BSC	Model Administrative Change Notice *Complete only applicable items.*	QA: QA Page 1 of 3

1. Document Number:	MDL-EBS-MD-000001	2. Revision:	00	3. ACN:	01
4. Title:	In-Drift Natural Convection and Condensation				
5. No. of Pages Attached	8				

6. Approvals:

	Print name and sign	Date
Preparer:	G.H. Nieder-Westermann [signature]	03/22/2005
Checker:	Cliff Howard W. J. DUFFY for C. HOWARD PER E-MAIL. [signature]	3/23/05
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Independent Technical Reviewer:	Jean Younker Jean R Younker	~~3-23-05~~ 3-24-05
Responsible Manager:	Ernest Hardin Paul R. Dixon For [signature]	3-24-05

7. Affected Pages	8. Description of Change:
1-4	Clarification: CR 4294 is an opportunity for improvement. Specifically, the CR requested additional clarification be provided with respect to how the model feeds TSPA-LA. To this end the following text was added in Section 1 **The intended use of the model results is to provide reasonable, parametrically bounding estimates for drift-wall condensation occurrence frequency and rate for use in *Total System Performance Assessment Model/Analysis for License Application*. The probability of condensation at a particular waste package location is described by a correlation function between occurrence and the local percolation flux. For locations at which condensation occurs, the condensation rate is described by another correlation function between rate and local percolation flux. Four equally weighted cases are used in TSPA, corresponding to the possible combinations of high- and low-invert transport, and high- and low-dispersion (Section 8.3.1.1). For each of the four cases, separate correlations are developed for commercial spent nuclear fuel (CSNF) and HLW waste packages (except where no condensation is predicted; see Appendix H). The drift wall condensation rate (which may be zero) is added to the seepage rate (which may be zero) to form the advective flow rate in the EBS flow model.** **Although the In-drift Natural Convection and Condensation report includes bounding cases that produce condensation under the drip shield and on the waste packages, only drift-wall condensation is used in the TSPA-LA. Condensation under the drip shield (or on the waste package) is screened out based on low consequence *(Engineered Barrier System Features, Events, and Processes, ANL-WIS-PA-000002, REV 03 (BSC 2004 [DIRS 169898], Section 6.2.41, Repository Resaturation Due to Waste Cooling, 2.1.08.11.0A)*. The four cases used for TSPA tend to maximize the rate of drift-wall condensation while minimizing the rate of condensation under the drip shield.**

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	This new text replaces existing text on pages 1-4 and 1-5, beginning with *"The in-drift condensation and convection model provides correlations for the TSPA-LA ..."* through the end of the section.
1-5	Page 1-5 changed to "intentionally left blank" as a result of the editorial changes in this ACN
6-67	Clarification: CR 4294 is an opportunity for improvement. Specifically the CR requests that the Drip Shield Ventilation Assumption in Section 6.3.3.2.7 be clarified. To this end the following change is being made: Change: *"Assumption: Two limits to the drip shield features are considered. The first limit (ventilated drip shield) presumes that the drip shield is designed to promote mixing of the gas from under the drip shield with gas outside the drip shield. Perfect mixing is used in this case. The second limit (unventilated drip shield) presumes that the drip shield is designed to prevent mixing of the gases inside and outside of the drip shield."* to: ***"Assumption: Two bounds to the drip shield functionality are considered. The first limit (ventilated drip shield) assumes mixing of the gas under the drip shield with gas outside the drip shield. The second limit (unventilated drip shield) assumes that the drip shield prevents mixing of the gases inside and outside of the drip shield."***
4-12	Citation update (Correct DIRS as appropriate) Table 4.1.3-7, under "Source" column, last Cell, change: *BSC 2004 [DIRS 169861]* To ***BSC 2004 [DIRS 169565]*** This correction is associated with TBV-6319.
6-67	Citation update (Correct DIRS as appropriate) Section 6.3.3.2.8, "Rational" section, 3rd line, change: *BSC 2004 [DIRS 169856], Table 6-1, pg. 6-1* To ***BSC 2004 [DIRS 172463], Table 6-1*** This correction is associated with TBV-6549

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6-108	Typographical error and citation update (Correct DIRS as appropriate) Section 6.3.5.1.4, 2nd paragraph, 3rd line, change: *BSC 2004 [DIRS 169856], p. 59* To ***BSC 2004 [DIRS 172463], p. 5-3*** This correction is associated with TBV-6549
6-115	Citation update (Correct DIRS as appropriate) Section 6.3.5.2.3, 2nd line, change: *BSC 2004 [DIRS 169861], Table 6.9-1* To ***BSC 2004 [DIRS 169565], Table 6.3-4*** This correction is associated with TBV-6549
9-3	Typographical Error (Correct DIRS as appropriate) Section 9.1 "Document Cited", reference number 26, change: *DIRS number 169856* To ***DIRS number 172463*** *Note: An Accession number DOC.20041201.0008 was added* This correction is associated with TBV-6549
9-4	Citation update (Correct DIRS as appropriate) Section 9.1 "Document Cited", change reference: *BSC 2004. UZ Flow Models and Submodels. MDL-NBS-HS-000006 REV 02. Las Vegas, Nevada: Bechtel SAIC Company. (DIRS number 169861)* To ***BSC 2004. Multiscale Thermohydrologic Model. ANL-EBS-MD-000049 REV 02. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20041014.0008. (DIRS number 169565)*** This correction is associated with TBV-6319

Direct Sources and Users of the Output of the AMR

The in-drift condensation and convection model uses qualified data obtained from project information (i.e. data tracking numbers (DTNs) and IEDs as presented in Section 4.1 of this report. Information is also obtained from the following reports:

- *UZ Flow Models and Submodels*
- *Drift-Scale THC Seepage Model*
- *In Situ Field Testing of Processes*
- *Calibrated Properties Model*
- *Thermal Conductivity of the Potential Repository Horizon Model Report*
- *Ventilation Model and Analysis Report*
- *Heat Capacity Analysis Report*
- *The Multiscale Thermohydrologic Model*
- The *Engineered Barrier System: Physical and Chemical Environment Model*
- *EBS Radionuclide Transport Abstraction*

The intended use of the model results is to provide reasonable, parametrically bounding estimates for drift-wall condensation occurrence frequency and rate for use in *Total System Performance Assessment Model/Analysis for License Application*. The probability of condensation at a particular waste package location is described by a correlation function between occurrence and the local percolation flux. For locations at which condensation occurs, the condensation rate is described by another correlation function between rate and local percolation flux. Four equally weighted cases are used in TSPA, corresponding to the possible combinations of high- and low-invert transport, and high- and low-dispersion (Section 8.3.1.1). For each of the four cases, separate correlations are developed for commercial spent nuclear fuel (CSNF) and HLW waste packages (except where no condensation is predicted; see Appendix H). The drift wall condensation rate (which may be zero) is added to the seepage rate (which may be zero) to form the advective flow rate in the EBS flow model.

Although the In-drift Natural Convection and Condensation Report includes bounding cases that produce condensation under the drip shield and on the waste packages, only drift-wall condensation is used in the TSPA-LA. Condensation under the drip shield (or on the waste package) is screened out based on low consequence (*Engineered Barrier System Features, Events, and Processes,* ANL-WIS-PA-000002, REV 03 (BSC 2004 [DIRS 169898], Section 6.2.41, *Repository Resaturation Due to Waste Cooling*, 2.1.08.11.0A). The four cases used for TSPA tend to maximize the rate of drift-wall condensation while minimizing the rate of condensation under the drip shield.

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Table 4.1.3-7 presents the repository layout and sources for percolation data. The geometric data, line-averaged powers, and ventilation efficiencies are used in Section 6.3.5.1.1 to calculate the repository temperature field. The discrete waste package powers are used in Section 6.3.5.1.2 to compute waste package temperatures. The percolation rates and time intervals are used in Section 6.3.5.1.1 to compute average percolation rates for each chosen drift. Note that the YMP uses several different data sets to represent the lower, mean and upper percolation rates at the repository horizon that were developed for different purposes. *Multiscale Thermohydrologic Model* (BSC 2004 [DIRS 169565], Appendix XII) provides a comparison of these different data sets and concludes that, for the purpose of thermohydrologic analysis, the data sets are in reasonable agreement, and therefore can be used to assess in-drift condensation. Some of the geometry information in Table 4.1.3-7 was updated after the analyses were completed. The changes to this information are discussed in Appendix K. These small changes will have a negligible impact on the results of this report, thereby justifying the information for its intended use.

Table 4.1.3-7. Repository Layout and Sources for Percolation Data

Model Input	Value	Units	Source
Waste package endpoint coordinates	-	-	BSC 2003 [DIRS 161727]
Minimum exhaust standoff	15	m	BSC 2004 [DIRS 171424]
Turnout radius	61	m	BSC 2004 [DIRS 171423]
Line-averaged powers	-	-	BSC 2004 [DIRS 167754]
Waste package sequence	-	-	BSC 2004 [DIRS 167754]
Discrete waste package powers	-	-	BSC 2004 [DIRS 167754]
Ventilation efficiencies	-	-	DTN: MO0307MWDAC8MV.000 [DIRS 165395]
Lower Percolation Rate	-	-	DTN: LL030608723122.028 [DIRS 164510] (Nevada_SMT_percolation_BIN_la.txt)
Mean Percolation Rate	-	-	DTN: LL030610323122.029 [DIRS 164513] (Nevada_SMT_percolation_BIN_ma.txt)
Upper Percolation Rate	-	-	DTN: LL030602723122.027 [DIRS 164514] (Nevada_SMT_percolation_BIN_ua.txt)
Time Intervals for Percolation Rates	-	-	BSC 2004 [DIRS 169565]

Waste package dimension are shown in Table 4.1.3-8. Drip shield dimensions are shown in Table 4.1.3-9. Additional dimensions are derived from these dimensions in Section 6.3.5.2.7. These dimensions are used in the calculation of heat and mass transfer coefficients (Section 6.3.5.1.3) and in the actual transport calculations (Section 6.3.5.1.2). Some of the geometry information in Tables 4.1.3-8 and 4.1.3-9 was updated after the analyses were completed. The changes to this information are discussed in Appendix K. These small changes will have a negligible impact on the results of this report as evaluated in Appendix K, thereby justifying the information for its intended use.

Properties specific to the repository site are implemented in the analysis through the file **Repository Description LA 2.mcd**. Fluid properties are implemented in the analysis through the file **Fluid Properties.mcd**. Refer to Appendix D, Section D.7 for a list of Mathcad files used in the analysis as well as instructions for their use.

6.3.3.2.6 Neglect of the Axial Relocation of Energy in the Calculation of Rock Temperatures

Assumption: The latent heat associated with the axial transport of water vapor causes a spatially nonuniform deposition of energy in the rock. This axial redistribution of energy in the rock is ignored.

Rationale: Water evaporated in the middle of the drift carries with it a latent heat that is released at the point of condensation. This modifies the spatially uniform line source used to estimate the drift wall temperatures (Section 6.3.5.1.1). The fully coupled problem that integrates this axial redistribution of energy represents a significant computational complication. The procedure used in this calculation is to calculate the rock temperature profiles using average line source representations for the decay heat. The axial redistribution of energy is then derived from the axial vapor fluxes. The appropriateness of the assumption is assessed at that point.

Confirmation Status: The assumption is assessed in Section 6.3.7.2.4.

Use in this Calculation: This assumption is used in Section 6.3.5.1.1.

6.3.3.2.7 Drip Shield Ventilation

Assumption: Two limits to the drip shield functionality are considered. The first limit (ventilated drip shield) assumes mixing of the gas under the drip shield with gas outside the drip shield. The second limit (unventilated drip shield) assumes that the drip shield prevents mixing of the gases inside and outside of the drip shield.

Rationale: These are the two extremes of gas mixing. By addressing both extremes, the analysis captures the full range of possibilities.

Confirmation Status: Because the two extremes capture the full range of possibilities, no further confirmation is needed.

Use in this Calculation: This assumption is used in Section 6.3 and Appendices D.1 and D.2.

6.3.3.2.8 Water Available for Evaporation in the Drift

Assumption: The water available for evaporation in the drift is limited by the percolation rate rather than the seepage rate.

Rationale: Water can enter the drift by evaporation from the drift wall and by liquid seepage (the portion of the liquid percolation that enters the drift) from the fractures. The two processes are coupled. The current thermal THC seepage model is two-dimensional (BSC 2004 [DIRS 172463], Table 6-1) and accounts for fracture-matrix interactions.

Because of the two-dimensional nature of the model, the drift vapor pressure in the current seepage analysis will be very close to saturation and the evaporation into the drift will be close to zero. This means that the matrix saturation near the drift wall in the current seepage model will be high, and the imbibition of water from the fracture into the matrix will be low.

$$m_{invert} = \frac{Nu\_mass_{wall}\ \rho_{gas}\ Dva}{D_{wall}} \left(\frac{Xst_{sat}(T_{invert}) - Xst_{in}}{1 - Xst_{in}} \right)$$

$$Nu\_mass_{wall} = \frac{2}{\left[-\ln\left[1 - \frac{2}{\left[\left(\left[\left(\frac{2}{1-e^{-0.25}} \right)^{5/3} + \left(0.587\ G\ Ra_{wall}^{1/4} \right)^{5/3} \right]^{5/3} \right)^{15} + \left(0.1\ Ra_{wall}^{1/3} \right)^{15} \right]^{1/15}} \right] \right]}$$

$$G = \left[\left(1 + \frac{0.6}{Sc_{gas}^{0.7}} \right)^{-5} + \left(0.4 + 2.6\, Sc_{gas}^{0.7} \right)^{-5} \right]^{-1/5}$$

$$Ra_{wall} = g \frac{\beta_{gas}}{\nu_{gas}^2} Sc_{gas}\ D_{wall}^3 \left| T_{wall} - T_{gas} \right|$$

(Eq. 6.3-47)

6.3.5.1.4 Evaporation Limits

The discussion of water entry into the drift begins by restating the conditions of interest. We are interested in the period when condensation can occur within the drift. At any axial location in the drift, the coolest surface will be the drift wall. The drip shield and waste packages will be hotter than the drift wall. Hence, for condensation to take place on any surface within the drift, the drift wall must be less than or equal to the saturation temperature (96ºC). At early times, the entire repository will be above the saturation temperature and condensation will be impossible. At sufficiently later times, the entire length of some or all of the emplacement drifts will be cooler than the saturation temperature, and condensation will be possible. The condensation model addresses this time period.

Water can enter the drift by evaporation from the drift wall and by liquid seepage (the portion of the liquid percolation that enters the drift) from the fractures. The two processes are coupled. The current thermohydraulic seepage model does not account for evaporation at the drift surface caused by axial vapor transport (BSC 2004 [DIRS 172463], p. 5-3). This means that the matrix saturation near the drift wall is high and the imbibition of water from the fracture into the rock matrix is low.

For this vapor dispersion analysis, upper evaporation limits are realized when the drift vapor pressure is significantly lower than the saturation value. When this occurs, the rock matrix desaturates in the vicinity of the drift wall. A portion of the percolated water will be imbibed into this desaturated rock matrix and "pumped" by capillary forces to the drift wall surface where it will evaporate. The resulting flow of liquid and vapor into the drift will be larger than the sum understates the actual curvilinear distance of the turnout, but provides a lower bound for the length of this "super coldtrap" region. Repository layout data are cited in Table 4.1.3-7. These data are used in Section 6.3.5.1.1, "Calculation of the Repository Temperature Field."

6.3.5.2.2 Rock Properties

The bulk of the repository is located in the lower lithophysal unit (Tptpll). The thermal and flow properties of this layer are used in this analysis to approximate the temperature distribution and near-field water flow. The flow properties are documented in DTN: LB0208UZDSCPMI.002 [DIRS 161243]. Thermal properties are documented in DTNs: SN0307T0510902.002 [DIRS 164196] and SN0404T0503102.011 [DIRS 169129]. The thermal diffusivity of the rock is calculated with an approximated saturation value of unity (1). Rock properties are listed in Table 4.1.3-1. Thermal rock properties are used in Section 6.3.5.1.1, "Calculation of the Repository Temperature Field." Matrix permeability and capillary pressure properties are used in Section 6.3.5.1.4, "Evaporation Limits."

6.3.5.2.3 Percolation Rates

Percolation rates are used to calculate the maximum amount of water available for evaporation at the drift and invert surfaces. Percolation rates vary with the expected climate (BSC 2004 [DIRS 169565], Table 6.3-4). The "modern" climate is projected to last until 600 years after emplacement. The "monsoon" climate extends from 600 to 2,000 years. The "glacial" climate begins at 2000 years and extends throughout the balance of the repository life (BSC 2004 [DIRS 169565], Table 6.3-4). Three percolation rates are associated with each climate: the lower bound (DTN: LL030608723122.028 [DIRS 164510]), the upper bound (DTN: LL030602723122.027 [DIRS 164514]), and the mean (DTN: LL030610323122.029 [DIRS 164513]). Percolation rates are cited in Table 4.1.3-7 and are used Section 6.3.5.1.4, "Evaporation Limits."

BSC 2004. *D&E / PA/C IED Typical Waste Package Components Assembly.* 800-IED-WIS0-00203-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20040202.0011. 167754

BSC 2004. *D&E / PA/C IED Typical Waste Package Components Assembly.* 800-IED-WIS0-00205-000-00D. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20040518.0001. 169990

BSC 2004. *D&E/PA/C IED Typical Waste Package Components Assembly.* 800-IED-WIS0-00202-000-00C. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20040517.0008. 169472

BSC 2004. *Design and Engineering, Interlocking Drip Shield Configuration.* 000-M00-SSE0-00102-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20040305.0021. 168067

BSC 2004. *The Development of the Total System Performance Assessment License Application Features, Events, and Processes.* TDR-WIS-MD-000003, Rev. 01. Las Vegas, Nevada: Bechtel SAIC Company. 168706

BSC 2004. *Drift-Scale THC Seepage Model.* MDL-NBS-HS-000001, REV. 03. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20041201.0008. 172463

BSC 2004. *EBS Radionuclide Transport Abstraction.* ANL-WIS-PA-000001, Rev. 01. Las Vegas, Nevada: Bechtel SAIC Company. 169868

BSC 2004. *Engineered Barrier System Features, Events, and Processes.* ANL-WIS-PA-000002, Rev. 03. Las Vegas, Nevada: Bechtel SAIC Company. 169898

BSC 2004. *In Situ Field Testing of Processes.* ANL-NBS-HS-000005, Rev. 03. Las Vegas, Nevada: Bechtel SAIC Company. 170004

BSC 2004. *Multiscale Thermohydrologic Model.* ANL-EBS-MD-000049 REV 02. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20041014.0008. 169565

BSC 2004. *Q-List.* 000-30R-MGR0-00500-000-000 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20040721.0007. 168361

BSC 2004. *Repository Subsurface Emplacement Drift Panel 2 General Arrangement.* 800-KM0-SSE0-00901-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20040213.0001. 171424

BSC 2004. *Repository Subsurface Emplacement Drifts Steel Invert Structure Plan & Elevation.* 800-SS0-SSE0-00101-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20040520.0004. 169503

BSC 2004. *Repository Subsurface Turnout Drift 1-8 Interface.* 800-KMO-SSD0-00301-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20040220.0009. 171423

BSC 2004. *Technical Work Plan for: Near-Field Environment and Transport In-Drift Heat and Mass Transfer Model and Analysis Reports Integration.* TWP-MGR-PA-000018 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20040729.0006. 170950

BSC 2004. *Thermal Conductivity of the Potential Repository Horizon.* MDL-NBS-GS-000005 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20040928.0006. 169854

BSC 2004. *Multiscale Thermohydrologic Model.* ANL-EBS-MD-000049 REV 02. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20041014.0008. 169565

BSC 2004. *Ventilation Model and Analysis Report.* ANL-EBS-MD-000030, Rev. 04. Las Vegas, Nevada: Bechtel SAIC Company. 169862

Buscheck, T.A.; Rosenberg, N.D.; Gansemer, J.; and Sun, Y. 2002. "Thermohydrologic Behavior at an Underground Nuclear Waste Repository." *Water Resources Research, 38,* (3), 10-1 through 10-19. Washington, D.C.: American Geophysical Union. TIC: 253566. 160749

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CertainTeed 1996. Submittal Sheet, Standard Fiber Glass Duct Wrap. Valley Forge, Pennsylvania: CertainTeed Corporation. TIC: 249257. 153512

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Choi, J.Y. and Kim, M-U. 1993. "Three-Dimensional Linear Stability of Natural Convective Flow Between Concentric Horizontal Cylinders." *International Journal of Heat and Mass Transfer, 36,* (17), 4173-4180. New York, New York: Pergamon. TIC: 255178. 164647