LLR.20080311.0066

	Model **Error Resolution Document** *Complete only applicable items.*	QA: QA Page 1 of 12

INITIATION

1. Originator: Ernest Hardin	2. Date: 03/06/2008	3. ERD No. **ANL-EBS-MD-000027 ERD 01**

4. Document Identifier: ANL-EBS-MD-000027 REV 03	5. Document Title: Drift Degradation Analysis

6. Description of and Justification for Change (Identify applicable CRs and TBVs):

The following evaluations/changes/corrections are posted to correct the conditions identified in CRs 7461, 8020, 10115, 11242 and 11752: Each CR is herein listed separately with the identified changes and justification for no impact to results of ANL-EBS-MD-000027 REV 03 or subsequent ACNs. See attached for a detailed description of each CR.

CONCURRENCE

	Printed Name	Signature	Date
7. Checker	Dwayne Kicker		3/7/08
8. QCS/QA Reviewer	Robert E. Spencer	Robert E Spencer	03/07/08

APPROVAL

9. Originator	Ernest Hardin		3/10/08
10. Responsible Manager	Kathryn Knowles For		3-10-08

CR 7461 Evaluation

I. Background Information Summary:

AMR ANL-EBS-MD-000027 Rev 03, Drift Degradation Analysis, did not identify a source used as direct input. The report and its DIRS identified a superseding DTN SN0307T0510902.003 [DIRS 164196] as a direct input, and the report justified the use of a superseded DTN (not identified in text); however, the superseded DTN was not cited in Section 4.1 or listed on the DIRS.

Section Q2 paragraph 1 states: The heat capacity data used in the thermal property calculation were preliminary data superseded by DTN: SN0307T0510902.003 [DIRS 164196] (Table E-19).

Contrary to LP-SIII.9Q-BSC, Attachment 2, Section 4.1 Direct Inputs the AMR Section 4.1 did not identify all technical product inputs.

II. Description of Change and Impact Evaluation

This analysis identifies DTN SN0210T0510902.001 as the original source of heat capacity data shown in Table C-4, and of the preliminary data shown in Table Q-3, of BSC 2004 ([DIRS 166107]; herein called the AMR). Unit-specific values for heat capacity from DTN SN0210T0510902.001 were combined in thickness-weighted averages following the same method used in Table E-19 of the AMR, to develop the weighted preliminary values in Tables C-4 and Q-3. Thickness averaging is performed using

$$Avg. = \frac{\sum_{units} Thickness \times HeatCapacity}{\sum_{units} Thickness}$$

III. Inputs and/or Software

There is no change to the input values or to the software.

IV. Results and Conclusions

Table 1 (see below) implements this unit thickness-averaging calculation of heat capacity, for all four units identified in the AMR, and for all three temperature ranges. The resulting weighted averaged heat capacity values compare closely to those from Table Q-3 of the AMR (to within the roundoff error, highlighted pairs of cells in Table 1).

In conclusion, the preliminary data used in the report are traceable to DTN SN0210T0510902.001 as the source. Justification for use of the preliminary data values in the AMR is already provided in its Appendix Q, Section Q.2. Thus there is no impact from the condition identified by CR-7461 on the use of these preliminary data and no impact to the results or conclusions of ANL-EBS-MD-000027 REV 03.

Table 1. Hand Calculation Showing Derivation of Preliminary Unit Averaged Values in AMR

Thermal/ Mechanical Unit	Stratigraphic Units from Table E-19	Thickness (m) from Table E-19	Stratigraphic Units from DTN[1]	Thickness (m) for Unit Average	Layer Weight	Heat Capacity from DTN[1] (J/kg-K)	Thickness Averaged Heat Capacity (J/kg-K)	Value from Table Q-3 (J/kg-K)	Heat Capacity from DTN[1] (J/kg-K)	Thickness Averaged Heat Capacity (J/kg-K)	Value from Table Q-3 (J/kg-K)	Heat Capacity from DTN[1] (J/kg-K)	Thickness Averaged Heat Capacity (J/kg-K)	Value from Table Q-3 (J/kg-K)
						T< 95°C			95°C<T<114°C			T>114°C		
TCw/ PTn	Tpcpv3	0.0	PTn	No average required	No average required	1158	1158	1158	11135	11135	11135	1010	1010	1010
	Tpcpv2	5.1												
	Tpcpv1	2.4												
	Tpbt4	0.5												
	Tpy	3.8												
	Tpbt3	3.8												
	Tpp	5.1												
	Tpbt2	8.3												
	Tptrv3	1.9												
	Tptrv2	1.2												
	Total >	32.1												
TSw1	Tptrv1	1.2	Tptrv1	1.2	0.0109	893	939	939	2306	5790	5791	1004	991	991
	Tptrn	35.6	Tptrnf	41.7	0.3801	893			4331			992		
	Tptrl	6.1												
	Tptpul	66.8	Tptpul	66.8	0.6089	969			6763			989		
	Total >	109.7		Sum >	1.0000									
TSw2/ TSw3	Tptpmn	38.3	Tptpmn	38.3	0.1906	941	937	937	5999	5714	5714	988	990	990
	Tptpll	95.6	Tptpll	95.6	0.4756	954			6369			989		
	Tptpln	55.1	Tptpln	55.1	0.2741	911			5016			990		
	Tptpv3	12.0	Tptpv23 (vitric)	12.0	0.0597	911			2784			1012		
	Total >	201.0		Sum >	1.0000									
CHn1/ CHn3	Tptpv2	4.7	Tptpv23 (vitric)	4.7	0.0563	911	1304	1304	2784	15773	15775	1012	1016	1016
	Tptpv1	15.4	Tptpv1bt1 (vitric)	17.4	0.2084	1285			15045			1012		
	Tpbt1	2.0												
	Calico	45.5	Average of units Tac1 through Tac4 (vitric)	45.5	0.5449	Mean of 1299, 1304, 1307, and 1312			Mean of 15810, 15815, 15818, and 15825			Mean of 1009, 1015, 1019, and 1024		
	Calicobt	15.9	Tacbt	15.9	0.1904	1434			20284			1020		
	Total >	83.5		Sum >	1.0000									

[1] DTN: SN0210T0510902.001, file *HeatCapacity10-23.xls*

CR- 8020 Evaluation

I. Background Information Summary:

A technical review for model validation was incompletely incorporated into ANL-EBS-MD-000027 Rev 03, Appendix S, Section S5.3.

Dr. Jaak Daemen provided a technical review for model validation for the Process Flow Code (PFC) modeling approach of stress corrosion with respect to rockfall and long-term drift stability. He reviewed a draft version of Appendix S (called Attachment XIX at the time), Estimating Long-term Damage Formation Surrounding Emplacement Drifts. His review, provided electronically, was re-formatted for inclusion in the report. Reformatting included changing references to an 'Attachment' to 'Appendix' and replacing references to pages in the draft to references to the subsection implied by the page number. References to figures were also reformatted from XIX-# to S-#. During this reformatting for inclusion in the report, one paragraph of the review was left out. The paragraph states:

While the logic, basis, for the selection of the lower bound curve in Fig. XIX-26 is not clear, arguments presented later (p. XIX-30) warrant accepting this lower bound as a true, or at least realistic, possibly excessively conservative, lower bound. Nevertheless, a somewhat more explicit justification for the selection of the lower bound would seem desirable.'

Thus, the review as presented in the report is not complete with respect to the version provided by Dr. Daemen.

Dr. Daemen's original review is included as an Attachment to this Condition Report.

II. Description of Change:

CR 8020 requires new text to be added as shown by vertical change bar.

S5.3 Independent Technical Review #1

The review from Dr. Jaak Daemen is provided in this section.

> This appendix presents a powerful analysis of potential time-dependent drift deterioration. The analysis is based on a convincing fundamental model of rock strength deterioration over time. The results provide considerable insight into what might be expected with regard to time-dependent drift deterioration.
>
> While the strategy developed in this appendix is very convincing, the significance of specific results is less so, because of the lack of experimental input data, as recognized by the authors.
>
> The shape of the bi-linear damage curves is eminently reasonable. However, the presentation of the sensitivity analysis (Section S3.2) and its implementation and results (Figure S-31) is exceedingly brief. It would help if this discussion could be expanded, could provide a bit more detail. The most convincing support for

the damage curves is the "calibration" of the results based on the ESF and ECRB observations (Section S3.4.1).

While the logic, basis, for the selection of the lower bound curve in Figure S-26 is not clear, arguments presented later (Section S3.3) warrant accepting this lower bound as a true, or at least realistic, possibly excessively conservative, lower bound. Nevertheless, a somewhat more explicit justification for the selection of the lower bound would seem desirable.

The results are eminently reasonable, and provide significant insight into the likely drift degradation mechanisms and time frame. Although, as the report recognizes, there is considerable input data uncertainty, the sensitivity analyses performed give considerable confidence that the results are good predictors of likely drift degradation.

The information presented appears accurate, and the analysis uses applicable models, assumptions, and recognized techniques.

The model documentation provides adequate confidence about the potential repository system component performance, and will support model validation. Limitations associated with the model, in particular with regard to the paucity of experimental input data, are clearly identified.

4/15

Additional comments

I am surprised that the analysis field 'calibration" does not include any comments or data from the heated drift test?

The influence of lithophysae on stability appears to be studied only through the influence of bulk porosity, and of fairly uniform distributions of essentially equidimensional voids. (Fig. XIX-5). Has consideration been given to a parallel analysis incorporating a broader range of lithophysal shapes, sizes, distributions?

The argument for using a linear static fatigue curve (p. XIX-13) is not altogether clear: is the main (unstated?) justification that it simplifies later calculations? Is it obvious that the differences are trivial (except at very high driving-stress ratios - which may be of less interest for long term degradation??). Some expansion of this discussion may be helpful.

On p. XIX-46, a brief definition of or reference to the seismic loading would be helpful.

A number of references appear to be to another document (e.g. Table 45, third line from bottom on p. XIX-49, Table 45, Table 36, second paragraph of p. XIX-50, Figure 106, Table 36, on p. XIX-21).

On my (black and white) copy it is difficult to identify several lines in Fig. XIX-26.

It is very difficult for me to see any detail on the stress plots in Fig. XIX-32. This may be less of an issue for people with read an electronic version? Alternatively, could these figures be enlarged? Are there page limitations? Anyway, these figures (regrettably) are essentially impossible to read.

The porosity contours (Fig. XIX-52) are very instructive. I wonder if it would be possible to include them for and on the 3 sections analyzed? (and/or with bulk modulus distributions (Fig. XIX-53) for all 3 sections?

Given the well known spatial variability of tuff properties, Section XIX.4 strikes me as a bit lighweight to address this topic. Certainly I would have liked to see the results for all three sections. But, more fundamentally, is an analysis of 3 variations really sufficient to address this variability issue?

The porosity simulation is referenced to Attachment XX (last paragraph on p. XIX-49), to which I do not have access, and presumably is explained there. At first glance, and even at second glance, it appears as if the porosity simulation is not a random simulation, but almost corresponds to a layered structure. Is this true? Intentional? (I recognize that question may be addressed in Attachment XX).

On p. XIX-50 (end of first paragraph) it is stated that "the use of a two-dimensional model is justified... accounting for actual variability of porosity and mechanical properties." To me this is not very convincing. I certainly believe strongly that some true 3-D analyses, including "unfavorable" lithophysal shapes, sizes and locations would be helpful. Also, I am not convinced that range of analyses presented captures the full actual ranges of porosities and mechanical properties.

Any possibility of longer term (fifty yr?) field calibrations with Nevada Test Site tunnels in tuff?

On p. XIX-27, second line below (Eq. XIX-6): replace "than" by 'then".

On p. XIX-30, first line of last paragraph, y is omitted in "lithophysal".

III. Inputs and/or Software

There is no change to the input values or to the software.

IV. Impact Evaluation:

The procedure in effect when ANL-EBS-MD-000027 Rev. 03 was approved on September 16, 2004 was AP-SIII.10Q/Rev. 2/ICN 6. It did not require the critical ITR (technical reviewer in 5.3.2.c.5) to document resolution of all comments in his report. Hence the resolution to CR-8020 in this ERD involves adding the additional comments from Prof. Jaak Daemen's report (MOL.20060407.0053), plus adding the following paragraphs as a general response. Note that this response is not intended to bring ANL-EBS-MD-000027 into compliance with current SCI PRO-006 Rev. 08 requirements for critical review, which is not necessary at this time.

The overall review of Appendix S by Prof. Jaak Daemen is considered to be supportive. Table numbers in Appendix S refer to tables within the appendix or other parts of the parent report. Legibility concerns expressed in the review are addressed in the final version.

Data limitations for developing or validating models of time-dependent behavior were recognized by the authors in the report, and were addressed in part by reliance on the study of time-dependence in Lac du Bonnet granite. Use of the Lac du Bonnet granite static fatigue curve can be justified because of the extensive work done by the team from Atomic Energy of Canada, Ltd. to model the behavior of this material, as noted in Appendix S, footnote 5. Observations from the heating phase of the Drift Scale Test were not used to calibrate time-dependence relationships for deformation of the host rock, because little time-dependent deformation (separate from temperature dependence) could be discerned from the observed data.

The modeling sensitivity tests are described transparently in the report, and suffice to show that UDEC simulations are not very sensitive to the results obtained using the Particle Flow Code (PFC). PFC simulations using circular voids implemented a similar methodology to that developed for the Lac du Bonnet study, which was not expanded here. Nonlinear static fatigue curves are evaluated in Section S2.2.5; linear curves were deemed acceptable for small driving stress ratios thought to be most relevant to long-term repository loading conditions. As pointed out in Section S3, the UDEC model with ground motion is the same as that described in detail in Sections 6.4 and 7.6 of the report, with the same dynamic boundary conditions.

Modeling of heterogeneity for the other two cross-sections taken through the realized three-dimensional porosity field was omitted for brevity, but similar rockfall was predicted as discussed in Section S4 (hence three cross-sections were considered sufficient for the study). Conditional simulation of rockmass porosity, incorporating random variability constrained by observations, is described in Appendix T. Variability in rock property values was assigned considering the ranges of observed lithophysal porosity and rock quality category data, as discussed in Section S4. Modeling of mechanical effects from three-dimensional geometry of lithophysal cavities was beyond of the scope of this report and of the supporting observational data. Calibration to tunnel stability data from the Nevada Test Site was also beyond the scope of this analysis.

V. Results and Conclusions:

The preceding text adequately addresses the condition and provides objective evidence of corrections and justification for no impact to the results or conclusions of ANL-EBS-MD-000027 REV 03.

CR 10115 Evaluation

I. Background Information Summary:

The Drift Degradation Analysis (ANL-EBS-MD-000027 REV 03) summarizes rockfall information in Tables 6-10, 6-13, 6-16, and 6-19 based on a drift length per simulation of 25 m. However, while 25 m is the length of the model space, there is a boundary condition that limits the length of drift over which rockfall can occur. The actual drift length per simulation is 21.74 m. This impacts the reported total length of drift simulated, the number of blocks (i.e., rockfalls) per km of drift, and the volume of rockfall per km of drift (Tables 6-10, 6-13, 6-16, and 6-19). This same impacted information is also contained in IED Geotechnical and Thermal Parameters III (800-IED-MGR0-00403-000-00A, Sections XVI, XVII, and XVIII), and output DTN: MO0408MWDDDMIO.002, files nonlith rockfall characteristics in emplacement drifts with 1e-4 gm.xls, nonlith rockfall characteristics in emplacement drifts with 1e-5 gm.xls, nonlith rockfall characteristics in emplacement drifts with 1e-6 gm.xls, and nonlith rockfall characteristics in emplacement drifts with 1e-7 gm.xls).

II. Description of Change (Corrected Information from *Drift Degradation Analysis)*

The discrepancy in drift length per simulation for the nonlithophysal rockfall model is documented in Condition Report 10115. The actual drift length per simulation is 21.74 m. The corrected information from *Drift Degradation Analysis* (BSC 2004 [DIRS 166107], Tables 6-10, 6-13, 6-16, 6-19, 6-26) is provided below, with the corrected preliminary information identified by vertical change bar.

Table 6-10. Summary of 3DEC Rockfall Prediction for 1 × 10^{-5} Annual Probability of Exceedance Hazard

Parameter	Value
Simulations Completed	50
Number of Simulations Predicting No Rockfall	1
Total Number of Rockfall	1767
Total Volume of Rockfall (m^3)	255.4
Total Length of Drift Simulated (m)	1087.0
Number of Blocks per km	1626
Volume of Rockfall per km (m^3)	234.9

NOTE: The drift length per simulation is 21.74 m.

Table 6-13. Summary of 3DEC Rockfall Prediction for 1 × 10^{-6} Annual Probability of Exceedance Hazard

Parameter	Value
Simulations Completed	50
Total Number of Rockfall	2797
Total Volume of Rockfall (m^3)	497.7
Total Length of Drift Simulated (m)	1087.0
Number of Blocks per km	2573
Volume of Rockfall per km (m^3)	457.8

NOTE: The drift length per simulation is 21.74 m.

Table 6-16. Summary of 3DEC Rockfall Prediction for 1 × 10^{-7} Annual Probability of Exceedance Hazard

Parameter	Value
Simulations Completed	44
Total Number of Rockfall	3387
Total Volume of Rockfall (m^3)	705.2
Total Length of Drift Simulated (m)	956.6
Number of Blocks per km	3541
Volume of Rockfall per km (m^3)	737.2

NOTE: The drift length per simulation is 21.74 m.

Table 6-19. Summary of 3DEC Rockfall Prediction for 1 × 10^{-4} Annual Probability of Exceedance Hazard

Parameter	Value
Simulations Completed	32
Total Number of Rockfall	428
Total Volume of Rockfall (m^3)	39.4
Total Length of Drift Simulated (m)	695.7
Number of Blocks per km	615
Volume of Rockfall per km (m^3)	56.7

NOTE: The drift length per simulation is 21.74 m.

Table 6-26. Comparison of Rockfall Statistics for Preclosure and Postclosure Events

Statistic	Ground Motion			
	10^{-4}	10^{-5}	10^{-6}	10^{-7}
Runs Completed	32	50	50	44
Total Number of Rockfall	428	1764	2797	3387
Total Volume of Rockfall (m^3)	39.4	255.4	497.7	705.2
Total Length of Drift Simulated (m)	695.7	1087.0	1087.0	956.6
Number of Blocks per km	615	1626	2573	3541
Volume of Rockfall per km (m^3/km)	56.7	234.9	457.8	737.2

NOTE: The drift length per simulation is 21.74 m.

III. Inputs and/or Software

There is no change to the input values or to the software.

IV. Impact Evaluation:

The impact is to the drift length per simulation for the nonlithophysal rockfall model, IED Geotechnical and Thermal Parameters III (800-IED-MGR0-00403-000-00A, Sections XVI, XVII, and XVIII), and output DTN: MO0408MWDDDMIO.002, files *nonlith rockfall characteristics in emplacement drifts with 1e-4 gm.xls, nonlith rockfall characteristics in emplacement drifts with 1e-5 gm.xls, nonlith rockfall characteristics in emplacement drifts with 1e-6 gm.xls, and nonlith rockfall characteristics in emplacement drifts with 1e-7 gm.xls*).

V. Results and Conclusions:

Recalculating the number of simulations completed with the listed parameters using the actual drift length per simulation of 21.74 m has corrected the discrepancy. There is no impact to the result or conclusions of ANL-EBS-MD-000027 REV 03.

CR 11242 Evaluation

I. Background Information Summary:

The Drift Degradation Analysis (BSC 2004 [DIRS 166107]) contains a typographical error in Table 6-1. Table 6-1 contains the heading, "Median Spacing (m)", which is incorrect, and should be changed to "Inter-Fracture Median Distance (m)". This error does not impact or change the conclusions from this document. Note that Table 6-1 contains a note referring to Table 6-2, which includes the same inter-fracture distance data, and is labeled correctly. To avoid confusion, it is recommended that median spacing be added to both Tables 6-1 and 6-2, which can be calculated knowing the inter-fracture median distance and the dip of the fracture set.

II. Description of Change:

To resolve CR-11242, the table heading and source note in Table 6-1 are corrected as follows (vertical change bar):

Table 6-1. General Characteristics of Fracture Sets in the Middle Nonlithophysal Unit

Set	Mean Azimuth/Dip	Inter-Fracture Median Distance (m)	Median Trace Length (m)	Comment
1	120/84	0.48	3.3	Rough to smooth, planar
2	215/88	1.08	2.8	Smooth but curved
3	302/38	3.40	3.7	Random fractures with generally flat to moderate dip
4	329/14	2.46	3.5	Vapor-phase partings, rough, cohesive with coating minerals, planar

Source: Median inter-fracture distance and trace length are from tunnel mapping data (see Table 6-2).

III. Inputs and/or Software

There is no change to the input values or to the software.

IV. Impact/Results and Conclusions:

The corrected text completes the needed clarification. There is no impact to the results or conclusions of ANL-EBS-MD-000027 REV 03.

CR 11752 Evaluation

I. Background Information Summary:

Figure 6-128 of Drift Degradation Analysis ANL-EBS-MD-000027 REV 03 contains a plot of Rockfall (m(cubed)/m of tunnel length) versus Peak Ground Velocity (cm/s). The caption for the figure indicates that rockfall is in units of m(squared)/m. It is obvious that the correct units are m(cubed)/m. This is a minor condition and should be a Level D opportunity for improvement.

II. Description of Change:

a. Change caption for Figure 6-128 to read: Estimate 1 × 10^{-5} Damage Level, Expressed as m^3/m of Emplacement Drift Length for Rock Strength Categories 1, 3, and 5 for the 15 Ground Motion Time Histories.

b. Near the bottom of Table E-7 on Page E-12 change “Summary Statistics for Tptpll” to “Summary Statistics for Tptpln”.

c. In Table 4-1 for the row containing parameter "Rock mass strength for lithophysal rock", "Young's modulus (GPa)", insert the following to the "Source/Supporting Information" column: MO0402DQRIRPPR.003 [DIRS 168901].

d. In the Note to Figure E-10, change: "*Drift Deg AMR AF T-A-P Fit.xls*" to "*Drift Deg AMR AF T-A-P Fit V1.xls*"

e. Table E-9, add the following text to note "b": Young's modulus data for Test ID's 1B through 8F are provided by DTN: MO0402DQRIRPPR.003 [DIRS 168901], rows 1561 to 1570.

III. Inputs and/or Software

There is no change to the input values or to the software.

IV. Impact/Results and Conclusion:

This was a typographical error and the corrected text completes the needed clarification. There is no impact to the results or conclusions of ANL-EBS-MD-000027 REV 03.

Note: Additional editorial corrections not identified in CR 11752 have also been implemented in this ERD.

General Note: The resolutions described herein are for the purpose of mitigating the conditions contained in the identified Condition Reports. They are hereby conveyed by this ERD, as a means to notify all users of ANL-EBS-MD-000027 REV 03 and subsequent ACNs, of additional data or information that augments the report and should be considered, by way of explanation, part of the report.