. dissolution for spent fuel. This would also have to involve a simple model of the rate of dissolution. Although not all the required data are available, there is a sufficient amount to permit a first order modeling of this effect and to include it in CONVO.

(5) Glass Dissolution. CONVO presently does not include a model of glass dissolution. Recent studies have provided the data necessary to incorporate a simple model of glass dissolution into CONVO. Also, there are studies using a geochemical code and preliminary data on groundwater interactions that reveal radiochemical species and concentrations as a function of total dissolution. This information can be modeled, and the appropriate response surface can be generated and incorporated into CONVO.

GENERAL IMPROVEMENTS TO CONVO

Prior to he development of CONVO, a number of issues were recognized as important to the full utilization of the modular convolution approach implemented in the code. Many of these were omitted either because of time pressure, lack of data, or the recognition that incorporating too much might make the scope of the effort so large that a working code would be impossible to achieve with the constraints of the program. Now that CONVO has been demonstrated, these additions and improvements should be addressed. They are discussed in order of priority in the following breakdown.

(1) Burnup and Cooling Times. The thermal module presently implemented in CONVO involves a Monte Carlo routine that samples parameters dealing with rock properties. This was appropriate to demonstrate the utility of the response surface technique, but the variation in rock properties, even in tuff are small compared to the variations in burn-up and cooling time for spent fuel. Consequently it is important that the thermal codes incorporate these parameters for sampling in the Monte Carlo routine. Furthermore these same calculations can be used to generate the quantities of radionuclides available for release. Clearly this is a high priority item for improving CONVO.

(2) Stand-By Failure Modes. The ease with which stand-by failures could be incorporated in the convolution approach was discussed in the original methodology report as one of the important virtues of modular convolution. It was not included in the original code largely because of a desire to keep the first version of the code simple and easy to diagnose if problems arose. The mathematics involved has been explored, some data on plausible stand-by failure modes have been developed, and techniques for dealing with tectonic events have been devised. Because the tuff site is in a region in

which there is considerably more tectonic activity than is expected in the basalt repository, the inclusion of stand-by failures takes on greater importance.

(3) Probabilistic Fluxes and Total Releases. The present version of CONVO implements a simple version of the release and transport module. It provides only the fractional release or normalized mass transfer rate. In order to carry out realistic repository evaluations a number of improvements are required at the EBS level. These include the prediction, in the probabilistic sense, of the outward flux of a given radionuclide at a selected boundary and the probabilistically predicted total release, both given as a function of time after canister failure.

Both of these quantities are dependent on the probabilistic input from the thermal calculations, assuming that the appropriate data on radionuclide abundance as a function of time have been recorded. The fluxes and releases can be derived from the simpler calculation by appropriate use of these data and the calculations based on diffusive or other release mechanisms.

(4) Pulse and Depletable Inventory Release. There are several radionuclides, ^{14}C, ^{127}I and ^{137}Cs in particular, that are released immediately upon breaching of a canister, or for which the major fraction of the inventory is readily available and will be released in a time that is short compared to the dissolution of the bulk of the spent fuel. These materials cannot be addressed by the same techniques as those that are released congruently with waste for dissolution.

For instantaneous release, the technique is relatively simple to implement. For depletable inventory, the techniques are more involved but still may be dealt with in a straight-forward way. The higher priority should be assigned the treatment of instantaneous ^{14}C release, because of its presumed impact on the meeting of the 10^{-5} fractional inventory release criterion.

(5) Radionuclide Decay During Transport. The decay of a radionuclide during its release and transport affects the concentration gradient that occurs. Consequently, the effect of decay is to increase the diffusive release rate, contrary to what might be expected. This effect should be taken in to account in the release module. There is available a simple modification to the diffusive transport equations that provides an entirely adequate approximation to the rigorous treatment of the effect. This approximation can be incorporated into the equations in the transport module of CONVO.

(6) Interactive Interface for Mainframe CONVO. The mainframe version of CONVO was not written in a way to permit changes in its parameters except by making the changes directly to the code. This limits its use to those who are sufficiently familiar with the code and the language in which it was written (FORTRAN) to make such changes.

Even so, changes would be difficult and time consuming. Before mainframe CONVO can be put to general use, an interactive interface will need to be developed, similar to the one available on CONVO-PC. As the complexity of the program increases, and the number of input variables increases, as will occur inevitably, the need for such an interface will become critical.

INTEGRATION OF CONVO WITH REPOSITORY PERFORMANCE CODES

As it is presently constituted, CONVO is applicable to a single waste package or EBS. That is, it does not yet provide the source term for a repository performance code. To integrate a waste package or EBS performance code with a far-field repository performance code, several specific problems must be addressed and solved. Important ones are described in the following.

(1) Coupling of Multiple EBSs. There may be an interaction of effects if a canister fails and nearby canisters have previously failed so that the release fields overlap the region of the newly failed canister. The effects may be large (diffusion controlled release) or small (advective controlled release), and there is a further effect on the local geochemistry that may affect corrosion (a stand-by failure mode).

Limited, preliminary work has indicated that these synergistic effects may not be significant for the tuff repository. Nevertheless, it is appropriate to do additional work. If these effects are found to be significant, techniques are available to treat the problem. The solutions may be dealt with in detail, or approximately, depending on the anticipated severity.

(2) Time History of Emplacement. The waste packages are not emplaced at a single instant in time, and this assumption is not a complete approximation of the emplacement history. Given the large number of canisters, it is possible to use a discrete convolution approach on subsets of the canisters which have been described using the Poisson process.

(3) Probability of Release as a Function of Time. The probabilistic release rates of subsets of failed canisters, modified by overlapping fields, are convolved to produce an overall probabilistic release rate as a function of time. This approach should result in a reasonable source term approximation.

Further elaboration of these approaches could include the release rate probability as a function of location in the repository as well as time, but such a degree of detail may not be necessary.

Once release rates are available, integration with a repository performance code could be accomplished. However, it will require diligence to assure consistency of assumptions, modeling, and computer implementation.