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Design Analysis Cover Sheet

Complete only applicable items.

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<p>The following individuals contributed to, and/or prepared, the following sections:</p> <p>Robert Elayer: 4.3.27, 5.23, 5.25, the third paragraph of section 6.0, 7.3.4.1.2. and he prepared Figure 10.</p> <p>Yiming Sun: 4.1.2, 4.1.3, 4.1.4, 4.1.5, 4.3.22, 4.3.23, 4.3.24, 4.3.25, 4.3.26, 4.3.29, 4.3.31, 5.18, 5.20, 5.21, 5.24, 5.26, 5.27, 5.29, first two paragraphs of section 6, 7.3.4.1.1, 7.3.4.1.1.1, 7.3.4.1.1.2, 7.3.4.1.1.3, 7.3.4.1.1.4, Attachment III, and he prepared Figures 6, 7, 8 and 9, and Attachments V and VI.</p> <p>Hang Yang contributed to sections 4.3.30, 5.28, and Attachment IV.</p> <p>John Beesley is responsible for all remaining sections.</p>			

Design Analysis Revision Record*Complete only applicable items.*

1.

2. DESIGN ANALYSIS TITLE

Subsurface Repository Performance Confirmation Facilities

3. DOCUMENT IDENTIFIER (Including Rev. No.)

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4. Revision No.	5. Description of Revision
00	Initial Issue

1. PURPOSE

The purpose of this analysis is to examine the subsurface Performance Confirmation (PC) program and to describe methodologies for gathering the PC parameters, the facilities needed to carry out the PC program, how these facilities can be incorporated into the overall repository design, and the limitations and impacts of these facilities on the overall repository design. The objective of this analysis is to describe the subsurface PC program and how it can be integrated into the repository viability assessment design.

The scope of this analysis covers: 1) Assessing the results of the Systems Engineering *Performance Confirmation Concepts Study Report* (Ref. 5.1). Appendix D of that study (see Attachment I) lists the PC parameters; 2) Determining methods for acquiring the PC data and preliminary concepts for the data acquisition stations, including configuration, location, and number of stations; 3) Determining how the PC program, including the data acquisition stations and data network systems, will be incorporated into the overall repository design. This task also addresses means of accessing the data acquisition stations, ventilation, and utilities requirements. 4) Evaluating PC parameters that may require periodic recovery of waste packages (WP).

The scope of this analysis does not include design of the data acquisition system for transmitting testing information from the PC monitoring stations to the surface PC facility, or the remote systems for PC data collection that will enter active emplacement drifts. These two items will be addressed by another analysis. Future work scopes will address changes in PC requirements that may result from evolution of the repository design and Performance Assessment (PA) program.

2. QUALITY ASSURANCE

The items which are the subject of this design analysis have not been classified in accordance with QAP-2-3. However, "Performance Confirmation Facilities" have been placed on the MGDS Q-list (Ref. 5.13, pp 12) by DOE direct inclusion, as important to safety. Since a QAP-2-3 classification analysis has not been performed, there are no PC specific QA controls.

This design analysis activity has been evaluated in accordance with QAP-2-0 and found to be applicable to the QA program.

Much of the input data used in this analysis is preliminary and unqualified and, therefore, the outputs are also unqualified. Because of the preliminary nature of this analysis all data shall be treated as unqualified/unconfirmed, and the formal TBV and TBD tracking system described in NLP-3-15, Rev 3, *To Be Verified (TBV) And To Be Determined (TBD) Monitoring System* is not applicable. The conclusions from this design analysis cannot be used as input into documents supporting procurement, fabrication, or construction.

3. METHOD

The analytical method is utilized. The design inputs of section 4 are analyzed to produce the design described in section 7. Specifically, the first section of the analysis, 7.1, describes the purpose and objectives of the PC program. The program description is derived from the criteria and assumptions, from section 4, which are based on the Repository Design Requirements Document (RDRD) (Ref. 5.2) and the Controlled Design Assumptions Document (CDA) (Ref. 5.3).

In section 7.2 the specific PC parameters from assumption 4.3.1 are evaluated. The parameters are found in reference 5.1 as Appendix D and are included in this analysis as Attachment I.

In section 7.3 specific methods for obtaining the PC data are developed from the design inputs and integrated with the PC parameters which are evaluated in section 7.2. One of the methods involves placing an observation drift above the emplacement horizon and finite element methods were used to evaluate the thermal effects of the emplacement horizon on that drift.

Section 7.4 then analyzes the specific PC data acquisition stations and facilities. The goal of the analysis is to show that the assumed PC parameters can be obtained using one or more of the strategies described in section 7.2 and that the current repository design can accommodate the PC facilities.

Extensive use of cross references, for example (4.3.1), are employed to assist the reader in tracking the design through each section of the analysis. The number in brackets refers to another section in this analysis.

4. DESIGN INPUTS

4.1 Design Parameters

4.1.1 Seven (7) test alcoves have been excavated for the Exploratory Studies Facility (ESF) testing activities. (Reference 5.4 through reference 5.10.) These alcoves will be utilized whenever possible for carrying out the PC strategies.

4.1.2 Rock Temperature and Thermal Gradient

Average rock temperature at ground surface of 18.7°C (Ref. 5.3, TDSS 002), and the rock mass thermal gradient, listed in Table 4.1, are used to estimate the initial temperature distribution and temperature boundary conditions.

Table 4.1. Rock Mass Thermal Gradient (Ref. 5.3, TDSS 002)

Depth (m)	Thermal Gradient (°C/m)
0 - 150	0.020
150 - 400	0.018
400 - 541	0.030

In this analysis, below 541 meters to the model depth of 611 meters (4.3.29), the thermal gradient continues to be .030°C/m. All thermal gradient values are currently unqualified.

4.1.3 Rock Thermal Properties

Thermal properties for the Yucca Mountain strata are listed in Tables 4.2 and 4.3.

**Table 4.2. Contact Depths, Thermal Conductivity, and Capacitance of Thermal/
Mechanical Units (Ref. 5.22, sections 1.12b and 1.1326a)**

Units	Upper Contact (m)	Lower Contact (m) ¹	Thermal Conductivity (W/m·K)	Thermal Capacitance ⁵ (J/cm ³ ·K)		
				T ≤ 94°C	94°C < T ≤ 114°C	T > 114°C
TCw	0	36.0	1.59 ²	2.0313	9.3748	2.0979
PTn	36.0	74.1	0.85 ³	2.2286	29.3110	1.5236
TSw1	74.1	204.2	1.60 ²	2.0775	12.2655	2.0219
TSw2	204.2	393.5	2.10	2.1414	10.4786	2.1839
TSw3	393.5	409.3	1.28	2.0530	4.5193	2.5535
CHn1v	409.3	414.5	1.20	2.5651	35.3680	1.6702
CHn1z	414.5	518.5	1.28	2.6709	35.3854	2.2835
CHn2	518.5	535.2 ⁶	1.56 ⁴	2.5486 ⁴	24.8363 ⁴	2.7544 ⁴

¹ Values from reference 5.22 are in feet, which are converted to meters by multiplying by .3048.

² Lithophysae rich

³ Nonwelded or bedded

⁴ CHn2z values in reference 5.22.

⁵ Values averaged over the listed temperature ranges

⁶ The thermal model extends to 611 meters (4.3.29). The CHn2 values in Table 4.2 and the CHn2z value in Table 4.3 are used from 518.5 to 611 meters.

Table 4.3. Rock In Situ Density of Thermal/Mechanical Units (g/cm³)

Thermal/Mechanical Unit	At In Situ Saturation
TCw	2.169 (Ref. 5.26, pp V-1)
PTn	1.299 (Ref. 5.26, pp V-1)
TSw1	2.163 (Ref. 5.26, pp V-1)
TSw2	2.274 (Ref. 5.26, pp V-1)
TSw3	2.271* (Ref. 5.22, section 1.1325)
CHn1v	1.972* (Ref. 5.22, section 1.1325)
CHn1z	1.886 (Ref. 5.22, section 1.1325)
CHn2z	2.070 (Ref. 5.22, section 1.1325)

* Average Values

4.1.4 Stefan-Boltzmann constant = $5.669 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^4$ (Ref. 5.20, pp 14)

4.1.5 Waste Package Characteristics

Density: 8.1310 g/cm³ (Ref. 5.27, Table 4.1-5)
 Thermal Conductivity: 41.709 W/m-K¹
 Specific Heat: 487.901 J/kg-K¹

¹ From reference 5.27, Table 4.1-4, these numbers are the average of values over the temperature range of 21.11° to 260° C.

4.2 Criteria

4.2.1 Monitoring, Testing, Detecting Radioactive Waste

The PC design shall provide for the capability to monitor and test leakage from radioactive waste packages.

[(RDRD 3.7.6.A.1.a), (RDRD 3.7.6.A.1.c), (RDRD 3.7.7.A.4)]

(This criteria is used in sections 7.1, 7.2.11 and 7.3.1.)

4.2.2 Not Used

4.2.3 Baseline PC Data

The PC design shall provide for collection of baseline environmental and geologic site data. Baseline data shall provide information on those data that could be changed by site

characterization, construction or repository operations.
[(RDRD 3.7.6.A.2), (RDRD 3.7.6.A.6.b)]
(This criteria is used in sections 7.1, 7.2.4, 7.2.7 and 7.3.5.)

4.2.4 Changes to PC Data

The PC design shall provide for the ability to monitor and analyze underground conditions. Changes to the environmental conditions shall be evaluated to ensure that changes are within predetermined levels.
[(RDRD 3.2.3.2.2.A.4), (RDRD 3.7.6.A.4.a), (RDRD 3.7.6.A.6.c), (RDRD 3.7.6.A.7)]
(This criteria is used in sections 7.1, 7.2.4, 7.2.7 and 7.3.5.)

4.2.5 Repository Operating as Planned With No Adverse Effects

The PC design shall provide for gathering data to verify that design assumptions are accurate or within acceptable limits, and that any unanticipated results are also gathered and assessed. Additionally, the data collection effort itself will not produce adverse effects on the repository.
[(RDRD 3.2.3.2.2.A.4), (RDRD 3.7.6.A.4.b), (RDRD 3.7.6.A.6.a), (RDRD 3.7.6.A.7), (RDRD 3.7.6.D)]
(This criteria is used in sections 7.1 and 7.3.4.1.2.)

4.2.6 Performance Confirmation Plan, Compliance with Subpart F, 10 CFR 60

The PC design will meet the requirements established by the NRC by utilizing the direction from the *Performance Confirmation Concepts Study Report*, B00000000-01717-5705-00035, Rev 01 (Ref. 5.1). The PC design information from that study is based on Subpart F of 10 CFR 60 (Ref. 5.1, pp 1-8).
[(RDRD 3.7.6.A.3), (RDRD 3.7.6.A.5), (RDRD 3.7.6.A.6.d)]
(This criteria is used in sections 7.1 and 7.2.)

4.2.7 In Situ Testing and Monitoring

Testing is required during site characterization and repository construction. Some testing has been completed in the ESF and other testing is in progress. In situ tests shall include studying the rock, groundwater, backfill, seals and thermal interactions. The in situ monitoring of the thermomechanical response to the rock of the emplacement areas shall continue until permanent closure.
[(RDRD 3.2.1.1.A), (RDRD 3.2.3.2.2.A.3.a), (RDRD 3.7.6.B), (RDRD 3.7.6.C), (RDRD 3.7.6.D), (RDRD 3.7.6.G)]
(This criteria is used in section 7.1.)

4.2.8 Backfill Testing

Though backfill testing could occur early in the PC program, the PC design shall allow backfill testing to commence at any time.

[(RDRD 3.7.6.B), (RDRD 3.7.6.F)]

(This criteria is used in sections 7.1 and 7.3.3.)

4.2.9 Access and Shaft Seals Testing

Testing of seals for the main accesses could occur at any time in a tunnel or shaft which is similar to that opening.

[(RDRD 3.7.6.B), (RDRD 3.7.6.G)]

(This criteria is used in sections 7.1 and 7.3.3.)

4.2.10 Sampling and Monitoring Fluids and Materials

The PC design shall provide for a system to monitor and account for all fluids and materials introduced into the repository, and to evaluate their potentially adverse effects on the waste isolation function.

[(RDRD 3.2.3.2.2.A.5), (RDRD 3.3.8.1.E), (RDRD 3.7.5.K.1), (RDRD 3.7.5.K.2)]

(This criteria is used in sections 7.2.9 and 7.3.1.)

4.2.11 Flexibility

The PC design shall be flexible to ensure adaptability to changes in other parts of the repository design.

[(RDRD 3.2.8), (RDRD 3.7.5.E.6), (3.7.5.H)]

(This criteria is used in sections 7.1, 7.2.8 and 7.3.7.)

4.2.12 Geologic Mapping

Geologic mapping shall be conducted during repository construction.

[(RDRD 3.4.6.B.3)]

(This criteria is used in sections 7.2.2, 7.2.3, 7.2.5 and 7.3.2.)

4.2.13 Seismic Monitoring

A program of seismic monitoring shall be established as part of the PC program.

[(RDRD 3.7.3.7.F.), (RDRD 3.7.3.7.H)]

(This criteria is used in sections 7.1, 7.2.1 and 7.3.3.)

4.2.14 Waste Packages

The repository design provides for waste package recovery. Therefore, the PC design shall provide for laboratory testing on any recovered waste packages. Waste packages shall be monitored underground to evaluate their performance.

[(RDRD 3.7.5.D), (RDRD 3.7.5.E.5), (RDRD 3.7.6.E)]

(This criteria is used in sections 7.2.10 and 7.3.8.)

4.3 Assumptions

Assumptions 4.3.1 through 4.3.17, 4.3.19 and 4.3.20, and parts of 4.3.22, 4.3.23, 4.3.25 and 4.3.26, are from the *Controlled Design Assumptions* (CDA) document (Ref. 5.3). The design rationale for these assumptions are found in the CDA.

Assumptions 4.3.1 through 4.3.10.o are from Key 061 in the CDA. The numbering scheme parallels the numbering used in Key 061 to assist in tracing the assumption to its origin. For example; Key 061, assumption 5, is assumption 4.3.5 in this analysis; Key 061, assumption 10.b, is assumption 4.3.10.b in this analysis.

4.3.1 Repository design and operation shall provide facilities, access, instrumentation, recording, maintenance, and support for measuring/monitoring the performance confirmation parameters identified in Appendix D (see Attachment I) of the FY 96 *Performance Confirmation Concepts Study Report*, B00000000-01717-5705-00035, Rev 01 (Ref. 5.1).
(This assumption is used throughout the analysis.)

4.3.2 The performance confirmation monitoring and measuring system shall have a maintainable service life of 125 years (100 years plus the duration of initial construction plus the duration of final closure plus any time period during site characterization for which the system must be operable). Specific equipment and components shall have maintainable service lives dependent upon their identified function. The service lives are to be determined (TBD).
(This assumption is used throughout the analysis.)

4.3.3 Planning of repository design and operations for performance confirmation test facilities and support shall consider the performance confirmation concepts identified in Section 5 of the *Performance Confirmation Concepts Study Report* (Ref. 5.1) as a point of departure.
(This assumption is used throughout the analysis.)

4.3.4 Not Used

4.3.5 Test locations/environments, samples, and specimens, on-site and off-site, shall be representative of the Repository environments and design elements.
(This assumption is used in section 7.2.2, 7.2.3, 7.2.4 and 7.3.1.)

4.3.6 Performance confirmation staff, measurement and monitoring hardware and software, shall be available to support the variable demand for analysis, assessment, and periodic reporting throughout the Performance Confirmation Program.
(This assumption is used throughout the analysis.)

4.3.7 Not Used

4.3.8 At least one alcove shall be provided for testing and monitoring the Ghost Dance Fault prior to and following waste emplacement.
(This assumption is used in sections 7.1, 7.3.3 and 7.3.3.1.)

4.3.9 Monitoring of at least two percent of the thermal rock mass behavior (to be related to the number of emplacement drifts) shall be performed; a portion of the rock mass to be monitored should be near the first emplacement drifts to contain waste.

This value is a lower bound. The upper bound is 100 percent. This analysis will examine methods to monitor between 2 and 100 percent of the thermal rock mass. However, the final amount of rock that must be monitored is to be determined.
(The assumption is used in sections 7.3.4.1.)

4.3.10 The Repository Subsurface Facilities shall provide underground openings (drifts, alcoves, boreholes, and ancillary excavations), access, data acquisition, and test support to implement performance confirmation monitoring and test recommendations including interface and coordination with Site Investigation Testing, Repository Testing, Waste Package Testing and Surface Support.
(This assumption is used throughout the analysis.)

These operations are to include, but are not to be limited to, capabilities for:

4.3.10.a Any ground support system (i.e., shotcrete or concrete) that covers the emplacement drift rock wall surface shall not be installed until after TBD necessary rock mapping is complete.
(This assumption is used in section 7.3.2.)

4.3.10.b TBD samples of rock core shall be acquired following emplacement drift excavation.
(This assumption is used in section 7.3.1.)

4.3.10.c Not Used

4.3.10.d Recovery of selected or malfunctioning waste packages shall be performed on a nonroutine basis, as required.
(This assumption is used in section 7.2.10 and 7.3.8.)

4.3.10.e Not Used

4.3.10.f Excavation of at least one permanent observation drift above the repository

horizon shall be developed in support of thermal monitoring.
(This assumption is used in sections 7.1, 7.3.1, 7.3.4 and 7.3.4.1.)

4.3.10.g At least one alcove shall be prepared for underground monitoring of seismic activities.
(This assumption is used in sections 7.1, 7.2.1 and 7.3.3.)

4.3.10.h The air temperature, relative humidity, and gaseous radioactive emissions of all emplacement drifts shall be monitored through the drift ventilation.
(This assumption is used in section 7.3.5.)

4.3.10.i The ventilation monitoring system shall be capable of identifying the specific drifts that are sources of gaseous radioactive emissions, if any, within TBD hours of detection of such emission.
(This assumption is used in section 7.3.5.)

4.3.10.j Not Used

4.3.10.k Subsurface facilities operations shall have a program to inspect for groundwater inflow and, if detected, for measuring groundwater inflow quantities, temperature and chemical composition.

Measurements shall be made by direct measurement for all underground openings except emplacement drifts.

Measurements shall be made by direct measurement during construction and prior to waste emplacement for emplacement drift.

Measurements shall be made by indirect or remote measurement in emplacement drifts after waste emplacement.
(This assumption is used in section 7.2.6.)

4.3.10.l Emplacement drift diameter changes shall be monitored periodically to track excavation convergence. These measurements are required in permanent observation drifts, and may be monitored directly or remotely. These measurements are also required in selected drifts as indicated by rockfall activities.
(This assumption is used in section 7.2.7 and 7.3.4.1.)

- 4.3.10.m** Alcoves or drifts shall be provided to support backfill performance and constructability experiments and tests, if backfill in emplacement drifts is required.
(This assumption is used in section 7.3.3.)
- 4.3.10.n** Alcoves shall be provided to support seal performance and constructability tests.
(This assumption is used in sections 7.1 and 7.3.3.)
- 4.3.10.o** Subsurface Facilities shall provide facilities and test support as required by Site Investigation Thermal Testing to characterize and monitor thermal interaction effects while heating and while cooling and as required by Waste Package Testing for materials in situ tests.
(This assumption is used in section 7.3.3.)
- 4.3.11** Not Used
- 4.3.12** To the extent practical, repository openings will be located to avoid Type I faults. Avoidance is assumed to be adequate by using a 60 m offset from the main trace of a fault at the repository level. (CDA, Key 023)
(This assumption is used in section 7.3.3.)
- 4.3.13** Where it is impractical to use mechanical methods, drill-and-blast may be used to a limited degree primarily in nonemplacement areas of the repository. (CDA, Key 028)
(This assumption is used in section 7.3.3.)
- 4.3.14** Emplacement drift ventilation will be maintained at a low, controlled volume for monitoring purposes. (CDA, Key 067)
(This assumption is used in section 7.3.5.)
- 4.3.15** The current subsurface repository layout contains the following features:
- Long parallel emplacement drifts
 - Only upper emplacement block (no lower emplacement block)
 - Indrift waste package emplacement
 - Central exhaust main below emplacement drifts
 - Two shafts and two ramps
 - One upper block perimeter/access drift
- (CDA, Key 072) This assumption is used throughout the analysis. Some modifications have been made by the repository design organization to the layout described in the CDA. The PC design in this analysis will accommodate the current unqualified repository layout, the layout referred to above in key assumption 072, or the layout described in the ACD report (Ref. 5.11, Page 8-77).

4.3.16 No human entry is planned in emplacement drifts while waste packages are present. The waste emplacement/recovery equipment may use robotics and/or remote control features to perform operations and monitoring within the emplacement drifts. Under off-normal conditions, human entry will be considered if protection to the workers can be provided. (CDA, Key 013)
(This assumption is used throughout the analysis.)

4.3.17 Air in underground excavations, including the shafts and ramps, will be monitored as required for health, safety, and performance confirmation. (CDA, DCSS 038)
(This assumption is used in sections 7.3.5.)

4.3.18 At least three cross-block ventilation drifts will be driven during repository construction and prior to full-scale excavation of the emplacement drifts. These drifts will not be used for waste emplacement and can be fully mapped and used for PC borehole drilling. (This assumption is used throughout the analysis.)

The assumption is based on engineering judgement and current repository construction ventilation concepts anticipated for repository construction. This assumption is a design solution that will be justified in future analyses for repository construction ventilation and repository layout.

4.3.19 The primary method of tunnel excavation will be mechanical. (CDA, Key 027)
(This assumption is used in sections 7.3.4.1.3)

4.3.20 Destructive testing of waste packages will be conducted if packages need to be recovered from the emplacement drift, on a contingency basis. Periodic or routine testing is not planned. (CDA, Key 063)
(This assumption is used in sections 7.2.10 and 7.3.8.)

4.3.21 The emplacement horizon drifts will have the following characteristics:

- 143 Drifts will be loaded with waste

- 3 Drifts will be left open for ventilation and cross-block traffic

- 2 Drifts will be left empty, but equipped for waste emplacement

All 148 drifts will be monitored if 100 percent coverage, as related to the number of emplacement drifts, is required. If each observation drift covers 6 emplacement drifts, a total of 25 observation drifts will be required to obtain 100 percent coverage.

(Assumption is used in sections 7.3.4, 7.3.4.1.3 and Attachment II.)

These numbers are based on an assumed thermal load, an assumed offset distance of waste packages to mains, an assumed drift length and other factors. The PC design uses the stated number of drifts to compare different PC options.

4.3.22 Areal Mass Loading

A thermal load of 85 metric tons of uranium (MTU)/acre is assumed as a reference design load. This value is justified since it falls within the 80 to 100 MTU/acre thermal load range being considered for repository design (CDA Key Assumption 019). Drift spacing of 22.5 meters is based on the horizontal indrift emplacement mode and the areal mass loading approach. Average waste package spacing of 18.92 meters is calculated in Attachment IV.

(This assumption is used in section 7.3.4.1.1.3.)

4.3.23 Emplacement Drift Parameters

An emplacement drift is assumed to be a circular TBM excavation in which waste packages will be horizontal, center-in-drift emplaced (CDA Key Assumption 011). Emplacement drift diameter is assumed to be 5.5 meters, based on waste package size, emplacement equipment size, and invert and ground support considerations. Waste package diameter is assumed to be 1.85m (CDA, EBD RD 3.7.1.J.1). The emplacement drifts slope up 0.5 percent from the East and West Mains based on a need to provide for drainage.

(This assumption is used throughout the analysis.)

4.3.24 Observation Drift Parameters

Observation drifts will be 4.5 m in diameter and mechanically excavated. Observation drift are 1200 meters long, ventilated from each end to the center, yielding ventilated segment lengths of 600 meters. PC alcoves are spaced every 100m for each observation drift. The thermal model also divides the drift into 100m segments.

These values are based on engineering judgement and provide a starting point for evaluating various mining options in this analysis. These assumptions must be studied in further detail in the future.

(Assumption is used in section 7.3.4.1.1.3, 7.3.4.1.2, 7.4 and Attachment II.)

4.3.25 Observation Drift Ventilation Parameters

Ventilation parameters include:

(1) Allowable air temperatures - The allowable air temperature for equipment and data acquisition systems in an observation drift is taken to be 50°C, based on the maximum allowable for the operation of equipment in emplacement drifts (CDA, DCSS 019). For periodic entry to an observation drift by personnel, a lower limit of 27°C (effective) air temperature is based on maximum allowable air temperature in access mains (CDA, DCSS 020).

(2) Air quantity - Air quantities assumed for numerical modeling are 5 and 10 m³/sec for the

observation drifts located at 20 and 10 meters above the emplacement drifts, respectively. Use of a higher value of air quantity may be justified if there is a need to maintain an air temperature lower than the limiting temperature of 50°C.

(3) Intake air temperature - Intake air temperature is assumed to be 26°C (299 K) for all cases.

(4) Convective Heat Transfer Coefficient - The convective heat transfer coefficients are 1.0787 and 1.8782 W/m²-K for air quantities of 5 and 10 m³/sec respectively. They are calculated using the following values. See Attachment III for the calculation.

Prandtl Number:	0.70828	Ref. 5.20, Table A-5
Dynamic Viscosity:	1.841256 x 10 ⁵ kg/m-sec	Ref. 5.20, Table A-5
Thermal Conductivity:	0.0261606 W/m - °C	Ref. 5.20, Table A-5
Air Density:	1.182108 kg/m ³	Ref. 5.20, Table A-5
Specific Heat:	1.0057 kJ/kg - K	Ref. 5.20, Table A-5

These values are based on a temperature of 299 K and were determined by linear interpolation of the values between 250 K and 300 K as listed in Table A-5, Ref. 5.20. (These assumptions are used in sections 7.3.4.1.1.2, 7.3.4.1.1.3, 7.4.1, Attachment III and Attachment V.)

4.3.26 Location of Observation Drifts

Observation drifts are assumed to be located mainly in the TSw2 thermal/mechanical geologic unit because of proximity to the repository horizon (CDA Key Assumption 022). To limit the potential for unfavorable rock mass disturbance between observation and emplacement drifts, the minimum vertical distance measured from the crowns of emplacement drifts to the inverts of observation drifts is assumed to be at least 10 meters (Ref. 5.24, pp 3-47). A maximum distance measured from the crowns of emplacement drifts to the inverts of observation drifts is assumed to be 20 meters, based on constructability considerations.

(Assumption is used in section 7.3.4.1, 7.3.4.1.1.3, 7.3.4.1.2 and Attachment II.)

4.3.27 Site Geologic Model

The site geologic model used in this analysis is YMP.MO3. This model is the current repository model and is a later version of the model used in reference 5.11 which was model two, YMP.MO2. The model will continue to mature and for the purposes of this analysis the more recent model provides the most current information.

This assumption is based on the latest geologic information from ESF mapping and drilling programs. The data is based on qualified and unqualified data. When the geologic model and all data input is qualified, this assumption can be qualified.

(This assumption is used in section 7.3.4.1.2)

4.3.28 Excavation Assumptions

The following assumptions are used in Attachment II to calculate the values in Table 7.1. These values are simple assumptions that are used only to aid in comparing different options presented in this analysis. They are based on engineering judgement and are reasonable values that will require additional analysis.

4.3.28.1	TBM Launch Chamber Length	40 meters
4.3.28.2	TBM Recovery Chamber Length	30 meters
4.3.28.3	Observation Drift Turnout Length	30 meters
4.3.28.4	Slope of Roadheader Access Ramps	8 percent
4.3.28.5	Lengths of Boreholes for Test Drilling	10 meters 17 meters 30 meters 43 meters

These borehole lengths are based on a spacing of 14 meters in the emplacement drift if the emplacement drift is located 10 meters below the drilling location. Actual length and accuracy will vary with cost, schedule and testing criteria. Boreholes may be considerably longer.

4.3.28.6	Length of Ventilation Cut-outs in Observation Drifts	5 meters
4.3.28.7	Length of Ventilation Cut-outs in West Main	10 meters

(These assumptions are used in Attachment II.)

4.3.29 Thermal Model Depth

The thermal model depth for this analysis is 611 meters. This assumption is based on the three layers above TSw2 being 204.2 meters (Table 4.2), the thickness of the TSw2 above the emplacement level of being 106.8 m (Ref. 5.29, pp 21), and an assumed thickness below the emplacement boundary of 300 meters which is sufficient to be considered as the bottom boundary for the thermal calculation.

(This assumption is used in section 7.3.4.1.1.3.)

4.3.30 Waste Stream

The waste stream information used in this analysis is found in Key Assumptions 003 and 004 of the CDA. However, an additional piece of information, the decay characteristics for that waste stream, was not included in the CDA. This information, included and discussed in Attachment IV, was obtained from Marc Rose of the M&O systems engineering group in Vienna, VA, see reference 5.28. All waste stream information is unqualified.

(This assumption is used in Attachment IV.)

4.3.31 Emissivity

The emissivity of the waste package is .80 based on reference 5.27, Table 4.1-5. The emissivity of

TSw2 is assumed to be .90 based on reference 5.20, Table A-10, *Normal Total Emissivity of Various Surfaces*, the model uses the average of the waste package emissivity and the TSw2 emissivity. The model input is .85.

(This assumptions are used in section 7.3.4.1.1.3.)

4.4 Codes and Standards

Not Used

5. REFERENCES

- 5.1 CRWMS/M&O, *Performance Confirmation Concepts Study Report*, B00000000-01717-5705-00035, Rev 01, November 22, 1996.
- 5.2 OCRWM, *Repository Design Requirements Document*, YMP/CM-0023, Rev 0, ICN 1.
- 5.3 CRWMS/M&O, *Controlled Design Assumptions Document (CDA)*, Las Vegas, Doc. No. B00000000-01717-4600-00032, Rev 04, September 30, 1996.
- 5.4 RSN, Exploratory Studies Facility, Package 1A - *Starter Tunnel Gen Arrangement*, Plan, (Sht. 2), YMP-025-1-MING-MG121, Rev 03.
- 5.5 CRWMS/M&O, Exploratory Studies Facility Package 2C - *TS North Ramp, Bow Ridge Fault Test Alcove GA, Plan*, BABEAF000-01717-2100-40147, Rev 02.
- 5.6 CRWMS/M&O, *TS North Ramp, Alcove #3, Plan & Section*, BABEAF000-01717-2100-40149-01, Sketch 40149SK1.
- 5.7 CRWMS/M&O, *TS North Ramp, Alcove #4, Plan & Sections*, BABEAF000-01717-2100-40149-01, Sketch 40149SK2.
- 5.8 CRWMS/M&O, Exploratory Studies Facility, *TS Main Drift, Thermal Test Area Phase I, Plan Sht. 1 of 2*, BABEAF000-01717-2100-40230, Rev 00.
- 5.9 CRWMS/M&O, Exploratory Studies Facility, *TS Main Drift, Northern Ghost Dance Fault Alcove, Plan*, BABEAF000-01717-2100-40232, Rev 00.
- 5.10 CRWMS/M&O, Exploratory Studies Facility, *TS Main Drift, Southern Ghost Dance Fault Alcove, Location Plan*, BABEAF000-01717-2100-40246, Rev 00.

- 5.11 CRWMS/M&O, *Mined Geologic Disposal System, Advanced Conceptual Design Report*, Volume II of IV, Repository, B00000000-01717-5705-00027, Rev 00.
- 5.12 CRWMS/M&O, *ESF Layout Calculation*, BABEAD000-01717-0200-00003, Rev 04.
- 5.13 DOE, Yucca Mountain Site Characterization Project, *Q-List*, YMP/90-55Q Revision 3, December 1994.
- 5.14 US NRC, *Staff Technical Position on Regulatory Considerations in the Design and Construction of the Exploratory Shaft Facility*, NUREG-1439.
- 5.15 YMP, *Tracer, Fluids, and Materials Data Reporting and Management*, Yucca Mountain Site Characterization Project, Procedure: YAP-2.8Q, Rev 01, ICN 00, January 5, 1996.
- 5.16 CRWMS/M&O, FY96 M&O Milestone MOL305, *Revision 1 of Volume II of the Near Field Environment Report*, WBS 1.2.3.12.1, August 29, 1996.
- 5.17 YMP, *Reportable Geologic Condition*, Yucca Mountain Site Characterization Project, Procedure No. YAP-30.27, Rev 00, ICN 00, July 24, 1995.
- 5.18 ANSYS 1995. *User's Manual Revision 5.2*. Vols. I, II, III, and IV. ANSYS, Inc.
- 5.19 DOE, December 1988, *Site Characterization Plan (SCP)*, Yucca Mountain Site, Office of Civilian Radioactive Waste Management, U.S. Department of Energy, Doc. No. DOE/RW-0199.
- 5.20 Holman, J.P. 1986. *Heat Transfer*, Sixth Edition, McGraw-Hill, Inc.
- 5.21 CRWMS/M&O, April 7, 1995, *Repository Heating and Cooling Scoping Analysis Report*, Las Vegas, Doc. No. BC0000000-01717-5705-00007, Rev 00.
- 5.22 YMP, 1995a. *Yucca Mountain Site Characterization Project Reference Information Base*. YMP/93-02, Rev 3, ICN 1, Las Vegas, Nevada.
- 5.23 CRWMS/M&O, *Definition of the Potential Repository Block*, BC0000000-01717-5705-00009, Rev 00, April 14, 1995.
- 5.24 CRWMS/M&O, *Engineered Barrier System Performance Requirements Systems Study Report*, BB0000000-01717-5705-00001, Rev 00, August 30, 1996.
- 5.25 Lynx Geosystems Inc., *Lynx User Documentation*, Version 3.0, September 1994.

- 5.26 CRWMS/M&O, *ESF Ground Support Design Analysis*, BABEE0000-01717-0200-00002, Rev 00.
- 5.27 CRWMS/M&O, *Emplacement Scale Thermal Evaluations of Large and Small WP Designs*, BB0000000-01717-0200-00009 Rev 00, December 18, 1995.
- 5.28 Decay Information for CDA Waste Stream - DGM Decay Info IOC.05, LV.RD.DGM.02/97.005, Interoffice Correspondence from D.G. McKenzie to Hang Yang, February 18, 1997.
- 5.29 CRWMS/M&O, *Thermomechanical Analyses*, BC0000000-01717-5705-00013, Rev 00.

6. USE OF COMPUTER SOFTWARE

A commercially available computer program, ANSYS (Ref. 5.18), was used for the numerical analysis of observation drift ventilation. The ANSYS program is installed on a Silicon Graphics Indigo² workstation. The release of the ANSYS program used in the thermal analysis is Revision 5.2. ANSYS Revision 5.2 was verified and validated according to the QAP-SI-series of CRWMS M&O *Computer Software Quality Assurance* procedures (CSCI: 30013 V5.2SGI). However, the software was verified and validated (2-14-97) after the program run was started (2-9-97), therefore, the results are considered unqualified. The input listing of the thermal model is found in Attachment VI.

ANSYS is a general-purpose program, meaning that the program can be used in many disciplines of engineering that deal with topics including structural, geotechnical, mechanical, thermal, and fluids. ANSYS Revision 5.2 is a menu-driven computer program and uses the Graphical User Interface (GUI) of the Unix X Window System.

The geologic structure and stratigraphy of the repository has been developed using a geologic model, Lynx Version 3.06 geologic modeling software (LYNX) (Ref. 5.25), running on a Silicon Graphics Indigo² workstation with an IRIX 5.3 operating system. LYNX version 3.06 was qualified for quality affecting work (CSCI: B00000000-01717-1200-30018). The LYNX geologic modeling software is appropriate for this application and was run within its range of validation. The use of the LYNX package, including its inputs, operation, and results, is described in reference 5.23.

Figures 8 and 9 and Attachment V were obtained using Lotus 1-2-3 for Windows, Release 5. Attachment III was obtained using Lotus 1-2-3 for Windows, Release 4. Lotus 1-2-3 is a common, off-the-shelf computer spreadsheet program.

7. DESIGN ANALYSIS

7.1 Performance Confirmation Program Purpose and Objectives

Performance confirmation is a “program of tests, experiments, and analyses ... conducted to ... determine with reasonable assurance that [repository] performance objectives ... will be met” (Ref. 5.1, pp 1-3). The basic design requirements for the PC program originated in 10 CFR 60, Subpart F, and this design is indirectly based on those requirements (4.2.6). The basis for the PC tests and experiments that may be required is found in section 4.3.1. They are also included as Attachment I which is Appendix D of the *Performance Confirmation Concepts Study Report* (Ref. 5.1).

The objective of this analysis includes describing the subsurface PC program and the related monitoring and data acquisition methods. The PC plan involves gathering data by several different methods. The subsurface repository design used in this analysis is based on assumption 4.3.15. The PC concepts are flexible as is the repository design, and accommodate the criteria for flexibility (4.2.11). An additional objective of this analysis is to ensure that the PC design is viable and compatible with the repository design.

The subsurface PC data collection effort has started in the ESF and some activities may continue until permanent closure of the repository (4.2.7). The NRC identified 16 out of 20 PC requirements from 10 CFR 60 for consideration in the ESF design (Ref. 5.14, pp C-4 and C-5). Therefore, the repository PC program is essentially a continuation of the program started during site characterization (Ref. 5.19).

The first stage of the PC strategy is collecting baseline data (4.2.3). Some parameters may change because of changes in the repository (4.2.4), and parameters resulting from these changes must also be monitored. The PC program will provide for collection and assessment of data to check for unacceptable adverse effects and that the testing itself does not cause potentially adverse effects (4.2.5).

The PC monitoring systems will have a maintainable design life of 125 years, with provisions for replacing and servicing instruments and for personnel access to PC facilities. Utilities, wiring, and items such as ground support in the PC facilities will be designed to accommodate periodic maintenance (4.3.2). However, some instrumentation in or around the emplacement drifts may be abandoned in place.

Existing ESF drifts and test alcoves (4.1.1) may be suitable for performing some of the tests for the PC program (4.3.10). In situ testing is needed to study the rock, groundwater, backfill, seals and thermal interactions (4.2.7). The repository PC design will use underground openings for monitoring the Ghost Dance fault (4.3.8), monitoring seismic activity (4.2.13 and 4.3.10.g), and performing constructability tests (4.3.10.n) if needed. Special alcoves for testing shaft and

access seals (4.2.9) may be required along the South Ramp (Ref. 5.1, pp 5-28) or the extension that connects to the West Main.

Thermal monitoring of the rock around emplacement drifts may occur until repository closure (4.2.7). The monitoring can be accomplished with instruments placed in boreholes, although personnel access to the borehole collars in the observation drifts through preclosure will be required to replace damaged and failed components (4.3.2). As entry into the emplacement drifts will not be permitted (4.3.16), permanent observation drifts above the emplacement block are proposed (4.3.10.f). Observation drifts are discussed in greater detail in section 7.3.4.1.

The repository PC design requirements (see section 3.7.6 in the RDRD) indicate that backfill, access seals and shaft seals will be tested as part of PC (4.2.8 and 4.2.9). Since parameters for these tests are not addressed by Appendix D (Attachment I), these parameters are not assessed by this analysis, although proposed facilities for backfill testing and seals testing are discussed.

Radiation monitoring is part of the PC program (4.2.1). Appendix D (Attachment I) states that remedial action will be taken if a radionuclide release occurs. If all repository design objectives are accomplished, no contamination will be released during the monitoring period. Models to determine release rates after closure are not within the scope of this analysis.

7.2 Evaluation of Performance Confirmation Parameters

This section evaluates the PC parameters from Appendix D of reference 5.1 (assumption 4.3.1 and included as Attachment I), and discusses how data for these parameters can be obtained (4.2.6). The parameters are either values that can be measured, or are descriptions of minerals, microbes and geology. Although there are often several ways to measure these values, this section describes only general methods for obtaining the values. Methods for measuring parameters are discussed in greater detail in section 7.3.

The PC parameters described in this analysis are *assumed* parameters and further analyses will be required to determine their adequacy or otherwise. This section assesses the parameters in Appendix D (see Attachment I) per section 1, item 1 of the scope.

Frequency of measuring PC parameters is included in this assessment, although no attempt is made to justify the time intervals for collecting all the parameters. Some instruments for measuring parameters such as seismic monitoring and groundwater inflow may operate continuously. Other instruments, such as those for measuring stress and strain, probably do not warrant continuous around the clock operation. Appendix D (see Attachment I) addresses frequency in a broad sense, and frequency in this analysis will only be addressed where applicable in assessing the parameters.

There are four general headings in Appendix D (see Attachment I), they are: *General Site*

Parameters; Unsaturated Zone Parameters; Repository Excavation and Borehole Parameters; and Waste Package Parameters. Under these four general heading are 34 subheadings, with 86 specific parameters located within the 34 subheadings. In this analysis the 34 subheadings are *italicized* with the 86 specific parameters following the *italicized* subheadings.

This analysis consolidates the 34 subheading into eleven categories of parameters:

1.	Seismic	(Discussed in section 7.2.1)
2.	Hydrocarbon and Mineral Resources	(Discussed in section 7.2.2)
3.	Stratigraphy	(Discussed in section 7.2.3)
4.	Altered Zone Characteristics	(Discussed in section 7.2.4)
5.	Fracture Zone Characteristics	(Discussed in section 7.2.5)
6.	Groundwater Characteristics	(Discussed in section 7.2.6)
7.	Emplacement Drift Geometry	(Discussed in section 7.2.7)
8.	Excavation Environment	(Discussed in section 7.2.8)
9.	Material Remaining in Repository after Closure	(Discussed in section 7.2.9)
10.	Waste Package Characteristics	(Discussed in section 7.2.10)
11.	Radionuclide Containment	(Discussed in section 7.2.11)

Sections 7.2.1 through 7.2.11 are organized in sequence with Appendix D (see Attachment I) to assist the reader in tracing the parameters to that source as indicated by assumption 4.3.1.

7.2.1 Evaluation of Seismic Parameters

Seismic monitoring is a basic repository design requirement (4.2.13) as well as a PC requirement.

There are three seismic parameters identified under *Seismicity*:

1. Location
2. Magnitude
3. Acceleration/Ground Motion

The location and magnitude of seismic events can be determined from the existing network of surface and subsurface seismograph stations. Seismic monitoring is already underway in the ESF under the historical and current seismicity field work package. Any future work should be a continuation of this program. A ground motion station is currently in place in one of the ESF alcoves.

7.2.2 Evaluation of Hydrocarbon and Mineral Resources Parameters

There are 2 hydrocarbon and mineral parameters identified under the subheading *Hydrocarbon (Coal, Oil and Gas) and Mineral Resource Exploration and Extraction*:

1. Location
2. Quantity

These parameters can be determined during underground construction and development from geologic mapping and sampling of potential areas of interest (as indicated by mapping and observation), and off-site laboratory analysis of the samples (4.3.1). Geologic mapping is a design requirement (4.2.12) and is further discussed in section 7.3.2. Sampling (4.3.5) is discussed in section 7.3.1.

7.2.3 Evaluation of Stratigraphy Parameters

Two parameters are identified under the subheading *Stratigraphy of the Alluvium/Colluvium and Rock Matrix*:

1. Rock types
2. Mineralogy

The preliminary PC concept for obtaining these parameters lists only geologic mapping (4.3.1) as a method for obtaining data for these parameters. Although geologic mapping (4.2.12), see section 7.3.2, will provide the required information, sampling (4.3.5) may also be required. Sampling, discussed in section 7.3.1, is applicable as a method for gathering these parameters.

7.2.4 Evaluation of Parameters for Altered Zone Characteristics

There are 13 PC parameters identified in Appendix D (see Attachment I), that need to be measured in the altered zone. The altered zone is where "... fundamental changes to hydrologic, mineralogic, or chemical conditions may take place within the natural system, but where these conditions do not interact directly with the waste package ..." (Ref. 5.16, pp 10.1-2). Since these values may change after waste emplacement, it will be necessary to establish baseline values before emplacement begins (4.2.3). Subsequent changes to the altered zone characteristics will be measured and assessed (4.2.4).

Altered zone parameters that involve fractures are included in this section as being altered zone characteristics. Fracture zone parameters that are not associated with the altered zone are covered in the fracture zone section, 7.2.5. Chemical composition parameters in Appendix D (see Attachment I) are included under the groundwater subheadings and are, therefore, covered in section 7.2.6 of this analysis. The altered zone parameters are listed under six subheadings.

Hydraulic Characteristics of Alluvium/Colluvium and Rock Matrix of Altered Zone:

1. Saturated hydraulic conductivity/permeability
2. Effective porosity
3. Dispersivity/dispersion coefficient
4. Hydraulic potential-moisture content relationship
5. Moisture content-hydraulic conductivity relationship

Pneumatic Characteristics of Alluvium/Colluvium and Rock Matrix of Altered Zone:

1. Air permeability

Pneumatic Characteristics of Rock Fracture Zones, Including Faults, of Altered Zone:

1. Air permeability
2. Gaseous dispersion coefficient

These parameters can be obtained through sampling and laboratory testing off-site (4.3.5), see section 7.3.1, and from instrumented boreholes drilled from accessible openings. Accessible openings are essentially observation drifts with alcoves located sufficiently close to the altered zone to allow drilling into the areas of interest. These openings are explained in section 7.3.4. If initial PC testing indicates that more information is warranted, additional boreholes could be drilled, and observation drifts or alcoves excavated in the areas of interest. See section 7.3.7 for further discussion on contingency plans to excavate additional openings for PC testing.

Mechanical Characteristics of Alluvium/Colluvium and Rock Matrix of Altered Zone:

1. In situ stress
2. Strain
3. Rock deformation & displacement

Thermal Characteristics of Alluvium/Colluvium and Rock Matrix of Altered Zone:

1. Soil & rock temperature

Thermal Characteristics of Rock Fracture Zones, Including Faults, of Altered Zone:

1. Rock Temperature

Determining the above parameters will require instruments installed in boreholes drilled from the observation drifts to penetrate the altered zone, see 7.3.4. Boreholes drilled from the access mains or the Exhaust Main could also be used to measure these parameters, although these

boreholes would not penetrate so far into the altered zone and could be affected by the cooler perimeter drifts.

Appendix D (see Attachment I) indicates that “continuous underground monitoring” will be required for these parameters. In practice, truly “continuous” monitoring of these parameters may not be necessary or even practical over 125 years (4.3.2). It would be more practical to query the permanently emplaced instruments at a reasonable frequency. The frequency of gathering these parameters requires additional analysis as the PC plan matures.

7.2.5 Evaluation of Parameters for Fracture Zone Characteristics

Sixteen parameters from Appendix D (see Attachment I) are identified for rock fractures that are not grouped with groundwater parameters, section 7.2.6, or grouped with altered zone parameters in section 7.2.4. Most of the fracture zone parameters will have been established before repository operations begin and these parameters will only be redetermined if new, untested fracture zones are encountered during repository construction.

The fracture zone parameters are listed under five subheadings.

Geometry, Including Future Displacements of Rock Fracture Zones (Including Faults):

1. Location
2. Width
3. Length
4. Orientation
5. Displacement
6. Fracture aperture
7. Fracture density

These parameters can be determined through geologic mapping (4.2.12) during underground excavation of the repository openings as indicated in Appendix D (see Attachment I).

Subsurface mapping is further discussed in section 7.3.2. If unanticipated fracture zones are encountered during any phase of repository construction, the above geometry parameters will be obtained.

Biological Characteristics of Rock Fracture Zones, Including Faults:

1. List of microbes
2. Microbial activity

Chemical/Mineralogical Characteristics of Infillings of Rock Fracture Zones, Including Faults:

1. Apparent age of minerals

Underground sampling as discussed in section 7.3.1 and subsequent analysis of the samples will provide the values for these parameter.

Hydraulic Characteristics of Rock Fracture Zone (Including Faults):

1. Saturated hydraulic conductivity/permeability
2. Effective porosity
3. Dispersivity/dispersion coefficient
4. Hydraulic potential-moisture content relationship
5. Moisture content-hydraulic conductivity relationship

These parameters can be obtained through underground sampling and off-site laboratory testing (7.3.1), and through testing in alcoves (7.3.3), if untested fracture zones are encountered during excavation. Testing in alcoves will provide this information initially, and if additional alcoves are required, they could be constructed (7.3.7).

Pneumatic Characteristics of Subsurface Air and Gases in Rock Matrix, Fractures, Fault Zones and Other Discontinuities:

1. Air pressure

Alcoves away from the emplacement block (7.3.3) provide a feasible site for monitoring air pressure. Air pressure was not identified in Appendix D (see Attachment I), as a parameter to be measured in the altered zone, however, if considered necessary an alcove-based test could be designed to measure air pressure in this zone or at any other location.

7.2.6 Evaluation of Parameters for Groundwater Characteristics

Subsurface facilities for measuring and detecting groundwater are assumed program requirements for the PC design (4.3.10.k). Some groundwater parameters will be monitored during construction and others as part of a continuous monitoring program. As indicated in Appendix D (see Attachment I), some characteristics may be determined from surface based testing. Surface based testing is not within the scope of this analysis.

The groundwater characteristics from Appendix D (see Attachment I) were subgrouped into three categories, i.e. chemical characteristics, hydraulic characteristics and thermal characteristics. There are a total of six parameters listed:

Chemical Characteristics of Groundwater in Rock Matrix, Fractures, Fault Zones and other Discontinuities:

1. Altered zone chemical composition, Eh & pH
2. Age (H-3, C-14, Cl-36)

Hydraulic Characteristics of Groundwater in Rock Matrix, Fractures, Fault Zones and Other Discontinuities:

1. In situ fluid potential
2. Altered zone moisture content
3. Altered zone water vapor content/humidity

Thermal Characteristics of Groundwater in Rock Matrix, Fractures, Fault Zones, and Other Discontinuities of Altered Zone:

1. Fluid Temperature

The preliminary PC concepts from Appendix D (see Attachment I), for gathering the above data, fall within the methods described in this analysis. Alcove-based testing (7.3.3) and sampling (7.3.1) provide a means for obtaining this information. Monitoring the ventilation system (7.3.5) may also provide data on the humidity of the air. Boreholes drilled into the altered zone (7.3.4) will also provide a means to obtaining data for some of the above parameters. The remote system designed to enter emplacement drifts could also visually inspect for water seepage (7.3.6). Once the test plan for obtaining these values has been finalized, PC facilities can be constructed as needed to accommodate the testing requirements.

7.2.7 Evaluation of Parameters for Emplacement Drift Geometry

Appendix D (see Attachment I) lists two parameters relating to emplacement drift geometry. Baseline drift geometry values must be established prior to emplacement, after which tunnel deformation and convergence may occur (4.2.3). Acceptable ranges for variation in opening geometry will be established and the changes monitored (4.2.4). If values for the two parameters stay within the established ranges, the emplacement drift ground support will be considered as functioning in accordance with the design.

The two parameters under the subheading *Geometry of Waste Emplacement Drifts* are:

1. Deformation/convergence
2. Rock fall/collapse size

The frequency of measuring these parameters has not been determined, and the design basis

currently states that the geometry should be monitored periodically (4.3.10.1). Determining the frequency of monitoring is beyond the scope of this analysis.

Measuring these values presents challenges because of heat and radiation in the emplacement drifts. Measuring movement of the rock mass surrounding an emplacement drift can be accomplished with borehole instruments (7.3.4) installed from the observation drifts, from empty emplacement drifts, or from within emplacement drifts. Monitoring convergence or deformation from the Exhaust Main or perimeter mains may also be feasible. Monitoring the emplacement drift ventilation (7.3.5) may provide data on airflow changes and airflow composition, such as increased dust levels, that could indicate rock movement and resulting changes in drift geometry. Sensitive underground seismic equipment (7.3.1) could be used to monitor ground falls.

A concept is under development for entering emplacement drifts with remote equipment (4.3.16) to conduct periodic inspections (4.3.1); that method is briefly reviewed in section 7.3.6. The design and operation of the remote equipment are being developed in another analysis. A concept is discussed in section 7.3.6.1 utilizing a laser for determining changes in drift geometry independent of remote equipment traveling the length of the emplacement drift.

7.2.8 Evaluation of Parameters for the Excavation Environment

There are five physical and chemical characteristics parameters relating to the excavation environment found in Appendix D (see Attachment I). They are listed under two subheadings.

Physical Characteristics of Excavation Environment, Ramps, Shafts, Alcoves and Emplacement Drifts:

1. Dry bulb air temperature
2. Relative humidity
3. Groundwater inflow rate into excavation
4. Groundwater inflow temperature

Chemical Characteristics of Excavation Environment, Ramps, Shafts, Alcoves and Emplacement Drifts:

1. Chemical composition, Eh & pH of groundwater inflow

Determining these characteristics during construction will occur as part of the sampling strategy (7.3.1) and by permanently monitoring the exhaust ventilation (7.3.5).

The probability of encountering perched water is unknown. The procedure that addresses unknown geologic conditions, including monitoring groundwater, is reference 5.17. Indications of perched water will likely occur during excavation (7.3.2). Significant groundwater inflows are

unlikely, but construction water may require special alcoves, sumps, pumps or piping and will form part of the repository design (4.2.11).

7.2.9 Evaluation of Parameters for Material Remaining in Repository after Repository Closure

A system will be established to monitor fluids and materials used for repository construction and operation, and to evaluate potentially adverse effects (4.2.10). Items remaining in the repository after closure are of primary interest. Appendix D (see Attachment I), lists nine parameters that the PC design should account for, although the actual number of parameter values will be greater since the nine parameters listed are general in nature.

The parameters listed for materials remaining in the repository after closure are listed under seven subheadings:

Construction and Fire Water, Including Accidental Spills Remaining after Repository Closure:

1. Quantity remaining in rock
2. Chemical composition, including Eh & pH

Hydrocarbons, Including Accidental Spills Remaining after Repository Closure, each type that may affect postclosure performance:

1. Quantity remaining in rock
2. Chemical composition, including Eh & pH

Concrete Remaining after Repository Closure:

1. Chemical composition/alteration

Steel Remaining after Repository Closure:

1. Chemical composition/alteration

Ground Support Remaining after Repository Closure:

1. Chemical composition/alteration

Railcars Remaining after Repository Closure:

1. Chemical composition/alteration

(At one time railcars were proposed as a means for emplacing waste. If another concept is used then railcars are unlikely to be left underground.)

Other Fluids and Materials Remaining in Repository after Closure, each type that may affect postclosure performance:

1. Chemical composition/alteration

Data for these parameters will be obtained during the construction and emplacement operations. The program will require a record keeping system similar to the Tracers, Fluids, and Materials (TFM) program currently in place in the ESF (Ref. 5.15). The sampling program (7.3.1) will determine the frequency, location, timing, and quantities of these data as part of the TFM program. Obtaining and recording the data for these parameters will not significantly impact the repository design. PA criteria which would restrict or control the use of construction materials is beyond the scope of this analysis.

7.2.10 Evaluation of Parameters for Waste Package Characteristics

Waste package parameters are grouped into seven subheadings (4.3.1). The final set of parameters for radionuclide containment is discussed in section 7.2.11. Generally, the listed parameters are not related to subsurface design and not within the scope of this analysis. However, there are exceptions and therefore the waste package parameters are assessed here for applicability to the subsurface design.

The scope of this analysis requires evaluation of PC parameters necessitating periodic recovery of waste packages. Design of the waste package recovery system is outside the scope of this analysis (4.2.14), although the overall repository design covers waste package recovery. No attempt is made to justify if recovery of waste packages should be planned or not; the analysis assumes that periodic recovery of waste packages would be a nonroutine event (4.3.20). Since the chance for failure of a waste package is low, it is possible that recovery of a waste package would only occur as a nonroutine event for PC testing (4.3.10.d).

Waste Form Characteristics, e.g. Spent Fuel and Glass Defense High-Level Waste:

1. Geometry/dimensions of waste form
2. Geometry/dimensions of waste pellets/particles
3. Surface area of waste pellets or particles
4. Weight & activity of each radionuclide
5. Gas composition inside fuel element

These five parameters could be determined from a failed waste package, if any, or from nonroutine recovery of a waste package that has not failed (4.3.10.d). Recovery of waste packages is discussed in section 7.3.8.

Regardless of whether or not waste packages are recovered for PC testing, waste form characteristic parameters can be determined by laboratory analysis of waste not emplaced as indicated in Appendix D (see Attachment I).

Parameters for waste package characteristics are listed under five subheadings.

Geometry of Waste Packages, Excluding Backfill:

1. Corrosion effects on barrier thickness & shape
2. Mechanical effects on barrier thickness & shape
3. Location & geometry of criticality control materials

Only the first two parameters are affected by repository design. Periodic remote visual inspection (4.3.1) to determine the first two parameters is discussed in section 7.3.6. Remote incursions into the emplacement drift would also retrieve preplaced sample specimens (4.3.1) for laboratory testing off-site. Remote entry into emplacement drifts for PC is discussed in section 7.3.6.

Corrosion and Other Degradation Characteristics of Each Waste Package Barrier, Excluding Backfill:

1. Threshold humidity for humid-air corrosion
2. Dry oxidation corrosion rate
3. Humid-air general corrosion rate
4. Aqueous general corrosion rate
5. Humid-air pit corrosion rate
6. Aqueous pit corrosion rate
7. Microbial corrosion rate
8. Cladding failure rate

The eight parameters listed will be determined by laboratory analysis of specimens recovered remotely from the emplacement drifts, recovered dummy waste packages, specimens from a long-term laboratory testing facility or from recovered waste packages. Dummy waste packages could be tested in alcoves as part of an alcove-based testing program (7.3.3) or placed in an active emplacement drift for future recovery after a given period of time.

Chemistry of Each Waste Package Barrier, Including Degradation Products, but Excluding Backfill:

1. Gas composition inside waste container
2. Chemical composition of criticality control material
3. Oxidation product composition
4. Aqueous corrosion product composition
5. Physical/chemical degree of embrittlement
6. Physical/chemical weld integrity

Off-site laboratory analysis of recovered dummy waste packages provide an effective method of obtaining these values (4.3.1). However, as with the other waste package characteristics, the six parameters could be determined by analyzing waste packages that fail (7.3.8), from dummy waste packages tested in an alcove (7.3.3), or from test samples exposed in a laboratory.

Mechanical Characteristics of Each Waste Package Barrier, Excluding Backfill:

1. In situ stress
2. Strain

Appendix D (see Attachment I), indicates that these two parameters will be determined by testing dummy waste packages or through laboratory analysis of waste packages at an off-site location. If a waste package failed and was subsequently recovered, these parameters could be determined from such a package also.

Thermal Characteristics of Each Waste Package Barrier, Excluding Backfill:

1. Barrier wall temperature

This parameter can be determined by remote equipment entering the emplacement drifts (4.3.16) as discussed in section 7.3.6. It may be possible to determine this value from an instrumented borehole drilled from an observation drift.

7.2.11 Evaluation of Parameters for Radionuclide Containment

The parameters to measure radionuclide containment, or the rate of radionuclide release, are among the most basic and driving parameters in the program. It will be both an operational as well as a PC goal to detect any radionuclides, however unlikely, leaking from the waste packages (4.2.1).

The three radionuclide release parameters are under the subheading *Waste Package Radionuclide Containment and Release for Each Waste Form, Package Design, and Important Radionuclides*, are:

1. Waste package life, or time of initial radionuclide release
2. Radionuclide release rate from waste form
3. Radionuclide release rate from waste package

It is likely that these parameters will never be detected by measurement during the preclosure period since the mean waste package lifetime should be well in excess of 1000 years (Ref. 5.3, Key 037). If an off-normal event occurs before repository closure and these parameters become measurable, a monitoring system will detect the release. Continuous monitoring of the exhaust air (7.3.5) during the preclosure period will provide the data if they become measurable. Boreholes drilled into the emplacement drifts from adjacent accessible openings (7.3.4) could also be fitted with radionuclide release detectors. The remote system designed to enter the emplacement drift could also be fitted with appropriate sampling equipment (7.3.6).

7.3 Performance Confirmation Test Methods

The strategy for configuration and operation of the PC program is based on eight principal methods for obtaining the identified parameters. The eight methods satisfy the PC requirements, assumptions, and design inputs.

The eight methods for acquiring the data for the PC parameters are listed below. Each method is described in the subsection indicated.

1. Sampling Program	(Discussed in section 7.3.1)
2. Geologic Mapping Program	(Discussed in section 7.3.2)
3. Alcove-Based Testing in Nonemplacement Areas	(Discussed in section 7.3.3)
4. Monitoring the Altered Zone	(Discussed in section 7.3.4)
5. Monitoring the Ventilation System	(Discussed in section 7.3.5)
6. Remote Systems in the Emplacement Drifts	(Discussed in section 7.3.6)
7. Contingency Plans for Alcoves and Drifts	(Discussed in section 7.3.7)
8. Recovery of Waste Packages
or Testing Dummy Waste Packages	(Discussed in section 7.3.8)

7.3.1 Sampling Program

Sampling is the study of a portion of rock or material which is representative of the remaining mass (4.3.5). Samples provide data for predicting the characteristics of the remaining rock or how it will behave under certain circumstances. Detailed sample collection techniques, sampling frequency, and sample management, are not within the scope of this analysis. However, it is

anticipated that samples will be collected under the existing "Consolidated Sampling Field Work Package" which will be revised to incorporate additional PC requirements.

The PC sampling program includes evaluating, monitoring, and recording fluids and materials, introduced into the repository during site characterization activities, repository construction, and repository emplacement operations. The program includes evaluation of the fluids and materials for potentially adverse impacts (4.2.10). A TFM program is currently in place in the ESF, and a similar program will continue throughout the repository preclosure period. See reference 5.15 (Ref. 5.15, pp 2 of 16) for details on implementation of the TFM program in the ESF.

The final ground support design will impact the ability to obtain rock samples in the emplacement drifts more than any other factor. However, regardless of the ground support design, a sampling program (4.3.10.b) can be developed to obtain the necessary samples. To achieve this goal, the design of the PC program and overall repository will be closely integrated.

There are two basic methods for gathering in situ rock samples - core drilling and bulk samples. During construction rock samples can be obtained when excavating the tunnels. Regardless of the final ground support system installed, rock core could be obtained by drilling through the precast concrete liner, or through windows created by omitting sections of lagging from the steel sets support (4.3.10.b). Bulk rock samples could be obtained in a similar manner. If a ground support lining is designed that covers the rock entirely, windows or ports for obtaining bulk samples and/or core could be provided.

A disadvantage to core drilling in the emplacement drifts is the possibility of creating a preferential pathway for water movement. The design must limit the potential for creating preferential pathways (Ref. 5.2, 3.7.5.G.2.). However, the holes could be sealed and the possible adverse effect could probably be mitigated.

Sampling the altered zone after emplacement begins should provide data on changes resulting from the emplacement of the waste packages. Coring will be possible in the altered zone by drilling from the observation drifts (4.3.10.f), the Exhaust Main below the emplacement drifts (4.3.15), the ventilation drifts (4.3.18), and the main accesses (4.3.15). The most feasible method for obtaining core samples from the altered zone in a systematic and uniform manner is from the observation drifts; core drilling from other locations can be used for supplemental data and in special circumstances.

Once waste emplacement has begun, rock sampling within the emplacement drifts is not anticipated. However, it will be possible to take air samples within and from the emplacement drifts, retrieve test coupons, and to take swipe samples from waste packages for radionuclide release testing (4.2.1).

7.3.2 Geologic Mapping Program

The requirement to conduct geologic mapping in the subsurface (4.2.12) is a basic repository design requirement, although the extent of mapping is not well defined. Some mapping may be necessary in all openings (4.3.10.a), but reaching a consensus on what constitutes necessary mapping remains to be determined. Mapping could be carried out with a continuation of the currently used "Geologic Mapping Field Work Package."

The preliminary PC concepts in Appendix D (see Attachment I), indicate that mapping is required to identify the location and quantity of hydrocarbons and mineral resources (7.2.2), rock types and mineralogy (7.2.3), and fracture zone geometry (7.2.5).

The current repository design includes a complete concrete liner in the emplacement drifts. There are basically two methods for installing the concrete liner. One method is to install precast segments during excavation and the other is to place a cast-in-place liner (Ref. 5.3, DCSS 034). A precast liner is installed directly behind the TBM and covers the rock entirely at the time of excavation thereby eliminating the opportunity to conduct mapping once installed. With a cast-in-place liner system temporary support, such as rock bolts, wire mesh, and steel sets (similar to that installed in the ESF) is installed behind the TBM for personnel safety and the final cast-in-place system is installed later. This latter approach would allow 100 percent mapping and is the preferred method if only the mapping function is considered. The cast-in-place liner system, however, would increase the overall cost of constructing the emplacement drifts because of the need to install the initial temporary support in addition to the final liner system. If PA found concrete unacceptable, steel sets (similar to those installed in the ESF) could be installed (Ref 5.3, DCSS 034). By leaving out alternate lagging pieces which would be installed later, steel sets afford a better mapping window than precast segments.

An alternative concept is to map a limited number of openings on a grid pattern. The current repository construction sequence requires initial excavation of the perimeter mains, three ventilation drifts across the emplacement horizon (4.3.15 and 4.3.18), and the Exhaust Main. These drifts would be fully mapped as they are excavated. Observation drifts driven across the top of the emplacement horizon would also be fully mapped (see section 7.3.4.1). Excavation of the cross-block observation drifts will commence during the preemplacement construction period, with the first drift located at the north end of the block above the first emplacement drifts to receive waste (7.3.4.1). Subsequent observation drifts would be excavated as repository development advances southwards across the block. Although the Exhaust Main and observation drifts are respectively 10 m below and above the emplacement drift horizon, they are considered sufficiently close to provide representative mapping data. This arrangement would provide a mapping grid as shown in Figure 1. Figure 1 illustrates a grid with three ventilation drifts in the emplacement plane and five observation drifts above. With additional observation drifts as shown in Figure 12, a smaller mapping grid would result with a consequently greater degree of confidence in the accuracy of the emplacement horizon geology. Any additional mapping in the

emplacement drift would be limited to reportable geologic conditions if encountered during TBM excavation (Ref. 5.17). A TBM configured with finger shields and an open shield below the spring line as shown in Figure 2, would facilitate scan line mapping if needed, and mapping and observation of specific geologic conditions when encountered.

Grid mapping allows installation of precast concrete segments in the emplacement drifts. These segments installed behind the TBM provide immediate support for personnel safety as well as long term stability of the opening. Installation of precast segments eliminates the need for temporary ground support. Precast segments are preferable from a PA standpoint since quality control of the concrete mix is facilitated by casting the concrete on the surface rather than casting-in-place underground.

If additional information is needed about the rock mass between ventilation drifts (4.3.18), perimeter mains, and the Exhaust Main, geophysical surveying techniques could be employed. Seismic and electromagnetic tomography are geophysical tools that could be used for this purpose.

Mapping 100 percent of the emplacement drifts will require either a mapping gantry behind the TBM similar to that employed in the ESF, or an independent gantry set up in a completed drift. Mapping is unlikely to impact the overall construction schedule but will have a minor impact on the construction logistics, as an emplacement drift for mapping (if not mapped behind the TBM) and another for liner installation must be included with the drifts in the construction cycle. Full mapping coverage will, however, increase the overall cost of emplacement drift construction because of the two ground support systems needed, the actual cost of the mapping itself, and more complex construction logistics.

Regardless of the final ground support design selected or the final mapping requirement (even for 100 percent detailed mapping of the openings), the PC mapping parameters can be obtained with the current repository design. The final decision on the extent of mapping emplacement drifts and the ground support system for those drifts, will be determined by other analyses.

FIGURE 2
5.5 m TBM ARRANGEMENT

7.3.3 Alcove-Based Testing in Nonemplacement Areas

Alcove-based testing in nonemplacement areas of the potential repository began during site characterization. Seven alcoves have been constructed in the ESF for this purpose (References 5.4 to 5.10). The alcoves provide a work location that does not conflict with normal construction traffic and activities. Alcoves are located in areas that are either representative of the emplacement area or provide access to faults, fracture zones, contacts between dissimilar units and other geologic features of interest.

The PC requirements and assumptions state that alcoves will be needed for seismic monitoring (4.2.13 and 4.3.10.g), backfill testing (4.2.8 and 4.3.10.m), seal performance (4.2.9 and 4.3.10.n), constructability tests (4.3.10.n), and Ghost Dance Fault monitoring (4.3.8). Subsurface facilities, probably alcoves, for thermal testing and waste package testing are also identified (4.3.10.o).

PC alcove construction can utilize similar methods employed in the ESF. The primary method of construction will utilize roadheaders to minimize rock damage, but drill-and-blast excavation may be required in some locations (4.3.13). The layout provides sufficient area for alcoves that avoid type I faults (4.3.12), although some alcoves may be located to intersect faults.

7.3.3.1 Utilizing Existing ESF Alcoves

Existing ESF alcoves can be utilized for some of the alcove-based testing functions. A seismic monitoring station, for example, could be located in one of the existing alcoves. Since two alcoves have been constructed specifically for studying the Ghost Dance Fault (References 5.9 and 5.10) it seems reasonable that one of them would be used as a test alcove for this purpose, as stated in assumption 4.3.8.

7.3.3.2 New Alcoves

When new alcoves are required, additional analyses will be conducted to address the specific requirements and parameters for each alcove. Additional alcoves may be needed for backfill testing, (probably some years in the future), to test seals in different geologic units, and for testing dummy waste packages. As the requirements for these alcoves are defined, the alcoves will be designed and located in appropriate areas.

The location and design of new alcoves is not considered critical to the viability assessment design. There is ample area available along the South Ramp or on the edges of the repository block for new alcoves as their need is determined. The PC parameters that require an alcove-based test can be obtained within the current repository design.

7.3.4 Monitoring the Altered Zone

The rock mass surrounding the emplacement drifts will be altered by the heat of the waste packages. Changes in temperature, strain, stress, moisture, fractures, and chemistry are expected to occur. PC monitoring of the altered zone will be designed to measure such changes and to provide a means to detect variations in the expected pattern of changes. Elevated temperature and radiation levels in the emplacement drifts will produce difficult operating conditions for monitoring equipment and other means of access will be necessary. For example, access for instrumentation can be provided by: (1) dedicated observation drifts (4.3.10.f and 7.3.4.1), (2) other nonemplacement drifts, such as spare emplacement drifts (4.3.18), perimeter mains (4.3.15), and the Exhaust Main below the emplacement drift horizon, and (3) boreholes drilled from these nonemplacement drifts. Sacrificial instruments may be installed in the emplacement drifts; but due to heat and radiation problems, the design and feasibility of using sacrificial instruments in emplacement drifts is not within the scope of this analysis.

Boreholes are expected to provide the principal means of placing instrumentation at locations selected for monitoring. Parameters that can be monitored by borehole include: (1) altered zone characteristics (7.2.4), (2) groundwater characteristics (7.2.6), and (3) emplacement drift geometric parameters (7.2.7). Radionuclide release (7.2.11) may also be monitored using borehole access, but this would require borehole penetration of emplacement drifts.

The current repository design would allow monitoring at least some portion of every emplacement drift from the Exhaust Main or from a perimeter access main. However, it is apparent that only an observation drift constructed parallel to an emplacement drift can provide full monitoring capabilities. Instrumentation could be located in boreholes or in the observation drift itself for monitoring the full length of an emplacement drift (4.3.10.f). Observation drifts and their potential location and configuration are discussed in the following sections. An observation drift could possibly monitor six (4.3.21) emplacement drifts as depicted in Figure 3 or each drift could monitor five emplacement drifts as shown in Figure 4.

Boreholes, drilled from perimeter drifts and appropriately oriented, can be used to monitor parameters in regions above, below, and between emplacement drifts, at least at the periphery of the emplacement area. Boreholes from the Exhaust Main can best monitor conditions in the region below the emplacement horizon and relatively close to the Exhaust Main. At the emplacement drift horizon, ventilation drifts that will not be used for waste emplacement (4.3.18) may be included for inspection, ventilation, cross-block transportation, and also for PC monitoring. Boreholes from these ventilation drifts can monitor the pillars protecting the emplacement drifts on each side. Boreholes of sufficient length could be used to monitor areas above and below the adjacent emplacement drifts. These various borehole configurations are shown on Figure 5.

7.3.4.1 Location of Observation Drifts

Observation drifts are nonemplacement drifts dedicated to PC monitoring. One concept is to locate the observation drifts parallel to emplacement drifts and above the repository horizon so as to facilitate the monitoring of rock mass displacement that may occur above the crown of the emplacement drifts (4.3.10.1). This location allows for rock mass monitoring in the vicinity of a number of emplacement drifts by appropriately oriented boreholes. Somewhat longer holes can be used to monitor conditions in the pillars between emplacement drifts and below the repository horizon.

Observation drifts are assumed to be located mainly in the TSw2 thermal/mechanical geologic unit because of proximity to the repository horizon (4.3.26 and 7.3.4.1.2). To limit the potential for unfavorable rock mass disturbance between observation and emplacement drifts, the minimum vertical distance measured from the crowns of emplacement drifts to the inverts of observation drifts is assumed to be at least 10 meters (4.3.26). To further limit interaction between observation and emplacement drifts, the observation drifts should be located above the pillar between two emplacement drifts rather than directly over an emplacement drift.

The required number of observation drifts will depend on how many emplacement drifts are to be monitored. A current assumption (4.3.10.f) is "Excavation of at least one permanent observation drift above the repository horizon shall be developed in support of thermal monitoring." Another assumption (4.3.9) is to monitor at least two percent of the "thermal rock mass behavior" (as related to the number of emplacement drifts) and this is determined as a percentage of the total number of emplacement drifts. It is also assumed that a portion of the rock mass to be monitored should be near the first emplacement drifts to contain waste.

Constructability and operation of observation drifts are affected by the distance from the repository horizon. An observation drift location close to the emplacement horizon will be exposed to higher temperatures from the emplacement horizon and consequently will have higher ventilation demands. Alternatively, a higher observation drift location will remain cooler, although it will require more excavation to gain access and monitoring boreholes drilled from a higher drift will have to be longer. A maximum distance measured from the crowns of emplacement drifts to the inverts of observation drifts is assumed to be 20 meters, based on constructability considerations (4.3.26). This distance will ultimately be determined by an analysis which considers the various constructability, thermal, ventilation and stability issues.

7.3.4.1.1 Observation Drift Ventilation and Thermal Considerations

The observation drift configuration shown in Figure 3, allows six emplacement drifts to be monitored from an observation drift located in the pillar between two emplacement drifts. This configuration was used in formulation of the thermal model of the observation drift.

FIGURE 3
TYPICAL OBSERVATION DRIFT
LAYOUT FOR SIX DRIFTS

NOTE:
ORIENTATION AND NUMBER OF
BOREHOLES AROUND EACH
EMPLACEMENT DRIFT MAY VARY

FIGURE 4
TYPICAL OBSERVATION DRIFT
LAYOUT FOR FIVE DRIFTS

MONITORING FROM EXHAUST MAIN

MONITORING FROM VENTILATION DRIFT

PLAN VIEW - MONITORING FROM PERIMETER MAIN

FIGURE 5
MONITORING EMPLACEMENT
DRIFT ALTERNATIVES

7.3.4.1.1.1 Heat Transfer Between Emplacement and Observation Drifts

Heat transfer between waste emplacement drifts and PC observation drifts involves conduction, convection, and radiation. Heat transfer in a waste emplacement drift occurs by thermal radiation from the waste packages to the drift wall as a result of temperature differences. In the rock mass, heat flow will occur by conduction due to the thermal gradient between the high-temperature drift wall and the low-temperature rock away from the drift. Heat transfer in an observation drift, located in the pillar above the emplacement drifts, will involve convection between the high-temperature drift wall and the low-temperature ventilating air. Heat flow in the rock mass adjacent to the observation drift will occur through conduction between the high-temperature rock away from the drift and the low-temperature drift wall.

According to the first law of conservation of energy, thermal energy is conserved. So the general three-dimensional heat-conduction equation (Fourier's law of heat conduction) for a drift can be expressed in Cartesian coordinates as:

$$\frac{\partial}{\partial x}(k \frac{\partial T}{\partial x}) + \frac{\partial}{\partial y}(k \frac{\partial T}{\partial y}) + \frac{\partial}{\partial z}(k \frac{\partial T}{\partial z}) + q''' = \rho c_p \frac{\partial T}{\partial t} \quad (7-1) \text{ (From Ref. 5.20, pp 4)}$$

where

- T = temperature, K
- t = time, s
- k = thermal conductivity, W/m·K
- ρ = density, kg/m³
- q''' = heat generation rate per unit volume, W/m³
- c_p = specific heat, J/kg·K

For an air-ventilated drift, the overall effect of convection can be evaluated using Newton's law of cooling:

$$q = hA(T_w - T_a) \quad (7-2) \text{ (From Ref. 5.20, pp 12)}$$

where

- q = heat flow rate, W
- h = convection heat transfer coefficient, W/m²·K
- A = surface area, m²
- T_w = drift wall temperature, K
- T_a = ventilation air temperature, K

Heat from the waste packages to the drift wall is transferred mainly through thermal radiation. In the analysis, it is assumed that the waste packages are completely enclosed by the drift wall, so the total radiant exchange can be calculated with the Stefan-Boltzmann law:

$$q = \epsilon \sigma F_{pw} A (T_p^4 - T_w^4) \quad (7-3) \text{ (Ref. 5.18, Vol. IV, pp 6-3)}$$

where

- ϵ = effective emissivity, dimensionless
- σ = Stefan-Boltzmann constant, $5.669 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^4$ (4.1.4)
- F_{pw} = view factor (calculated and used by ANSYS)
- T_p = absolute temperature of the waste package surface, K
- T_w = absolute temperature of the drift surface, K

Thermal response in the observation drifts varies with time and location, for example, modeling inputs, such as the ventilating air temperature, vary with time and location. Despite these complexities, the simplified approach used herein is considered to be of sufficient accuracy to model the emplacement/observation drift thermal interaction.

7.3.4.1.1.2 Ventilation of Observation Drifts

Observation drifts will be maintainable and accessible during the repository preclosure period so data acquisition systems can perform properly and to maintain periodic access by personnel for data acquisition and maintenance. These two requirements may be met by: (1) Continuous ventilation with a low air quantity during the entire PC period and (2) Periodic rapid cooling with a high air quantity whenever entry by personnel is needed.

Continuous ventilation with a low air quantity can be used to simultaneously keep the air temperature in a number of observation drifts below the limit of 50°C (4.3.25). Thermal analysis results indicate that it will take 3 to 5 years after waste emplacement for the wall rock temperature in the observation drifts to reach to about 50°C without ventilation. Eventually, more and more heat will have to be removed by the ventilating air in order to keep the air temperature below the operating limit. The air quantity required for continuous ventilation is not constant, and will depend on several factors, such as the thermal load for waste emplacement, the location and size of observation drifts, the operating temperature limit for data acquisition systems, and the time span for PC operation. In this design analysis, two different air quantities, 5 and 10 m³/sec, are chosen to demonstrate the design concept of continuous ventilation (4.3.25).

Because observation drifts will have been continuously cooled, periodic rapid cooling with a high air quantity can reduce the air temperature from 50°C to an acceptable limit of 27°C effective for personnel access. In addition, PC activities can be scheduled such that only one or two observation drifts will be accessed simultaneously, therefore, a short-term periodic rapid cooling

will not interrupt continuous ventilation in other observation drifts.

7.3.4.1.1.3 Numerical Model Descriptions

Model Configurations

The results of two different computer modeling configurations are shown in Figures 6 and 7, corresponding to the cases for observation drifts located 20 and 10 meters (4.3.26) above the emplacement drifts, respectively. The model is symmetric along a vertical plane through the center of the observation drift, so only half of the region is actually modeled.

The vertical dimension, although not completely shown in the figures, represents about a 600 meter thickness of rock and includes all thermal/mechanical units above the emplacement drift horizon and 300 meters below (4.3.29). The number of emplacement drifts which will be covered by an observation drift is assumed to be six in these models, although results can generally be extended to evaluate cases with one observation drift covering more or less than six drifts.

Initial Conditions

Initial temperature of the thermal/mechanical geologic units is based on a rock temperature at the ground surface of 18.7°C (4.1.2) and a rock thermal gradient as listed in Table 4.1. Ventilating intake air temperature is 26°C (4.3.25).

Boundary Conditions

The constant boundary temperature at the top of the model is 18.7°C (4.1.2). The boundary temperature at the bottom of the model, at 611 meters depth (4.3.29) is 32.53°C. The bottom temperature is calculated from the values in Table 4.1: $(150 \times 0.020) + (250 \times 0.018) + (211 \times 0.030) = 13.83$ $13.83 + 18.7 = 32.53$. Based on thermal symmetry, the vertical model boundaries are prescribed as adiabatic, or zero heat flow, boundaries.

Wall boundaries of the observation drifts are convection boundaries, and the air and wall temperatures are time-dependent. The convective heat transfer coefficient, which is related to the air quantity and the air and wall temperatures, is assumed to only rely on the air quantity and initial air and wall temperatures because overall temperature changes for this analysis are not substantial and the resulting variations in the convective heat transfer coefficients due to these temperature changes are minimal. The convective heat transfer coefficient and the convective heat area are calculated in Attachment III. Details on determination of the ventilating air temperatures are discussed in the following.

ANSYS 5.2
FEB 15 1997
08:26:49
PLOT NO. 7
NODAL SOLUTION
TIME=150 YEARS
TEMPERATURE - C
MIN =18.7
MAX =134.114

18.7
50
60
70
85
100
115
130
150

150 Years after Emplacement

Distance from OD to ED: 20 meters

Air Quantity: $5.0 \text{ m}^3/\text{s}$

Intake Air Temperature: 26 C

Thermal Load: 85 MTU/acre

Drift Spacing: 22.5 meters

WP Spacing: 18.92 meters

Diameter of OD: 4.5 meters

Diameter of ED: 5.5 meters

Figure 6
Thermal Profile - D = 20m, Q = $5 \text{ m}^3/\text{sec}$

Figure 7
 Thermal Profile - $D = 10\text{m}$, $Q = 10\text{m}^3/\text{sec}$

Modeling Approach

The approach used to simulate the thermal response in the repository due to both the waste emplacement in emplacement drifts and the ventilation in observation drifts is similar to that employed for modeling continuous ventilation in emplacement drifts, which was part of the repository heating and cooling scoping analyses for thermal management in FY95 (Ref. 5.21). The only difference in the current models is that ventilation is applied to the observation drift walls and there is no direct heat removal in the emplacement drifts. In the previous models, part of the heat generated by waste packages was directly removed by the ventilation applied in the emplacement drifts and observation drifts were not considered. A detailed description of the approach follows.

First, the entire observation drift with a length L is divided into a finite number of drift segments of equal length Δl , so the total number of drift segments, m , will be equal to $L/\Delta l$. During modeling, the drift segments are treated as a series of connected elements, and the exit air temperature at a segment is used as an intake air temperature for the following segment. The ventilating air and wall rock temperatures at a specific modeling time are assumed to be constant along the longitudinal direction of each individual drift segment. Theoretically, the length of drift segments should be selected as short as possible so that the changing air and wall temperatures along a drift can be reasonably represented by their averaged constants, but practically, a relatively long drift segment used in the analysis can be justified as long as overall accuracy of the models is guaranteed. The computation for temperatures is performed for every drift segment sequentially over a prespecified ventilation time, t_{vent} , so the total number of computational runs for each case is the same as that of the drift division, m . In this analysis, the 600 meter long drift (4.3.24) was divided into six segments, with a length of 100 meters for each segment.

Second, the ventilation time, t_{vent} , is partitioned into a number of time-steps, n , for each computational run. The size of each time-step, Δt_j , $j=1,2,\dots,n$, is determined based on the required degree of computational accuracy because it is assumed that the ventilating air temperature in a drift segment is constant over each time-step and the heat decay of waste packages in the emplacement drifts varies piece-wisely linearly over the same time-step. Two factors are considered when determining the time-step size, Δt_j , $j=1,2,\dots,n$. One is the heat generation rate of the waste packages in the emplacement drifts because the heat generated by the waste packages varies with time. Initially, more heat may be generated and transferred to the rock mass. With time, the heat decay rate will drop, and less heat will be generated. Therefore, a small time-step is required at the beginning and a relatively larger time-step can be justified for the later time period. The other factor considered is the air temperature variation with time, which plays a more important role in selecting the size of time-steps. Small time-steps during the first 50 years of modeling time are necessary to accurately simulate anticipated changes in air temperature. For the later time periods, larger time-steps may be used without loss of accuracy. For this analysis, the 150-year duration for ventilation time, t_{vent} , was divided into a total of 12

time-steps of unequal sizes (see Attachments IV and V).

Third, after the selection of segment length and time-step size, the ANSYS program (Ref. 5.18) is executed sequentially for a total number of m times for each case. Resulting wall temperatures for the currently modeled drift segment are utilized to calculate the average exit air temperatures of the segment by means of Newton's cooling law, presented in equation (7-2). These exit air temperatures then become inputs for the ventilating air temperatures of the computational run for the following drift segment. This process is repeated until the computational run for the last drift segment is completed.

The inputs to the thermal model are found in Attachment VI. The waste package characteristics in the model are in parameter 4.1.5 and assumption 4.3.31. Attachments III, IV and V are provided to present additional calculations that are used in the thermal model. Attachment IV contains the waste stream data and shows the calculation for determining heat output and Attachment V contains the intermediate data that was generated between each drift segment.

7.3.4.1.1.4 Results of Numerical Modeling

Thermal numerical modeling for an observation drift and six emplacement drifts was performed using the ANSYS program for a time of 150 years after waste emplacement for ventilation air quantities of 5 and 10 m³/sec. Results include time-histories of air temperatures at each drift segment of the observation drifts and rock temperatures in the vicinity of observation drifts and emplacement drifts.

Air and Wall Rock Temperatures at Observation Drifts

Figure 8 shows the air temperature distributions over time and space for the 5 m³/sec case with a distance of 20 m from the crown of the emplacement drifts to the invert of the observation drifts. It is seen that the peak air temperature experienced near the exit end of the observation drifts is about 49°C, which occurs at 150 years after waste emplacement. Results indicate that the maximum air temperature requirement for the observation drifts can be marginally met based on a relatively low air quantity of 5 m³/sec for the drifts located in the middle of pillar between the emplacement drifts with a distance of 20 meters from the emplacement drifts. For this case, the peak wall rock temperature is about 60°C at 150 years.

Figure 9 shows the distribution of air temperature for the 10 m³/sec case with a distance of 10 meters from the crown of emplacement drifts to the invert of observation drifts. Doubling the air quantity, from 5 m³/sec to 10 m³/sec, while reducing the distance by half (from 20 meters to 10 meters) substantially reduces the air temperature in the observation drift to about 41°C. The peak air temperature is experienced at about 80 years after waste emplacement, occurring earlier than the 5 m³/sec case, while the wall rock temperature never exceeds 50°C over the 150-year

period of continuous ventilation.

Results for the two cases described above demonstrate that air temperatures in the observation drifts can be maintained at an operating temperature of 50°C with a reasonable continuous ventilation effort for the repository preclosure period. For personnel access on a periodic basis, previous study of the thermal management strategies presented in the ACD report (Ref. 5.11, section 8.7.6.3) showed that reducing the air temperature from 50°C to 27°C effective within a short period of time, say 1 to 2 days, can be readily accomplished using ventilation with high air quantities.

Rock Temperatures

Rock temperatures in the vicinity of observation and emplacement drifts are shown in Figures 6 and 7, for the 5 and 10 m³/sec cases, respectively, at 150 years. These figures indicate that continuous ventilation of observation drifts, which removes part of the heat transferred from waste packages, lowers rock temperatures in the vicinity of the emplacement drifts. The modification of the temperature field depends on the distance between the observation drift and the emplacement drift, the quantity of ventilation, and the duration of ventilation.

For the observation drift at a 20 meter distance and 5 m³/sec air flow, the peak wall temperature experienced at the closest emplacement drift (the left-most one shown in Figure 6) is about 137°C at about 50 years after waste emplacement, while the peak wall temperature at the most distant emplacement drift (the right-most one in Figure 6) is about 141°C at about 57 years.

The greater perturbation in the rock temperature field occurs when the air quantity is increased and at the same time the distance of observation drifts is decreased, that is, the observation drift is at a 10 meter distance and the air flow is 10 m³/sec, see Figure 7. Peak wall rock temperatures experienced at the closest and most distant emplacement drifts are about 128°C and 139°C, at 36 and 53 years, respectively.

The impact of the observation drifts on the emplacement horizon may be significant and their heat sink effect must be further evaluated. The cooler observation drifts could cause ground stability problems due to the temperature difference or they could become saturated with water inflow from condensation. The overall effect of these cooler drifts on ground stability and groundwater requires additional analysis. The model in this analysis did not factor in the evaporative cooling affect that moisture flow to the observation drifts would cause.

Ventilating Air Temperatures in Observation Drift for 20m Case

(AT=26C; AQ=5.0m³/s; TL=85MTU/ac; DS=22.5m; PS=18.92m; DOD=4.5m; DFED=20m; LOD:MOP)

c:\y97\pca\pca85mr.wk4

Figure 8
Air Temperatures - D = 20 m, Q = 5m³/sec

c:\y97\pca\pca85mr.wk4

Figure 9
Air Temperatures - D = 10 m, Q = 10m³/sec

7.3.4.1.2 Observation Drift Geologic Setting

Observation drifts are to be constructed and located so as not to adversely affect the repository (4.2.5). Because the repository horizon, for the reference mass loading of 80-100 metric tons of uranium (MTU) per acre, will be located mainly in the TSw2 geologic unit (Key 022) and because this unit was selected as having characteristics that enhance the development and maintenance of stable openings, observation drifts will be similarly located mainly in the TSw2 unit to the extent practical. Key assumption 022 also states that a portion of the TSw1 geologic unit is suitable for the repository horizon.

To determine the geologic strata that may contain the proposed observation drifts, a map and section were developed from the current three-dimensional site geologic model (4.3.27) defining the upper limit for observation drifts lying above the repository horizon. Figure 10 shows the geologic units encountered within a plane oriented to intercept the crowns of all observation drifts, 4.5 meters in diameter (4.3.24) which have inverts 20 meters (4.3.26) above the crowns of emplacement drifts, 5.5 meters in diameter (4.3.23).

This plan view indicates that, although observation drifts on the east side of the repository block may extend above the TSw2 unit, these drifts lie within the identified repository host horizon (4.3.27). The host horizon includes the lower portion of the TSw1 unit that is similar in thermal and mechanical characteristics to the lithophysal portion of the TSw2. The cross section in Figure 10, constructed along the north-south East Main, also shows the location of the observation drift with respect to the host horizon.

Also shown on Figure 10, in addition to the geologic criterion, is an irregular line marking the base of the 200-meter minimum overburden thickness. The observation drift upper horizon extends above this boundary in a number of places. The significance of observation drifts extending above the overburden boundary has not been determined at this time, however, these areas could be avoided if necessary.

Figure 10

Plan view and cross section along ESF Main Drift. Plan view is constructed in plane coinciding with the crown of the observation drifts.

7.3.4.1.3 Observation Drift Layout Concepts

Several observation drift concepts are possible for PC monitoring. From a construction and operations perspective, the observation drifts could be located either above or below the emplacement horizon. In either location, drift construction methods, access, and ventilation would be similar. In the current repository the Exhaust Main, which will carry exhaust air from the emplacement drifts to the ventilation shaft, will be located below the emplacement horizon. Cross-block observation drifts below the emplacement horizon would interfere with the Exhaust Main unless located at a different elevation. With PC observation drifts above the block, boreholes can be drilled down to the emplacement drifts for monitoring ground movement at the tunnel crown. For these reasons, although primarily for the latter reason, the observation drifts should be located above the emplacement drifts, though observation drifts below the emplacement horizon cannot be ruled out entirely.

The first concept was described in section 7.3.4.1, in which the observation drifts were located above the block and parallel to the emplacement drifts. This concept is illustrated in Figures 1, 11, and 12. Figure 3 shows a typical cross-block observation drift set up to cover six emplacement drifts, and Figure 4, five emplacement drifts. In both arrangements access is from the east side by means of a ramp. The ramp and observation drift would have floors suitable for trackless rubber tired construction and service vehicles. Alternatively, the access ramp could be excavated on the west side, although for operational convenience, access logistics from the east would probably be better. An access ramp on both the east and west sides is not required as the access/ventilation raise at the far end of the drift can be equipped with a ladderway and small service hoist for personnel egress and handling small items. If observation drifts are located 10 m above the emplacement horizon, this raise would be approximately 10 m deep.

Figures 1 and 11 show five observation drifts crossing the emplacement horizon parallel to the emplacement drifts. If each drift can monitor five emplacement drifts, then a total of 25 emplacement drifts will be monitored. For 143 (4.3.21) loaded emplacement drifts, approximately 17 percent will be covered by the five observation drifts. With an observation drift set up to monitor 6 emplacement drifts, 30 emplacement drifts will be covered which represents approximately 21 percent of the emplacement area. Figure 12 shows 25 observation drifts, with each drift monitoring six emplacement drifts, this arrangement would basically cover all emplacement drifts.

Figure 13 illustrates a concept with two observation drifts running the length of the emplacement horizon and excavated parallel to the main entries and Exhaust Main. This concept would provide borehole coverage to portions of every emplacement drift. Similarly, portions of every emplacement drift could also be covered from the perimeter mains and Exhaust Main.

Figures 14 and 15 depict a concept for excavating five (5) observation drifts diagonally across the emplacement horizon. This concept also provides coverage to a portion of all emplacement

drifts. However, with the diagonal drifts a potential arises for them to cross from the emplacement side to the development side thus negating the required isolation of emplacement and construction activities. To overcome this potential problem a bulkhead would have to be located in the observation drift to prevent airflow and traffic between the two sides. The bulkhead would be removed once the entire drift was in the emplacement side. In Figure 15, the observation drift is shown enlarged along its sides so that boreholes and instrumentation can be located out of the central travelway of the drift.

Table 7.1 provides a summary of PC development estimated for the different concepts described above. The summary is intended to show that as the extent of the PC program increases to provide greater coverage of the emplacement area, the amount of development needed becomes significant. For 25 observation drifts approximately 46,000 m of development is required, this would increase overall repository development by 20 percent, from approximately 228 km (Ref. 5.11, pp 8-89) to 274 km (228+46). Determining the extent of the PC program, and consequently the amount of development and borehole drilling needed to effectively execute the program, will require further study and is beyond the scope of this analysis. Further analysis is also needed to address the ground stability and waste isolation concerns resulting from the PC observation drifts.

PLAN VIEW

SCALE: 1:2000

GRAPHIC SCALE

0 25 50 75 100 m

1:2000

FIGURE 15 - BOREHOLE
ALCOVE EXCAVATED DIAGONAL
TO EMPLACEMENT DRIFTS

Table 7.1. Summary of PC Development & Boreholes for Different Observation Drift Arrangements

Development Description	5 Drifts (Parallel)	5 Drifts (Diagonal)	25 Drifts (Parallel)	2 Drifts (Longitudinal)
Launch Drift (TBM)	–	–	4,400m ¹	–
Observation Drifts (TBM)	–	–	30,000m ²	16,000m ³
Observation Drift (Roadheader)	6,000m ⁴	6,000m ⁵	–	–
Launch/Recovery Chambers (Roadheader)	–	–	790m ⁶	70m ⁷
Access Ramps (Roadheader)	1,100m ⁸	1,100m ⁹	–	–
Vent.Crosscuts (Roadheader)	75m ¹⁰	75m ¹¹	375m ¹²	1,600m ¹³
Borehole Alcoves (Roadheader)	2,000m ¹⁴	3,250m ¹⁵	10,000m ¹⁶	–
Ventilation Raises (Raise Borer)	180m ¹⁷	180m ¹⁸	890m ¹⁹	80m ²⁰
Total Excavation	9,355m	10,605m	46,455m	17,750m
Instrumentation Boreholes	6,000m²¹	14,820m²²	30,000m²³	54,340m²⁴

¹⁻²⁴ See Attachment II for the method utilized to obtain these values.

Observation drifts would be excavated by mechanical means, both TBMs and roadheaders are suitable equipment for this purpose (4.3.19). The TBM represents a proven method for rapid excavation of long tunnels (1,000- 2,000m plus) in hard rock, such as occurs at Yucca Mountain. Roadheaders are being developed for hard rock although, as yet are not widely used for this purpose. Current repository design is considering roadheaders for excavating emplacement drift starter tunnels (“turnouts” in repository parlance) and short connecting drifts between the TBM openings. In general, roadheader excavation could be used for limited drifting, such as one to nine cross-block observation drifts and TBMs where ten or more PC observation drifts are indicated. Figure 11 shows the layout for roadheader excavation and Figure 12 for TBM excavation of the observation drifts.

Roadheaders typically excavate a horseshoe shaped tunnel with a flat floor suitable for trackless equipment. Trackless service equipment is recommended as it can operate on steeper gradients than rail and will keep the access ramps to a reasonable length. TBM tunnels are round and consequently will require addition of a flat invert surface for the trackless equipment. In both

cases boreholes should be drilled from short alcoves to protect monitoring equipment and the data acquisition system from vehicles traveling in the drift itself. Figures 3 and 12 show a larger diameter TBM excavated launch main necessary for transporting and launching the smaller observation drift TBM.

Selection of the excavation method, size and configuration of openings, ground support, gradient of the access ramp, and ventilation quantities would be decided during detailed design. Detailed excavation and construction design will consider constructability issues, costs, and schedule impacts.

7.3.5 Monitoring the Ventilation System

Monitoring the ventilation system is a basic design requirement for the repository and the PC program (4.3.17). Permanent monitors will provide baseline data on the subsurface environment and subsequent changes to those data (4.2.3, 4.2.4 and 4.3.17). The parameters can be obtained from the repository exhaust air stream, from low volume emplacement drift ventilation (4.3.14), leakage, or periodic sampling. The PC parameters that will be monitored are groundwater, which would be measured as humidity (7.2.6), the excavation environment (7.2.8) and radionuclide leakage (7.2.11).

Monitors could be installed in the Exhaust Main and in the raises to the emplacement drifts. A data network (which is not within the scope of this analysis) would collect information from radionuclide leakage measurement instruments. In the simplest arrangement, instruments at the bottom of the ventilation raise would be unable to determine from which side of the emplacement drift the radionuclide leakage originated.

Another concept involves installing a return air monitoring duct in the Exhaust Main with two separate and smaller sampling pipes that go up the emplacement drift exhaust raise, side by side, and split to each respective side of the emplacement drift, see Figure 16. The sampling pipes contain all of the airflow from the emplacement drifts. This system would more accurately determine from which side of an emplacement drift the leakage occurred. In the event of radionuclide leakage, the contaminated air is contained inside the duct in the Exhaust Main, thereby reducing the potential for more widespread contamination.

Other concepts for sampling the emplacement drift air involve the use of either remote equipment or sampling from the perimeter mains. These concepts do not readily permit continuous sampling of the exhaust stream and only provide limited coverage.

FIGURE 16
EMPLACEMENT DRIFT AIR
MONITORING ARRANGEMENT

The frequency with which samples must be taken is not addressed in this analysis. The monitoring network in the Exhaust Main will determine where radionuclide contamination originates from within TBD hours of detection (4.3.10.i). However, the exhaust side monitoring system for air temperature, relative humidity, and gaseous radioactive emissions (4.3.10.h) must be activated fairly often, perhaps from a frequency of every few minutes to daily. Longer frequencies, monthly or longer, may be warranted when the time for closure approaches.

Locating the Exhaust Main below the emplacement horizon and continuous ventilation of this main (4.3.15) will allow access for maintenance of monitoring equipment during the preclosure period. The ventilation rate in the Exhaust Main will be considerably higher than the rate in the observation drifts and human entry will be possible. Separate analyses will be prepared for the ventilation system and the associated monitoring systems. However, the PC parameters that require monitoring the ventilation system for radionuclide contamination, temperature and relative humidity, can be obtained within the current repository design.

7.3.6 Remote Systems in the Emplacement Drifts

The anticipated heat and radiation levels in the emplacement drifts will necessitate use of remote equipment if entry is required (4.3.16). The PC assumptions (4.3.1) indicate that the following concepts may be used to obtain the PC data. These concepts may involve a remote incursion into emplacement drifts: These concepts may include:

1. Visually inspecting for groundwater or condensate seepage (7.2.6).
2. Inspections to evaluate emplacement drift geometry, convergence, deformation and/or rock falls (7.2.7).
3. Periodic visual inspections (7.2.10) of waste packages.
4. Retrieval of waste package sample specimens (7.2.10).
5. Determining temperature of waste package barrier wall (7.2.10).
6. Detecting radionuclides (7.2.11).

Since the details of the type and frequency of indrift observations and concepts for accommodating indrift observations are extensive, these details will be covered in a separate analysis.

7.3.6.1 Utilizing Lasers to Investigate Emplacement Drifts

A concept for detecting ground falls involves setting up a laser outside the isolation doors and directing the laser to targets inside the emplacement drift. It may be possible to place small and durable reflectors on the ground support so that the laser could survey the entire drift. The current plan is to drive emplacement drifts up at a slope of 0.5 percent (4.3.23) from the perimeter mains with a peak in the middle. If laser targets are installed in the drifts near the central ventilation raise, then coverage of the emplacement drift will be as depicted on Figure 17.

With a zero gradient emplacement drift, a straight line of monitoring would be possible between the East Main and the West Main.

7.3.7 Contingency Plans for Alcoves and Drifts

Flexibility of the PC facilities to deal with unexpected conditions has been considered throughout the design (4.2.11). Design of the repository layout and operating systems (covered by other analyses) must also consider unexpected conditions and events, including changes to the PC facilities design. To ensure that the repository and PC design can accommodate such changes contingency must be considered early in the design and construction of the facilities. At this stage of the repository program a considerable amount of design and excavation must still be completed. The repository will consist of approximately 228 km (Ref. 5.11, pp 8-89) of excavated openings with 7.9 km excavated in the ESF (Ref. 5.12, pp 26). This represents less than 3.4 percent of the openings so far mined, and so the opportunity to include flexibility in the repository design at this stage of the design is maintained.

The PC facilities will consist mainly of drifts, alcoves, boreholes, utilities, and the monitoring systems. The final PC design will indicate the overall PC facilities required, with details of typical drifts, alcoves, and utilities systems. However, the need for additional observation drifts, alcoves, and monitoring equipment for obtaining information on unexpected conditions, such as water, and fracture zones (4.3.10), may be identified during construction. It is also possible that some PC facilities as originally planned may not be needed. The overall repository design will (4.2.11) accommodate deletion or addition of a limited number of observation drifts and alcoves. These changes can be effected if and when needed.

The current repository design (4.3.15) is based on many assumptions, including many details of the site geology. The emplacement area may be affected by unexpected geologic conditions. To obtain PC data in areas where conditions differ from those expected, it may be necessary to remove an area from consideration for waste emplacement. Modifications to the design will be made at the time such conditions are encountered. The current layout design has sufficient reserve to accommodate withdrawal of between 15 and 20 drifts from emplacement (4.2.11). Further analysis will be needed to determine the extent and impact of such changes on the overall repository design.

Many of the PC parameters are related to monitoring in situ water (7.2.4, 7.2.5, 7.2.6 and 7.2.8). If water is encountered during construction, depending on quantity and other characteristics, additional construction of alcoves, sumps or testing niches may be needed. However, as a matter of routine underground practice the repository design will include sumps, pumps, and water discharge lines for handling water from construction activities - such as TBM and roadheader excavation, fire water, ruptured water lines, and perched water if encountered.

FIGURE 17
EMPLACEMENT DRIFT
LASER SURVEYING

7.3.8 Recovery of Waste Packages or Dummy Waste Packages

Removing waste packages from emplacement drifts is currently not expected to occur under normal circumstances (4.3.10.d). However, the ability to remove a waste package and return it to the surface is a repository design function (4.2.14). The current gantry emplacement system design (the subject of other analyses) under normal conditions will have the capability to recover waste packages from the emplacement drifts. Recovery systems for dealing with off-normal systems are also under development.

Testing dummy waste packages (that is an empty waste package) may be required to confirm PC waste package parameters. Emplaced dummy waste packages would be subsequently recovered from emplacement drifts for off-site testing as if they were true waste packages. Dummy packages may also be placed in special alcoves for in situ testing.

The PC parameters that require testing waste packages (7.2.10) rely on the fact that waste packages or dummy waste packages can be placed underground, recovered and tested in a laboratory. Destructive testing of a waste package will be carried out only on a recovered waste package, otherwise, destructive testing is not required (4.3.20).

7.4 Data Acquisition Stations

The scope of this analysis includes determining how the PC program and PC data acquisition stations will be incorporated into the overall repository layout. PC data acquisition stations will be located in a number of areas of the underground, but primarily in alcoves and observation drifts.

PC facilities alternatives include excavating observation drifts above the emplacement block with test alcoves located every 100 m within each observation drift (4.3.24). A 1200 m long observation drift would have approximately 10 drilling and data collection areas. For five observation drifts, this would amount to a total of 50 data acquisition stations; for 25 observation drifts, each with 10 alcoves, the number of data acquisition stations increases to 250. In addition, data acquisition stations would be located in the main drifts, access ramps, emplacement drift turnouts, the Exhaust Main, and any other openings where monitoring stations may be installed. Design of the data acquisition system is covered by another analysis.

7.4.1 PC Data Acquisition Stations Locations

The primary data acquisition stations will be located in the observation drifts. The temperature in the observation drifts is a direct function of the ventilation airflow quantity and distance from the emplacement drift. The temperature in these drifts will normally be kept to less than 50° C (4.3.25) so as not to cause problems with the electronics of the data acquisition systems, and for personnel access the ventilation quantity would be increased to lower the temperature to 27° C

(4.3.25). A typical data acquisition station for monitoring boreholes drilled from the observation drifts to the emplacement horizon is shown in Figure 18.

Though the primary location for data acquisition stations will be in the observation drifts, they could also be located in the following areas:

1. In the Exhaust Main - for monitoring air and boreholes drilled up to the emplacement horizon
2. In the perimeter mains - for monitoring air and boreholes drilled between emplacement drifts
3. In alcoves - for monitoring borehole tests in progress and alcove-based tests such as detection of ground motion.
4. In empty emplacement drifts - for monitoring boreholes drilled to adjacent drifts and for monitoring the ventilation system.

7.4.2 Ventilation Issues

Ventilating the observation drifts will be considered in the overall repository design. Observation drifts will become heated because of their proximity to the emplacement drifts, and ventilation will be required to maintain air temperatures at reasonable levels for equipment and personnel. As discussed in section 7.3.4.1.1.4, observation drifts located 10 m above the emplacement drifts may require an airflow of approximately 10 m³/sec to maintain a temperature of 50° C. That means that overall repository ventilation will have to be increased by 50 m³/sec for five observation drifts and to 250 m³/sec for 25 drifts. The current ventilation airflow quantity for repository emplacement operations is around 250 to 300 m³/sec. Continuously ventilating a large number of observation drifts would require a significant increase in the overall repository ventilation airflow. For 25 drifts this would almost double the amount of air needed, and could require additional primary airways, such ventilation shafts, to provide the necessary air flow.

Figure 19 shows the arrangement for ventilating five cross-block observation drifts. Ventilation air enters the observation drift via the access ramp on the east side and a short access/ventilation raise on the west side. Exhaust air returns to the Exhaust Main through the central exhaust air raise. A similar arrangement would serve for any number of cross-block drifts, for example 25 drifts as shown in Figure 12, and diagonal drifts as shown in Figure 14. For longitudinal observation drifts as shown in Figure 13, air would enter the observation drifts at the East and West Mains and exhaust through crosscuts and ventilation raises to the Exhaust Main.

7.4.3 Service/Access/Utilities

Utility and access requirements are also included in the scope of the PC design. In general such items will be similar to those required by standard underground design practice, and should not present too many challenges for final design. If specific testing that requires large amounts of electrical power or compressed air is identified in subsequent analyses, special arrangements would be made at that time for their provision.

Access to the PC facilities will be along the same openings as utilized for the entire underground operations. Ramps to the observation drifts will be accessible by roadheaders and rubber tired construction and service vehicles.

8. CONCLUSIONS

The analysis describes an overall system for obtaining PC parameters listed in Appendix D (see Attachment I) of the Performance Confirmation Concepts Study Report (Ref. 5.1), and identifies eight methodologies for that purpose. The methodologies are discussed in sections 7.3.1 through 7.3.8, and conclusions on each of the methodologies are presented in sections 8.7.1 through 8.7.8. In addition, more general conclusions are presented in sections 8.1 through 8.6.

As identified in section 2.0, the use of any data from this analysis cannot be used as input into documents supporting procurement, fabrication or construction, unless it is controlled as TBV or TBD in accordance with NLP-3-15.

8.1 Acquisition of the PC Parameters

The eight acquisition methodologies described in sections 7.3.1 through 7.3.8 provide means for obtaining the required PC parameters. Table 8.1 compares the acquisition methodologies with the required categories of PC parameters evaluated in section 7.2.

Table 8.1 Matrix of PC Parameters vs Acquisition Methodologies

		Acquisition Methodologies							
		1	2	3	4	5	6	7	8
P C P a r a m e t e r s	A			X					
	B	X	X						
	C	X	X						
	D	X			X			X	
	E	X	X	X	X			X	
	F	X		X	X	X		X	
	G			X	X		X		
	H	X			X	X		X	
	I	X							
	J			X			X	X	X
	K				X	X	X		

Acquisition Methodologies

1- Sampling
2- Mapping
3- Alcove-Based Testing
4- Borehole Instruments
5- Ventilation
6- Remote Operations
7- Contingency Plans
8- WP Recovery & Testing

PC Parameters

A - Seismic
B - Hydrocarbons/Mineralogy
C - Stratigraphy
D - Altered Zone Characteristics
E - Fracture Zone Characteristics
F - Groundwater Characteristics
G - Emplacement Drift Geometry
H - Excavation Environment
I - Materials Remaining after Closure
J - Waste Package Characteristics
K - Radionuclide Containment

In some cases, parameters can be obtained by more than one methodology, and likewise an acquisition methodology can provide data for several parameters. In all cases, at least one method has been identified for obtaining the required parameter.

8.2 Extent of PC Program

Determining the extent of the PC program including the amount of underground development, detailed configuration of excavations, such as observation drifts and alcoves, amount of borehole drilling, and the precise type and location of monitoring instrumentation is beyond the scope of this preliminary analysis. The analysis does, however, describe methodologies for gathering the PC parameters, the facilities needed to carry out the PC program, how these facilities can be incorporated into the overall repository design, and the limitations and impacts of these facilities on the overall repository design.

The final design of the PC program must consider not only the needs of the PA and PC programs, but also practical limitations imposed by construction logistics and schedules, ventilation requirements, operational parameters, and construction and operating costs.

8.3 Location of Observation Drifts

From an excavation standpoint, the observation drifts can be located above or below the emplacement drifts. In either location current mining and tunneling technology can accomplish the task. PA concerns in regard to drift location have not been established. Observation drifts above the emplacement drifts are recommended to facilitate monitoring the crown of the emplacement drifts where most displacement will occur, though observation drifts below the emplacement horizon cannot be ruled out.

8.4 PC Layout Configuration

Three basic PC layout configurations are discussed in the analysis: - 1) Observation drifts parallel to the emplacement drifts (Figures 1, 11, and 12), 2) Observation drifts excavated normal to the emplacement drifts and parallel to the East and West Mains and Exhaust Main (Figure 13), and 3) Observation drifts diagonal to the emplacement drifts (Figure 14).

Observation drifts excavated parallel to the emplacement drifts allow coverage of the full length of a set of emplacement drifts. The longitudinal arrangement provides coverage at two points for each drift. The diagonal drifts provide coverage at one point for each drift they cross.

The number of emplacement drifts covered by an observation drift depends on its elevation above the emplacement drifts and the acceptable length and orientation of the boreholes; these factors are to be determined. The spacing of test alcoves along the observation drift is also to be determined, although for this analysis a 100 m spacing is assumed to be reasonable. The number of observation drifts is also to be determined, this analysis depicts five observation drifts (Figure 11) and 25 drifts (Figure 12). The observation drifts will be excavated in step with the repository development as it advances across the block from north to south. The first observation drift will be excavated at the north end of the block over the first active emplacement drifts. The final observation drift will be excavated some 20 - 25 years later.

A combination of observation drifts parallel and diagonal to the emplacement drifts provide a layout that utilizes the benefits of both options. For example, a layout that has five observation drifts, with three parallel to the emplacement horizon and two diagonal to the emplacement horizon, may provide coverage for substantial emplacement drift areas.

If more observation drifts are ultimately desired, for example ten, then TBM excavation would probably be warranted and the drifts should all be parallel to one another.

Excavating the observation drifts in conjunction with the associated emplacement drifts would spread the work over the entire construction and development periods (20 - 25 years), thereby minimizing impacts on a complex and busy initial construction effort, and spreading the costs over a longer time frame.

Mechanical excavation methods are a requirement for repository openings, and the PC facilities design described in this analysis can be excavated by mechanical means. Roadheader and TBM methods are available for lateral openings, and raise borers for the ventilation raises. The TBM provides a proven method for rapid excavation of long tunnels. Roadheaders are more maneuverable than TBMs and easier to set up, although their cutting capability in hard rock (as occurs at Yucca Mountain) is poor. Roadheaders are now under development for hard rock, and machines with acceptable performance could well be available for repository construction and development. Roadheaders (provided machines with adequate hard rock cutting capability are available) are recommended for a small number of cross-block drifts (between 1 and 9). For a more extensive program TBMs would be preferred. Provided facilities are available for the PC program, selection of an excavation method should have no impact on the program. Final selection of the excavation method will depend on costs and general constructability issues, and will be made at the time of final design and construction.

8.5 Ventilation Requirements

Ventilation requirements for observation drifts could significantly impact the overall repository ventilation design. The observation drifts will be subjected to a high thermal load for a long period of time and maintaining ventilation to protect the monitoring equipment and for personnel access will require a significant investment in equipment and operating costs. Full coverage of the emplacement area would almost double the emplacement side ventilation needs. For this reason limited coverage as would be obtainable from five to ten cross-block drifts is recommended.

A ventilation plan that covers five observation drifts would result in an increase in total repository ventilation of only approximately 50 m³/sec (5 x 10 m³/sec). The ventilation network would be fairly simple and would parallel the ventilation network that ventilates the emplacement drifts. The plan depicted on Figure 19 would have minimal impact to the overall repository design.

8.6 Changes in the PC Parameters

As repository design advances, the PC parameters may change, and the program for acquiring the PC parameters may also change. The data acquisition methodologies identified in this analysis are currently available, widely used technologies, and can be adapted to reasonable changes in the PC program.

8.7 Assessment of Performance Confirmation Test Methods

8.7.1 Sampling Program

Although rock sampling requirements are to be determined, the borehole and bulk sampling methods described in section 7.3.1 represent proven methods for sampling rock during tunnel excavation. PC parameters that require sampling in emplacement drifts underground can be acquired. Sampling requirements should be developed in conjunction with the design of the subsurface facilities, and provisions made in the final design for sampling. Sampling for TFM materials can be accomplished using methods adapted for the ESF.

8.7.2 Geologic Mapping Program

The extent of the geologic mapping is to be determined. Two approaches have been examined in this analysis: 1) Complete mapping of the main tunnels and emplacement drifts, and 2) Grid mapping - that is mapping of the main drifts, ventilation drifts and spare drifts on the emplacement horizon, and the observation drifts. In either case mapping the main tunnels can be accomplished. The ground support system under development for the main tunnels requires installation of temporary ground support to facilitate the construction process - this would also facilitate the mapping, and installation of the permanent liner later. One hundred percent mapping of the emplacement drifts will require a similar approach. The current emplacement drift ground support design is leaning towards use of precast concrete liner segments. This is a single pass system, and because of the volume of emplacement drift development compared to main drift development, it is a more cost effective approach than installing both temporary and permanent ground support.

The mapping program must consider the PC and PA needs and construction requirements. The emplacement drift TBM can be designed to allow some mapping below the shield. From an excavation perspective grid mapping with limited observation and mapping at the TBM, would provide sufficient information for layout, ground support, and construction design.

This analysis concludes that 100 percent mapping of the emplacement horizon would be costly and would adversely impact the construction schedule. The mapping scheme, see Figure 1, portrays detailed mapping of the following drifts:

1. All observation drifts, currently recommended to be five,
2. Three emplacement horizon drifts, excavated during construction,
3. The Exhaust Main, and
4. All perimeter mains.

8.7.3 Alcove-Based Testing in Nonemplacement Drifts

The current repository and ESF design provide sufficient area for alcoves that may be needed for

alcove-based testing. The PC parameters that are dependent upon alcove-based testing can be determined either in existing alcoves or in new alcoves specifically designed for their intended purpose.

8.7.4 Monitoring the Altered Zone

Boreholes can be drilled from alcoves excavated along the observation drifts to monitor the altered zone. Monitoring instruments would be placed in the boreholes and connected to the data acquisitions system. Cross-block observation drifts are well placed to facilitate drilling boreholes into the altered zone, although the extent of borehole drilling and instrumentation is to be determined. The observation drifts and alcove concepts described in this analysis would, however, accommodate a wide range of borehole testing requirements.

8.7.5 Monitoring the Ventilation system

The analysis describes concepts for monitoring the ventilation to obtain the required PC parameters. A concept utilizing small sampling pipes from each side of the emplacement drifts as shown in Figure 16 is recommended for this purpose. This system would provide better control of air flow through the emplacement drift and minimize the potential for leakage of radionuclides from a waste package to cause widespread contamination of the Exhaust Main and shaft.

8.7.6 Remote Systems in the Emplacement Drifts

Those PC parameters that will require remote entry into emplacement drifts can be determined by utilizing remote entry equipment. The remote entry concept details are not within the scope of this document. Other concepts, such as laser systems, could be utilized to supplement remote monitoring of emplacement drift geometry, and warrant further examination.

8.7.7 Contingency Plans for Alcoves and Drifts

The repository design and PC program (as described in this analysis) provide considerable flexibility to add or delete PC facilities, such as observation drifts and alcoves. Development of the PC facilities design must be fully integrated into ongoing development of the repository design to ensure all related concerns and issues are adequately addressed in both areas.

8.7.8 Recovery of Waste Packages or Dummy Waste Packages

The current gantry emplacement concept, now under development as part of repository design, will permit removal of waste packages and dummy (empty) waste packages from emplacement drifts for off-site testing. Dummy waste packages can also be placed in test alcoves located away from the emplacement area for in situ observation and testing.

9. ATTACHMENTS

Attachment I, Key Performance Confirmation Parameters for Design, Ref. 5.1., 9 pages

Attachment II, Method for determining values in Table 7.1, 5 pages

Attachment III, Calculation of Convective Heat Transfer Coefficient, 1 page

Attachment IV, Waste Receipt and Heat Decay, 2 pages

Attachment V, Thermal Model Intermediate Calculations, 15 pages

Attachment VI, Computer Input Listing for Thermal Calculations, 120 pages

APPENDIX D - Key Performance Confirmation Parameters for Design from Reference 5.1.

Parameters	Selection Criteria											Performance Confirmation Parameters		Preliminary Performance Confirmation Concepts
	Screen 1 (one must apply)				Screen 2 (one must apply)			Screen 3 (all must apply)			Screen 4			
	10 CFR 60 Subpart F	Con-fine & Isolate Waste Funct.	Con-tain. & Isol. Strategy	TSPA & PA process models	Sub-surface conditions	Affected by const./emplacment	Time dependent variable	Can be measured or derived	Can be predicted or estimated	Important to performance	Reduce uncertainty	All perf. conf. parameters	Key parameters for design	
GENERAL SITE PARAMETERS														
Seismicity														
Location				X			X	X	X	X	X	X	X	Continuous monitoring at existing surface-based & new underground seismic stations
Magnitude				X			X	X	X	X	X	X	X	
Acceleration/ground motion				X			X	X	X	X	X	X	X	
Hydrocarbon (Coal, Oil and Gas) and Mineral Resource Exploration and Extraction														
Location	X				X			X	X	X	X	X	X	Geologic mapping during underground excavation & off-site lab analysis
Quantity	X				X			X	X	X	X	X	X	
UNSATURATED ZONE PARAMETERS														
Stratigraphy of the Alluvium/colluvium and Rock Matrix														
Rock types	X	X	X	X	X			X	X	X	X	X	X	Geologic mapping during underground excavation
Mineralogy	X	X	X	X	X		X	X	X	X	X	X	X	
Hydraulic Characteristics of Alluvium/Colluvium and Rock Matrix of Altered Zone														
Saturated hydraulic conductivity/permeability	X	X	X	X	X	X		X	X	X	X	X	X	Underground testing/sampling & off-site lab analysis
Effective porosity	X	X	X	X	X	X		X	X	X	X	X	X	

Parameters	Selection Criteria											Performance Confirmation Parameters		Preliminary Performance Confirmation Concepts
	Screen 1 (one must apply)				Screen 2 (one must apply)			Screen 3 (all must apply)			Screen 4			
	10 CFR 60 Sub-part F	Con- fine & Isolate Waste Funct.	Con- tain. & Isol. Stra- tegy	TSPA & PA process models	Sub- surface condi- tions	Affec- ted by const./ empla- cement	Time depen- dent variable	Can be mea- sured or derived	Can be pre- dicted or esti- mated	Import- ant to per- form- ance	Reduce uncer- tainty	All perf. conf. para- meters	Key para- meters for design	
Dispersivity/dispersion coefficient	X	X	X	X	X	X		X	X	X	X	X	X	Underground testing/sampling & off-site lab analysis
Hydraulic potential - moisture content relationship	X	X	X	X	X	X		X	X	X	X	X	X	
Moisture content - hydraulic conductivity relationship	X	X	X	X	X	X		X	X	X	X	X	X	
Pneumatic Characteristics of Alluvium/Colluvium and Rock Matrix of Altered Zone														
Air permeability	X	X		X	X	X		X	X	X	X	X	X	Underground testing/sampling & off-site lab analysis
Mechanical Characteristics of Alluvium/Colluvium and Rock Matrix of Altered Zone														
In situ stress	X	X		X	X	X	X	X	X	X	X	X	X	Continuous underground monitoring
Strain	X			X	X	X	X	X	X	X	X	X	X	
Rock deformation & displacement	X	X		X		X	X	X	X	X	X	X	X	
Thermal Characteristics of Alluvium/Colluvium and Rock Matrix of Altered Zone														
Soil & rock temperature	X	X	X	X	X	X	X	X	X	X	X	X	X	Continuous surface-based & underground monitoring
Geometry, Including Future Displacements of Rock Fracture Zones (Including Faults)														
Location	X	X	X	X	X		X	X	X	X	X	X	X	Geologic mapping during underground excavation
Width	X	X	X	X	X		X	X	X	X	X	X	X	
Length	X	X	X	X	X		X	X	X	X	X	X	X	
Orientation	X	X	X	X	X		X	X	X	X	X	X	X	

Parameters	Selection Criteria											Performance Confirmation Parameters		Preliminary Performance Confirmation Concepts
	Screen 1 (one must apply)				Screen 2 (one must apply)			Screen 3 (all must apply)			Screen 4			
	10 CFR 60 Sub-part F	Con-fine & Isolate Waste Funct.	Con-tain. & Isol. Strategy	TSPA & PA process models	Sub-surface conditions	Affected by const./emplacement	Time dependent variable	Can be measured or derived	Can be predicted or estimated	Important to performance	Reduce uncertainty	All perf. conf. parameters	Key parameters for design	
Displacement				X			X	X	X	X	X	X	X	Geologic mapping during underground excavation
Fracture aperture	X	X	X	X	X		X	X	X	X	X	X	X	
Fracture density	X			X	X		X	X	X	X	X	X	X	
Biological Characteristics of Rock Fracture Zones (Including Faults)														
List of microbes	X	X	X	X	X	X	X	X	X	X	X	X	X	Underground sampling & off-site lab analysis
Microbial activity	X	X	X	X	X	X	X	X	X	X	X	X	X	
Chemical/Mineralogical Characteristics of Infillings of Rock Fracture Zones (Including Faults)														
Apparent age of minerals	X	X		X	X	X	X	X	X	X	X	X	X	Underground sampling & off-site lab analysis
Hydraulic Characteristics of Rock Fracture Zones (Including Faults)														
Saturated hydraulic conductivity/permeability		X	X	X	X	X		X	X	X	X	X	X	Underground testing/sampling & off-site lab analysis if untested fracture zones encountered during excavations
Effective porosity		X	X	X	X	X		X	X	X	X	X	X	
Dispersivity/dispersion coefficient		X	X	X	X	X		X	X	X	X	X	X	
Hydraulic potential - moisture content relationship		X	X	X	X	X		X	X	X	X	X	X	
Moisture content - hydraulic conductivity relationship		X	X	X	X	X		X	X	X	X	X	X	
Pneumatic Characteristics of Rock Fracture Zones (Including Faults) of Altered Zone														
Air permeability	X	X		X	X	X		X	X	X	X	X	X	Underground testing/sampling & off-site lab analysis

Parameters	Selection Criteria											Performance Confirmation Parameters		Preliminary Performance Confirmation Concepts
	Screen 1 (one must apply)				Screen 2 (one must apply)			Screen 3 (all must apply)			Screen 4			
	10 CFR 60 Sub-part F	Con- fine & Isolate Waste Funct.	Con- tain. & Isol. Stra- tegy	TSPA & PA process models	Sub- surface condi- tions	Affec- ted by const./ empla- cement	Time depend- ent vari- able	Can be mea- sured or derived	Can be pre- dicted or esti- mated	Import- ant to per- form- ance	Reduce uncer- tainty	All perf. conf. para- meters	Key para- meters for design	
Gaseous dispersion coefficient	X	X		X	X			X	X	X	X	X	X	Underground testing/sampling & off-site lab analysis
Thermal Characteristics of Rock Fracture Zones (Including Faults) of Altered Zone														
Rock temperature	X	X	X	X	X	X	X	X	X	X	X	X	X	Continuous surface-based & underground monitoring
Chemical Characteristics of Ground Water (In Rock Matrix, Fractures, Fault Zones, and Other Discontinuities)														
Altered zone chemical composition, Eh & pH	X	X	X	X	X	X	X	X	X	X	X	X	X	Surface-based & underground sampling & off-site lab analysis
Age (H-3, C-14, Cl-36)				X			X	X	X	X	X	X	X	
Hydraulic Characteristics of Ground Water (In Rock Matrix, Fractures, Fault Zones, and Other Discontinuities)														
In situ fluid potential	X	X	X	X		X	X	X	X	X	X	X	X	Continuous surface-based & underground monitoring
Altered zone moisture content	X	X	X	X	X	X	X	X	X	X	X	X	X	Continuous underground monitoring
Altered zone water vapor content/humidity	X	X	X	X	X	X	X	X	X	X	X	X	X	Continuous surface-based & underground monitoring
Thermal Characteristics of Ground Water (In Rock Matrix, Fractures, Fault Zones, and Other Discontinuities) of Altered Zone														
Fluid temperature	X	X	X	X	X	X	X	X	X	X	X	X	X	Continuous surface-based & underground monitoring
Pneumatic Characteristics of Subsurface Air and Gases (In Rock Matrix, Fractures, Fault Zones, and Other Discontinuities)														
Air pressure	X			X	X	X	X	X	X	X	X	X	X	Continuous surface-based & underground monitoring

[illegible]

Parameters	Selection Criteria											Performance Confirmation Parameters		Preliminary Performance Confirmation Concepts
	Screen 1 (one must apply)				Screen 2 (one must apply)			Screen 3 (all must apply)			Screen 4			
	10 CFR 60 Sub-part F	Con- fine & Isolate Waste Funct.	Con- tain. & Isol. Stra- tegy	TSPA & PA process models	Sub- surface condi- tions	Affec- ted by const./ empla- cement	Time depen- dent vari- able	Can be mea- sured or derived	Can be pre- dicted or esti- mated	Import- ant to per- form- ance	Reduce uncer- tainty	All perf. conf. para- meters	Key para- meters for design	
Hydrocarbons, Including Accidental Spills Remaining after Repository Closure (each type that may affect postclosure performance)														
Quantity remaining in rock		X		X		X	X	X	X	X	X	X	X	Periodic rock sampling at selected underground locations & off-site lab analyses
Chemical composition, incl. Eh & pH		X		X		X	X	X	X	X	X	X	X	
Concrete Remaining after Repository Closure														
Chemical composition/alteration		X		X		X	X	X	X	X	X	X	X	Periodic inspection & off-site lab analysis of samples
Steel Remaining after Repository Closure														
Chemical composition/alteration		X		X		X	X	X	X	X	X	X	X	Periodic inspection & off-site lab analysis of samples
Ground Support Remaining after Repository Closure														
Chemical composition/alteration		X		X		X	X	X	X	X	X	X	X	Periodic inspection & off-site lab analysis of specimens
Railcars Remaining after Repository Closure														
Chemical composition/alteration		X		X		X	X	X	X	X	X	X	X	Periodic inspection & off-site lab analysis of specimens
Other Fluids and Materials Remaining in Repository after Closure (each type that may affect postclosure performance)														
Chemical composition/alteration		X		X		X	X	X	X	X	X	X	X	Periodic inspection & off-site lab analysis of specimens or rock samples, as applicable

Parameters	Selection Criteria											Performance Confirmation Parameters		Preliminary Performance Confirmation Concepts	
	Screen 1 (one must apply)				Screen 2 (one must apply)			Screen 3 (all must apply)			Screen 4				
	10 CFR 60 Sub-part F	Con- fine & Isolate Waste Funct.	Con- tain. & Isol. Stra- tegy	TSPA & PA process models	Sub- surface condi- tions	Affec- ted by const./ empla- cement	Time depen- dent vari- able	Can be mea- sured or derived	Can be pre- dicted or esti- mated	Import- ant to per- form- ance	Reduce uncer- tainty	All perf. conf. para- meters	Key para- meters for design		
WASTE PACKAGE PARAMETERS															
Waste Form Characteristics (E.g., of Spent Fuel and Glass Defense High-Level Waste)															
Geometry/dimensions of waste form	X	X	X	X			X	X	X	X	X	X	X	On-site lab analyses of failed waste packages, if any, and of waste not emplaced	
Geometry/dimensions of waste pellets/particles	X	X	X	X			X	X	X	X	X	X	X		
Surface area of waste pellets or particles	X	X	X	X			X	X	X	X	X	X	X		
Weight & activity of each radionuclide		X	X	X			X	X	X	X	X	X	X		
Gas composition inside fuel element		X	X	X			X	X	X	X	X	X	X		
Geometry of Waste Package (Excluding Backfill)															
Corrosion effects on barrier thickness & shape		X	X	X		X	X	X	X	X	X	X	X	Periodic visual inspection, on-site lab analyses of pulled specimens & nonwaste packages	
Mechanical effects on barrier thickness & shape		X		X		X	X	X	X	X	X	X	X	Periodic visual inspection	
Location & geometry of criticality control materials		X		X			X	X	X	X	X	X	X	Nonwaste package off-site & pulled dummy waste package on-site lab analysis	
Corrosion and Other Degradation Characteristics of Each Waste Package Barrier (Excluding Backfill)															
Threshold humidity for humid-air corrosion			X	X			X	X	X	X	X	X	X	On-site lab analysis of pulled specimens & dummy waste packages	

Parameters	Selection Criteria											Performance Confirmation Parameters		Preliminary Performance Confirmation Concepts
	Screen 1 (one must apply)				Screen 2 (one must apply)			Screen 3 (all must apply)			Screen 4			
	10 CFR 60 Subpart F	Con- fine & Isolate Waste Funct.	Con- tain. & Isol. Strat- egy	TSPA & PA process models	Sub- surface condi- tions	Affec- ted by const./ empla- cement	Time depen- dent vari- able	Can be mea- sured or derived	Can be pre- dicted or esti- mated	Import- ant to per- form- ance	Reduce uncer- tainty	All perf. conf. para- meters	Key para- meters for design	
Dry oxidation corrosion rate		X	X	X		X		X	X	X	X	X	X	On-site lab analysis of pulled specimens & dummy waste packages
Humid-air general corrosion rate		X	X	X		X		X	X	X	X	X	X	
Aqueous general corrosion rate		X	X	X		X		X	X	X	X	X	X	
Humid-air pit corrosion rate		X	X	X		X		X	X	X	X	X	X	
Aqueous pit corrosion rate		X	X	X		X		X	X	X	X	X	X	
Microbial corrosion rate				X		X		X	X	X	X	X	X	On-site lab analysis of pulled waste packages
Cladding failure rate ¹		X		X		X		X	X	X	X	X	X	
Chemistry of Each Waste Package Barrier (Including Degradation Products but Excluding Backfill)														
Gas composition inside waste container		X	X	X			X	X	X	X	X	X	X	On-site lab analyses of failed waste packages, if any, and of waste not emplaced
Chemical composition of criticality control materials		X		X			X	X	X	X	X	X	X	Nonwaste package off-site & pulled dummy waste package on-site lab analysis
Oxidation product composition			X	X			X	X	X	X	X	X	X	
Aqueous corrosion product composition			X	X			X	X	X	X	X	X	X	

¹ Needed only if (a) credit will be taken for cladding performance or (b) its performance will adversely affect the performance of other engineered barrier system components.

Parameters	Selection Criteria											Performance Confirmation Parameters		Preliminary Performance Confirmation Concepts
	Screen 1 (one must apply)				Screen 2 (one must apply)			Screen 3 (all must apply)			Screen 4			
	10 CFR 60 Sub-part F	Con- fine & Isolate Waste Funct.	Con- tain. & Isol. Strat- egy	TSPA & PA process models	Sub- surface condi- tions	Affec- ted by const./ empla- cement	Time depen- dent vari- able	Can be mea- sured or derived	Can be pre- dicted or esti- mated	Import- ant to per- form- ance	Reduce uncer- tainty	All perf. conf. para- meters	Key para- meters for design	
Physical/chemical degree of embrittlement				X		X	X	X	X	X	X	X	X	Nonwaste package off-site & pulled dummy waste package on-site lab analysis
Physical/chemical weld integrity	X			X		X	X	X	X	X	X	X	X	
Mechanical Characteristics of Each Waste Package Barrier (Excluding Backfill)														
In situ stress		X		X		X	X	X	X	X	X	X	X	Nonwaste package off-site & pulled dummy waste package on-site lab analysis
Strain				X		X	X	X	X	X	X	X	X	
Thermal Characteristics of Each Waste Package Barrier (Excluding Backfill)														
Barrier wall temperature		X	X	X		X	X	X	X	X	X	X	X	In situ monitoring of selected waste packages in emplacement drifts & at underground test location
Waste Package Radionuclide Containment and Release for Each Waste Form, Package Design, and Important Radionuclide (see TSPA-1995 list at end of table)														
Waste package life or time of initial radionuclide release	X	X	X	X		X	X	X	X	X	X	X	X	Continuous radiation monitoring of excavation air
Radionuclide release rate from waste form	X	X	X	X		X	X	X	X	X	X	X	X	Remedial action if needed
Radionuclide release rate from waste package	X	X	X	X		X	X	X	X	X	X	X	X	

Abbreviations:

CFR = Code of Federal Regulations, ESF = Exploratory Studies Facility, PA = performance assessment, TSPA = total system performance assessment, WP = waste package.

TSPA-1995 Radionuclide List (for spent-fuel inventory):

Ac-227, Am-241, Am-242M, Am-243, C-14 (gaseous), Cl-36 (gaseous), Cm-244, Cm-245, Cm-246, Cs-135, I-129 (gaseous), Nb-93M, Nb-94, Ni-59, Ni-63, Np-237, Pa-231, Pb-210, Pd-107, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Ra-226, Ra-228, Se-79, Sm-151, Sn-126, Tc-99, Th-229, Th-230, Th-232, U-233, U-234, U-235, U-236, U-238, Zr-93.

This attachment explains the method for obtaining or calculating the values in Table 7.1.

4,400m ¹	The length of the Observation Drift Launch Main was determined from Figure 12 by approximating the distance utilizing the graphic scale.
30,000m ²	The observation drift lengths were approximated from Figure 12. Using the graphic scale, each observation drift is approximately 1,200 meters long. There are 25 observation drifts shown. $1,200\text{m} \times 25 = 30,000\text{m}$.
16,000m ³	The length of the longitudinal drift was estimated from Figure 13 using the graphic scale provided on that figure.
6,000m ⁴	The observation drifts on Figure 11 are estimated to be 1,200 meters long. That distance does not include the access ramps. Five drifts are shown. $5 \times 1,200\text{m} = 6,000\text{m}$.
6,000m ⁵	The observation drifts on Figure 14 are estimated to be 1,200 meters long. That distance does not include the access ramps. Five drifts are shown. $5 \times 1,200\text{m} = 6,000\text{m}$.
790m ⁶	See Figure 12. Launch chambers for TBMs are estimated to be 40 meters long (4.3.28.1). One launch chamber is needed for the Observation Drift Launch Main. Observation Drift Turnouts are assumed to be 30 meters long (4.3.28.3) and 25 are needed for the Observation Drifts. $(40 \times 1) + (25 \times 30) = 790\text{m}$.
70m ⁷	See Figure 13. Launch chambers for TBMs are estimated to be 40m (4.3.28.1). Recovery chambers are estimated to be 30m (4.3.28.2). One of each is shown on Figure 13. $40 + 30 = 70\text{m}$.
1,100m ⁸	See Figure 11. The access ramps must go up and over the ESF Main Drift. The ESF Main Drift is 7.62 meters (Ref. 5.12, pp 5). The distance between drifts will be 10 meters (4.3.26). Therefore, the ramp must climb $10 + 7.62 = 17.62$ meters. A reasonable slope is 8 percent (4.3.28.4). The length of each ramp is $17.62 / .08 = 220$. Five access ramps are shown. $5 \times 220 = 1,100\text{m}$.
1,100m ⁹	See Figure 14. The access ramps must go up and over the ESF Main Drift. The ESF Main Drift is 7.62 meters (Ref. 5.12, pp 5). The distance between drifts will be 10 meters (4.3.26). Therefore, the ramp must climb $10 + 7.62 = 17.62$ meters. A reasonable slope is 8 percent (4.3.28.4). The length of each ramp is $17.62 / .08 = 220$. Five access ramps are shown. $5 \times 220 = 1,100\text{m}$.

- 75m¹⁰ The ventilation cut-out at the center of the observation drift on Figure 3 is estimated to be 5 meters (4.3.28.6). A similar cut-out will be needed off the West Main at the end of each observation drift, see Figure 11, and is estimated to be 10 meters (4.3.28.7). Therefore, each observation drift requires 15 meters of vent cut-outs, see ¹⁷ below. Figure 11 has 5 observation drifts. $5 \times 15 = 75$ meters.
- 75m¹¹ The ventilation cut-out at the center of the observation drift on Figure 15 is estimated to be 5 meters (4.3.28.6). A similar cut-out will be needed off the West Main at the end of each observation drift, see Figure 14, and is estimated to be 10 meters (4.3.28.7). Therefore, each observation drift requires 15 meters of vent cut-outs, see ¹⁷ below. Figure 14 has 5 observation drifts. $5 \times 15 = 75$ meters.
- 375m¹² The ventilation cut-out at the center of the observation drift on Figure 3 is estimated to be 5 meters (4.3.28.6). A similar cut-out will be needed off the West Main at the end of each observation drift, see Figure 12, and is estimated to be 10 meters (4.3.28.7). Therefore, each observation drift requires 15 meters of vent cut-outs, see ¹⁷ below. Figure 12 has 25 observation drifts. $15 \times 25 = 375$ meters.
- 1,600m¹³ Three ventilation cross-cuts are shown on Figure 13. Using the graphic scale on the figure these cross-cuts are estimated to be 600, 600 and 400 meters long. $600\text{m} + 600\text{m} + 400\text{m} = 1,600\text{m}$.
- 2,000m¹⁴ On Figure 3 the Longhole Drilling Alcove is estimated to be 45 meters long. That is based on an emplacement drift spacing of 22.5 meter (4.3.22) and the alcove spans two full emplacement drift spacings. $22.5 \times 2 = 45$ meters. However, the observation drift width of 4.5 meters (4.3.24) has already been excavated, therefore, the alcove excavation length is $45 - 4.5 = 40.5$. The value is rounded to 40m. Observation drifts in Figure 11 are 1,200 meters. If Longhole Drilling Alcoves (Figure 3) are spaced every 100 meters (4.3.24) and if a drilling alcove is not included at the center point over the Exhaust Main, as illustrated below, 10 drilling alcoves are needed per 1,200m drift. $10 \times 40 = 400$ meters per observation drift. Five observation drifts are shown on Figure 11. $5 \times 400\text{m} = 2,000\text{m}$.

3,250m¹⁵ The Borehole Alcove shown on Figure 15 is estimated to be 250 meters long by using the graphic scale. The alcove is assumed to be widened to twice the width of the observation drift. Therefore, each alcove essentially amounts to an additional 250 meters of drift excavation. There are 13 alcoves shown on Figure 14. $13 \times 250 = 3,250\text{m}$.

10,000m¹⁶ As discussed in ¹⁴, each observation drift requires 400 meters of alcove drifting. Figure 11 shows 25 observation drifts. $25 \times 400 = 10,000\text{m}$.

180m¹⁷ Each observation drift will require a ventilation raise to the Exhaust Main and a ventilation raise to the West Main, see Figure 3. The Exhaust Main raise is 25.5 meters. The West Main raise is 10 meters. $25.5 + 10 = 35.5$ meters of raise per observation drift. Figure 11 shows five observation drifts. $5 \times 35.5 = 177.5\text{m}$. This value is rounded to 180m.

180m¹⁸ Each observation drift will require a ventilation raise to the Exhaust Main and a ventilation raise to the West Main, see Figures 14 and 15. The Exhaust Main raise is 25.5 meters. The West Main raise is 10 meters. $25.5 + 10 = 35.5$ meters of raise per observation drift. Figure 14 shows five observation drifts. $5 \times 35.5 = 177.5\text{m}$. This value is rounded to 180m.

890m¹⁹ Each observation drift will require a ventilation raise to the Exhaust Main and a ventilation raise to the West Main, see Figure 12. The Exhaust Main raise is 25.5 meters. The West Main raise is 10 meters. $25.5 + 10 = 35.5$ meters of raise per observation drift. Figure 12 shows 25 observation drifts. $25 \times 35.5 = 887.5\text{m}$. This value is rounded to 890m.

80m²⁰ There are three ventilation drifts on Figure 13. Each will require a 25.5 meter raise to the Exhaust Main. $3 \times 25.5 = 76.5$. Value is rounded to 80m.

6,000m²¹ One hole will be drilled from each Longhole Drilling Alcove to each emplacement drift, see Figure 3. Using simple trigonometry, the holes are 35m, 15m and 10m long in each half. The total hole length for each alcove is $35+35+15+15+10+10 = 120$ m. Each drift in Figure 11 will have 10 drilling alcoves as shown in ¹⁴. Therefore, total borehole length for each drift is $10 \times 120 = 1,200$ m/observation drift. Figure 11 has 5 drifts, therefore total borehole length is $1,200 \times 5 = 6,000$ m.

14,820m²² A total of seven boreholes will be drilled to each emplacement drift from each Drilling Location as shown on Figure 15. They will be 10m, 17m, 30m and 43m (4.3.28.5) as illustrated below, totaling $10+17+17+30+30+43+43=190$ m. Each Borehole Alcove will have 6 Drilling Locations as shown on Figure 15. $6 \times 190 = 1,140$ m. Figure 14 shows 13 total Borehole Alcoves. $13 \times 1,140\text{m} = 14,820\text{m}$

30,000m²³ As noted above in ²¹, a total of 1,200 meters of borehole will be drilled from each observation drift. Figure 12 shows 25 observation drifts. $25 \times 1,200 = 30,000$ m.

54,340m²⁴ Each time the Observation Drift in Figure 13 crosses an emplacement drift, seven (7) boreholes will be drilled. The total length will be 10+17+17+30+30+43+43= 190m (4.3.28.5). Each emplacement drift will be crossed twice. 2 x 190 = 380m/emplacement drift. There will be 143 (4.3.21) loaded emplacement drifts. 380 x 143=54,340.

This attachment shows how the Convective Heat Transfer Coefficient is determined for 5 and 10 cubic meters/second ventilation rates. Boxed values are input. All other values are calculated.

5 Cubic Meters / Second Ventilation Rate

Air Quantity:	5	cubic meters/sec.	(4.3.25)
Diameter (D):	4.5	meters	(4.3.24)
Area:	15.9043	square meters	calculated - $(\pi \cdot D \cdot D / 4)$
	15.90	square meters	input value
Velocity:	0.3145	meters/sec	calculated - (quantity/area)
Density:	1.182108	kg/cubic meter	(4.3.25)
Prandtl Number:	0.70828		(4.3.25)
Dynamic Viscosity:	1.841256E-05	kg/meter-sec	(4.3.25)
Thermal Conductivity:	0.0261606	W/m - degree C	(4.3.25)

Reynold's Number calculation:

$$\text{Reynolds Number} = (\text{density} \times \text{velocity} \times \text{diameter}) / (\text{dynamic viscosity}) \quad (\text{Ref. 5.20, Inside Front Cover, Basic Heat Transfer Relations})$$

$$\text{RE} = 90,850.720$$

Nusselt number calculation:

$$\text{Nusselt Number} = (.023) \times (\text{Reynolds number})^{.8} \times (\text{Prandtl number})^{.4} \quad (\text{Ref. 5.20, page 274, equation 6-4, } n = .4 \text{ for heating, see top of page 275})$$

$$\text{Nusselt Number} = 185.554943$$

Convective Heat Transfer Coefficient is Calculated last:

$$\text{Convective Heat Transfer Coefficient} = (\text{Nusselt Number}) \times (\text{Thermal Conductivity}) / (\text{diameter})$$

$$\text{Convective Heat Transfer Coefficient} = \underline{\underline{1.0787}} \text{ W/m}^2 \text{ - K} \quad (\text{Ref. 5.20, page 250, derived from equation 5-107})$$

For 5 cubic Meter Case

10 Cubic Meters / Second Ventilation Rate

Air Quantity:	10	cubic meters/sec.	(4.3.25)
Velocity:	0.6289	meters/sec	calculated - (quantity/area)

Reynold's number calculation:

$$\text{Reynolds Number} = (\text{density} \times \text{velocity} \times \text{diameter}) / (\text{dynamic viscosity}) \quad (\text{Ref. 5.20, Inside Front Cover, Basic Heat Transfer Relations})$$

$$\text{RE} = 181701.441$$

Next the Nusselt number is calculated:

$$\text{Nusselt Number} = (.023) \times (\text{Reynolds number})^{.8} \times (\text{Prandtl number})^{.4} \quad (\text{Ref. 5.20, page 274, equation 6-4, } n = .4 \text{ for heating, see top of page 275})$$

$$\text{Nusselt Number} = 323.06992$$

Convective Heat Transfer Coefficient is Calculated last:

$$\text{Convective Heat Transfer Coefficient} = (\text{Nusselt Number}) \times (\text{Thermal Conductivity}) / (\text{diameter})$$

$$\text{Convective Heat Transfer Coefficient} = \underline{\underline{1.8782}} \text{ W/m}^2 \text{ - K} \quad (\text{Ref. 5.20, page 250, derived from equation 5-107})$$

For 10 cubic Meter Case

Convective Heat Area Calculation:

Drift Diameter, (D):	4.5	(4.3.24)
Drift Segment Length, (L):	100	(4.3.24)
Convective Heat Area:	1,413.72	square meters $(\pi \cdot D) \cdot (L)$

This assumed waste stream (4.3.30) is used to calculate the average spacing of waste packages.
The waste stream utilizes the 21-PWR package only.

	A	B	<u>A x B</u>
	(CDA, Key 003)	(CDA, Key 004)	
	Number of	Average	Annual
	Packages	MTU per pk	MTU
<u>Year</u>	<u>(21-PWR)</u>	<u>(21-PWR)</u>	<u>(21-PWR)</u>
2010	21	9.28	194.88
2011	40	9.03	361.20
2012	74	8.94	661.56
2013	134	9.00	1,206.00
2014	211	8.96	1,890.56
2015	186	8.98	1,670.28
2016	203	9.05	1,837.15
2017	190	8.91	1,692.90
2018	189	8.94	1,689.66
2019	179	9.04	1,618.16
2020	186	9.02	1,677.72
2021	193	9.05	1,746.65
2022	167	9.06	1,513.02
2023	197	8.95	1,763.15
2024	155	9.03	1,399.65
2025	177	8.94	1,582.38
2026	185	8.42	1,557.70
2027	205	8.68	1,779.40
2028	204	8.92	1,819.68
2029	208	9.09	1,890.72
2030	214	8.82	1,887.48
2031	234	8.97	2,098.98
2032	224	9.00	2,016.00
2033	161	9.00	1,449.00
Total packages:	4,137	Total MTU:	37,003.88

The average MTU per package is, therefore, $37,003.88 \div 4,137 = 8.94$ MTU/Package

To calculate the average spacing the following values are used:

4,047 m²/ acre (constant) Thermal Load: 85 MTU / acre (4.3.22)
8.94 MTU/ package (from above) Drift Spacing: 22.5 m (4.3.22)

4,047 m²/ acre x 8.94 MTU/ package = **18.92 m / package**
85 MTU/acre x 22.5 m

The total heat output decay rate (4.3.30) is assumed to be as listed in column **B** below. The value in column **C** is calculated from the value in column **B** by dividing the total heat output by the total number of packages.

For example, at year 10, $\frac{30.536741 \text{ MW} * 1000 \text{ kW}}{4137 \text{ packages MW package}} = 7.381373 \text{ kW}$

The input to the ANSYS program is column **D**. It is calculated from the waste package surface area and then multiplied by the number of seconds in a year. The calculation assumes that the waste package is 18.92 meters long and that its heat output is spread over that area. The waste packages will be closer to 5 meters long, but for the purposes of this analysis, spreading the heat over a longer distance will not affect the heat flux at the observation drift.

The calculation also involves converting the energy-time units from kilowatts to joules.

Area: $(\pi * 1.85) * 18.92 = 109.962026 \text{ m}^2/\text{package}$
Seconds per year: $(365 * 24 * 60 * 60) = 31,536,000 \text{ sec/year}$
1,000 joules/sec = 1 kW

For Example:

At year 10: $\frac{(7.381373 \text{ kW package} * 31,536,000 \text{ sec} * 1000 \text{ joules})}{\text{package } 109.962026 \text{ m}^2 \text{ year kW sec}}$

 $= 2.1169 \times 10^9 \text{ joules/year - meter}^2$

A Year	B Total Heat from 4137, 21-PWR Pkgs (Ref. 5.28) (MW)	C Heat Output Per Waste Package (Average)	D Ave Heat Flux Over the WP Side-Surf (J/Yr-m ²)
0	37.436260	9.049132	2.5952e+09
1	36.479542	8.817873	2.5289e+09
5	33.491405	8.095578	2.3217e+09
10	30.536741	7.381373	2.1169e+09
20	25.862371	6.251480	1.7929e+09
30	22.215593	5.369977	1.5401e+09
40	19.329458	4.672337	1.3400e+09
50	16.991320	4.107160	1.1779e+09
60	15.112725	3.653064	1.0477e+09
70	13.588046	3.284517	9.4197e+08
80	12.335578	2.981769	8.5514e+08
100	10.456422	2.527537	7.2487e+08
150	7.878865	1.904488	5.4619e+08

ATTACHMENT V

Calculation of Ventilating Air Temperature at Intermediate Steps

**V.1 Worksheets for Calculation of Ventilating Air
Temperature for Air Quantity of 5 m³/sec Case**

DRIFT SEGMENT # 1 (0 - 100 m)

Sheet: A

Air Quantity (Q)	5	m ³ /s	PCOD Distance	20	meters
Thermal Load	85	MTU/acre	Drift Spacing	22.5	meters
			WP Spacing	18.92	meters
Effective D.L.	600	meters	Segment D.L.	100	meters
Conv. Coef. (h)	1.0787	W/m ² -K	Segment No.	1	
Air Density (rho)	1.1821	kg/m ³	Drift Diameter	4.5	meters
Specific Heat (c)	1.0057	kJ/kg-K	Conv. Area (A)	1413.72	m ²

NOTE: Tin=Intake air temperature; Tw=Average drift wall temperature; Tout=Exit air temperature; D.L.=Drift length

Time Step 3	Tin =	26.00	deg. C							
(0-1 yr)	Tw =	26.00	deg. C							
	delta q =	(A)(h)*(Tw-Tin)		1524.98	*	0.00	=	0.00		kW
	Tout =	Tin+(delta q)/(Q*rho*c)		26.00	+	0.00	=	26.00		deg. C

Time Step 4	Tin =	26.00	deg. C							
(1-5 yr)	Tw =	28.34	deg. C							
	delta q =	(A)(h)*(Tw-Tin)		1524.98	*	2.34	=	3.57		kW
	Tout =	Tin+(delta q)/(Q*rho*c)		26.00	+	0.60	=	26.60		deg. C

Time Step 5	Tin =	26.00	deg. C							
(5-10 yr)	Tw =	31.98	deg. C							
	delta q =	(A)(h)*(Tw-Tin)		1524.98	*	5.98	=	9.12		kW
	Tout =	Tin+(delta q)/(Q*rho*c)		26.00	+	1.53	=	27.53		deg. C

Time Step 6	Tin =	26.00	deg. C							
(10-20 yr)	Tw =	36.23	deg. C							
	delta q =	(A)(h)*(Tw-Tin)		1524.98	*	10.23	=	15.60		kW
	Tout =	Tin+(delta q)/(Q*rho*c)		26.00	+	2.62	=	28.62		deg. C

Time Step 7	Tin =	26.00	deg. C							
(20-30 yr)	Tw =	38.51	deg. C							
	delta q =	(A)(h)*(Tw-Tin)		1524.98	*	12.51	=	19.08		kW
	Tout =	Tin+(delta q)/(Q*rho*c)		26.00	+	3.21	=	29.21		deg. C

Time Step 8	Tin =	26.00	deg. C							
(30-40 yr)	Tw =	40.04	deg. C							
	delta q =	(A)(h)*(Tw-Tin)		1524.98	*	14.04	=	21.41		kW
	Tout =	Tin+(delta q)/(Q*rho*c)		26.00	+	3.60	=	29.60		deg. C

Time Step 9	Tin =	26.00	deg. C							
(40-50 yr)	Tw =	41.12	deg. C							
	delta q =	(A)(h)*(Tw-Tin)		1524.98	*	15.12	=	23.06		kW
	Tout =	Tin+(delta q)/(Q*rho*c)		26.00	+	3.88	=	29.88		deg. C

Time Step 10	Tin =	26.00	deg. C							
(50-60 yr)	Tw =	41.88	deg. C							
	delta q =	(A)(h)*(Tw-Tin)		1524.98	*	15.88	=	24.22		kW
	Tout =	Tin+(delta q)/(Q*rho*c)		26.00	+	4.07	=	30.07		deg. C

Time Step 11	Tin =	26.00	deg. C							
(60-70 yr)	Tw =	42.38	deg. C							
	delta q =	(A)(h)*(Tw-Tin)		1524.98	*	16.38	=	24.98		kW
	Tout =	Tin+(delta q)/(Q*rho*c)		26.00	+	4.20	=	30.20		deg. C

Time Step 12	Tin =	26.00	deg. C							
(70-80 yr)	Tw =	42.72	deg. C							
	delta q =	(A)(h)*(Tw-Tin)		1524.98	*	16.72	=	25.50		kW
	Tout =	Tin+(delta q)/(Q*rho*c)		26.00	+	4.29	=	30.29		deg. C

Time Step 13	Tin =	26.00	deg. C							
(80-100 yr)	Tw =	43.09	deg. C							
	delta q =	(A)(h)*(Tw-Tin)		1524.98	*	17.09	=	26.06		kW
	Tout =	Tin+(delta q)/(Q*rho*c)		26.00	+	4.38	=	30.38		deg. C

Time Step 14	Tin =	26.00	deg. C							
(100-150 yr)	Tw =	43.24	deg. C							
	delta q =	(A)(h)*(Tw-Tin)		1524.98	*	17.24	=	26.29		kW
	Tout =	Tin+(delta q)/(Q*rho*c)		26.00	+	4.42	=	30.42		deg. C

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Attachment V

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DRIFT SEGMENT # 2 (100 - 200 m)

Sheet B

Air Quantity (Q)	5	m ³ /s	PCOD Distance	20	meters
Thermal Load	85	MTU/acre	Drift Spacing	22.5	meters
			WP Spacing	18.92	meters
Effective D.L.	600	meters	Segment D.L.	100	meters
Conv. Coef. (h)	1.0787	W/m ² -K	Segment No.	2	
Air Density (rho)	1.1821	kg/m ³	Drift Diameter	4.5	meters
Specific Heat (c)	1.0057	kJ/kg-K	Conv. Area (A)	1413.72	m ²

NOTE: Tin=Intake air temperature; Tw=Average drift wall temperature; Tout=Exit air temperature; D.L.=Drift length

Time Step 3 (0-1 yr)	Tin = 26.00 deg. C Tw = 26.00 deg. C delta q = (A)(h)*(Tw-Tin) = 1524.98 Tout = Tin+(delta q)/(Q*rho*c) = 26.00	*	0.00	=	0.00	kW
		+	0.00	=	26.00	deg. C
Time Step 4 (1-5 yr)	Tin = 26.60 deg. C Tw = 26.73 deg. C delta q = (A)(h)*(Tw-Tin) = 1524.98 Tout = Tin+(delta q)/(Q*rho*c) = 26.60	*	2.13	=	3.25	kW
		+	0.55	=	27.15	deg. C
Time Step 5 (5-10 yr)	Tin = 27.53 deg. C Tw = 33.05 deg. C delta q = (A)(h)*(Tw-Tin) = 1524.98 Tout = Tin+(delta q)/(Q*rho*c) = 27.53	*	5.52	=	8.42	kW
		+	1.42	=	28.95	deg. C
Time Step 6 (10-20 yr)	Tin = 28.62 deg. C Tw = 38.15 deg. C delta q = (A)(h)*(Tw-Tin) = 1524.98 Tout = Tin+(delta q)/(Q*rho*c) = 28.62	*	9.53	=	14.53	kW
		+	2.44	=	31.06	deg. C
Time Step 7 (20-30 yr)	Tin = 29.21 deg. C Tw = 40.93 deg. C delta q = (A)(h)*(Tw-Tin) = 1524.98 Tout = Tin+(delta q)/(Q*rho*c) = 29.21	*	11.72	=	17.87	kW
		+	3.01	=	32.22	deg. C
Time Step 8 (30-40 yr)	Tin = 29.60 deg. C Tw = 42.78 deg. C delta q = (A)(h)*(Tw-Tin) = 1524.98 Tout = Tin+(delta q)/(Q*rho*c) = 29.60	*	13.18	=	20.10	kW
		+	3.38	=	32.98	deg. C
Time Step 9 (40-50 yr)	Tin = 29.88 deg. C Tw = 44.11 deg. C delta q = (A)(h)*(Tw-Tin) = 1524.98 Tout = Tin+(delta q)/(Q*rho*c) = 29.88	*	14.23	=	21.70	kW
		+	3.65	=	33.53	deg. C
Time Step 10 (50-60 yr)	Tin = 30.07 deg. C Tw = 45.03 deg. C delta q = (A)(h)*(Tw-Tin) = 1524.98 Tout = Tin+(delta q)/(Q*rho*c) = 30.07	*	14.96	=	22.81	kW
		+	3.84	=	33.91	deg. C
Time Step 11 (60-70 yr)	Tin = 30.20 deg. C Tw = 45.66 deg. C delta q = (A)(h)*(Tw-Tin) = 1524.98 Tout = Tin+(delta q)/(Q*rho*c) = 30.20	*	15.46	=	23.58	kW
		+	3.97	=	34.17	deg. C
Time Step 12 (70-80 yr)	Tin = 30.29 deg. C Tw = 46.09 deg. C delta q = (A)(h)*(Tw-Tin) = 1524.98 Tout = Tin+(delta q)/(Q*rho*c) = 30.29	*	15.80	=	24.09	kW
		+	4.05	=	34.34	deg. C
Time Step 13 (80-100 yr)	Tin = 30.38 deg. C Tw = 46.56 deg. C delta q = (A)(h)*(Tw-Tin) = 1524.98 Tout = Tin+(delta q)/(Q*rho*c) = 30.38	*	16.18	=	24.67	kW
		+	4.15	=	34.53	deg. C
Time Step 14 (100-150 yr)	Tin = 30.42 deg. C Tw = 46.80 deg. C delta q = (A)(h)*(Tw-Tin) = 1524.98 Tout = Tin+(delta q)/(Q*rho*c) = 30.42	*	16.38	=	24.98	kW
		+	4.20	=	34.62	deg. C

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Attachment V

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DRIFT SEGMENT # 3 (200 - 300 m)

Sheet C

Air Quantity (Q)	5	m ³ /s	PCOD Distance	20	meters
Thermal Load	85	MTU/acre	Drift Spacing	22.5	meters
			WP Spacing	18.92	meters
Effective D.L.	600	meters	Segment D.L.	100	meters
Conv. Coef. (h)	1.0787	W/m ² -K	Segment No.	3	
Air Density (rho)	1.1821	kg/m ³	Drift Diameter	4.5	meters
Specific Heat (c)	1.0057	kJ/kg-K	Conv. Area (A)	1413.72	m ²

NOTE: T_{in}=Intake air temperature; T_w=Average drift wall temperature; T_{out}=Exit air temperature; D.L.=Drift length

Time Step 3 (0-1 yr)	T _{in} = 26.00 deg. C T _w = 26.00 deg. C	delta q = (A)(h)*(T _w -T _{in}) = 1524.98	*	0.00	= 0.00 kW
	T _{out} = T _{in} +(delta q)/(Q*rho*c) = 26.00		+	0.00	= 26.00 deg. C
Time Step 4 (1-5 yr)	T _{in} = 27.15 deg. C T _w = 29.10 deg. C	delta q = (A)(h)*(T _w -T _{in}) = 1524.98	*	1.95	= 2.97 kW
	T _{out} = T _{in} +(delta q)/(Q*rho*c) = 27.15		+	0.50	= 27.65 deg. C
Time Step 5 (5-10 yr)	T _{in} = 28.95 deg. C T _w = 34.04 deg. C	delta q = (A)(h)*(T _w -T _{in}) = 1524.98	*	5.09	= 7.76 kW
	T _{out} = T _{in} +(delta q)/(Q*rho*c) = 28.95		+	1.31	= 30.26 deg. C
Time Step 6 (10-20 yr)	T _{in} = 31.06 deg. C T _w = 39.94 deg. C	delta q = (A)(h)*(T _w -T _{in}) = 1524.98	*	8.88	= 13.54 kW
	T _{out} = T _{in} +(delta q)/(Q*rho*c) = 31.06		+	2.28	= 33.34 deg. C
Time Step 7 (20-30 yr)	T _{in} = 32.22 deg. C T _w = 43.19 deg. C	delta q = (A)(h)*(T _w -T _{in}) = 1524.98	*	10.97	= 16.73 kW
	T _{out} = T _{in} +(delta q)/(Q*rho*c) = 32.22		+	2.81	= 35.03 deg. C
Time Step 8 (30-40 yr)	T _{in} = 32.98 deg. C T _w = 45.35 deg. C	delta q = (A)(h)*(T _w -T _{in}) = 1524.98	*	12.37	= 18.86 kW
	T _{out} = T _{in} +(delta q)/(Q*rho*c) = 32.98		+	3.17	= 36.15 deg. C
Time Step 9 (40-50 yr)	T _{in} = 33.53 deg. C T _w = 46.91 deg. C	delta q = (A)(h)*(T _w -T _{in}) = 1524.98	*	13.38	= 20.40 kW
	T _{out} = T _{in} +(delta q)/(Q*rho*c) = 33.53		+	3.43	= 36.96 deg. C
Time Step 10 (50-60 yr)	T _{in} = 33.91 deg. C T _w = 48.00 deg. C	delta q = (A)(h)*(T _w -T _{in}) = 1524.98	*	14.09	= 21.49 kW
	T _{out} = T _{in} +(delta q)/(Q*rho*c) = 33.91		+	3.61	= 37.52 deg. C
Time Step 11 (60-70 yr)	T _{in} = 34.17 deg. C T _w = 48.75 deg. C	delta q = (A)(h)*(T _w -T _{in}) = 1524.98	*	14.58	= 22.23 kW
	T _{out} = T _{in} +(delta q)/(Q*rho*c) = 34.17		+	3.74	= 37.91 deg. C
Time Step 12 (70-80 yr)	T _{in} = 34.34 deg. C T _w = 49.26 deg. C	delta q = (A)(h)*(T _w -T _{in}) = 1524.98	*	14.92	= 22.75 kW
	T _{out} = T _{in} +(delta q)/(Q*rho*c) = 34.34		+	3.83	= 38.17 deg. C
Time Step 13 (80-100 yr)	T _{in} = 34.53 deg. C T _w = 49.84 deg. C	delta q = (A)(h)*(T _w -T _{in}) = 1524.98	*	15.31	= 23.35 kW
	T _{out} = T _{in} +(delta q)/(Q*rho*c) = 34.53		+	3.93	= 38.46 deg. C
Time Step 14 (100-150 yr)	T _{in} = 34.62 deg. C T _w = 50.18 deg. C	delta q = (A)(h)*(T _w -T _{in}) = 1524.98	*	15.56	= 23.73 kW
	T _{out} = T _{in} +(delta q)/(Q*rho*c) = 34.62		+	3.99	= 38.61 deg. C

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Attachment V

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Sheet D

Air Quantity (Q)	5	m ³ /s	PCOD Distance	20	meters
Thermal Load	85	MTU/acre	Drift Spacing	22.5	meters
			WP Spacing	18.92	meters
Effective D.L.	600	meters	Segment D.L.	100	meters
Conv. Coef. (h)	1.0787	W/m ² -K	Segment No.	4	
Air Density (rho)	1.1821	kg/m ³	Drift Diameter	4.5	meters
Specific Heat (c)	1.0057	kJ/kg-K	Conv. Area (A)	1413.72	m ²

NOTE: T_{in} =Intake air temperature; T_w =Average drift wall temperature; T_{out} =Exit air temperature; D.L.=Drift length

Time Step 3	T _{in} =	26.00	deg. C						
(0-1 yr)	T _w =	26.00	deg. C						
	delta q =	(A)(h)*(T _w -T _{in})	=	1524.98	*	0.00	=	0.00	kW
	T _{out} =	T _{in} +(delta q)/(Q*rho*c)	=	26.00	+	0.00	=	26.00	deg. C

Time Step 4	T _{in} =	27.65	deg. C						
(1-5 yr)	T _w =	29.42	deg. C						
	delta q =	(A)(h)*(T _w - T _{in})	=	1524.98	*	1.77	=	2.70	kW
	T _{out} =	T _{in} + (delta q)/(Q*rho*c)	=	27.65	+	0.45	=	28.10	deg. C

Time Step 5	T _{in} =	30.26	deg. C						
(5-10 yr)	T _w =	34.95	deg. C						
	delta q =	(A)(h)*(T _w - T _{in})	=	1524.88	*	4.69	=	7.15	kW
	T _{out} =	T _{in} + (delta q)/(Q*rho*c)	=	30.26	+	1.20	=	31.46	deg. C

Time Step 6	T _{in} =	33.34	deg. C						
(10-20 yr)	T _w =	41.61	deg. C						
	delta q =	(A)(h)*(T _w - T _{in})	=	1524.98	*	8.27	=	12.61	kW
	T _{out} =	T _{in} + (delta q)/(Q*rho*c)	=	33.34	+	2.12	=	35.46	deg. C

Time Step 7	T _{in} =	35.03	deg. C					
(20-30 yr)	T _w =	45.30	deg. C					
	della q =	(A)(h)*(T _w -T _{in})	=	1524.98	*	10.27	=	15.66 kW
	T _{out} =	T _{in} +(della q)/(Q*rho*c)	=	35.03	+	2.63	=	37.66 deg. C

Time Step 8 (30-40 yr)	Tin =	<input type="text" value="36.15"/>	deg. C						
	Tw =	<input type="text" value="47.76"/>	deg. C						
	della q =	(A)(h)*(Tw -Tin)	=	1524.98	*	11.61	=	17.70	kW
	Tout =	Tin+(della q)/(Q*rho*c)	=	36.15	+	2.98	=	<input type="text" value="39.13"/>	deg. C

Time Step 9	T _{in} =	36.96	deg. C						
(40-50 yr)	T _w =	49.54	deg. C						
	della q =	(A)(h)*(T _w -T _{in})	=	1524.98	*	12.58	=	19.18	kW
	T _{out} =	T _{in} +(della q)/(Q*rho*c)	=	36.96	+	3.23	=	40.19	deg. C

Time Step 10	T _{in} =	37.52	deg. C						
(50-60 yr)	T _w =	50.79	deg. C						
	delta q =	(A)(h)*(T _w - T _{in})	=	1524.98	*	13.27	=	20.24	kW
	T _{out} =	T _{in} + (delta q)/(Q*rho*c)	=	37.52	+	3.40	=	40.92	deg. C

Time Step 11	Tin =	37.91	deg. C						
(60-70 yr)	Tw =	51.66	deg. C						
	delta q =	(A)(h)*(Tw-Tin)	=	1524.98	*	13.75	=	20.97	kW
	Tout =	Tin+(delta q)/(Q*rho*c)	=	37.91	+	3.53	=	41.44	deg. C

Time Step 12	Tin =	38.17	deg. C						
(70-80 yr)	Tw =	52.26	deg. C						
	delta q =	(A)(h) ³ (Tw-Tin)	=	1524.98	*	14.09	=	21.49	kW
	Tout =	Tin+(delta q)/(Q*rho*c)	=	38.17	+	3.61	=	41.78	deg. C

Time Step 13	Tin =	38.46	deg. C						
(80-100 yr)	Tw =	52.94	deg. C						
	delta q =	(A)(h) ³ (Tw - Tin)	=	1524.98	*	14.48	=	22.08	kW
	Tout =	Tin + (delta q)/(Q*rho*c)	=	38.46	+	3.71	=	42.17	deg. C

Time Step 14 (100-150 yr)	T _{in} =	38.61	deg. C					
	T _w =	53.39	deg. C					
	delta q =	(A)(h)*(T _w -T _{in})	=	1524.98	*	14.78	=	22.54 kW
	T _{out} =	T _{in} +(delta q)/(Q*rho*c)	=	38.61	+	3.79	=	42.40 deg. C

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Attachment V

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DRIFT SEGMENT # 5 (400 - 500 m)

Sheet E

Air Quantity (Q)	5	m ³ /s	PCOD Distance	20	meters
Thermal Load	85	MTU/acre	Drift Spacing	22.5	meters
			WP Spacing	18.92	meters
Effective D.L.	600	meters	Segment D.L.	100	meters
Conv. Coef. (h)	1.0787	W/m ² -K	Segment No.	5	
Air Density (rho)	1.1821	kg/m ³	Drift Diameter	4.5	meters
Specific Heat (c)	1.0057	kJ/kg-K	Conv. Area (A)	1413.72	m ²

NOTE: Tin=Intake air temperature; Tw=Average drift wall temperature; Tout=Exit air temperature; D.L.=Drift length

Time Step 3 (0-1 yr)	Tin =	26.00	deg. C						
	Tw =	26.00	deg. C						
	delta q =	(A)(h)*(Tw-Tin)	=	1524.98	*	0.00	=	0.00	kW
	Tout =	Tin+(delta q)/(Q*rho*c)	=	26.00	+	0.00	=	26.00	deg. C

Time Step 4 (1-5 yr)	Tin =	28.10	deg. C						
	Tw =	29.72	deg. C						
	delta q =	(A)(h)*(Tw-Tin)	=	1524.98	*	1.62	=	2.47	kW
	Tout =	Tin+(delta q)/(Q*rho*c)	=	28.10	+	0.42	=	28.52	deg. C

Time Step 5 (5-10 yr)	Tin =	31.46	deg. C						
	Tw =	35.78	deg. C						
	delta q =	(A)(h)*(Tw-Tin)	=	1524.98	*	4.32	=	6.59	kW
	Tout =	Tin+(delta q)/(Q*rho*c)	=	31.46	+	1.11	=	32.57	deg. C

Time Step 6 (10-20 yr)	Tin =	35.46	deg. C						
	Tw =	43.17	deg. C						
	delta q =	(A)(h)*(Tw-Tin)	=	1524.98	*	7.71	=	11.76	kW
	Tout =	Tin+(delta q)/(Q*rho*c)	=	35.46	+	1.98	=	37.44	deg. C

Time Step 7 (20-30 yr)	Tin =	37.66	deg. C						
	Tw =	47.27	deg. C						
	delta q =	(A)(h)*(Tw-Tin)	=	1524.98	*	9.61	=	14.66	kW
	Tout =	Tin+(delta q)/(Q*rho*c)	=	37.66	+	2.47	=	40.13	deg. C

Time Step 8 (30-40 yr)	Tin =	39.13	deg. C						
	Tw =	50.02	deg. C						
	delta q =	(A)(h)*(Tw-Tin)	=	1524.98	*	10.89	=	16.61	kW
	Tout =	Tin+(delta q)/(Q*rho*c)	=	39.13	+	2.79	=	41.92	deg. C

Time Step 9 (40-50 yr)	Tin =	40.19	deg. C						
	Tw =	52.02	deg. C						
	delta q =	(A)(h)*(Tw-Tin)	=	1524.98	*	11.83	=	18.04	kW
	Tout =	Tin+(delta q)/(Q*rho*c)	=	40.19	+	3.03	=	43.22	deg. C

Time Step 10 (50-60 yr)	Tin =	40.92	deg. C						
	Tw =	53.42	deg. C						
	delta q =	(A)(h)*(Tw-Tin)	=	1524.98	*	12.50	=	19.06	kW
	Tout =	Tin+(delta q)/(Q*rho*c)	=	40.92	+	3.21	=	44.13	deg. C

Time Step 11 (60-70 yr)	Tin =	41.44	deg. C						
	Tw =	54.41	deg. C						
	delta q =	(A)(h)*(Tw-Tin)	=	1524.98	*	12.97	=	19.78	kW
	Tout =	Tin+(delta q)/(Q*rho*c)	=	41.44	+	3.33	=	44.77	deg. C

Time Step 12 (70-80 yr)	Tin =	41.78	deg. C						
	Tw =	55.08	deg. C						
	delta q =	(A)(h)*(Tw-Tin)	=	1524.98	*	13.30	=	20.28	kW
	Tout =	Tin+(delta q)/(Q*rho*c)	=	41.78	+	3.41	=	45.19	deg. C

Time Step 13 (80-100 yr)	Tin =	42.17	deg. C						
	Tw =	55.87	deg. C						
	delta q =	(A)(h)*(Tw-Tin)	=	1524.98	*	13.70	=	20.89	kW
	Tout =	Tin+(delta q)/(Q*rho*c)	=	42.17	+	3.51	=	45.68	deg. C

Time Step 14 (100-150 yr)	Tin =	42.40	deg. C						
	Tw =	56.43	deg. C						
	delta q =	(A)(h)*(Tw-Tin)	=	1524.98	*	14.03	=	21.40	kW
	Tout =	Tin+(delta q)/(Q*rho*c)	=	42.40	+	3.60	=	46.00	deg. C

DRIFT SEGMENT # 6 (500 - 600 m)

Sheet F

Air Quantity (Q)	5	m ³ /s	PCOD Distance	20	meters
Thermal Load	85	MTU/acre	Drift Spacing	22.5	meters
			WP Spacing	18.92	meters
Effective D.L.	600	meters	Segment D.L.	100	meters
Conv. Coef. (h)	1.0787	W/m ² -K	Segment No.	6	
Air Density (rho)	1.1821	kg/m ³	Drift Diameter	4.5	meters
Specific Heat (c)	1.0057	kJ/kg-K	Conv. Area (A)	1413.72	m ²

NOTE: T_{in} =Intake air temperature; T_w =Average drift wall temperature; T_{out} =Exit air temperature; D.L.=Drift length

Time Step 3	Tin =	26.00	deg. C						
(0.1 yr)	Tw =	26.00	deg. C						
	delta q =	(A)(h)*(Tw-Tin)	=	1524.98	*	0.00	=	0.00	kW
	Tout =	Tin+(delta q)/(Q*rho*c)	=	26.00	+	0.00	=	26.00	deg. C

Time Step 4	Tin =	28.52	deg. C						
(1-5 yr)	Tw =	30.00	deg. C						
	delta q =	(A)(h)*(Tw-Tin)	=	1524.98	*	1.48	=	2.26	kW
	Tout =	Tin+(delta q)/(Q*rho*c)	=	28.52	+	0.38	=	28.90	deg. C

Time Step 5	T _{in} =	32.57	deg. C						
(5-10 yr)	T _w =	36.56	deg. C						
	delta q =	(A)(h)*(T _w -T _{in})	=	1524.98	*	3.99	=	6.08	kW
	T _{out} =	T _{in} + (delta q)/(Q*rho*c)	=	32.57	+	1.02	=	33.59	deg. C

Time Step 6 (10-20 yr)	Tin =	37.44	deg. C						
	Tw =	44.62	deg. C						
	delta q =	(A)(h)*(Tw -Tin)	=	1524.98	*	7.18	=	10.95	kW
	Tout =	Tin+(delta q)/(Q*rho*c)	=	37.44	+	1.84	=	39.28	deg. C

Time Step 7	Tin =	40.13	deg. C							
(20-30 yr)	Tw =	49.12	deg. C							
	$\text{delta } q = (A)(h)^*(T_w - T_{in})$	=	1524.98	*	8.99	=	13.71	kW		
	$T_{out} = T_{in} + (\text{delta } q) / (Q * \rho * c)$	=	40.13	+	2.31	=	42.44	deg. C		

Time Step 8	Tin =	41.92	deg. C						
(30-40 yr)	Tw =	52.14	deg. C						
	delta q =	(A)(h)*(Tw-Tin)	=	1524.98	*	10.22	=	15.59	kW
	Tout =	Tin+(delta q)/(Q*rho*c)	=	41.92	+	2.62	=	44.54	deg. C

Time Step 9	T _{in} =	43.22	deg. C						
(40-50 yr)	T _w =	54.34	deg. C						
	delta q =	(A)(h) ³ (T _w -T _{in})	=	1524.98	*	11.12	=	16.96	kW
	T _{out} =	T _{in} + (delta q)/(Q*rho*c)	=	43.22	+	2.85	=	46.07	deg. C

Time Step 10	Tin =	44.13	deg. C						
(50-60 yr)	Tw =	55.90	deg. C						
	delta q =	(A)(h) ³ (Tw - Tin)	=	1524.98	*	11.77	=	17.95	kW
	Tout =	Tin + (delta q)/(Q*rho*c)	=	44.13	+	3.02	=	47.15	deg. C

Time Step 11	Tin =	44.77	deg. C						
(60-70 yr)	Tw =	57.00	deg. C						
	delta q =	(A)(h)*(Tw-Tin)	=	1524.98	*	12.23	=	18.65	kW
	Tout =	Tin+(delta q)/(Q*rho*c)	=	44.77	+	3.14	=	47.91	deg. C

Time Step 12	Tin =	45.19	deg. C						
(70-80 yr)	Tw =	57.75	deg. C						
	delta q =	(A)(h) ² (Tw -Tin)	=	1524.98	*	12.56	=	19.15	kW
	Tout =	Tin + (delta q)/(Q*rho*c)	=	45.19	+	3.22	=	48.41	deg. C

Time Step 13	Tin =	45.68	deg. C						
(80-100 yr)	Tw =	58.64	deg. C						
	delta q =	(A)(h)*(Tw -Tin)	=	1524.98	*	12.96	=	19.76	kW
	Tout =	Tin + (delta q)/(Q*rho*c)	=	45.68	+	3.32	=	49.00	deg. C

Time Step 14	Tin =	46.00	deg. C						
(100-150 yr)	Tw =	59.32	deg. C						
	delta q =	(A)(h)*(Tw-Tin)	=	1524.98	*	13.32	=	20.31	kW
	Tout =	Tin+(delta q)/(Q*rho*c)	=	46.00	+	3.42	=	49.42	deg. C

**V.1 Worksheets for Calculation of Ventilating Air
Temperature for Air Quantity of 10 m³/sec Case**

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Attachment V

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DRIFT SEGMENT # 1 (0 - 100 m)

Sheet A

Air Quantity (Q)	10	m ³ /s	PCOD Distance	10	meters
Thermal Load	85	MTU/acre	Drift Spacing	22.5	meters
			WP Spacing	18.92	meters
Effective D.L.	600	meters	Segment D.L.	100	meters
Conv. Coef. (h)	1.8782	W/m ² -K	Segment No.	1	
Air Density (rho)	1.1821	kg/m ³	Drift Diameter	4.5	meters
Specific Heat (c)	1.0057	kJ/kg-K	Conv. Area (A)	1413.72	m ²

NOTE: Tin=Intake air temperature; Tw=Average drift wall temperature; Tout=Exit air temperature; D.L.=Drift length

Time Step 3 (0-1 yr)	Tin = 26.00 deg. C	Tw = 26.29 deg. C	delta q = (A)(h)*(Tw-Tin) = 2655.24	*	0.29	= 0.77 kW
			Tout = Tin+(delta q)/(Q*rho*c) = 26.00	+	0.06	= 26.06 deg. C
Time Step 4 (1-5 yr)	Tin = 26.00 deg. C	Tw = 30.47 deg. C	delta q = (A)(h)*(Tw-Tin) = 2655.24	*	4.47	= 11.87 kW
			Tout = Tin+(delta q)/(Q*rho*c) = 26.00	+	1.00	= 27.00 deg. C
Time Step 5 (5-10 yr)	Tin = 26.00 deg. C	Tw = 33.33 deg. C	delta q = (A)(h)*(Tw-Tin) = 2655.24	*	7.33	= 19.46 kW
			Tout = Tin+(delta q)/(Q*rho*c) = 26.00	+	1.64	= 27.64 deg. C
Time Step 6 (10-20 yr)	Tin = 26.00 deg. C	Tw = 35.96 deg. C	delta q = (A)(h)*(Tw-Tin) = 2655.24	*	9.96	= 26.45 kW
			Tout = Tin+(delta q)/(Q*rho*c) = 26.00	+	2.22	= 28.22 deg. C
Time Step 7 (20-30 yr)	Tin = 26.00 deg. C	Tw = 37.17 deg. C	delta q = (A)(h)*(Tw-Tin) = 2655.24	*	11.17	= 29.66 kW
			Tout = Tin+(delta q)/(Q*rho*c) = 26.00	+	2.49	= 28.49 deg. C
Time Step 8 (30-40 yr)	Tin = 26.00 deg. C	Tw = 37.86 deg. C	delta q = (A)(h)*(Tw-Tin) = 2655.24	*	11.86	= 31.49 kW
			Tout = Tin+(delta q)/(Q*rho*c) = 26.00	+	2.65	= 28.65 deg. C
Time Step 9 (40-50 yr)	Tin = 26.00 deg. C	Tw = 38.25 deg. C	delta q = (A)(h)*(Tw-Tin) = 2655.24	*	12.25	= 32.53 kW
			Tout = Tin+(delta q)/(Q*rho*c) = 26.00	+	2.74	= 28.74 deg. C
Time Step 10 (50-60 yr)	Tin = 26.00 deg. C	Tw = 38.47 deg. C	delta q = (A)(h)*(Tw-Tin) = 2655.24	*	12.47	= 33.11 kW
			Tout = Tin+(delta q)/(Q*rho*c) = 26.00	+	2.79	= 28.79 deg. C
Time Step 11 (60-70 yr)	Tin = 26.00 deg. C	Tw = 38.57 deg. C	delta q = (A)(h)*(Tw-Tin) = 2655.24	*	12.57	= 33.38 kW
			Tout = Tin+(delta q)/(Q*rho*c) = 26.00	+	2.81	= 28.81 deg. C
Time Step 12 (70-80 yr)	Tin = 26.00 deg. C	Tw = 38.59 deg. C	delta q = (A)(h)*(Tw-Tin) = 2655.24	*	12.59	= 33.43 kW
			Tout = Tin+(delta q)/(Q*rho*c) = 26.00	+	2.81	= 28.81 deg. C
Time Step 13 (80-100 yr)	Tin = 26.00 deg. C	Tw = 38.51 deg. C	delta q = (A)(h)*(Tw-Tin) = 2655.24	*	12.51	= 33.22 kW
			Tout = Tin+(delta q)/(Q*rho*c) = 26.00	+	2.79	= 28.79 deg. C
Time Step 14 (100-150 yr)	Tin = 26.00 deg. C	Tw = 38.12 deg. C	delta q = (A)(h)*(Tw-Tin) = 2655.24	*	12.12	= 32.18 kW
			Tout = Tin+(delta q)/(Q*rho*c) = 26.00	+	2.71	= 28.71 deg. C

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DRIFT SEGMENT # 2 (100 - 200 m)

Sheet B

Air Quantity (Q)	10	m ³ /s	PCOD Distance	10	meters
Thermal Load	85	MTU/acre	Drift Spacing	22.5	meters
			WP Spacing	18.92	meters
Effective D.L.	600	meters	Segment D.L.	100	meters
Conv. Coef. (h)	1.8782	W/m ² -K	Segment No.	2	
Air Density (rho)	1.1821	kg/m ³	Drift Diameter	4.5	meters
Specific Heat (c)	1.0057	kJ/kg-K	Conv. Area (A)	1413.72	m ²

NOTE: Tin=Intake air temperature; Tw=Average drift wall temperature; Tout=Exit air temperature; D.L.=Drift length

Time Step 3 (0-1 yr)	Tin = 26.06 deg. C	Tw = 26.33 deg. C	delta q = (A)(h)*(Tw-Tin) = 2655.24	*	0.27	= 0.72 kW
			Tout = Tin+(delta q)/(Q*rho*c) = 26.06	+	0.06	= 26.12 deg. C
Time Step 4 (1-5 yr)	Tin = 27.00 deg. C	Tw = 31.24 deg. C	delta q = (A)(h)*(Tw-Tin) = 2655.24	*	4.24	= 11.26 kW
			Tout = Tin+(delta q)/(Q*rho*c) = 27.00	+	0.95	= 27.95 deg. C
Time Step 5 (5-10 yr)	Tin = 27.64 deg. C	Tw = 34.66 deg. C	delta q = (A)(h)*(Tw-Tin) = 2655.24	*	7.02	= 18.64 kW
			Tout = Tin+(delta q)/(Q*rho*c) = 27.64	+	1.57	= 29.21 deg. C
Time Step 6 (10-20 yr)	Tin = 28.22 deg. C	Tw = 37.80 deg. C	delta q = (A)(h)*(Tw-Tin) = 2655.24	*	9.58	= 25.44 kW
			Tout = Tin+(delta q)/(Q*rho*c) = 28.22	+	2.14	= 30.36 deg. C
Time Step 7 (20-30 yr)	Tin = 28.49 deg. C	Tw = 39.26 deg. C	delta q = (A)(h)*(Tw-Tin) = 2655.24	*	10.77	= 28.60 kW
			Tout = Tin+(delta q)/(Q*rho*c) = 28.49	+	2.41	= 30.90 deg. C
Time Step 8 (30-40 yr)	Tin = 28.65 deg. C	Tw = 40.10 deg. C	delta q = (A)(h)*(Tw-Tin) = 2655.24	*	11.45	= 30.40 kW
			Tout = Tin+(delta q)/(Q*rho*c) = 28.65	+	2.56	= 31.21 deg. C
Time Step 9 (40-50 yr)	Tin = 28.74 deg. C	Tw = 40.59 deg. C	delta q = (A)(h)*(Tw-Tin) = 2655.24	*	11.85	= 31.46 kW
			Tout = Tin+(delta q)/(Q*rho*c) = 28.74	+	2.65	= 31.39 deg. C
Time Step 10 (50-60 yr)	Tin = 28.79 deg. C	Tw = 40.87 deg. C	delta q = (A)(h)*(Tw-Tin) = 2655.24	*	12.08	= 32.08 kW
			Tout = Tin+(delta q)/(Q*rho*c) = 28.79	+	2.70	= 31.49 deg. C
Time Step 11 (60-70 yr)	Tin = 28.81 deg. C	Tw = 40.99 deg. C	delta q = (A)(h)*(Tw-Tin) = 2655.24	*	12.18	= 32.34 kW
			Tout = Tin+(delta q)/(Q*rho*c) = 28.81	+	2.72	= 31.53 deg. C
Time Step 12 (70-80 yr)	Tin = 28.81 deg. C	Tw = 41.02 deg. C	delta q = (A)(h)*(Tw-Tin) = 2655.24	*	12.21	= 32.42 kW
			Tout = Tin+(delta q)/(Q*rho*c) = 28.81	+	2.73	= 31.54 deg. C
Time Step 13 (80-100 yr)	Tin = 28.79 deg. C	Tw = 40.94 deg. C	delta q = (A)(h)*(Tw-Tin) = 2655.24	*	12.15	= 32.26 kW
			Tout = Tin+(delta q)/(Q*rho*c) = 28.79	+	2.71	= 31.50 deg. C
Time Step 14 (100-150 yr)	Tin = 28.71 deg. C	Tw = 40.51 deg. C	delta q = (A)(h)*(Tw-Tin) = 2655.24	*	11.80	= 31.33 kW
			Tout = Tin+(delta q)/(Q*rho*c) = 28.71	+	2.64	= 31.35 deg. C

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Attachment V

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DRIFT SEGMENT # 3 (200 - 300 m)

Sheet C

Air Quantity (Q)	10	m ³ /s	PCOD Distance	10	meters
Thermal Load	85	MTU/acre	Drift Spacing	22.5	meters
			WP Spacing	18.92	meters
Effective D.L.	600	meters	Segment D.L.	100	meters
Conv. Coef. (h)	1.8782	W/m ² -K	Segment No.	3	
Air Density (rho)	1.1821	kg/m ³	Drift Diameter	4.5	meters
Specific Heat (c)	1.0057	kJ/kg-K	Conv. Area (A)	1413.72	m ²

NOTE: T_{in}=intake air temperature; T_w=Average drift wall temperature; T_{out}=Exit air temperature; D.L.=Drift length

Time Step 3 (0-1 yr)	T _{in} = 26.12 deg. C	T _w = 26.37 deg. C	delta q = (A)(h)(T _w -T _{in}) = 2655.24	*	0.25	= 0.66 kW
			T _{out} = T _{in} +(delta q)/(Q*rho*c) = 26.12	+	0.06	= 26.18 deg. C
Time Step 4 (1-5 yr)	T _{in} = 27.95 deg. C	T _w = 31.98 deg. C	delta q = (A)(h)(T _w -T _{in}) = 2655.24	*	4.03	= 10.70 kW
			T _{out} = T _{in} +(delta q)/(Q*rho*c) = 27.95	+	0.90	= 28.85 deg. C
Time Step 5 (5-10 yr)	T _{in} = 29.21 deg. C	T _w = 35.93 deg. C	delta q = (A)(h)(T _w -T _{in}) = 2655.24	*	6.72	= 17.84 kW
			T _{out} = T _{in} +(delta q)/(Q*rho*c) = 29.21	+	1.50	= 30.71 deg. C
Time Step 6 (10-20 yr)	T _{in} = 30.36 deg. C	T _w = 39.57 deg. C	delta q = (A)(h)(T _w -T _{in}) = 2655.24	*	9.21	= 24.45 kW
			T _{out} = T _{in} +(delta q)/(Q*rho*c) = 30.36	+	2.06	= 32.42 deg. C
Time Step 7 (20-30 yr)	T _{in} = 30.90 deg. C	T _w = 41.28 deg. C	delta q = (A)(h)(T _w -T _{in}) = 2655.24	*	10.38	= 27.56 kW
			T _{out} = T _{in} +(delta q)/(Q*rho*c) = 30.90	+	2.32	= 33.22 deg. C
Time Step 8 (30-40 yr)	T _{in} = 31.21 deg. C	T _w = 42.27 deg. C	delta q = (A)(h)(T _w -T _{in}) = 2655.24	*	11.06	= 29.37 kW
			T _{out} = T _{in} +(delta q)/(Q*rho*c) = 31.21	+	2.47	= 33.68 deg. C
Time Step 9 (40-50 yr)	T _{in} = 31.39 deg. C	T _w = 42.85 deg. C	delta q = (A)(h)(T _w -T _{in}) = 2655.24	*	11.46	= 30.43 kW
			T _{out} = T _{in} +(delta q)/(Q*rho*c) = 31.39	+	2.56	= 33.95 deg. C
Time Step 10 (50-60 yr)	T _{in} = 31.49 deg. C	T _w = 43.18 deg. C	delta q = (A)(h)(T _w -T _{in}) = 2655.24	*	11.69	= 31.04 kW
			T _{out} = T _{in} +(delta q)/(Q*rho*c) = 31.49	+	2.61	= 34.10 deg. C
Time Step 11 (60-70 yr)	T _{in} = 31.53 deg. C	T _w = 43.33 deg. C	delta q = (A)(h)(T _w -T _{in}) = 2655.24	*	11.80	= 31.33 kW
			T _{out} = T _{in} +(delta q)/(Q*rho*c) = 31.53	+	2.64	= 34.17 deg. C
Time Step 12 (70-80 yr)	T _{in} = 31.54 deg. C	T _w = 43.38 deg. C	delta q = (A)(h)(T _w -T _{in}) = 2655.24	*	11.84	= 31.44 kW
			T _{out} = T _{in} +(delta q)/(Q*rho*c) = 31.54	+	2.64	= 34.18 deg. C
Time Step 13 (80-100 yr)	T _{in} = 31.50 deg. C	T _w = 43.29 deg. C	delta q = (A)(h)(T _w -T _{in}) = 2655.24	*	11.79	= 31.31 kW
			T _{out} = T _{in} +(delta q)/(Q*rho*c) = 31.50	+	2.63	= 34.13 deg. C
Time Step 14 (100-150 yr)	T _{in} = 31.35 deg. C	T _w = 42.83 deg. C	delta q = (A)(h)(T _w -T _{in}) = 2655.24	*	11.48	= 30.48 kW
			T _{out} = T _{in} +(delta q)/(Q*rho*c) = 31.35	+	2.56	= 33.91 deg. C

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Attachment V

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DRIFT SEGMENT # 5 (400 - 500 m)

Sheet E

Air Quantity (Q)	10	m ³ /s	PCOD Distance	10	meters
Thermal Load	85	MTU/acre	Drift Spacing	22.5	meters
			WP Spacing	18.92	meters
Effective D.L.	600	meters	Segment D.L.	100	meters
Conv. Coef. (h)	1.8782	W/m ² -K	Segment No.	5	
Air Density (rho)	1.1821	kg/m ³	Drift Diameter	4.5	meters
Specific Heat (c)	1.0057	kJ/kg-K	Conv. Area (A)	1413.72	m ²

NOTE: T_{in}=Intake air temperature; T_w=Average drift wall temperature; T_{out}=Exit air temperature; D.L.=Drift length

Time Step 3 (0-1 yr)	T _{in} = 26.23 deg. C	T _w = 26.45 deg. C	delta q = (A)(h)*(T _w -T _{in}) = 2655.24	*	0.22	= 0.58 kW
			T _{out} = T _{in} +(delta q)/(Q*rho*c) = 26.23	+	0.05	= 26.28 deg. C
Time Step 4 (1-5 yr)	T _{in} = 29.71 deg. C	T _w = 33.34 deg. C	delta q = (A)(h)*(T _w -T _{in}) = 2655.24	*	3.63	= 9.64 kW
			T _{out} = T _{in} +(delta q)/(Q*rho*c) = 29.71	+	0.81	= 30.52 deg. C
Time Step 5 (5-10 yr)	T _{in} = 32.15 deg. C	T _w = 38.30 deg. C	delta q = (A)(h)*(T _w -T _{in}) = 2655.24	*	6.15	= 16.33 kW
			T _{out} = T _{in} +(delta q)/(Q*rho*c) = 32.15	+	1.37	= 33.52 deg. C
Time Step 6 (10-20 yr)	T _{in} = 34.40 deg. C	T _w = 42.92 deg. C	delta q = (A)(h)*(T _w -T _{in}) = 2655.24	*	8.52	= 22.62 kW
			T _{out} = T _{in} +(delta q)/(Q*rho*c) = 34.40	+	1.90	= 36.30 deg. C
Time Step 7 (20-30 yr)	T _{in} = 35.46 deg. C	T _w = 45.11 deg. C	delta q = (A)(h)*(T _w -T _{in}) = 2655.24	*	9.65	= 25.62 kW
			T _{out} = T _{in} +(delta q)/(Q*rho*c) = 35.46	+	2.16	= 37.62 deg. C
Time Step 8 (30-40 yr)	T _{in} = 36.07 deg. C	T _w = 46.39 deg. C	delta q = (A)(h)*(T _w -T _{in}) = 2655.24	*	10.32	= 27.40 kW
			T _{out} = T _{in} +(delta q)/(Q*rho*c) = 36.07	+	2.30	= 38.37 deg. C
Time Step 9 (40-50 yr)	T _{in} = 36.42 deg. C	T _w = 47.14 deg. C	delta q = (A)(h)*(T _w -T _{in}) = 2655.24	*	10.72	= 28.46 kW
			T _{out} = T _{in} +(delta q)/(Q*rho*c) = 36.42	+	2.39	= 38.81 deg. C
Time Step 10 (50-60 yr)	T _{in} = 36.63 deg. C	T _w = 47.58 deg. C	delta q = (A)(h)*(T _w -T _{in}) = 2655.24	*	10.95	= 29.07 kW
			T _{out} = T _{in} +(delta q)/(Q*rho*c) = 36.63	+	2.45	= 39.08 deg. C
Time Step 11 (60-70 yr)	T _{in} = 36.72 deg. C	T _w = 47.80 deg. C	delta q = (A)(h)*(T _w -T _{in}) = 2655.24	*	11.08	= 29.42 kW
			T _{out} = T _{in} +(delta q)/(Q*rho*c) = 36.72	+	2.47	= 39.19 deg. C
Time Step 12 (70-80 yr)	T _{in} = 36.74 deg. C	T _w = 47.87 deg. C	delta q = (A)(h)*(T _w -T _{in}) = 2655.24	*	11.13	= 29.55 kW
			T _{out} = T _{in} +(delta q)/(Q*rho*c) = 36.74	+	2.49	= 39.23 deg. C
Time Step 13 (80-100 yr)	T _{in} = 36.69 deg. C	T _w = 47.80 deg. C	delta q = (A)(h)*(T _w -T _{in}) = 2655.24	*	11.11	= 29.50 kW
			T _{out} = T _{in} +(delta q)/(Q*rho*c) = 36.69	+	2.48	= 39.17 deg. C
Time Step 14 (100-150 yr)	T _{in} = 36.40 deg. C	T _w = 47.27 deg. C	delta q = (A)(h)*(T _w -T _{in}) = 2655.24	*	10.87	= 28.86 kW
			T _{out} = T _{in} +(delta q)/(Q*rho*c) = 36.40	+	2.43	= 38.83 deg. C

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DRIFT SEGMENT # 6 (500 - 600 m)

Sheet F

Air Quantity (Q)	10	m ³ /s	PCOD Distance	10	meters
Thermal Load	85	MTU/acre	Drift Spacing	22.5	meters
			WP Spacing	18.92	meters
Effective D.L.	600	meters	Segment D.L.	100	meters
Conv. Coef. (h)	1.8782	W/m ² -K	Segment No.	6	
Air Density (rho)	1.1821	kg/m ³	Drift Diameter	4.5	meters
Specific Heat (c)	1.0057	kJ/kg-K	Conv. Area (A)	1413.72	m ²

NOTE: Tin=Intake air temperature; Tw=Average drift wall temperature; Tout=Exit air temperature; D.L.=Drift length

Time Step 3 (0-1 yr)	Tin =	26.28	deg. C						
	Tw =	26.48	deg. C						
	delta q =	(A)(h)*(Tw - Tin)		2655.24	*	0.20	=	0.53	kW
	Tout =	Tin+(delta q)/(Q*rho*c)		26.28	+	0.04	=	26.32	deg. C

Time Step 4 (1-5 yr)	Tin =	30.52	deg. C						
	Tw =	33.97	deg. C						
	delta q =	(A)(h)*(Tw - Tin)		2655.24	*	3.45	=	9.16	kW
	Tout =	Tin+(delta q)/(Q*rho*c)		30.52	+	0.77	=	31.29	deg. C

Time Step 5 (5-10 yr)	Tin =	33.52	deg. C						
	Tw =	39.41	deg. C						
	delta q =	(A)(h)*(Tw - Tin)		2655.24	*	5.89	=	15.64	kW
	Tout =	Tin+(delta q)/(Q*rho*c)		33.52	+	1.32	=	34.84	deg. C

Time Step 6 (10-20 yr)	Tin =	36.30	deg. C						
	Tw =	44.49	deg. C						
	delta q =	(A)(h)*(Tw - Tin)		2655.24	*	8.19	=	21.75	kW
	Tout =	Tin+(delta q)/(Q*rho*c)		36.30	+	1.83	=	38.13	deg. C

Time Step 7 (20-30 yr)	Tin =	37.62	deg. C						
	Tw =	46.92	deg. C						
	delta q =	(A)(h)*(Tw - Tin)		2655.24	*	9.30	=	24.69	kW
	Tout =	Tin+(delta q)/(Q*rho*c)		37.62	+	2.08	=	39.70	deg. C

Time Step 8 (30-40 yr)	Tin =	38.37	deg. C						
	Tw =	48.33	deg. C						
	delta q =	(A)(h)*(Tw - Tin)		2655.24	*	9.96	=	26.45	kW
	Tout =	Tin+(delta q)/(Q*rho*c)		38.37	+	2.22	=	40.59	deg. C

Time Step 9 (40-50 yr)	Tin =	38.81	deg. C						
	Tw =	49.17	deg. C						
	delta q =	(A)(h)*(Tw - Tin)		2655.24	*	10.36	=	27.51	kW
	Tout =	Tin+(delta q)/(Q*rho*c)		38.81	+	2.31	=	41.12	deg. C

Time Step 10 (50-60 yr)	Tin =	39.08	deg. C						
	Tw =	49.68	deg. C						
	delta q =	(A)(h)*(Tw - Tin)		2655.24	*	10.60	=	28.15	kW
	Tout =	Tin+(delta q)/(Q*rho*c)		39.08	+	2.37	=	41.45	deg. C

Time Step 11 (60-70 yr)	Tin =	39.19	deg. C						
	Tw =	49.92	deg. C						
	delta q =	(A)(h)*(Tw - Tin)		2655.24	*	10.73	=	28.49	kW
	Tout =	Tin+(delta q)/(Q*rho*c)		39.19	+	2.40	=	41.59	deg. C

Time Step 12 (70-80 yr)	Tin =	39.23	deg. C						
	Tw =	50.01	deg. C						
	delta q =	(A)(h)*(Tw - Tin)		2655.24	*	10.78	=	28.62	kW
	Tout =	Tin+(delta q)/(Q*rho*c)		39.23	+	2.41	=	41.64	deg. C

Time Step 13 (80-100 yr)	Tin =	39.17	deg. C						
	Tw =	49.95	deg. C						
	delta q =	(A)(h)*(Tw - Tin)		2655.24	*	10.78	=	28.62	kW
	Tout =	Tin+(delta q)/(Q*rho*c)		39.17	+	2.41	=	41.58	deg. C

Time Step 14 (100-150 yr)	Tin =	38.83	deg. C						
	Tw =	49.40	deg. C						
	delta q =	(A)(h)*(Tw - Tin)		2655.24	*	10.57	=	28.07	kW
	Tout =	Tin+(delta q)/(Q*rho*c)		38.83	+	2.36	=	41.19	deg. C

/BATCH,LIST

```

!
!*****
!#
!#                               ANSYS INPUT
!#
!#      Filename:      pca2d85m51
!#
!#      Input File:    pca2d85m51.dat
!#
!#      Output File:   pca2d85m51.out
!#
!#      Description:   2D Analysis for temperature at performance
!#                    confirmation observation drift (pca2d)
!#                    Thermal load:      85 MTU/acre & 21 PWR (85)
!#                    Emplacement mode:   Center-in-drift
!#                    Drift diameter:     5.5 meters
!#                    Drift spacing:      22.5 meters
!#                    WP spacing:         18.92 meters
!#                    Initial heat output: 9.05 kW/package
!#                    WP diameter:        1.85 meters
!#                    Observation drift size: 4.5 meters in diameter
!#                                         15.90 m^2 in area
!#                                         600 meters long
!#
!#                    Distance from emplace.
!#                      drift crown to obser.
!#                      drift floor:      20 meters
!#                    Location of O.D.:   Mid-of-pillar (m)
!#                    Ventilation air temp.: Varied
!#                    Ventilation quantity: 5.0 m^3/s (5)
!#                    Coef. of convection: 1.0787 W/m^2-K
!#                    Modeling time period: 150 years
!#                    Ventilation segment: No. 1 (0 - 100 m) (1)
!#
!#      Code Version:   ANSYS Revision 5.2
!#
!#      Created By:     Yiming Sun
!#
!#      Last Modified:  02/09/97
!#
!*****

```

/COM,ANSYS MEDIA REV. 5.2

```

!
!FILNAM,pca2d85m51      !      Jobname to use for all subsequent files
!TITLE,2D Model (PCA;TL:85MTU/ac;AQ:5.0m^3/s;AT:26C;DOD:20m;SN:1)
!UNITS,SI
!SHOW
!

```

/NOPR

```

*ABB,SAVE_DB,SAVE
*ABB,RESUM_DB,RESUME
*ABB,QUIT,Fnc_/EXIT
*ABB,SHFR,/SHOW,FILE,,,8
*ABB,SHFV,/SHOW,FILE,,1
*ABB,X11C,/SHOW,X11C,,,8
*ABB,X11,/SHOW,X11,,1
*ABB,REPLOTT,/REPLOTT
*ABB,K1,/PNUM,KP,1
*ABB,K0,/PNUM,KP,0
*ABB,POWRGRPH,Fnc_/GRAPHICS
*ABB,ANSYSWEB,Fnc_HomePage
/GO
!

```

```

/FDELE,EMAT,DELE
/FDELE,ESAV,DELE
/FDELE,EROT,DELE
/FDELE,DSUB,DELE
/FDELE,TRI,DELE
/FDELE,OSAV,DELE
/FDELE,PAGE,DELE
!

```

/PREP7

! Define element types

```

!
ET,1,PLANE55      !      4-node, 2-D thermal solid element
ET,2,LINK32      !      2-D conduction bar
R,1,1,0
ET,3,MATRIX50    !      Superelement for radiation
KEYOPT,3,1,1     !      Superelement behavior: radiation substructure
KEYOPT,3,6,0
!

```

! Define material properties

```

!
!      Material number 1 (TCw unit)
MP,DENS,1,2169    !      Density (kg/m^3)
MP,KXX,1,5.014E7 !      Thermal conductivity (J/yr-m-C)
!
!      Material number 2 (PTn unit)
MP,DENS,2,1299    !      Density (kg/m^3)
MP,KXX,2,2.681E7 !      Thermal conductivity (J/yr-m-C)
!
!      Material number 3 (TSw1 unit)
MP,DENS,3,2163    !      Density (kg/m^3)
MP,KXX,3,5.046E7 !      Thermal conductivity (J/yr-m-C)
!
!      Material number 4 (TSw2 unit)

```

```

MP,DENS,4,2274      !      Density (kg/m^3)
MP,KXX, 4,6.623E7   !      Thermal conductivity (J/yr-m-C)
MP,EMIS,4,0.9       !      Emissivity
!
!      Material number 5 (TSw3 unit)
MP,DENS,5,2271      !      Density (kg/m^3)
MP,KXX, 5,4.037E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 6 (CHn1v unit)
MP,DENS,6,1972      !      Density (kg/m^3)
MP,KXX, 6,3.784E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 7 (CHn1z unit)
MP,DENS,7,1886      !      Density (kg/m^3)
MP,KXX, 7,4.037E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 8 (CHn2 unit)
MP,DENS,8,2070      !      Density (kg/m^3)
MP,KXX, 8,4.92E7    !      Thermal conductivity (J/yr-m-C)
!
!      Material number 9 (Waste package)
MP,DENS,9,8131      !      Density (kg/m^3)
MP,KXX, 9,131.534E7 !      Thermal conductivity (J/yr-m-C)
MP,C, 9,487.901     !      Specific heat (J/kg-C)
MP,EMIS,9,0.8       !      Emissivity
!
!      Material number 10 (link elements for radiation)
MP,EMIS,10,0.85     !      Emissivity
!
!      Material number 11 (Radiation superelement element)
MP,EMIS,11,0.85     !      Emissivity
!
MPTEMP,1,25,94,95,114,115,250 ! Temperature table for temperature
! dependent specific heat (C)
!
!      Specific heat (J/kg-C)
MPDATA,C,1,1,936.5,936.5,4322.2,4322.2,967.2,967.2 ! TCw unit
MPDATA,C,2,1,1715.6,1715.6,22564.3,22564.3,1172.9,1172.9 ! PTn unit
MPDATA,C,3,1,960.5,960.5,5670.6,5670.6,934.8,934.8 ! TSw1 unit
MPDATA,C,4,1,941.7,941.7,4608.0,4608.0,960.4,960.4 ! TSw2 unit
MPDATA,C,5,1,904.0,904.0,1990.0,1990.0,1124.4,1124.4 ! TSw3 unit
MPDATA,C,6,1,1300.8,1300.8,17935.1,17935.1,847.0,847.0 ! CHn1v unit
MPDATA,C,7,1,1416.2,1416.2,18762.1,18762.1,1210.8,1210.8 ! CHn1z unit
MPDATA,C,8,1,1231.2,1231.2,11998.2,11998.2,1330.6,1330.6 ! CHn2 unit
!
!
!      Parameters for model generation
!
ORIG=0.0
X1=5.5
X2=11.25
DS=22.5
Y1=5.5
Y2=19.5
Y3=25
Y4=30.5
R1=2.75
RW=0.925
ROD=2.25
TSW2_UP=106.8
TSW2_LOW=-82.5
TSW1=236.9
PTN=275.0
TCW=311.0
TSW3=-98.3
CHN1V=-103.5
CHN1Z=-207.5
CHN2=-300.0
XOFF=33.75
YOFF=25.0
!
WPOFF,X2,0,0
CSYS,4
RECTNG,ORIG,X1,ORIG,Y1,
PCIRC,R1,,0,90,
ASBA,1,2
PCIRC,RW,,0,90,
ARSYM,Y,ALL,,,0,0
RECTNG,ORIG,X1, Y1, Y2,
RECTNG,ORIG,X1, Y2, Y3,
RECTNG,ORIG,X1, Y3, Y4,
RECTNG,ORIG,X1, Y4, TSW2_UP,
RECTNG,ORIG,X1, TSW2_UP, TSW1,
RECTNG,ORIG,X1, TSW1, PTN,
RECTNG,ORIG,X1, PTN, TCW,
RECTNG,ORIG,X1, -Y1,TSW2_LOW,
RECTNG,ORIG,X1,TSW2_LOW, TSW3,
RECTNG,ORIG,X1, TSW3, CHN1V,
RECTNG,ORIG,X1, CHN1V, CHN1Z,
RECTNG,ORIG,X1, CHN1Z, CHN2,
!
RECTNG, X1,X2, ORIG, Y1,
RECTNG, X1,X2, Y1, Y2,
RECTNG, X1,X2, Y2, Y3,
RECTNG, X1,X2, Y3, Y4,
RECTNG, X1,X2, Y4, TSW2_UP,
RECTNG, X1,X2, TSW2_UP, TSW1,
RECTNG, X1,X2, TSW1, PTN,
RECTNG, X1,X2, PTN, TCW,

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RECTNG, X1,X2, ORIG, -Y1,
RECTNG, X1,X2, -Y1,TSW2_LOW,
RECTNG, X1,X2,TSW2_LOW, TSW3,
RECTNG, X1,X2, TSW3, CHN1V,
RECTNG, X1,X2, CHN1V, CHN1Z,
RECTNG, X1,X2, CHN1Z, CHN2,
!
ARSYM,X,ALL,,,0,0
WPOFF,X2,0,0
ASEL,S,LOC,X,-X2,0,,1
ARSYM,X,ALL,,,0,0
ALLSEL
WPOFF,X2,0,0
ARSYM,X,ALL,,,0,0
WPOFF,-XOFF,YOFF,0
!
PCIRC,ROD, ,0,90,
PCIRC,ROD, ,0,-90,
!
ASBA,50,181
ASBA,49,182
WPOFF,0,-YOFF,0
AGLUE,ALL
/TRIAD,ROBOT
APLOT
SAVE
!
! Meshing
!
TYPE,1, ! Mesh the waste package
MAT,9,
ESYS,0,
ESHAPE,2,0
MOPT,EXPND,1,
MOPT,TRANS,2,
MOPT,IESZ,0,
ESIZE,0.5,0,
AMESH,1,
AMESH,49
AMESH,181
AMESH,187
AMESH,182
AMESH,188
AMESH,184
AMESH,61
AMESH,185
AMESH,189
AMESH,186
AMESH,91
!
LCCAT,2,3 ! Concatenates lines
LCCAT,14,825
LCCAT,891,835
LCCAT,128,830
LCCAT,912,608
LCCAT,992,915
LCCAT,254,878
LCCAT,248,249
LCCAT,943,488
LCCAT,1005,948
LCCAT,374,938
LCCAT,368,369
LCCAT,769,845
LCCAT,841,894
!
TYPE,1, ! Mesh the TSw2 unit
MAT,4,
ESYS,0,
LSEL,S,LINE,,1044 ! Observation drift
LSEL,A,LINE,,724
!
LSEL,A,LINE,,5 ! Emplacement drift
LSEL,A,LINE,,1032
LSEL,A,LINE,,1034
LSEL,A,LINE,,1033
LSEL,A,LINE,,1036
LSEL,A,LINE,,1037
LSEL,A,LINE,,1035
LSEL,A,LINE,,251
LSEL,A,LINE,,1039
LSEL,A,LINE,,1040
LSEL,A,LINE,,1038
LSEL,A,LINE,,371
LESIZE,ALL,,10
!
LSEL,S,LINE,,1041,
LSEL,A,LINE,,1043,
LSEL,A,LINE,,1042,
LSEL,A,LINE,,127,
LSEL,A,LINE,,8,
LSEL,A,LINE,,9,
LSEL,A,LINE,,15,
LSEL,A,LINE,,247,
LSEL,A,LINE,,607,
LSEL,A,LINE,,250,
LSEL,A,LINE,,255,
LSEL,A,LINE,,367
LSEL,A,LINE,,487

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LSEL,A,LINE,,370
LSEL,A,LINE,,375
LESIZE,ALL,,5
!
LSEL,S,LINE,,845,
LSEL,A,LINE,,769,
LSEL,A,LINE,,841,
LSEL,A,LINE,,894,
LSEL,A,LINE,,830,
LSEL,A,LINE,,3,
LSEL,A,LINE,,2,
LSEL,A,LINE,,825,
LSEL,A,LINE,,14,
LSEL,A,LINE,,835,
LSEL,A,LINE,,891,
LSEL,A,LINE,,128
LSEL,A,LINE,,249
LSEL,A,LINE,,912
LSEL,A,LINE,,608
LSEL,A,LINE,,992,
LSEL,A,LINE,,915
LSEL,A,LINE,,254
LSEL,A,LINE,,878
LSEL,A,LINE,,248
LSEL,A,LINE,,369
LSEL,A,LINE,,943
LSEL,A,LINE,,488
LSEL,A,LINE,,1005,
LSEL,A,LINE,,948
LSEL,A,LINE,,374
LSEL,A,LINE,,938
LSEL,A,LINE,,368
LSEL,A,LINE,,766
LESIZE,ALL,,5
!
LSEL,S,LINE,,738
LSEL,A,LINE,,764
LSEL,A,LINE,,821
LSEL,A,LINE,,795
LSEL,A,LINE,,823
LESIZE,ALL,,4
!
LSEL,S,LINE,,840
LSEL,A,LINE,,23
LSEL,A,LINE,,263
LSEL,A,LINE,,918
LSEL,A,LINE,,383
LSEL,A,LINE,,953
LESIZE,ALL,,5
!
ALLSEL
ESIZE,1,0,
AMESH,353,354,1,
AMESH,3
AMESH,344,346,1
AMESH,63
AMESH,347,349,1
AMESH,93
AMESH,350,352,1
ESIZE,1.5,0
AMESH,204
AMESH,271
AMESH,190
AMESH,233
AMESH,203
AMESH,258
AMESH,231
AMESH,318
AMESH,218
AMESH,293
AMESH,232
AMESH,331
!
AMESH,272
AMESH,235
AMESH,191
AMESH,239
AMESH,241
AMESH,193
AMESH,194
AMESH,234
AMESH,259
AMESH,238
AMESH,240
AMESH,260
AMESH,261
AMESH,206
AMESH,281
AMESH,208
AMESH,209
AMESH,283
AMESH,284
AMESH,319
AMESH,294
AMESH,320
AMESH,298
AMESH,321
AMESH,300
```

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AMESH,219
AMESH,295
AMESH,221
AMESH,299
AMESH,222
AMESH,301
AMESH,332
AMESH,334
AMESH,335
!
ESIZE,2,0
AMESH,205
AMESH,243
AMESH,195
AMESH,242
AMESH,262
AMESH,210
AMESH,285
AMESH,322
AMESH,302
AMESH,223
AMESH,303
AMESH,336
AMESH,273
AMESH,237
AMESH,192
AMESH,236
AMESH,266
AMESH,207
AMESH,282
AMESH,326
AMESH,296
AMESH,220
AMESH,297
AMESH,333
!
TYPE,1,                                !      Mesh the TSwl unit
MAT,3,
ESYS,0,
ESIZE,3.0,0,
AMESH,274
AMESH,245
AMESH,196
AMESH,244
AMESH,263
AMESH,211
AMESH,286
AMESH,323
AMESH,304
AMESH,224
AMESH,305
AMESH,337
!
TYPE,1,                                !      Mesh the PTn unit
MAT,2,
ESYS,0,
ESIZE,7.5,0,
AMESH,275
AMESH,247
AMESH,197
AMESH,246
AMESH,264
AMESH,212
AMESH,287
AMESH,324
AMESH,306
AMESH,225
AMESH,307
AMESH,338
!
TYPE,1,                                !      Mesh the TCw unit
MAT,1,
ESYS,0,
ESIZE,15.0,0,
AMESH,276
AMESH,249
AMESH,198
AMESH,248
AMESH,265
AMESH,213
AMESH,288
AMESH,325
AMESH,308
AMESH,226
AMESH,309
AMESH,339
!
TYPE,1,                                !      Mesh the TSw3 unit
MAT,5,
ESYS,0,
ESIZE,3.0,0,
AMESH,277
AMESH,250
AMESH,199
AMESH,251
AMESH,267
AMESH,214
AMESH,289
```

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AMESH,327
AMESH,311
AMESH,227
AMESH,310
AMESH,340
!
TYPE,1,          !      Mesh the CHn1v unit
MAT,6,
ESYS,0,
ESIZE,3.0,0,
AMESH,278
AMESH,252
AMESH,200
AMESH,253
AMESH,268
AMESH,215
AMESH,290
AMESH,328
AMESH,313
AMESH,228
AMESH,312
AMESH,341
!
TYPE,1,          !      Mesh the CHn1z unit
MAT,7,
ESYS,0,
ESIZE,7.5,0,
AMESH,279
AMESH,254
AMESH,201
AMESH,255
AMESH,269
AMESH,216
AMESH,291
AMESH,329
AMESH,315
AMESH,229
AMESH,314
AMESH,342
!
TYPE,1,          !      Mesh the CHn2 unit
MAT,8,
ESYS,0,
ESIZE,15,0,
AMESH,280
AMESH,256
AMESH,202
AMESH,257
AMESH,270
AMESH,217
AMESH,292
AMESH,330
AMESH,317
AMESH,230
AMESH,316
AMESH,343
!
TYPE,2,          !      Define link elements
MAT,10,
REAL,1,
ESYS,0,
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
LSEL,A,LINE,,5          !      Drift wall
LSEL,A,LINE,,1033
LSEL,A,LINE,,1034
LSEL,A,LINE,,1032
LSEL,A,LINE,,1036
LSEL,A,LINE,,251
LSEL,A,LINE,,1035
LSEL,A,LINE,,1037
LSEL,A,LINE,,1039
LSEL,A,LINE,,371
LSEL,A,LINE,,1038
LSEL,A,LINE,,1040
NSLL,S,1
ESURF,ALL
PLOT
!
/AUX12          !      Generate superelement for thermal
EMIS,2,0.85,      !      radiation calculation
STEF,1.7878,
GEOM,1,0,
SPACE, ,
ESEL,S,TYPE,,2,2
NSLE,S
VTYPE,0, ,
MPRINT,0

```

```

WRITE,pca2d85m51      !      Save radiation matrices
FINISH
!
/PREP7
TYPE,3,
MAT,11,
REAL,1,
ESYS,0,
SE,pca2d85m51
!
ESEL,S,TYPE,,2,2
EDELE,ALL
ALLSEL
!
/SOLU                  !      Solution phase
ANTYPE,TRANS           !      Transient analysis
NROPT,AUTO             !      Programchosen Newton-Raphson option
TOFFST,273            !      Specify the temperature offset: 273 C
TINTP,0.005,, ,0.5,0.5,0.2 !      Use defaults of transient integration
!                      parameters
OUTPR,NSOL,5,          !      Solution printout at every 5 substeps
OUTRES,NSOL,5,         !      Solution data written to database
!                      at every 5 substeps
IC,ALL,TEMP,26,        !      Initial temperature at all nodes
NSEL,S,LOC,Y,311.0     !      Select all nodes on top surface
D,ALL,TEMP,18.7
NSEL,S,LOC,Y,-300.0    !      Select all nodes on bottom surface
D,ALL,TEMP,32.53
ALLSEL
SAVE
!
!      Load step number 1
TIMINT,OFF             !      Turn off transient effects at the
!                      first load step
TIME,1e-7
AUTOTS,1
DELTIM,1e-8,1e-8,1e-7,0
KBC,0
LSWRITE,1,
!
TIMINT,ON              !      Turn on transient effects at the
!                      rest of load steps
!      Load step number 2
TIME,0.5e-2
AUTOTS,1
DELTIM,0.5e-4,0.5e-4,0.5e-3,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,26
KBC,0
LSEL,S,LINE,,1         !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.5952e9,
ALLSEL
LSWRITE,2,
!
!      Load step number 3
TIME,1
AUTOTS,1
DELTIM,0.01,0.01,0.1,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,26
KBC,0
LSEL,S,LINE,,1         !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.5289e9,
ALLSEL
LSWRITE,3,
!
!      Load step number 4
TIME,5
AUTOTS,1
DELTIM,0.05,0.05,0.5,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift

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LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,26
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.3217e9,
ALLSEL
LSWRITE,4,
!
!          Load step number 5
TIME,10
AUTOTS,1
DELTIM,0.05,0.05,0.5,0
KBC,1
LSEL,S,LINE,,1044       !          Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,26
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.1169e9,
ALLSEL
LSWRITE,5,
!
!          Load step number 6
TIME,20
AUTOTS,1
DELTIM,0.1,0.1,0.75,0
KBC,1
LSEL,S,LINE,,1044       !          Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,26
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.7929e9,
ALLSEL
LSWRITE,6,
!
!          Load step number 7
TIME,30
AUTOTS,1
DELTIM,0.1,0.1,0.75,0
KBC,1
LSEL,S,LINE,,1044       !          Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,26
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.5401e9,
ALLSEL
LSWRITE,7,
!
!          Load step number 8
TIME,40
AUTOTS,1
DELTIM,0.15,0.15,0.75,0
```



```
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,26
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.3400e9,
ALLSEL
LSWRITE,8,
!
!      Load step number 9
TIME,50
AUTOTS,1
DELTIM,0.15,0.15,0.75,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,26
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.1779e9,
ALLSEL
LSWRITE,9,
!
!      Load step number 10
TIME,60
AUTOTS,1
DELTIM,0.15,0.15,1.0,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,26
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.0477e9,
ALLSEL
LSWRITE,10,
!
!      Load step number 11
TIME,70
AUTOTS,1
DELTIM,0.15,0.15,1.0,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,26
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,9.4197e8,
ALLSEL
LSWRITE,11,
!
!      Load step number 12
TIME,80
```

```
AUTOTS,1
DELTIM,0.15,0.15,1.5,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,26
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,8.5514e8,
ALLSEL
LSWRITE,12,
!
!      Load step number 13
TIME,100
AUTOTS,1
DELTIM,0.15,0.15,2.5,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,26
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,7.2487e8,
ALLSEL
LSWRITE,13,
!
!      Load step number 14
TIME,150
AUTOTS,1
DELTIM,0.2,0.2,5.0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,26
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,5.4619e8,
ALLSEL
LSWRITE,14,
!
ALLSEL
LSSOLVE,1,14,1,      !      Solve with 14 load steps
FINISH
```

/BATCH,LIST

```

!
!*****
!#
!#                               ANSYS INPUT
!#
!#   Filename:      pca2d85m52
!#
!#   Input File:    pca2d85m52.dat
!#
!#   Output File:   pca2d85m52.out
!#
!#   Description:   2D Analysis for temperature at performance
!#                  confirmation observation drift (pca2d)
!#                  Thermal load:      85 MTU/acre & 21 PWR (85)
!#                  Emplacement mode:  Center-in-drift
!#                  Drift diameter:    5.5 meters
!#                  Drift spacing:     22.5 meters
!#                  WP spacing:        18.92 meters
!#                  Initial heat output: 9.05 kW/package
!#                  WP diameter:       1.85 meters
!#                  Observation drift size: 4.5 meters in diameter
!#                                      15.90 m^2 in area
!#                                      600 meters long
!#
!#                  Distance from emplace.
!#                  drift crown to obser.
!#                  drift floor:      20 meters
!#                  Location of O.D.:  Mid-of-pillar (m)
!#                  Ventilation air temp.: Varied
!#                  Ventilation quantity: 5.0 m^3/s (5)
!#                  Coef. of convection: 1.0787 W/m^2-K
!#                  Modeling time period: 150 years
!#                  Ventilation segment: No. 2 (100 - 200 m) (2)
!#
!#   Code Version:  ANSYS Revision 5.2
!#
!#   Created By:    Yiming Sun
!#
!#   Last Modified: 02/10/97
!#
!*****

```

/COM,ANSYS MEDIA REV. 5.2

```

!
!*****
!#
!#   Jobname to use for all subsequent files
!#   /FILNAM,pca2d85m52
!#   /TITLE,2D Model (PCA;TL:85MTU/ac;AQ:5.0m^3/s;AT:26C;DOD:20m;SN:2)
!#   /UNITS,SI
!#   /SHOW
!#
!#
!#   /NOPR
!#   *ABB,SAVE_DB,SAVE
!#   *ABB,RESUM_DB,RESUME
!#   *ABB,QUIT,Fnc_/EXIT
!#   *ABB,SHFR,/,SHOW,FILE,,,8
!#   *ABB,SHFV,/,SHOW,FILE,,1
!#   *ABB,X11C,/,SHOW,X11C,,,8
!#   *ABB,X11,/,SHOW,X11,,1
!#   *ABB,REPLOTT,/,REPLOTT
!#   *ABB,K1,/,PNUM,KP,1
!#   *ABB,K0,/,PNUM,KP,0
!#   *ABB,POWRGRPH,Fnc_/GRAPHICS
!#   *ABB,ANSYSWEB,Fnc_HomePage
!#   /GO
!#
!#
!#   /FDELE,EMAT,DELE
!#   /FDELE,ESAV,DELE
!#   /FDELE,EROT,DELE
!#   /FDELE,DSUB,DELE
!#   /FDELE,TRI,DELE
!#   /FDELE,OSAV,DELE
!#   /FDELE,PAGE,DELE
!#
!#
!#   /PREP7
!#
!#
!#   Define element types
!#
!#   ET,1,PLANE55      !      4-node, 2-D thermal solid element
!#   ET,2,LINK32       !      2-D conduction bar
!#   R,1,1.0
!#   ET,3,MATRIX50     !      Superelement for radiation
!#   KEYOPT,3,1,1      !      Superelement behavior: radiation substructure
!#   KEYOPT,3,6,0
!#
!#
!#   Define material properties
!#
!#   Material number 1 (TCw unit)
!#   MP,DENS,1,2169     !      Density (kg/m^3)
!#   MP,KXX,1,5.014E7   !      Thermal conductivity (J/yr-m-C)
!#
!#   Material number 2 (PTn unit)
!#   MP,DENS,2,1299     !      Density (kg/m^3)
!#   MP,KXX,2,2.681E7   !      Thermal conductivity (J/yr-m-C)
!#
!#   Material number 3 (TSw1 unit)
!#   MP,DENS,3,2163     !      Density (kg/m^3)
!#   MP,KXX,3,5.046E7   !      Thermal conductivity (J/yr-m-C)
!#
!#   Material number 4 (TSw2 unit)

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MP,DENS,4,2274      !      Density (kg/m^3)
MP,KXX, 4,6.623E7   !      Thermal conductivity (J/yr-m-C)
MP,EMIS,4,0.9       !      Emissivity
!
!      Material number 5 (TSw3 unit)
MP,DENS,5,2271      !      Density (kg/m^3)
MP,KXX, 5,4.037E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 6 (CHnlv unit)
MP,DENS,6,1972      !      Density (kg/m^3)
MP,KXX, 6,3.784E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 7 (CHnlz unit)
MP,DENS,7,1886      !      Density (kg/m^3)
MP,KXX, 7,4.037E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 8 (CHn2 unit)
MP,DENS,8,2070      !      Density (kg/m^3)
MP,KXX, 8,4.92E7    !      Thermal conductivity (J/yr-m-C)
!
!      Material number 9 (Waste package)
MP,DENS,9,8131      !      Density (kg/m^3)
MP,KXX, 9,131.534E7 !      Thermal conductivity (J/yr-m-C)
MP,C, 9,487.901     !      Specific heat (J/kg-C)
MP,EMIS,9,0.8       !      Emissivity
!
!      Material number 10 (link elements for radiation)
MP,EMIS,10,0.85     !      Emissivity
!
!      Material number 11 (Radiation superelement element)
MP,EMIS,11,0.85     !      Emissivity
!
MPTEMP,1,25,94,95,114,115,250 ! Temperature table for temperature
!                               dependent specific heat (C)
!
!      Specific heat (J/kg-C)
MPDATA,C,1,1,936.5,936.5,4322.2,4322.2,967.2,967.2 ! TCw unit
MPDATA,C,2,1,1715.6,1715.6,22564.3,22564.3,1172.9,1172.9 ! PTn unit
MPDATA,C,3,1,960.5,960.5,5670.6,5670.6,934.8,934.8 ! TSw1 unit
MPDATA,C,4,1,941.7,941.7,4608.0,4608.0,960.4,960.4 ! TSw2 unit
MPDATA,C,5,1,904.0,904.0,1990.0,1990.0,1124.4,1124.4 ! TSw3 unit
MPDATA,C,6,1,1300.8,1300.8,17935.1,17935.1,847.0,847.0 ! CHnlv unit
MPDATA,C,7,1,1416.2,1416.2,18762.1,18762.1,1210.8,1210.8 ! CHnlz unit
MPDATA,C,8,1,1231.2,1231.2,11998.2,11998.2,1330.6,1330.6 ! CHn2 unit
!
!
!      Parameters for model generation
!
ORIG=0.0
X1=5.5
X2=11.25
DS=22.5
Y1=5.5
Y2=19.5
Y3=25
Y4=30.5
R1=2.75
RW=0.925
ROD=2.25
TSW2_UP=106.8
TSW2_LOW=-82.5
TSW1=236.9
PTN=275.0
TCW=311.0
TSW3=-98.3
CHN1V=-103.5
CHN1Z=-207.5
CHN2=-300.0
XOFF=33.75
YOFF=25.0
!
WPOFF,X2,0,0
CSYS,4
RECTNG,ORIG,X1,ORIG,Y1,
PCIRC,R1,,0,90,
ASBA,1,2
PCIRC,RW,,0,90,
ARSYM,Y,ALL,,,0,0
RECTNG,ORIG,X1, Y1, Y2,
RECTNG,ORIG,X1, Y2, Y3,
RECTNG,ORIG,X1, Y3, Y4,
RECTNG,ORIG,X1, Y4, TSW2_UP,
RECTNG,ORIG,X1, TSW2_UP, TSW1,
RECTNG,ORIG,X1, TSW1, PTN,
RECTNG,ORIG,X1, PTN, TCW,
RECTNG,ORIG,X1, -Y1,TSW2_LOW,
RECTNG,ORIG,X1,TSW2_LOW, TSW3,
RECTNG,ORIG,X1, TSW3, CHN1V,
RECTNG,ORIG,X1, CHN1V, CHN1Z,
RECTNG,ORIG,X1, CHN1Z, CHN2,
!
RECTNG, X1,X2, ORIG, Y1,
RECTNG, X1,X2, Y1, Y2,
RECTNG, X1,X2, Y2, Y3,
RECTNG, X1,X2, Y3, Y4,
RECTNG, X1,X2, Y4, TSW2_UP,
RECTNG, X1,X2, TSW2_UP, TSW1,
RECTNG, X1,X2, TSW1, PTN,
RECTNG, X1,X2, PTN, TCW,

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RECTNG, X1,X2, ORIG, -Y1,
RECTNG, X1,X2, -Y1,TSW2_LOW,
RECTNG, X1,X2,TSW2_LOW, TSW3,
RECTNG, X1,X2, TSW3, CHN1V,
RECTNG, X1,X2, CHN1V, CHN1Z,
RECTNG, X1,X2, CHN1Z, CHN2,
!
ARSYM,X,ALL,,,0,0
WPOFF,X2,0,0
ASEL,S,LOC,X,-X2,0,,1
ARSYM,X,ALL,,,0,0
ALLSEL
WPOFF,X2,0,0
ARSYM,X,ALL,,,0,0
WPOFF,-XOFF,YOFF,0
!
PCIRC,ROD, ,0,90,
PCIRC,ROD, ,0,-90,
!
ASBA,50,181
ASBA,49,182
WPOFF,0,-YOFF,0
AGLUE,ALL
/TRIAD,RBOT
APLOT
SAVE
!
!           Meshing
!
TYPE,1,
MAT,9,
ESYS,0,
ESHAPE,2,0
MOPT,EXPND,1,
MOPT,TRANS,2,
MOPT,IESZ,0,
ESIZE,0.5,0,
AMESH,1,
AMESH,49
AMESH,181
AMESH,187
AMESH,182
AMESH,188
AMESH,184
AMESH,61
AMESH,185
AMESH,189
AMESH,186
AMESH,91
!
LCCAT,2,3
LCCAT,14,825
LCCAT,891,835
LCCAT,128,830
LCCAT,912,608
LCCAT,992,915
LCCAT,254,878
LCCAT,248,249
LCCAT,943,488
LCCAT,1005,948
LCCAT,374,938
LCCAT,368,369
LCCAT,769,845
LCCAT,841,894
!
TYPE,1,
MAT,4,
ESYS,0,
LSEL,S,LINE,,1044
LSEL,A,LINE,,724
!
LSEL,A,LINE,,5
LSEL,A,LINE,,1032
LSEL,A,LINE,,1034
LSEL,A,LINE,,1033
LSEL,A,LINE,,1036
LSEL,A,LINE,,1037
LSEL,A,LINE,,1035
LSEL,A,LINE,,251
LSEL,A,LINE,,1039
LSEL,A,LINE,,1040
LSEL,A,LINE,,1038
LSEL,A,LINE,,371
LESIZE,ALL,,10
!
LSEL,S,LINE,,1041,
LSEL,A,LINE,,1043,
LSEL,A,LINE,,1042,
LSEL,A,LINE,,127,
LSEL,A,LINE,,8,
LSEL,A,LINE,,9,
LSEL,A,LINE,,15,
LSEL,A,LINE,,247,
LSEL,A,LINE,,607,
LSEL,A,LINE,,250,
LSEL,A,LINE,,255,
LSEL,A,LINE,,367
LSEL,A,LINE,,487

```

! Mesh the waste package

! Concatenates lines

! Mesh the TSw2 unit

! Observation drift

! Emplacement drift

```
LSEL,A,LINE,,370
LSEL,A,LINE,,375
LESIZE,ALL,,5
!
LSEL,S,LINE,,845,
LSEL,A,LINE,,769,
LSEL,A,LINE,,841,
LSEL,A,LINE,,894,
LSEL,A,LINE,,830,
LSEL,A,LINE,,3,
LSEL,A,LINE,,2,
LSEL,A,LINE,,825,
LSEL,A,LINE,,14,
LSEL,A,LINE,,835,
LSEL,A,LINE,,891,
LSEL,A,LINE,,128
LSEL,A,LINE,,249
LSEL,A,LINE,,912
LSEL,A,LINE,,608
LSEL,A,LINE,,992,
LSEL,A,LINE,,915
LSEL,A,LINE,,254
LSEL,A,LINE,,878
LSEL,A,LINE,,248
LSEL,A,LINE,,369
LSEL,A,LINE,,943
LSEL,A,LINE,,488
LSEL,A,LINE,,1005,
LSEL,A,LINE,,948
LSEL,A,LINE,,374
LSEL,A,LINE,,938
LSEL,A,LINE,,368
LSEL,A,LINE,,766
LESIZE,ALL,,5
!
LSEL,S,LINE,,738
LSEL,A,LINE,,764
LSEL,A,LINE,,821
LSEL,A,LINE,,795
LSEL,A,LINE,,823
LESIZE,ALL,,4
!
LSEL,S,LINE,,840
LSEL,A,LINE,,23
LSEL,A,LINE,,263
LSEL,A,LINE,,918
LSEL,A,LINE,,383
LSEL,A,LINE,,953
LESIZE,ALL,,5
!
ALLSEL
ESIZE,1,0,
AMESH,353,354,1,
AMESH,3
AMESH,344,346,1
AMESH,63
AMESH,347,349,1
AMESH,93
AMESH,350,352,1
ESIZE,1,5,0
AMESH,204
AMESH,271
AMESH,190
AMESH,233
AMESH,203
AMESH,258
AMESH,231
AMESH,318
AMESH,218
AMESH,293
AMESH,232
AMESH,331
!
AMESH,272
AMESH,235
AMESH,191
AMESH,239
AMESH,241
AMESH,193
AMESH,194
AMESH,234
AMESH,259
AMESH,238
AMESH,240
AMESH,260
AMESH,261
AMESH,206
AMESH,281
AMESH,208
AMESH,209
AMESH,283
AMESH,284
AMESH,319
AMESH,294
AMESH,320
AMESH,298
AMESH,321
AMESH,300
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AMESH,219
AMESH,295
AMESH,221
AMESH,299
AMESH,222
AMESH,301
AMESH,332
AMESH,334
AMESH,335
!
ESIZE,2,0
AMESH,205
AMESH,243
AMESH,195
AMESH,242
AMESH,262
AMESH,210
AMESH,285
AMESH,322
AMESH,302
AMESH,223
AMESH,303
AMESH,336
AMESH,273
AMESH,237
AMESH,192
AMESH,236
AMESH,266
AMESH,207
AMESH,282
AMESH,326
AMESH,296
AMESH,220
AMESH,297
AMESH,333
!
TYPE,1,           ! Mesh the TSw1 unit
MAT,3,
ESYS,0,
ESIZE,3.0,0,
AMESH,274
AMESH,245
AMESH,196
AMESH,244
AMESH,263
AMESH,211
AMESH,286
AMESH,323
AMESH,304
AMESH,224
AMESH,305
AMESH,337
!
TYPE,1,           ! Mesh the PTn unit
MAT,2,
ESYS,0,
ESIZE,7.5,0,
AMESH,275
AMESH,247
AMESH,197
AMESH,246
AMESH,264
AMESH,212
AMESH,287
AMESH,324
AMESH,306
AMESH,225
AMESH,307
AMESH,338
!
TYPE,1,           ! Mesh the TCw unit
MAT,1,
ESYS,0,
ESIZE,15.0,0,
AMESH,276
AMESH,249
AMESH,198
AMESH,248
AMESH,265
AMESH,213
AMESH,288
AMESH,325
AMESH,308
AMESH,226
AMESH,309
AMESH,339
!
TYPE,1,           ! Mesh the TSw3 unit
MAT,5,
ESYS,0,
ESIZE,3.0,0,
AMESH,277
AMESH,250
AMESH,199
AMESH,251
AMESH,267
AMESH,214
AMESH,289
```

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AMESH,327
AMESH,311
AMESH,227
AMESH,310
AMESH,340
!
TYPE,1,          !      Mesh the CHn1v unit
MAT,6,
ESYS,0,
ESIZE,3.0,0,
AMESH,278
AMESH,252
AMESH,200
AMESH,253
AMESH,268
AMESH,215
AMESH,290
AMESH,328
AMESH,313
AMESH,228
AMESH,312
AMESH,341
!
TYPE,1,          !      Mesh the CHn1z unit
MAT,7,
ESYS,0,
ESIZE,7.5,0,
AMESH,279
AMESH,254
AMESH,201
AMESH,255
AMESH,269
AMESH,216
AMESH,291
AMESH,329
AMESH,315
AMESH,229
AMESH,314
AMESH,342
!
TYPE,1,          !      Mesh the CHn2 unit
MAT,8,
ESYS,0,
ESIZE,15,0,
AMESH,280
AMESH,256
AMESH,202
AMESH,257
AMESH,270
AMESH,217
AMESH,292
AMESH,330
AMESH,317
AMESH,230
AMESH,316
AMESH,343
!
TYPE,2,          !      Define link elements
MAT,10,
REAL,1,
ESYS,0,
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
LSEL,A,LINE,,5          !      Drift wall
LSEL,A,LINE,,1033
LSEL,A,LINE,,1034
LSEL,A,LINE,,1032
LSEL,A,LINE,,1036
LSEL,A,LINE,,251
LSEL,A,LINE,,1035
LSEL,A,LINE,,1037
LSEL,A,LINE,,1039
LSEL,A,LINE,,371
LSEL,A,LINE,,1038
LSEL,A,LINE,,1040
NSLL,S,1
ESURF,ALL
PLOT
!
/AUX12          !      Generate superelement for thermal
EMIS,2.0,85,    !      radiation calculation
STEF,1.7878,
GEOM,1,0,
SPACE, ,
ESEL,S,TYPE,,2,2
NSLE,S
VTYPE,0, ,
MPRINT,0

```



```

WRITE,pca2d85m52      !      Save radiation matrices
FINISH
!
/PREP7
TYPE,3,
MAT,11,
REAL,1,
ESYS,0,
SE,pca2d85m52
!
ESEL,S,TYPE,,2,2
EDELE,ALL
ALLSEL
!
/SOLU                  !      Solution phase
ANTYPE,TRANS          !      Transient analysis
NROPT,AUTO            !      Program chosen Newton-Raphson option
TOFFST,273           !      Specify the temperature offset: 273 C
TINTP,0.005,,0.5,0.5,0.2 !      Use defaults of transient integration
!                      parameters
OUTPR,NSOL,5,         !      Solution printout at every 5 substeps
OUTRES,NSOL,5,        !      Solution data written to database
!                      at every 5 substeps
IC,ALL,TEMP,26,       !      Initial temperature at all nodes
D,ALL,TEMP,18.7       !      Select all nodes on top surface
NSEL,S,LOC,Y,-300.0   !
D,ALL,TEMP,32.53      !      Select all nodes on bottom surface
ALLSEL
SAVE
!
!      Load step number 1
TIMINT,OFF            !      Turn off transient effects at the
!                      first load step
!
TIME,1e-7
AUTOTS,1
DELTIM,1e-8,1e-8,1e-7,0
KBC,0
LSWRITE,1,
!
TIMINT,ON             !      Turn on transient effects at the
!                      rest of load steps
!
!      Load step number 2
TIME,0.5e-2
AUTOTS,1
DELTIM,0.5e-4,0.5e-4,0.5e-3,0
KBC,1
LSEL,S,LINE,,1044     !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,26
KBC,0
LSEL,S,LINE,,1        !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.5952e9,
ALLSEL
LSWRITE,2,
!
!      Load step number 3
TIME,1
AUTOTS,1
DELTIM,0.01,0.01,0.1,0
KBC,1
LSEL,S,LINE,,1044     !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,26
KBC,0
LSEL,S,LINE,,1        !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.5289e9,
ALLSEL
LSWRITE,3,
!
!      Load step number 4
TIME,5
AUTOTS,1
DELTIM,0.05,0.05,0.5,0
KBC,1
LSEL,S,LINE,,1044     !      Observation drift

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```
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,26.60
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.3217e9,
ALLSEL
LSWRITE,4,
!
!          Load step number 5
TIME,10
AUTOTS,1
DELTIM,0.05,0.05,0.5,0
KBC,1
LSEL,S,LINE,,1044       !          Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,27.53
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.1169e9,
ALLSEL
LSWRITE,5,
!
!          Load step number 6
TIME,20
AUTOTS,1
DELTIM,0.1,0.1,0.75,0
KBC,1
LSEL,S,LINE,,1044       !          Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,28.62
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.7929e9,
ALLSEL
LSWRITE,6,
!
!          Load step number 7
TIME,30
AUTOTS,1
DELTIM,0.1,0.1,0.75,0
KBC,1
LSEL,S,LINE,,1044       !          Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,29.21
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.5401e9,
ALLSEL
LSWRITE,7,
!
!          Load step number 8
TIME,40
AUTOTS,1
DELTIM,0.15,0.15,0.75,0
```

```
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,29.60
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.3400e9,
ALLSEL
LSWRITE,8,
!
!      Load step number 9
TIME,50
AUTOTS,1
DELTIM,0.15,0.15,0.75,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,29.88
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.1779e9,
ALLSEL
LSWRITE,9,
!
!      Load step number 10
TIME,60
AUTOTS,1
DELTIM,0.15,0.15,1.0,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,30.07
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.0477e9,
ALLSEL
LSWRITE,10,
!
!      Load step number 11
TIME,70
AUTOTS,1
DELTIM,0.15,0.15,1.0,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,30.20
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,9.4197e8,
ALLSEL
LSWRITE,11,
!
!      Load step number 12
TIME,80
```

```

AUTOTS,1
DELTIM,0.15,0.15,1.5,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,30.29
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,8.5514e8,
ALLSEL
LSWRITE,12,
!
!      Load step number 13
TIME,100
AUTOTS,1
DELTIM,0.15,0.15,2.5,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,30.38
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,7.2487e8,
ALLSEL
LSWRITE,13,
!
!      Load step number 14
TIME,150
AUTOTS,1
DELTIM,0.2,0.2,5,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,30.42
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,5.4619e8,
ALLSEL
LSWRITE,14,
!
ALLSEL
LSSOLVE,1,14,1,          !      Solve with 14 load steps
FINISH

```

```

/BATCH,LIST
!
!*****
!#
!#                               ANSYS INPUT
!#
!#   Filename:      pca2d85m53
!#
!#   Input File:    pca2d85m53.dat
!#
!#   Output File:   pca2d85m53.out
!#
!#   Description:   2D Analysis for temperature at performance
!#                  confirmation observation drift (pca2d)
!#                  Thermal load:      85 MTU/acre & 21 PWR (85)
!#                  Emplacement mode:  Center-in-drift
!#                  Drift diameter:    5.5 meters
!#                  Drift spacing:     22.5 meters
!#                  WP spacing:        18.92 meters
!#                  Initial heat output: 9.05 kW/package
!#                  WP diameter:       1.85 meters
!#                  Observation drift size: 4.5 meters in diameter
!#                                      15.90 m^2 in area
!#                                      600 meters long
!#
!#                  Distance from emplace.
!#                  drift crown to obser.
!#                  drift floor:      20 meters
!#                  Location of O.D.:  Mid-of-pillar (m)
!#                  Ventilation air temp.: Varied
!#                  Ventilation quantity: 5.0 m^3/s (5)
!#                  Coef. of convection: 1.0787 W/m^2-K
!#                  Modeling time period: 150 years
!#                  Ventilation segment: No. 3 (200 - 300 m) (3)
!#
!#   Code Version:  ANSYS Revision 5.2
!#
!#   Created By:    Yiming Sun
!#
!#   Last Modified: 02/11/97
!#
!*****
/COM,ANSYS MEDIA REV. 5.2
!
/FILNAM,pca2d85m53      !      Jobname to use for all subsequent files
/TITLE,2D Model (PCA;TL:85MTU/ac;AQ:5.0m^3/s;AT:26C;DOD:20m;SN:3)
/UNITS,SI
/SHOW
!
/NOPR
*ABB,SAVE_DB,SAVE
*ABB,RESUM_DB,RESUME
*ABB,QUIT,Fnc_/EXIT
*ABB,SHFR,./SHOW,FILE,,8
*ABB,SHFV,./SHOW,FILE,,1
*ABB,X11C,./SHOW,X11C,,8
*ABB,X11,./SHOW,X11,,1
*ABB,REPLOTT,/REPLOTT
*ABB,K1,/PNUM,KP,1
*ABB,K0,/PNUM,KP,0
*ABB,POWRGRPH,Fnc_/GRAPHICS
*ABB,ANSYSWEB,Fnc_HomePage
/GO
!
/FDELE,EMAT,DELE
/FDELE,ESAV,DELE
/FDELE,EROT,DELE
/FDELE,DSUB,DELE
/FDELE,TRI,DELE
/FDELE,OSAV,DELE
/FDELE,PAGE,DELE
!
/PREP7
!
!      Define element types
!
ET,1,PLANE55      !      4-node, 2-D thermal solid element
ET,2,LINK32      !      2-D conduction bar
R,1,1,0
ET,3,MATRIX50    !      Superelement for radiation
KEYOPT,3,1,1     !      Superelement behavior: radiation substructure
KEYOPT,3,6,0
!
!      Define material properties
!
!      Material number 1 (TCw unit)
MP,DENS,1,2169    !      Density (kg/m^3)
MP,KXX,1,5.014E7  !      Thermal conductivity (J/yr-m-C)
!
!      Material number 2 (PTn unit)
MP,DENS,2,1299    !      Density (kg/m^3)
MP,KXX,2,2.681E7  !      Thermal conductivity (J/yr-m-C)
!
!      Material number 3 (TSw1 unit)
MP,DENS,3,2163    !      Density (kg/m^3)
MP,KXX,3,5.046E7  !      Thermal conductivity (J/yr-m-C)
!
!      Material number 4 (TSw2 unit)

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MP,DENS,4,2274      !      Density (kg/m^3)
MP,KXX, 4,6.623E7   !      Thermal conductivity (J/yr-m-C)
MP,EMIS,4,0.9       !      Emissivity
!
!      Material number 5 (TSw3 unit)
MP,DENS,5,2271      !      Density (kg/m^3)
MP,KXX, 5,4.037E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 6 (CHn1v unit)
MP,DENS,6,1972      !      Density (kg/m^3)
MP,KXX, 6,3.784E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 7 (CHn1z unit)
MP,DENS,7,1886      !      Density (kg/m^3)
MP,KXX, 7,4.037E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 8 (CHn2 unit)
MP,DENS,8,2070      !      Density (kg/m^3)
MP,KXX, 8,4.92E7    !      Thermal conductivity (J/yr-m-C)
!
!      Material number 9 (Waste package)
MP,DENS,9,8131      !      Density (kg/m^3)
MP,KXX, 9,131.534E7 !      Thermal conductivity (J/yr-m-C)
MP,C, 9,487.901     !      Specific heat (J/kg-C)
MP,EMIS,9,0.8       !      Emissivity
!
!      Material number 10 (link elements for radiation)
MP,EMIS,10,0.85     !      Emissivity
!
!      Material number 11 (Radiation superelement element)
MP,EMIS,11,0.85     !      Emissivity
!
MPTEMP,1,25,94,95,114,115,250 ! Temperature table for temperature
!                               dependent specific heat (C)
!
!      Specific heat (J/kg-C)
MPDATA,C,1,1,936.5,936.5,4322.2,4322.2,967.2,967.2 ! TCw unit
MPDATA,C,2,1,1715.6,1715.6,22564.3,22564.3,1172.9,1172.9 ! PTn unit
MPDATA,C,3,1,960.5,960.5,5670.6,5670.6,934.8,934.8 ! TSw1 unit
MPDATA,C,4,1,941.7,941.7,4608.0,4608.0,960.4,960.4 ! TSw2 unit
MPDATA,C,5,1,904.0,904.0,1990.0,1990.0,1124.4,1124.4 ! TSw3 unit
MPDATA,C,6,1,1300.8,1300.8,17935.1,17935.1,847.0,847.0 ! CHn1v unit
MPDATA,C,7,1,1416.2,1416.2,18762.1,18762.1,1210.8,1210.8 ! CHn1z unit
MPDATA,C,8,1,1231.2,1231.2,11998.2,11998.2,1330.6,1330.6 ! CHn2 unit
!
!      Parameters for model generation
!
ORIG=0.0
X1=5.5
X2=11.25
DS=22.5
Y1=5.5
Y2=19.5
Y3=25
Y4=30.5
R1=2.75
RW=0.925
ROD=2.25
TSW2_UP=106.8
TSW2_LOW=-82.5
TSW1=236.9
PTN=275.0
TCW=311.0
TSW3=-98.3
CHN1V=-103.5
CHN1Z=-207.5
CHN2=-300.0
XOFF=33.75
YOFF=25.0
!
WPOFF,X2,0,0
CSYS,4
RECTNG,ORIG,X1,ORIG,Y1,
PCIRC,R1,,0,90,
ASBA,1,2
PCIRC,RW,,0,90,
ARSYM,Y,ALL,,,0,0
RECTNG,ORIG,X1, Y1, Y2,
RECTNG,ORIG,X1, Y2, Y3,
RECTNG,ORIG,X1, Y3, Y4,
RECTNG,ORIG,X1, Y4, TSW2_UP,
RECTNG,ORIG,X1, TSW2_UP, TSW1,
RECTNG,ORIG,X1, TSW1, PTN,
RECTNG,ORIG,X1, PTN, TCW,
RECTNG,ORIG,X1, -Y1,TSW2_LOW,
RECTNG,ORIG,X1,TSW2_LOW, TSW3,
RECTNG,ORIG,X1, TSW3, CHN1V,
RECTNG,ORIG,X1, CHN1V, CHN1Z,
RECTNG,ORIG,X1, CHN1Z, CHN2,
!
RECTNG, X1,X2, ORIG, Y1,
RECTNG, X1,X2, Y1, Y2,
RECTNG, X1,X2, Y2, Y3,
RECTNG, X1,X2, Y3, Y4,
RECTNG, X1,X2, Y4, TSW2_UP,
RECTNG, X1,X2, TSW2_UP, TSW1,
RECTNG, X1,X2, TSW1, PTN,
RECTNG, X1,X2, PTN, TCW,

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```

RECTNG, X1,X2, ORIG, -Y1,
RECTNG, X1,X2, -Y1,TSW2_LOW,
RECTNG, X1,X2,TSW2_LOW, TSW3,
RECTNG, X1,X2, TSW3, CHN1V,
RECTNG, X1,X2, CHN1V, CHN1Z,
RECTNG, X1,X2, CHN1Z, CHN2,
!
ARSYM,X,ALL,,,0,0
WPOFF,X2,0,0
ASEL,S,LOC,X,-X2,0,,1
ARSYM,X,ALL,,,0,0
ALLSEL
WPOFF,X2,0,0
ARSYM,X,ALL,,,0,0
WPOFF,-XOFF,YOFF,0
!
PCIRC,ROD, ,0,90,
PCIRC,ROD, ,0,-90,
!
ASBA,50,181
ASBA,49,182
WPOFF,0,-YOFF,0
AGLUE,ALL
/TRIAD,RBOT
APLOT
SAVE
!
!           Meshing
!
TYPE,1,
MAT,9,
ESYS,0,
ESHAPE,2,0
MOPT,EXPND,1,
MOPT,TRANS,2,
MOPT,IESZ,0,
ESIZE,0.5,0,
AMESH,1,
AMESH,49
AMESH,181
AMESH,187
AMESH,182
AMESH,188
AMESH,184
AMESH,61
AMESH,185
AMESH,189
AMESH,186
AMESH,91
!
LCCAT,2,3
LCCAT,14,825
LCCAT,891,835
LCCAT,128,830
LCCAT,912,608
LCCAT,992,915
LCCAT,254,878
LCCAT,248,249
LCCAT,943,488
LCCAT,1005,948
LCCAT,374,938
LCCAT,368,369
LCCAT,769,845
LCCAT,841,894
!
TYPE,1,
MAT,4,
ESYS,0,
LSEL,S,LINE,,1044
LSEL,A,LINE,,724
!
LSEL,A,LINE,,5
LSEL,A,LINE,,1032
LSEL,A,LINE,,1034
LSEL,A,LINE,,1033
LSEL,A,LINE,,1036
LSEL,A,LINE,,1037
LSEL,A,LINE,,1035
LSEL,A,LINE,,251
LSEL,A,LINE,,1039
LSEL,A,LINE,,1040
LSEL,A,LINE,,1038
LSEL,A,LINE,,371
LESIZE,ALL,,10
!
LSEL,S,LINE,,1041,
LSEL,A,LINE,,1043,
LSEL,A,LINE,,1042,
LSEL,A,LINE,,127,
LSEL,A,LINE,,8,
LSEL,A,LINE,,9,
LSEL,A,LINE,,15,
LSEL,A,LINE,,247,
LSEL,A,LINE,,607,
LSEL,A,LINE,,250,
LSEL,A,LINE,,255,
LSEL,A,LINE,,367
LSEL,A,LINE,,487

```

! Mesh the waste package

! Concatenates lines

! Mesh the TSw2 unit

! Observation drift

! Emplacement drift

```
LSEL,A,LINE,,370
LSEL,A,LINE,,375
LESIZE,ALL,,5
!
LSEL,S,LINE,,845,
LSEL,A,LINE,,769,
LSEL,A,LINE,,841,
LSEL,A,LINE,,894,
LSEL,A,LINE,,830,
LSEL,A,LINE,,3,
LSEL,A,LINE,,2,
LSEL,A,LINE,,825,
LSEL,A,LINE,,14,
LSEL,A,LINE,,835,
LSEL,A,LINE,,891,
LSEL,A,LINE,,128
LSEL,A,LINE,,249
LSEL,A,LINE,,912
LSEL,A,LINE,,608
LSEL,A,LINE,,992,
LSEL,A,LINE,,915
LSEL,A,LINE,,254
LSEL,A,LINE,,878
LSEL,A,LINE,,248
LSEL,A,LINE,,369
LSEL,A,LINE,,943
LSEL,A,LINE,,488
LSEL,A,LINE,,1005,
LSEL,A,LINE,,948
LSEL,A,LINE,,374
LSEL,A,LINE,,938
LSEL,A,LINE,,368
LSEL,A,LINE,,766
LESIZE,ALL,,5
!
LSEL,S,LINE,,738
LSEL,A,LINE,,764
LSEL,A,LINE,,821
LSEL,A,LINE,,795
LSEL,A,LINE,,823
LESIZE,ALL,,4
!
LSEL,S,LINE,,840
LSEL,A,LINE,,23
LSEL,A,LINE,,263
LSEL,A,LINE,,918
LSEL,A,LINE,,383
LSEL,A,LINE,,953
LESIZE,ALL,,5
!
ALLSEL
ESIZE,1,0,
AMESH,353,354,1,
AMESH,3
AMESH,344,346,1
AMESH,63
AMESH,347,349,1
AMESH,93
AMESH,350,352,1
ESIZE,1,5,0
AMESH,204
AMESH,271
AMESH,190
AMESH,233
AMESH,203
AMESH,258
AMESH,231
AMESH,318
AMESH,218
AMESH,293
AMESH,232
AMESH,331
!
AMESH,272
AMESH,235
AMESH,191
AMESH,239
AMESH,241
AMESH,193
AMESH,194
AMESH,234
AMESH,259
AMESH,238
AMESH,240
AMESH,260
AMESH,261
AMESH,206
AMESH,281
AMESH,208
AMESH,209
AMESH,283
AMESH,284
AMESH,319
AMESH,294
AMESH,320
AMESH,298
AMESH,321
AMESH,300
```



```
AMESH,219
AMESH,295
AMESH,221
AMESH,299
AMESH,222
AMESH,301
AMESH,332
AMESH,334
AMESH,335
!
ESIZE,2,0
AMESH,205
AMESH,243
AMESH,195
AMESH,242
AMESH,262
AMESH,210
AMESH,285
AMESH,322
AMESH,302
AMESH,223
AMESH,303
AMESH,336
AMESH,273
AMESH,237
AMESH,192
AMESH,236
AMESH,266
AMESH,207
AMESH,282
AMESH,326
AMESH,296
AMESH,220
AMESH,297
AMESH,333
!
TYPE,1,                                !      Mesh the TSwl unit
MAT,3,
ESYS,0,
ESIZE,3.0,0,
AMESH,274
AMESH,245
AMESH,196
AMESH,244
AMESH,263
AMESH,211
AMESH,286
AMESH,323
AMESH,304
AMESH,224
AMESH,305
AMESH,337
!
TYPE,1,                                !      Mesh the PTn unit
MAT,2,
ESYS,0,
ESIZE,7.5,0,
AMESH,275
AMESH,247
AMESH,197
AMESH,246
AMESH,264
AMESH,212
AMESH,287
AMESH,324
AMESH,306
AMESH,225
AMESH,307
AMESH,338
!
TYPE,1,                                !      Mesh the TCw unit
MAT,1,
ESYS,0,
ESIZE,15.0,0,
AMESH,276
AMESH,249
AMESH,198
AMESH,248
AMESH,265
AMESH,213
AMESH,288
AMESH,325
AMESH,308
AMESH,226
AMESH,309
AMESH,339
!
TYPE,1,                                !      Mesh the TSw3 unit
MAT,5,
ESYS,0,
ESIZE,3.0,0,
AMESH,277
AMESH,250
AMESH,199
AMESH,251
AMESH,267
AMESH,214
AMESH,289
```

```

AMESH,327
AMESH,311
AMESH,227
AMESH,310
AMESH,340
!
TYPE,1,          !      Mesh the CHn1v unit
MAT,6,
ESYS,0,
ESIZE,3.0,0,
AMESH,278
AMESH,252
AMESH,200
AMESH,253
AMESH,268
AMESH,215
AMESH,290
AMESH,328
AMESH,313
AMESH,228
AMESH,312
AMESH,341
!
TYPE,1,          !      Mesh the CHn1z unit
MAT,7,
ESYS,0,
ESIZE,7.5,0,
AMESH,279
AMESH,254
AMESH,201
AMESH,255
AMESH,269
AMESH,216
AMESH,291
AMESH,329
AMESH,315
AMESH,229
AMESH,314
AMESH,342
!
TYPE,1,          !      Mesh the CHn2 unit
MAT,8,
ESYS,0,
ESIZE,15,0,
AMESH,280
AMESH,256
AMESH,202
AMESH,257
AMESH,270
AMESH,217
AMESH,292
AMESH,330
AMESH,317
AMESH,230
AMESH,316
AMESH,343
!
TYPE,2,          !      Define link elements
MAT,10,
REAL,1,
ESYS,0,
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
LSEL,A,LINE,,5          !      Drift wall
LSEL,A,LINE,,1033
LSEL,A,LINE,,1034
LSEL,A,LINE,,1032
LSEL,A,LINE,,1036
LSEL,A,LINE,,251
LSEL,A,LINE,,1035
LSEL,A,LINE,,1037
LSEL,A,LINE,,1039
LSEL,A,LINE,,371
LSEL,A,LINE,,1038
LSEL,A,LINE,,1040
NSLL,S,1
ESURF,ALL
PLOT
!
/AUX12          !      Generate superelement for thermal
EMIS,2,0.85,    !      radiation calculation
STEF,1.7878,
GEOM,1,0,
SPACE, ,
ESEL,S,TYPE,,2,2
NSLE,S
VTYPE,0, ,
MPRINT,0

```

```

WRITE,pca2d85m53      !      Save radiation matrices
FINISH
!
/PREP7
TYPE,3,
MAT,11,
REAL,1,
ESYS,0,
SE,pca2d85m53
!
ESEL,S,TYPE,,2,2
EDELE,ALL
ALLSEL
!
/SOLU                  !      Solution phase
ANTYPE,TRANS           !      Transient analysis
NROPT,AUTO             !      Program chosen Newton-Raphson option
TOFFST,273             !      Specify the temperature offset: 273 C
TINTP,0.005, , ,0.5,0.5,0.2 !      Use defaults of transient integration
!                      parameters
OUTPR,NSOL,5,          !      Solution printout at every 5 substeps
OUTRES,NSOL,5,         !      Solution data written to database
!                      at every 5 substeps
IC,ALL,TEMP,26,        !      Initial temperature at all nodes
NSEL,S,LOC,Y,311.0     !      Select all nodes on top surface
D,ALL,TEMP,18.7
NSEL,S,LOC,Y,-300.0    !      Select all nodes on bottom surface
D,ALL,TEMP,32.53
ALLSEL
SAVE
!
!      Load step number 1
TIMINT,OFF             !      Turn off transient effects at the
!                      first load step
TIME,1e-7
AUTOTS,1
DELTIM,1e-8,1e-8,1e-7,0
KBC,0
LSWRITE,1,
!
TIMINT,ON              !      Turn on transient effects at the
!                      rest of load steps
!      Load step number 2
TIME,0.5e-2
AUTOTS,1
DELTIM,0.5e-4,0.5e-4,0.5e-3,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,26
KBC,0
LSEL,S,LINE,,1         !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.5952e9,
ALLSEL
LSWRITE,2,
!
!      Load step number 3
TIME,1
AUTOTS,1
DELTIM,0.01,0.01,0.1,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,26
KBC,0
LSEL,S,LINE,,1         !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.5289e9,
ALLSEL
LSWRITE,3,
!
!      Load step number 4
TIME,5
AUTOTS,1
DELTIM,0.05,0.05,0.5,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift

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```
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,27.15
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.3217e9,
ALLSEL
LSWRITE,4,
!
!          Load step number 5
TIME,10
AUTOTS,1
DELTIM,0.05,0.05,0.5,0
KBC,1
LSEL,S,LINE,,1044       !          Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,28.95
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.1169e9,
ALLSEL
LSWRITE,5,
!
!          Load step number 6
TIME,20
AUTOTS,1
DELTIM,0.1,0.1,0.75,0
KBC,1
LSEL,S,LINE,,1044       !          Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,31.06
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.7929e9,
ALLSEL
LSWRITE,6,
!
!          Load step number 7
TIME,30
AUTOTS,1
DELTIM,0.1,0.1,0.75,0
KBC,1
LSEL,S,LINE,,1044       !          Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,32.22
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.5401e9,
ALLSEL
LSWRITE,7,
!
!          Load step number 8
TIME,40
AUTOTS,1
DELTIM,0.15,0.15,0.75,0
```

```

KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,32.98
KBC,0
LSEL,S,LINE,,1              !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.3400e9,
ALLSEL
LSWRITE,8,
!
!      Load step number 9
TIME,50
AUTOTS,1
DELTIM,0.15,0.15,0.75,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,33.53
KBC,0
LSEL,S,LINE,,1              !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.1779e9,
ALLSEL
LSWRITE,9,
!
!      Load step number 10
TIME,60
AUTOTS,1
DELTIM,0.15,0.15,1.0,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,33.91
KBC,0
LSEL,S,LINE,,1              !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.0477e9,
ALLSEL
LSWRITE,10,
!
!      Load step number 11
TIME,70
AUTOTS,1
DELTIM,0.15,0.15,1.0,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,34.17
KBC,0
LSEL,S,LINE,,1              !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,9.4197e8,
ALLSEL
LSWRITE,11,
!
!      Load step number 12
TIME,80

```

```
AUTOTS,1
DELTIM,0.15,0.15,1.5,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,34.34
KBC,0
LSEL,S,LINE,,1         !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,8.5514e8,
ALLSEL
LSWRITE,12,
!
!      Load step number 13
TIME,100
AUTOTS,1
DELTIM,0.15,0.15,2.5,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,34.53
KBC,0
LSEL,S,LINE,,1         !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,7.2487e8,
ALLSEL
LSWRITE,13,
!
!      Load step number 14
TIME,150
AUTOTS,1
DELTIM,0.2,0.2,5,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,34.62
KBC,0
LSEL,S,LINE,,1         !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,5.4619e8,
ALLSEL
LSWRITE,14,
!
ALLSEL
LSSOLVE,1,14,1,      !      Solve with 14 load steps
FINISH
```

```

/BATCH,LIST
!
!#####
!#
!#                               ANSYS INPUT
!#
!#   Filename:      pca2d85m54
!#
!#   Input File:    pca2d85m54.dat
!#
!#   Output File:   pca2d85m54.out
!#
!#   Description:   2D Analysis for temperature at performance
!#                  confirmation observation drift (pca2d)
!#                  Thermal load:      85 MTU/acre & 21 PWR (85)
!#                  Emplacement mode:  Center-in-drift
!#                  Drift diameter:    5.5 meters
!#                  Drift spacing:     22.5 meters
!#                  WP spacing:        18.92 meters
!#                  Initial heat output: 9.05 kW/package
!#                  WP diameter:       1.85 meters
!#                  Observation drift size: 4.5 meters in diameter
!#                                      15.90 m^2 in area
!#                                      600 meters long
!#
!#                  Distance from emplace.
!#                  drift crown to obser.
!#                  drift floor:      20 meters
!#                  Location of O.D.:  Mid-of-pillar (m)
!#                  Ventilation air temp.: Varied
!#                  Ventilation quantity: 5.0 m^3/s (5)
!#                  Coef. of convection: 1.0787 W/m^2-K
!#                  Modeling time period: 150 years
!#                  Ventilation segment: No. 4 (300 - 400 m) (4)
!#
!#   Code Version:  ANSYS Revision 5.2
!#
!#   Created By:    Yiming Sun
!#
!#   Last Modified:  02/12/97
!#
!#####
/COM,ANSYS MEDIA REV. 5.2
!
/FILNAM,pca2d85m54      !      Jobname to use for all subsequent files
/TITLE,2D Model (PCA;TL:85MTU/ac;AQ:5.0m^3/s;AT:26C;DOD:20m;SN:4)
/UNITS,SI
/SHOW
!
/NOPR
*ABB,SAVE_DB,SAVE
*ABB,RESUM_DB,RESUME
*ABB,QUIT,Fnc_/EXIT
*ABB,SHFR,/SHOW,FILE,,8
*ABB,SHFV,/SHOW,FILE,,1
*ABB,X11C,/SHOW,X11C,,8
*ABB,X11,/SHOW,X11,,1
*ABB,REPLOTT,/REPLOTT
*ABB,K1,/PNUM,KP,1
*ABB,K0,/PNUM,KP,0
*ABB,POWERGRPH,Fnc_/GRAPHICS
*ABB,ANSYSWEB,Fnc_HomePage
/GO
!
/FDELE,EMAT,DELE
/FDELE,ESAV,DELE
/FDELE,EROT,DELE
/FDELE,DSUB,DELE
/FDELE,TRI,DELE
/FDELE,OSAV,DELE
/FDELE,PAGE,DELE
!
/PREP7
!
!      Define element types
!
ET,1,PLANE55      !      4-node, 2-D thermal solid element
ET,2,LINK32      !      2-D conduction bar
R,1,1,0
ET,3,MATRIX50    !      Superelement for radiation
KEYOPT,3,1,1     !      Superelement behavior: radiation substructure
KEYOPT,3,6,0
!
!      Define material properties
!
!      Material number 1 (TCw unit)
MP,DENS,1,2169    !      Density (kg/m^3)
MP,KXX,1,5.014E7  !      Thermal conductivity (J/yr-m-C)
!
!      Material number 2 (PTn unit)
MP,DENS,2,1299    !      Density (kg/m^3)
MP,KXX,2,2.681E7  !      Thermal conductivity (J/yr-m-C)
!
!      Material number 3 (TSw1 unit)
MP,DENS,3,2163    !      Density (kg/m^3)
MP,KXX,3,5.046E7  !      Thermal conductivity (J/yr-m-C)
!
!      Material number 4 (TSw2 unit)

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MP,DENS,4,2274      !      Density (kg/m^3)
MP,KXX, 4,6.623E7   !      Thermal conductivity (J/yr-m-C)
MP,EMIS,4,0.9       !      Emissivity
!
!      Material number 5 (TSw3 unit)
MP,DENS,5,2271      !      Density (kg/m^3)
MP,KXX, 5,4.037E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 6 (CHn1v unit)
MP,DENS,6,1972      !      Density (kg/m^3)
MP,KXX, 6,3.784E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 7 (CHn1z unit)
MP,DENS,7,1886      !      Density (kg/m^3)
MP,KXX, 7,4.037E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 8 (CHn2 unit)
MP,DENS,8,2070      !      Density (kg/m^3)
MP,KXX, 8,4.92E7    !      Thermal conductivity (J/yr-m-C)
!
!      Material number 9 (Waste package)
MP,DENS,9,8131      !      Density (kg/m^3)
MP,KXX, 9,131.534E7 !      Thermal conductivity (J/yr-m-C)
MP,C, 9,487.901     !      Specific heat (J/kg-C)
MP,EMIS,9,0.8       !      Emissivity
!
!      Material number 10 (link elements for radiation)
MP,EMIS,10,0.85     !      Emissivity
!
!      Material number 11 (Radiation superelement element)
MP,EMIS,11,0.85     !      Emissivity
!
MPTEMP,1,25,94,95,114,115,250 ! Temperature table for temperature
!                               dependent specific heat (C)
!
!      Specific heat (J/kg-C)
MPDATA,C,1,1,936.5,936.5,4322.2,4322.2,967.2,967.2 ! TCw unit
MPDATA,C,2,1,1715.6,1715.6,22564.3,22564.3,1172.9,1172.9 ! PTn unit
MPDATA,C,3,1,960.5,960.5,5670.6,5670.6,934.8,934.8 ! TSw1 unit
MPDATA,C,4,1,941.7,941.7,4608.0,4608.0,960.4,960.4 ! TSw2 unit
MPDATA,C,5,1,904.0,904.0,1990.0,1990.0,1124.4,1124.4 ! TSw3 unit
MPDATA,C,6,1,1300.8,1300.8,17935.1,17935.1,847.0,847.0 ! CHn1v unit
MPDATA,C,7,1,1416.2,1416.2,18762.1,18762.1,1210.8,1210.8 ! CHn1z unit
MPDATA,C,8,1,1231.2,1231.2,11998.2,11998.2,1330.6,1330.6 ! CHn2 unit
!
!      Parameters for model generation
!
ORIG=0.0
X1=5.5
X2=11.25
DS=22.5
Y1=5.5
Y2=19.5
Y3=25
Y4=30.5
R1=2.75
RW=0.925
ROD=2.25
TSW2_UP=106.8
TSW2_LOW=-82.5
TSW1=236.9
PTN=275.0
TCW=311.0
TSW3=-98.3
CHN1V=-103.5
CHN1Z=-207.5
CHN2=-300.0
XOFF=33.75
YOFF=25.0
!
WPOFF,X2,0,0
CSYS,4
RECTNG,ORIG,X1,ORIG,Y1,
PCIRC,R1,,0,90,
ASBA,1,2
PCIRC,RW,,0,90,
ARSYM,Y,ALL,,,0,0
RECTNG,ORIG,X1, Y1, Y2,
RECTNG,ORIG,X1, Y2, Y3,
RECTNG,ORIG,X1, Y3, Y4,
RECTNG,ORIG,X1, Y4, TSW2_UP,
RECTNG,ORIG,X1, TSW2_UP, TSW1,
RECTNG,ORIG,X1, TSW1, PTN,
RECTNG,ORIG,X1, PTN, TCW,
RECTNG,ORIG,X1, -Y1,TSW2_LOW,
RECTNG,ORIG,X1,TSW2_LOW, TSW3,
RECTNG,ORIG,X1, TSW3, CHN1V,
RECTNG,ORIG,X1, CHN1V, CHN1Z,
RECTNG,ORIG,X1, CHN1Z, CHN2,
!
RECTNG, X1,X2, ORIG, Y1,
RECTNG, X1,X2, Y1, Y2,
RECTNG, X1,X2, Y2, Y3,
RECTNG, X1,X2, Y3, Y4,
RECTNG, X1,X2, Y4, TSW2_UP,
RECTNG, X1,X2, TSW2_UP, TSW1,
RECTNG, X1,X2, TSW1, PTN,
RECTNG, X1,X2, PTN, TCW,

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RECTNG, X1,X2, ORIG, -Y1,
RECTNG, X1,X2, -Y1,TSW2_LOW,
RECTNG, X1,X2,TSW2_LOW, TSW3,
RECTNG, X1,X2, TSW3, CHN1V,
RECTNG, X1,X2, CHN1V, CHN1Z,
RECTNG, X1,X2, CHN1Z, CHN2,
!
ARSYM,X,ALL,,,0,0
WPOFF,X2,0,0
ASEL,S,LOC,X,-X2,0,,1
ARSYM,X,ALL,,,0,0
ALLSEL
WPOFF,X2,0,0
ARSYM,X,ALL,,,0,0
WPOFF,-XOFF,YOFF,0
!
PCIRC,ROD, ,0,90,
PCIRC,ROD, ,0,-90,
!
ASBA,50,181
ASBA,49,182
WPOFF,0,-YOFF,0
AGLUE,ALL
/TRIAD, RBOT
APLOT
SAVE
!
! Meshing
!
TYPE,1,
MAT,9,
ESYS,0,
ESHAPE,2,0
MOPT,EXPND,1,
MOPT,TRANS,2,
MOPT,IESZ,0,
ESIZE,0.5,0,
AMESH,1,
AMESH,49
AMESH,181
AMESH,187
AMESH,182
AMESH,188
AMESH,184
AMESH,61
AMESH,185
AMESH,189
AMESH,186
AMESH,91
!
LCCAT,2,3
LCCAT,14,825
LCCAT,891,835
LCCAT,128,830
LCCAT,912,608
LCCAT,992,915
LCCAT,254,878
LCCAT,248,249
LCCAT,943,488
LCCAT,1005,948
LCCAT,374,938
LCCAT,368,369
LCCAT,769,845
LCCAT,841,894
!
TYPE,1,
MAT,4,
ESYS,0,
LSEL,S,LINE,,1044
LSEL,A,LINE,,724
!
LSEL,A,LINE,,5
LSEL,A,LINE,,1032
LSEL,A,LINE,,1034
LSEL,A,LINE,,1033
LSEL,A,LINE,,1036
LSEL,A,LINE,,1037
LSEL,A,LINE,,1035
LSEL,A,LINE,,251
LSEL,A,LINE,,1039
LSEL,A,LINE,,1040
LSEL,A,LINE,,1038
LSEL,A,LINE,,371
LESIZE,ALL,,10
!
LSEL,S,LINE,,1041,
LSEL,A,LINE,,1043,
LSEL,A,LINE,,1042,
LSEL,A,LINE,,127,
LSEL,A,LINE,,8,
LSEL,A,LINE,,9,
LSEL,A,LINE,,15,
LSEL,A,LINE,,247,
LSEL,A,LINE,,607,
LSEL,A,LINE,,250,
LSEL,A,LINE,,255,
LSEL,A,LINE,,367
LSEL,A,LINE,,487

```

! Mesh the waste package

! Concatenates lines

! Mesh the TSw2 unit

! Observation drift

! Emplacement drift

```
LSEL,A,LINE,,370
LSEL,A,LINE,,375
LESIZE,ALL,,5
!
LSEL,S,LINE,,845,
LSEL,A,LINE,,769,
LSEL,A,LINE,,841,
LSEL,A,LINE,,894,
LSEL,A,LINE,,830,
LSEL,A,LINE,,3,
LSEL,A,LINE,,2,
LSEL,A,LINE,,825,
LSEL,A,LINE,,14,
LSEL,A,LINE,,835,
LSEL,A,LINE,,891,
LSEL,A,LINE,,128
LSEL,A,LINE,,249
LSEL,A,LINE,,912
LSEL,A,LINE,,608
LSEL,A,LINE,,992,
LSEL,A,LINE,,915
LSEL,A,LINE,,254
LSEL,A,LINE,,878
LSEL,A,LINE,,248
LSEL,A,LINE,,369
LSEL,A,LINE,,943
LSEL,A,LINE,,488
LSEL,A,LINE,,1005,
LSEL,A,LINE,,948
LSEL,A,LINE,,374
LSEL,A,LINE,,938
LSEL,A,LINE,,368
LSEL,A,LINE,,766
LESIZE,ALL,,5
!
LSEL,S,LINE,,738
LSEL,A,LINE,,764
LSEL,A,LINE,,821
LSEL,A,LINE,,795
LSEL,A,LINE,,823
LESIZE,ALL,,4
!
LSEL,S,LINE,,840
LSEL,A,LINE,,23
LSEL,A,LINE,,263
LSEL,A,LINE,,918
LSEL,A,LINE,,383
LSEL,A,LINE,,953
LESIZE,ALL,,5
!
ALLSEL
ESIZE,1,0,
AMESH,353,354,1,
AMESH,3
AMESH,344,346,1
AMESH,63
AMESH,347,349,1
AMESH,93
AMESH,350,352,1
ESIZE,1.5,0
AMESH,204
AMESH,271
AMESH,190
AMESH,233
AMESH,203
AMESH,258
AMESH,231
AMESH,318
AMESH,218
AMESH,293
AMESH,232
AMESH,331
!
AMESH,272
AMESH,235
AMESH,191
AMESH,239
AMESH,241
AMESH,193
AMESH,194
AMESH,234
AMESH,259
AMESH,238
AMESH,240
AMESH,260
AMESH,261
AMESH,206
AMESH,281
AMESH,208
AMESH,209
AMESH,283
AMESH,284
AMESH,319
AMESH,294
AMESH,320
AMESH,298
AMESH,321
AMESH,300
```

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AMESH,219
AMESH,295
AMESH,221
AMESH,299
AMESH,222
AMESH,301
AMESH,332
AMESH,334
AMESH,335
!
ESIZE,2,0
AMESH,205
AMESH,243
AMESH,195
AMESH,242
AMESH,262
AMESH,210
AMESH,285
AMESH,322
AMESH,302
AMESH,223
AMESH,303
AMESH,336
AMESH,273
AMESH,237
AMESH,192
AMESH,236
AMESH,266
AMESH,207
AMESH,282
AMESH,326
AMESH,296
AMESH,220
AMESH,297
AMESH,333
!
TYPE,1,                      !      Mesh the TSw1 unit
MAT,3,
ESYS,0,
ESIZE,3.0,0,
AMESH,274
AMESH,245
AMESH,196
AMESH,244
AMESH,263
AMESH,211
AMESH,286
AMESH,323
AMESH,304
AMESH,224
AMESH,305
AMESH,337
!
TYPE,1,                      !      Mesh the PTn unit
MAT,2,
ESYS,0,
ESIZE,7.5,0,
AMESH,275
AMESH,247
AMESH,197
AMESH,246
AMESH,264
AMESH,212
AMESH,287
AMESH,324
AMESH,306
AMESH,225
AMESH,307
AMESH,338
!
TYPE,1,                      !      Mesh the TCw unit
MAT,1,
ESYS,0,
ESIZE,15.0,0,
AMESH,276
AMESH,249
AMESH,198
AMESH,248
AMESH,265
AMESH,213
AMESH,288
AMESH,325
AMESH,308
AMESH,226
AMESH,309
AMESH,339
!
TYPE,1,                      !      Mesh the TSw3 unit
MAT,5,
ESYS,0,
ESIZE,3.0,0,
AMESH,277
AMESH,250
AMESH,199
AMESH,251
AMESH,267
AMESH,214
AMESH,289
```

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AMESH,327
AMESH,311
AMESH,227
AMESH,310
AMESH,340
!
TYPE,1,          !      Mesh the CHn1v unit
MAT,6,
ESYS,0,
ESIZE,3.0,0,
AMESH,278
AMESH,252
AMESH,200
AMESH,253
AMESH,268
AMESH,215
AMESH,290
AMESH,328
AMESH,313
AMESH,228
AMESH,312
AMESH,341
!
TYPE,1,          !      Mesh the CHn1z unit
MAT,7,
ESYS,0,
ESIZE,7.5,0,
AMESH,279
AMESH,254
AMESH,201
AMESH,255
AMESH,269
AMESH,216
AMESH,291
AMESH,329
AMESH,315
AMESH,229
AMESH,314
AMESH,342
!
TYPE,1,          !      Mesh the CHn2 unit
MAT,8,
ESYS,0,
ESIZE,15,0,
AMESH,280
AMESH,256
AMESH,202
AMESH,257
AMESH,270
AMESH,217
AMESH,292
AMESH,330
AMESH,317
AMESH,230
AMESH,316
AMESH,343
!
TYPE,2,          !      Define link elements
MAT,10,
REAL,1,
ESYS,0,
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
LSEL,A,LINE,,5          !      Drift wall
LSEL,A,LINE,,1033
LSEL,A,LINE,,1034
LSEL,A,LINE,,1032
LSEL,A,LINE,,1036
LSEL,A,LINE,,251
LSEL,A,LINE,,1035
LSEL,A,LINE,,1037
LSEL,A,LINE,,1039
LSEL,A,LINE,,371
LSEL,A,LINE,,1038
LSEL,A,LINE,,1040
NSLL,S,1
ESURF,ALL
PLOT
!
/AUX12          !      Generate superelement for thermal
EMIS,2,0.85,    !      radiation calculation
STEF,1.7878,
GEOM,1,0,
SPACE,,
ESEL,S,TYPE,,2,2
NSLE,S
VTYPE,0,,
MPRINT,0
  
```

```

WRITE,pca2d85m54      !      Save radiation matrices
FINISH
!
/PREP7
TYPE,3,
MAT,11,
REAL,1,
ESYS,0,
SE,pca2d85m54
!
ESEL,S,TYPE,,2,2
EDELE,ALL
ALLSEL
!
/SOLU                  !      Solution phase
ANTYPE,TRANS           !      Transient analysis
NROPT,AUTO             !      Program chosen Newton-Raphson option
TOFFST,273             !      Specify the temperature offset: 273 C
TINTP,0.005, , ,0.5,0.5,0.2 !      Use defaults of transient integration
!                      parameters
OUTPR,NSOL,5,          !      Solution printout at every 5 substeps
OUTRES,NSOL,5,         !      Solution data written to database
!                      at every 5 substeps
IC,ALL,TEMP,26,        !      Initial temperature at all nodes
NSEL,S,LOC,Y,311.0     !      Select all nodes on top surface
D,ALL,TEMP,18.7
NSEL,S,LOC,Y,-300.0    !      Select all nodes on bottom surface
D,ALL,TEMP,32.53
ALLSEL
SAVE
!
!      Load step number 1
TIMINT,OFF             !      Turn off transient effects at the
!                      first load step
TIME,1e-7
AUTOTS,1
DELTIM,1e-8,1e-8,1e-7,0
KBC,0
LSWRITE,1,
!
TIMINT,ON              !      Turn on transient effects at the
!                      rest of load steps
!      Load step number 2
TIME,0.5e-2
AUTOTS,1
DELTIM,0.5e-4,0.5e-4,0.5e-3,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,26
KBC,0
LSEL,S,LINE,,1         !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.5952e9,
ALLSEL
LSWRITE,2,
!
!      Load step number 3
TIME,1
AUTOTS,1
DELTIM,0.01,0.01,0.1,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,26
KBC,0
LSEL,S,LINE,,1         !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.5289e9,
ALLSEL
LSWRITE,3,
!
!      Load step number 4
TIME,5
AUTOTS,1
DELTIM,0.05,0.05,0.5,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift

```

```
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,27.65
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.3217e9,
ALLSEL
LSWRITE,4,
!
!      Load step number 5
TIME,10
AUTOTS,1
DELTIM,0.05,0.05,0.5,0
KBC,1
LSEL,S,LINE,,1044       !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,30.26
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.1169e9,
ALLSEL
LSWRITE,5,
!
!      Load step number 6
TIME,20
AUTOTS,1
DELTIM,0.1,0.1,0.75,0
KBC,1
LSEL,S,LINE,,1044       !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,33.34
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.7929e9,
ALLSEL
LSWRITE,6,
!
!      Load step number 7
TIME,30
AUTOTS,1
DELTIM,0.1,0.1,0.75,0
KBC,1
LSEL,S,LINE,,1044       !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,35.03
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.5401e9,
ALLSEL
LSWRITE,7,
!
!      Load step number 8
TIME,40
AUTOTS,1
DELTIM,0.15,0.15,0.75,0
```

```
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,36.15
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.3400e9,
ALLSEL
LSWRITE,8,
!
!      Load step number 9
TIME,50
AUTOTS,1
DELTIM,0.15,0.15,0.75,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,36.96
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.1779e9,
ALLSEL
LSWRITE,9,
!
!      Load step number 10
TIME,60
AUTOTS,1
DELTIM,0.15,0.15,1.0,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,37.52
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.0477e9,
ALLSEL
LSWRITE,10,
!
!      Load step number 11
TIME,70
AUTOTS,1
DELTIM,0.15,0.15,1.0,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,37.91
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,9.4197e8,
ALLSEL
LSWRITE,11,
!
!      Load step number 12
TIME,80
```

```
AUTOTS,1
DELTIM,0.15,0.15,1.5,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,38.17
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,8.5514e8,
ALLSEL
LSWRITE,12,
!
!      Load step number 13
TIME,100
AUTOTS,1
DELTIM,0.15,0.15,2.5,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,38.46
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,7.2487e8,
ALLSEL
LSWRITE,13,
!
!      Load step number 14
TIME,150
AUTOTS,1
DELTIM,0.2,0.2,5,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,38.61
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,5.4619e8,
ALLSEL
LSWRITE,14,
!
!      ALLSEL
LSSOLVE,1,14,1,           !      Solve with 14 load steps
FINISH
```



```

MP,DENS,4,2274      !      Density (kg/m^3)
MP,KXX, 4,6.623E7   !      Thermal conductivity (J/yr-m-C)
MP,EMIS,4,0.9       !      Emissivity
!
!      Material number 5 (TSw3 unit)
MP,DENS,5,2271      !      Density (kg/m^3)
MP,KXX, 5,4.037E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 6 (CHn1v unit)
MP,DENS,6,1972      !      Density (kg/m^3)
MP,KXX, 6,3.784E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 7 (CHn1z unit)
MP,DENS,7,1886      !      Density (kg/m^3)
MP,KXX, 7,4.037E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 8 (CHn2 unit)
MP,DENS,8,2070      !      Density (kg/m^3)
MP,KXX, 8,4.92E7    !      Thermal conductivity (J/yr-m-C)
!
!      Material number 9 (Waste package)
MP,DENS,9,8131      !      Density (kg/m^3)
MP,KXX, 9,131.534E7 !      Thermal conductivity (J/yr-m-C)
MP,C, 9,487.901     !      Specific heat (J/kg-C)
MP,EMIS,9,0.8       !      Emissivity
!
!      Material number 10 (link elements for radiation)
MP,EMIS,10,0.85     !      Emissivity
!
!      Material number 11 (Radiation superelement element)
MP,EMIS,11,0.85     !      Emissivity
!
MPTEMP,1,25,94,95,114,115,250 ! Temperature table for temperature
!                               dependent specific heat (C)
!      Specific heat (J/kg-C)
MPDATA,C,1,1,936.5,936.5,4322.2,4322.2,967.2,967.2 ! TCw unit
MPDATA,C,2,1,1715.6,1715.6,22564.3,22564.3,1172.9,1172.9 ! PTn unit
MPDATA,C,3,1,960.5,960.5,5670.6,5670.6,934.8,934.8 ! TSw1 unit
MPDATA,C,4,1,941.7,941.7,4608.0,4608.0,960.4,960.4 ! TSw2 unit
MPDATA,C,5,1,904.0,904.0,1990.0,1990.0,1124.4,1124.4 ! TSw3 unit
MPDATA,C,6,1,1300.8,1300.8,17935.1,17935.1,847.0,847.0 ! CHn1v unit
MPDATA,C,7,1,1416.2,1416.2,18762.1,18762.1,1210.8,1210.8 ! CHn1z unit
MPDATA,C,8,1,1231.2,1231.2,11998.2,11998.2,1330.6,1330.6 ! CHn2 unit
!
!      Parameters for model generation
!
ORIG=0.0
X1=5.5
X2=11.25
DS=22.5
Y1=5.5
Y2=19.5
Y3=25
Y4=30.5
R1=2.75
RW=0.925
ROD=2.25
TSW2_UP=106.8
TSW2_LOW=-82.5
TSW1=236.9
PTN=275.0
TCW=311.0
TSW3=-98.3
CHN1V=-103.5
CHN1Z=-207.5
CHN2=-300.0
XOFF=33.75
YOFF=25.0
!
WPOFF,X2,0,0
CSYS,4
RECTNG,ORIG,X1,ORIG,Y1,
PCIRC,R1,,0,90,
ASBA,1,2
PCIRC,RW,,0,90,
ARSYM,Y,ALL,,,0,0
RECTNG,ORIG,X1, Y1, Y2,
RECTNG,ORIG,X1, Y2, Y3,
RECTNG,ORIG,X1, Y3, Y4,
RECTNG,ORIG,X1, Y4, TSW2_UP,
RECTNG,ORIG,X1, TSW2_UP, TSW1,
RECTNG,ORIG,X1, TSW1, PTN,
RECTNG,ORIG,X1, PTN, TCW,
RECTNG,ORIG,X1, -Y1,TSW2_LOW,
RECTNG,ORIG,X1,TSW2_LOW, TSW3,
RECTNG,ORIG,X1, TSW3, CHN1V,
RECTNG,ORIG,X1, CHN1V, CHN1Z,
RECTNG,ORIG,X1, CHN1Z, CHN2,
!
RECTNG, X1,X2, ORIG, Y1,
RECTNG, X1,X2, Y1, Y2,
RECTNG, X1,X2, Y2, Y3,
RECTNG, X1,X2, Y3, Y4,
RECTNG, X1,X2, Y4, TSW2_UP,
RECTNG, X1,X2, TSW2_UP, TSW1,
RECTNG, X1,X2, TSW1, PTN,
RECTNG, X1,X2, PTN, TCW,

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RECTNG, X1,X2, ORIG, -Y1,
RECTNG, X1,X2, -Y1,TSW2_LOW,
RECTNG, X1,X2,TSW2_LOW, TSW3,
RECTNG, X1,X2, TSW3, CHN1V,
RECTNG, X1,X2, CHN1V, CHN1Z,
RECTNG, X1,X2, CHN1Z, CHN2,
!
ARSYM,X,ALL,,,0,0
WPOFF,X2,0,0
ASEL,S,LOC,X,-X2,0,,1
ARSYM,X,ALL,,,0,0
ALLSEL
WPOFF,X2,0,0
ARSYM,X,ALL,,,0,0
WPOFF,-XOFF,YOFF,0
!
PCIRC,ROD, ,0,90,
PCIRC,ROD, ,0,-90,
!
ASBA,50,181
ASBA,49,182
WPOFF,0,-YOFF,0
AGLUE,ALL
/TRIAD,ROD
APLOT
SAVE
!
! Meshing
!
TYPE,1, ! Mesh the waste package
MAT,9,
ESYS,0,
ESHAPE,2,0
MOPT,EXPND,1,
MOPT,TRANS,2,
MOPT,IESZ,0,
ESIZE,0.5,0,
AMESH,1,
AMESH,49
AMESH,181
AMESH,187
AMESH,182
AMESH,188
AMESH,184
AMESH,61
AMESH,185
AMESH,189
AMESH,186
AMESH,91
!
LCCAT,2,3 ! Concatenates lines
LCCAT,14,825
LCCAT,891,835
LCCAT,128,830
LCCAT,912,608
LCCAT,992,915
LCCAT,254,878
LCCAT,248,249
LCCAT,943,488
LCCAT,1005,948
LCCAT,374,938
LCCAT,368,369
LCCAT,769,845
LCCAT,841,894
!
TYPE,1, ! Mesh the TSw2 unit
MAT,4,
ESYS,0,
LSEL,S,LINE,,1044 ! Observation drift
LSEL,A,LINE,,724
!
LSEL,A,LINE,,5 ! Emplacement drift
LSEL,A,LINE,,1032
LSEL,A,LINE,,1034
LSEL,A,LINE,,1033
LSEL,A,LINE,,1036
LSEL,A,LINE,,1037
LSEL,A,LINE,,1035
LSEL,A,LINE,,251
LSEL,A,LINE,,1039
LSEL,A,LINE,,1040
LSEL,A,LINE,,1038
LSEL,A,LINE,,371
LESIZE,ALL,,10
!
LSEL,S,LINE,,1041,
LSEL,A,LINE,,1043,
LSEL,A,LINE,,1042,
LSEL,A,LINE,,127,
LSEL,A,LINE,,8,
LSEL,A,LINE,,9,
LSEL,A,LINE,,15,
LSEL,A,LINE,,247,
LSEL,A,LINE,,607,
LSEL,A,LINE,,250,
LSEL,A,LINE,,255,
LSEL,A,LINE,,367
LSEL,A,LINE,,487

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LSEL,A,LINE,,370
LSEL,A,LINE,,375
LESIZE,ALL,,5
!
LSEL,S,LINE,,845,
LSEL,A,LINE,,769,
LSEL,A,LINE,,841,
LSEL,A,LINE,,894,
LSEL,A,LINE,,830,
LSEL,A,LINE,,3,
LSEL,A,LINE,,2,
LSEL,A,LINE,,825,
LSEL,A,LINE,,14,
LSEL,A,LINE,,835,
LSEL,A,LINE,,891,
LSEL,A,LINE,,128,
LSEL,A,LINE,,249,
LSEL,A,LINE,,912,
LSEL,A,LINE,,608,
LSEL,A,LINE,,992,
LSEL,A,LINE,,915,
LSEL,A,LINE,,254,
LSEL,A,LINE,,878,
LSEL,A,LINE,,248,
LSEL,A,LINE,,369,
LSEL,A,LINE,,943,
LSEL,A,LINE,,488,
LSEL,A,LINE,,1005,
LSEL,A,LINE,,948,
LSEL,A,LINE,,374,
LSEL,A,LINE,,938,
LSEL,A,LINE,,368,
LSEL,A,LINE,,766
LESIZE,ALL,,5
!
LSEL,S,LINE,,738
LSEL,A,LINE,,764
LSEL,A,LINE,,821
LSEL,A,LINE,,795
LSEL,A,LINE,,823
LESIZE,ALL,,4
!
LSEL,S,LINE,,840
LSEL,A,LINE,,23
LSEL,A,LINE,,263
LSEL,A,LINE,,918
LSEL,A,LINE,,383
LSEL,A,LINE,,953
LESIZE,ALL,,5
!
ALLSEL
ESIZE,1,0,
AMESH,353,354,1,
AMESH,3
AMESH,344,346,1
AMESH,63
AMESH,347,349,1
AMESH,93
AMESH,350,352,1
ESIZE,1.5,0
AMESH,204
AMESH,271
AMESH,190
AMESH,233
AMESH,203
AMESH,258
AMESH,231
AMESH,318
AMESH,218
AMESH,293
AMESH,232
AMESH,331
!
AMESH,272
AMESH,235
AMESH,191
AMESH,239
AMESH,241
AMESH,193
AMESH,194
AMESH,234
AMESH,259
AMESH,238
AMESH,240
AMESH,260
AMESH,261
AMESH,206
AMESH,281
AMESH,208
AMESH,209
AMESH,283
AMESH,284
AMESH,319
AMESH,294
AMESH,320
AMESH,298
AMESH,321
AMESH,300
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AMESH,219
AMESH,295
AMESH,221
AMESH,299
AMESH,222
AMESH,301
AMESH,332
AMESH,334
AMESH,335
!
ESIZE,2,0
AMESH,205
AMESH,243
AMESH,195
AMESH,242
AMESH,262
AMESH,210
AMESH,285
AMESH,322
AMESH,302
AMESH,223
AMESH,303
AMESH,336
AMESH,273
AMESH,237
AMESH,192
AMESH,236
AMESH,266
AMESH,207
AMESH,282
AMESH,326
AMESH,296
AMESH,220
AMESH,297
AMESH,333
!
TYPE,1,                      !      Mesh the TSwl unit
MAT,3,
ESYS,0,
ESIZE,3.0,0,
AMESH,274
AMESH,245
AMESH,196
AMESH,244
AMESH,263
AMESH,211
AMESH,286
AMESH,323
AMESH,304
AMESH,224
AMESH,305
AMESH,337
!
TYPE,1,                      !      Mesh the PTn unit
MAT,2,
ESYS,0,
ESIZE,7.5,0,
AMESH,275
AMESH,247
AMESH,197
AMESH,246
AMESH,264
AMESH,212
AMESH,287
AMESH,324
AMESH,306
AMESH,225
AMESH,307
AMESH,338
!
TYPE,1,                      !      Mesh the TCw unit
MAT,1,
ESYS,0,
ESIZE,15.0,0,
AMESH,276
AMESH,249
AMESH,198
AMESH,248
AMESH,265
AMESH,213
AMESH,288
AMESH,325
AMESH,308
AMESH,226
AMESH,309
AMESH,339
!
TYPE,1,                      !      Mesh the TSwt unit
MAT,5,
ESYS,0,
ESIZE,3.0,0,
AMESH,277
AMESH,250
AMESH,199
AMESH,251
AMESH,267
AMESH,214
AMESH,289
```

```

AMESH,327
AMESH,311
AMESH,227
AMESH,310
AMESH,340
!
TYPE,1,          !      Mesh the CHn1v unit
MAT,6,
ESYS,0,
ESIZE,3.0,0,
AMESH,278
AMESH,252
AMESH,200
AMESH,253
AMESH,268
AMESH,215
AMESH,290
AMESH,328
AMESH,313
AMESH,228
AMESH,312
AMESH,341
!
TYPE,1,          !      Mesh the CHn1z unit
MAT,7,
ESYS,0,
ESIZE,7.5,0,
AMESH,279
AMESH,254
AMESH,201
AMESH,255
AMESH,269
AMESH,216
AMESH,291
AMESH,329
AMESH,315
AMESH,229
AMESH,314
AMESH,342
!
TYPE,1,          !      Mesh the CHn2 unit
MAT,8,
ESYS,0,
ESIZE,15,0,
AMESH,280
AMESH,256
AMESH,202
AMESH,257
AMESH,270
AMESH,217
AMESH,292
AMESH,330
AMESH,317
AMESH,230
AMESH,316
AMESH,343
!
TYPE,2,          !      Define link elements
MAT,10,
REAL,1,
ESYS,0,
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
LSEL,A,LINE,,5          !      Drift wall
LSEL,A,LINE,,1033
LSEL,A,LINE,,1034
LSEL,A,LINE,,1032
LSEL,A,LINE,,1036
LSEL,A,LINE,,251
LSEL,A,LINE,,1035
LSEL,A,LINE,,1037
LSEL,A,LINE,,1039
LSEL,A,LINE,,371
LSEL,A,LINE,,1038
LSEL,A,LINE,,1040
NSLL,S,1
ESURF,ALL
PLOT
!
/AUX12          !      Generate superelement for thermal
EMIS,2,0.85,    !      radiation calculation
STEF,1.7878,
GEOM,1,0,
SPACE,
ESEL,S,TYPE,,2,2
NSLE,S
VTYPE,0,
MPRINT,0
  
```

```

WRITE,pca2d85m55      !      Save radiation matrices
FINISH
!
/PREP7
TYPE,3,
MAT,11,
REAL,1,
ESYS,0,
SE,pca2d85m55
!
ESEL,S,TYPE,,2,2
EDELE,ALL
ALLSEL
!
/SOLU                  !      Solution phase
ANTYPE,TRANS           !      Transient analysis
NROPT,AUTO             !      Program chosen Newton-Raphson option
TOFFST,273            !      Specify the temperature offset: 273 C
TINTP,0.005, , ,0.5,0.5,0.2 !      Use defaults of transient integration
!                      parameters
OUTPR,NSOL,5,          !      Solution printout at every 5 substeps
OUTRES,NSOL,5,         !      Solution data written to database
!                      at every 5 substeps
IC,ALL,TEMP,26,        !      Initial temperature at all nodes
NSEL,S,LOC,Y,311.0     !      Select all nodes on top surface
D,ALL,TEMP,18.7
NSEL,S,LOC,Y,-300.0    !      Select all nodes on bottom surface
D,ALL,TEMP,32.53
ALLSEL
SAVE
!
!      Load step number 1
TIMINT,OFF             !      Turn off transient effects at the
!                      first load step
TIME,1e-7
AUTOTS,1
DELTIM,1e-8,1e-8,1e-7,0
KBC,0
LSWRITE,1,
!
TIMINT,ON              !      Turn on transient effects at the
!                      rest of load steps
!      Load step number 2
TIME,0.5e-2
AUTOTS,1
DELTIM,0.5e-4,0.5e-4,0.5e-3,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,26
KBC,0
LSEL,S,LINE,,1         !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.5952e9,
ALLSEL
LSWRITE,2,
!
!      Load step number 3
TIME,1
AUTOTS,1
DELTIM,0.01,0.01,0.1,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,26
KBC,0
LSEL,S,LINE,,1         !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.5289e9,
ALLSEL
LSWRITE,3,
!
!      Load step number 4
TIME,5
AUTOTS,1
DELTIM,0.05,0.05,0.5,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift

```

```
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,28.10
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.3217e9,
ALLSEL
LSWRITE,4,
!
!          Load step number 5
TIME,10
AUTOTS,1
DELTIM,0.05,0.05,0.5,0
KBC,1
LSEL,S,LINE,,1044       !          Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,31.46
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.1169e9,
ALLSEL
LSWRITE,5,
!
!          Load step number 6
TIME,20
AUTOTS,1
DELTIM,0.1,0.1,0.75,0
KBC,1
LSEL,S,LINE,,1044       !          Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,35.46
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.7929e9,
ALLSEL
LSWRITE,6,
!
!          Load step number 7
TIME,30
AUTOTS,1
DELTIM,0.1,0.1,0.75,0
KBC,1
LSEL,S,LINE,,1044       !          Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,37.66
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.5401e9,
ALLSEL
LSWRITE,7,
!
!          Load step number 8
TIME,40
AUTOTS,1
DELTIM,0.15,0.15,0.75,0
```

```
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,39.13
KBC,0
LSEL,S,LINE,,1            !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.3400e9,
ALLSEL
LSWRITE,8,
!
!      Load step number 9
TIME,50
AUTOTS,1
DELTIM,0.15,0.15,0.75,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,40.19
KBC,0
LSEL,S,LINE,,1            !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.1779e9,
ALLSEL
LSWRITE,9,
!
!      Load step number 10
TIME,60
AUTOTS,1
DELTIM,0.15,0.15,1.0,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,40.92
KBC,0
LSEL,S,LINE,,1            !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.0477e9,
ALLSEL
LSWRITE,10,
!
!      Load step number 11
TIME,70
AUTOTS,1
DELTIM,0.15,0.15,1.0,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,41.44
KBC,0
LSEL,S,LINE,,1            !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,9.4197e8,
ALLSEL
LSWRITE,11,
!
!      Load step number 12
TIME,80
```



```
AUTOTS,1
DELTIM,0.15,0.15,1.5,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,41.78
KBC,0
LSEL,S,LINE,,1        !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,8.5514e8,
ALLSEL
LSWRITE,12,
!
!      Load step number 13
TIME,100
AUTOTS,1
DELTIM,0.15,0.15,2.5,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,42.17
KBC,0
LSEL,S,LINE,,1        !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,7.2487e8,
ALLSEL
LSWRITE,13,
!
!      Load step number 14
TIME,150
AUTOTS,1
DELTIM,0.2,0.2,5,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,42.40
KBC,0
LSEL,S,LINE,,1        !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,5.4619e8,
ALLSEL
LSWRITE,14,
!
ALLSEL
LSSOLVE,1,14,1,      !      Solve with 14 load steps
FINISH
```

```

/BATCH,LIST
!
!#####
!#
!#                               ANSYS INPUT
!#
!#      Filename:      pca2d85m56
!#
!#      Input File:    pca2d85m56.dat
!#
!#      Output File:   pca2d85m56.out
!#
!#      Description:   2D Analysis for temperature at performance
!#                    confirmation observation drift (pca2d)
!#                    Thermal load:      85 MTU/acre & 21 PWR (85)
!#                    Emplacement mode:  Center-in-drift
!#                    Drift diameter:    5.5 meters
!#                    Drift spacing:     22.5 meters
!#                    WP spacing:        18.92 meters
!#                    Initial heat output: 9.05 kW/package
!#                    WP diameter:       1.85 meters
!#                    Observation drift size: 4.5 meters in diameter
!#                                         15.90 m^2 in area
!#                                         600 meters long
!#
!#                    Distance from emplace.
!#                      drift crown to obser.
!#                      drift floor:     20 meters
!#                    Location of O.D.:  Mid-of-pillar (m)
!#                    Ventilation air temp.: Varied
!#                    Ventilation quantity: 5.0 m^3/s (5)
!#                    Coef. of convection: 1.0787 W/m^2-K
!#                    Modeling time period: 150 years
!#                    Ventilation segment: No. 6 (500 - 600 m) (6)
!#
!#      Code Version:  ANSYS Revision 5.2
!#
!#      Created By:    Yiming Sun
!#
!#      Last Modified: 02/14/97
!#
!#####
!
/COM,ANSYS MEDIA REV. 5.2
!
/FILNAM,pca2d85m56      !      Jobname to use for all subsequent files
/TITLE,2D Model (PCA;TL:85MTU/ac;AQ:5.0m^3/s;AT:26C;DOD:20m;SN:6)
/UNITS,SI
/SHOW
!
/NOPR
*ABB,SAVE_DB,SAVE
*ABB,RESUM_DB,RESUME
*ABB,QUIT,Fnc_/EXIT
*ABB,SHFR,/SHOW,FILE,,,8
*ABB,SHFV,/SHOW,FILE,,1
*ABB,X11C,/SHOW,X11C,,,8
*ABB,X11,/SHOW,X11,,1
*ABB,REPLOTT,/REPLOTT
*ABB,K1,/PNUM,KP,1
*ABB,K0,/PNUM,KP,0
*ABB,POWRGRPH,Fnc_/GRAPHICS
*ABB,ANSYSWEB,Fnc_HomePage
/GO
!
/FDELE,EMAT,DELE
/FDELE,ESAV,DELE
/FDELE,EROT,DELE
/FDELE,DSUB,DELE
/FDELE,TRI,DELE
/FDELE,OSAV,DELE
/FDELE,PAGE,DELE
!
/PREP7
!
!      Define element types
!
ET,1,PLANE55      !      4-node, 2-D thermal solid element
ET,2,LINK32      !      2-D conduction bar
R,1,1,0
ET,3,MATRIX50    !      Superelement for radiation
KEYOPT,3,1,1     !      Superelement behavior: radiation substructure
KEYOPT,3,6,0
!
!      Define material properties
!
!      Material number 1 (TCw unit)
MP,DENS,1,2169    !      Density (kg/m^3)
MP,KXX,1,5.014E7  !      Thermal conductivity (J/yr-m-C)
!
!      Material number 2 (PTn unit)
MP,DENS,2,1299    !      Density (kg/m^3)
MP,KXX,2,2.681E7  !      Thermal conductivity (J/yr-m-C)
!
!      Material number 3 (TSw1 unit)
MP,DENS,3,2163    !      Density (kg/m^3)
MP,KXX,3,5.046E7  !      Thermal conductivity (J/yr-m-C)
!
!      Material number 4 (TSw2 unit)

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MP,DENS,4,2274      !      Density (kg/m^3)
MP,KXX, 4,6.623E7   !      Thermal conductivity (J/yr-m-C)
MP,EMIS,4,0.9       !      Emissivity
!
!      Material number 5 (TSw3 unit)
MP,DENS,5,2271      !      Density (kg/m^3)
MP,KXX, 5,4.037E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 6 (CHn1v unit)
MP,DENS,6,1972      !      Density (kg/m^3)
MP,KXX, 6,3.784E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 7 (CHn1z unit)
MP,DENS,7,1886      !      Density (kg/m^3)
MP,KXX, 7,4.037E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 8 (CHn2 unit)
MP,DENS,8,2070      !      Density (kg/m^3)
MP,KXX, 8,4.92E7    !      Thermal conductivity (J/yr-m-C)
!
!      Material number 9 (Waste package)
MP,DENS,9,8131      !      Density (kg/m^3)
MP,KXX, 9,131.534E7 !      Thermal conductivity (J/yr-m-C)
MP,C, 9,487.901     !      Specific heat (J/kg-C)
MP,EMIS,9,0.8       !      Emissivity
!
!      Material number 10 (link elements for radiation)
MP,EMIS,10,0.85     !      Emissivity
!
!      Material number 11 (Radiation superelement element)
MP,EMIS,11,0.85     !      Emissivity
!
MPTEMP,1,25,94,95,114,115,250 ! Temperature table for temperature
!                               dependent specific heat (C)
!      Specific heat (J/kg-C)
MPDATA,C,1,1,936.5,936.5,4322.2,4322.2,967.2,967.2 ! TCw unit
MPDATA,C,2,1,1715.6,1715.6,22564.3,22564.3,1172.9,1172.9 ! PTn unit
MPDATA,C,3,1,960.5,960.5,5670.6,5670.6,934.8,934.8 ! TSw1 unit
MPDATA,C,4,1,941.7,941.7,4608.0,4608.0,960.4,960.4 ! TSw2 unit
MPDATA,C,5,1,904.0,904.0,1990.0,1990.0,1124.4,1124.4 ! TSw3 unit
MPDATA,C,6,1,1300.8,1300.8,17935.1,17935.1,847.0,847.0 ! CHn1v unit
MPDATA,C,7,1,1416.2,1416.2,18762.1,18762.1,1210.8,1210.8 ! CHn1z unit
MPDATA,C,8,1,1231.2,1231.2,11998.2,11998.2,1330.6,1330.6 ! CHn2 unit
!
!      Parameters for model generation
!
ORIG=0.0
X1=5.5
X2=11.25
DS=22.5
Y1=5.5
Y2=19.5
Y3=25
Y4=30.5
R1=2.75
RW=0.925
ROD=2.25
TSW2_UP=106.8
TSW2_LOW=-82.5
TSW1=236.9
PTN=275.0
TCW=311.0
TSW3=-98.3
CHN1V=-103.5
CHN1Z=-207.5
CHN2=-300.0
XOFF=33.75
YOFF=25.0
!
WPOFF,X2,0,0
CSYS,4
RECTNG,ORIG,X1,ORIG,Y1,
PCIRC,R1,,0,90,
ASBA,1,2
PCIRC,RW,,0,90,
ARSYM,Y,ALL,,,0,0
RECTNG,ORIG,X1, Y1, Y2,
RECTNG,ORIG,X1, Y2, Y3,
RECTNG,ORIG,X1, Y3, Y4,
RECTNG,ORIG,X1, Y4, TSW2_UP,
RECTNG,ORIG,X1, TSW2_UP, TSW1,
RECTNG,ORIG,X1, TSW1, PTN,
RECTNG,ORIG,X1, PTN, TCW,
RECTNG,ORIG,X1, -Y1,TSW2_LOW,
RECTNG,ORIG,X1,TSW2_LOW, TSW3,
RECTNG,ORIG,X1, TSW3, CHN1V,
RECTNG,ORIG,X1, CHN1V, CHN1Z,
RECTNG,ORIG,X1, CHN1Z, CHN2,
!
RECTNG, X1,X2, ORIG, Y1,
RECTNG, X1,X2, Y1, Y2,
RECTNG, X1,X2, Y2, Y3,
RECTNG, X1,X2, Y3, Y4,
RECTNG, X1,X2, Y4, TSW2_UP,
RECTNG, X1,X2, TSW2_UP, TSW1,
RECTNG, X1,X2, TSW1, PTN,
RECTNG, X1,X2, PTN, TCW,

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RECTNG, X1,X2, ORIG, -Y1,
RECTNG, X1,X2, -Y1,TSW2_LOW,
RECTNG, X1,X2,TSW2_LOW, TSW3,
RECTNG, X1,X2, TSW3, CHN1V,
RECTNG, X1,X2, CHN1V, CHN1Z,
RECTNG, X1,X2, CHN1Z, CHN2,
!
ARSYM,X,ALL,,,0,0
WPOFF,X2,0,0
ASEL,S,LOC,X,-X2,0,,1
ARSYM,X,ALL,,,0,0
ALLSEL
WPOFF,X2,0,0
ARSYM,X,ALL,,,0,0
WPOFF,-XOFF,YOFF,0
!
PCIRC,ROD, ,0,90,
PCIRC,ROD, ,0,-90,
!
ASBA,50,181
ASBA,49,182
WPOFF,0,-YOFF,0
AGLUE,ALL
/TRIAD,ROBOT
APLOT
SAVE
!
! Meshing
!
TYPE,1, ! Mesh the waste package
MAT,9,
ESYS,0,
ESHAPE,2,0
MOPT,EXPND,1,
MOPT,TRANS,2,
MOPT,IESZ,0,
ESIZE,0.5,0,
AMESH,1,
AMESH,49
AMESH,181
AMESH,187
AMESH,182
AMESH,188
AMESH,184
AMESH,61
AMESH,185
AMESH,189
AMESH,186
AMESH,91
!
LCCAT,2,3 ! Concatenates lines
LCCAT,14,825
LCCAT,891,835
LCCAT,128,830
LCCAT,912,608
LCCAT,992,915
LCCAT,254,878
LCCAT,248,249
LCCAT,943,488
LCCAT,1005,948
LCCAT,374,938
LCCAT,368,369
LCCAT,769,845
LCCAT,841,894
!
TYPE,1, ! Mesh the TSw2 unit
MAT,4,
ESYS,0,
LSEL,S,LINE,,1044 ! Observation drift
LSEL,A,LINE,,724
!
LSEL,A,LINE,,5 ! Emplacement drift
LSEL,A,LINE,,1032
LSEL,A,LINE,,1034
LSEL,A,LINE,,1033
LSEL,A,LINE,,1036
LSEL,A,LINE,,1037
LSEL,A,LINE,,1035
LSEL,A,LINE,,251
LSEL,A,LINE,,1039
LSEL,A,LINE,,1040
LSEL,A,LINE,,1038
LSEL,A,LINE,,371
LESIZE,ALL,,10
!
LSEL,S,LINE,,1041,
LSEL,A,LINE,,1043,
LSEL,A,LINE,,1042,
LSEL,A,LINE,,127,
LSEL,A,LINE,,8,
LSEL,A,LINE,,9,
LSEL,A,LINE,,15,
LSEL,A,LINE,,247,
LSEL,A,LINE,,607,
LSEL,A,LINE,,250,
LSEL,A,LINE,,255,
LSEL,A,LINE,,367,
LSEL,A,LINE,,487

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LSEL,A,LINE,,370
LSEL,A,LINE,,375
LESIZE,ALL,,5
!
LSEL,S,LINE,,845,
LSEL,A,LINE,,769,
LSEL,A,LINE,,841,
LSEL,A,LINE,,894,
LSEL,A,LINE,,830,
LSEL,A,LINE,,3,
LSEL,A,LINE,,2,
LSEL,A,LINE,,825,
LSEL,A,LINE,,14,
LSEL,A,LINE,,835,
LSEL,A,LINE,,891,
LSEL,A,LINE,,128,
LSEL,A,LINE,,249,
LSEL,A,LINE,,912,
LSEL,A,LINE,,608,
LSEL,A,LINE,,992,
LSEL,A,LINE,,915,
LSEL,A,LINE,,254,
LSEL,A,LINE,,878,
LSEL,A,LINE,,248,
LSEL,A,LINE,,369,
LSEL,A,LINE,,943,
LSEL,A,LINE,,488,
LSEL,A,LINE,,1005,
LSEL,A,LINE,,948,
LSEL,A,LINE,,374,
LSEL,A,LINE,,938,
LSEL,A,LINE,,368,
LSEL,A,LINE,,766,
LESIZE,ALL,,5
!
LSEL,S,LINE,,738
LSEL,A,LINE,,764
LSEL,A,LINE,,821
LSEL,A,LINE,,795
LSEL,A,LINE,,823
LESIZE,ALL,,4
!
LSEL,S,LINE,,840
LSEL,A,LINE,,23
LSEL,A,LINE,,263
LSEL,A,LINE,,918
LSEL,A,LINE,,383
LSEL,A,LINE,,953
LESIZE,ALL,,5
!
ALLSEL
ESIZE,1,0,
AMESH,353,354,1,
AMESH,3
AMESH,344,346,1
AMESH,63
AMESH,347,349,1
AMESH,93
AMESH,350,352,1
ESIZE,1.5,0
AMESH,204
AMESH,271
AMESH,190
AMESH,233
AMESH,203
AMESH,258
AMESH,231
AMESH,318
AMESH,218
AMESH,293
AMESH,232
AMESH,331
!
AMESH,272
AMESH,235
AMESH,191
AMESH,239
AMESH,241
AMESH,193
AMESH,194
AMESH,234
AMESH,259
AMESH,238
AMESH,240
AMESH,260
AMESH,261
AMESH,206
AMESH,281
AMESH,208
AMESH,209
AMESH,283
AMESH,284
AMESH,319
AMESH,294
AMESH,320
AMESH,298
AMESH,321
AMESH,300
```

```
AMESH,219
AMESH,295
AMESH,221
AMESH,299
AMESH,222
AMESH,301
AMESH,332
AMESH,334
AMESH,335
!
ESIZE,2,0
AMESH,205
AMESH,243
AMESH,195
AMESH,242
AMESH,262
AMESH,210
AMESH,285
AMESH,322
AMESH,302
AMESH,223
AMESH,303
AMESH,336
AMESH,273
AMESH,237
AMESH,192
AMESH,236
AMESH,266
AMESH,207
AMESH,282
AMESH,326
AMESH,296
AMESH,220
AMESH,297
AMESH,333
!
TYPE,1,           !      Mesh the TSw1 unit
MAT,3,
ESYS,0,
ESIZE,3.0,0,
AMESH,274
AMESH,245
AMESH,196
AMESH,244
AMESH,263
AMESH,211
AMESH,286
AMESH,323
AMESH,304
AMESH,224
AMESH,305
AMESH,337
!
TYPE,1,           !      Mesh the PTn unit
MAT,2,
ESYS,0,
ESIZE,7.5,0,
AMESH,275
AMESH,247
AMESH,197
AMESH,246
AMESH,264
AMESH,212
AMESH,287
AMESH,324
AMESH,306
AMESH,225
AMESH,307
AMESH,338
!
TYPE,1,           !      Mesh the TCw unit
MAT,1,
ESYS,0,
ESIZE,15.0,0,
AMESH,276
AMESH,249
AMESH,198
AMESH,248
AMESH,265
AMESH,213
AMESH,288
AMESH,325
AMESH,308
AMESH,226
AMESH,309
AMESH,339
!
TYPE,1,           !      Mesh the TSw3 unit
MAT,5,
ESYS,0,
ESIZE,3.0,0,
AMESH,277
AMESH,250
AMESH,199
AMESH,251
AMESH,267
AMESH,214
AMESH,289
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AMESH,327
AMESH,311
AMESH,227
AMESH,310
AMESH,340
!
TYPE,1,          !      Mesh the CHn1v unit
MAT,6,
ESYS,0,
ESIZE,3.0,0,
AMESH,278
AMESH,252
AMESH,200
AMESH,253
AMESH,268
AMESH,215
AMESH,290
AMESH,328
AMESH,313
AMESH,228
AMESH,312
AMESH,341
!
TYPE,1,          !      Mesh the CHn1z unit
MAT,7,
ESYS,0,
ESIZE,7.5,0,
AMESH,279
AMESH,254
AMESH,201
AMESH,255
AMESH,269
AMESH,216
AMESH,291
AMESH,329
AMESH,315
AMESH,229
AMESH,314
AMESH,342
!
TYPE,1,          !      Mesh the CHn2 unit
MAT,8,
ESYS,0,
ESIZE,15,0,
AMESH,280
AMESH,256
AMESH,202
AMESH,257
AMESH,270
AMESH,217
AMESH,292
AMESH,330
AMESH,317
AMESH,230
AMESH,316
AMESH,343
!
TYPE,2,          !      Define link elements
MAT,10,
REAL,1,
ESYS,0,
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
LSEL,A,LINE,,5          !      Drift wall
LSEL,A,LINE,,1033
LSEL,A,LINE,,1034
LSEL,A,LINE,,1032
LSEL,A,LINE,,1036
LSEL,A,LINE,,251
LSEL,A,LINE,,1035
LSEL,A,LINE,,1037
LSEL,A,LINE,,1039
LSEL,A,LINE,,371
LSEL,A,LINE,,1038
LSEL,A,LINE,,1040
NSLL,S,1
ESURF,ALL
PLOT
!
/AUX12          !      Generate superelement for thermal
EMIS,2,0.85,    !      radiation calculation
STEF,1.7878,
GEOM,1,0,
SPACE, ,
ESEL,S,TYPE,,2,2
NSLE,S
VTYPE,0, ,
MPRINT,0

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```

WRITE,pca2d85m56      !      Save radiation matrices
FINISH
!
/PREP7
TYPE,3,
MAT,11,
REAL,1,
ESYS,0,
SE,pca2d85m56
!
ESEL,S,TYPE,,2,2
EDELE,ALL
ALLSEL
!
/SOLU                  !      Solution phase
ANTYPE,TRANS           !      Transient analysis
NROPT,AUTO             !      Program chosen Newton-Raphson option
TOFFST,273             !      Specify the temperature offset: 273 C
TINTP,0.005, , ,0.5,0.5,0.2 !      Use defaults of transient integration
!                      parameters
OUTPR,NSOL,5,          !      Solution printout at every 5 substeps
OUTRES,NSOL,5,         !      Solution data written to database
!                      at every 5 substeps
IC,ALL,TEMP,26,        !      Initial temperature at all nodes
NSEL,S,LOC,Y,311.0     !      Select all nodes on top surface
D,ALL,TEMP,18.7
NSEL,S,LOC,Y,-300.0    !      Select all nodes on bottom surface
D,ALL,TEMP,32.53
ALLSEL
SAVE
!
!      Load step number 1
TIMINT,OFF             !      Turn off transient effects at the
!                      first load step
TIME,1e-7
AUTOTS,1
DELTIM,1e-8,1e-8,1e-7,0
KBC,0
LSWRITE,1,
!
!      Load step number 2
TIMINT,ON              !      Turn on transient effects at the
!                      rest of load steps
TIME,0.5e-2
AUTOTS,1
DELTIM,0.5e-4,0.5e-4,0.5e-3,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,26
KBC,0
LSEL,S,LINE,,1         !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.5952e9,
ALLSEL
LSWRITE,2,
!
!      Load step number 3
TIME,1
AUTOTS,1
DELTIM,0.01,0.01,0.1,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,26
KBC,0
LSEL,S,LINE,,1         !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.5289e9,
ALLSEL
LSWRITE,3,
!
!      Load step number 4
TIME,5
AUTOTS,1
DELTIM,0.05,0.05,0.5,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift

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LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,28.52
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.3217e9,
ALLSEL
LSWRITE,4,
!
!          Load step number 5
TIME,10
AUTOTS,1
DELTIM,0.05,0.05,0.5,0
KBC,1
LSEL,S,LINE,,1044       !          Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,32.57
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.1169e9,
ALLSEL
LSWRITE,5,
!
!          Load step number 6
TIME,20
AUTOTS,1
DELTIM,0.1,0.1,0.75,0
KBC,1
LSEL,S,LINE,,1044       !          Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,37.44
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.7929e9,
ALLSEL
LSWRITE,6,
!
!          Load step number 7
TIME,30
AUTOTS,1
DELTIM,0.1,0.1,0.75,0
KBC,1
LSEL,S,LINE,,1044       !          Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,40.13
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.5401e9,
ALLSEL
LSWRITE,7,
!
!          Load step number 8
TIME,40
AUTOTS,1
DELTIM,0.15,0.15,0.75,0
```

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KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,41.92
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.3400e9,
ALLSEL
LSWRITE,8,
!
!      Load step number 9
TIME,50
AUTOTS,1
DELTIM,0.15,0.15,0.75,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,43.22
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.1779e9,
ALLSEL
LSWRITE,9,
!
!      Load step number 10
TIME,60
AUTOTS,1
DELTIM,0.15,0.15,1.0,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,44.13
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.0477e9,
ALLSEL
LSWRITE,10,
!
!      Load step number 11
TIME,70
AUTOTS,1
DELTIM,0.15,0.15,1.0,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,44.77
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,9.4197e8,
ALLSEL
LSWRITE,11,
!
!      Load step number 12
TIME,80
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AUTOTS,1
DELTIM,0.15,0.15,1.5,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,45.19
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,8.5514e8,
ALLSEL
LSWRITE,12,
!
!      Load step number 13
TIME,100
AUTOTS,1
DELTIM,0.15,0.15,2.5,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,45.68
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,7.2487e8,
ALLSEL
LSWRITE,13,
!
!      Load step number 14
TIME,150
AUTOTS,1
DELTIM,0.2,0.2,5,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,3.4018e7,,46.00
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,5.4619e8,
ALLSEL
LSWRITE,14,
!
ALLSEL
LSSOLVE,1,14,1,          !      Solve with 14 load steps
FINISH

```

```

/BATCH,LIST
!
!*****
!#
!#                               ANSYS INPUT
!#
!#   Filename:      pca2d85m101
!#
!#   Input File:    pca2d85m101.dat
!#
!#   Output File:   pca2d85m101.out
!#
!#   Description:   2D Analysis for temperature at performance
!#                  confirmation observation drift (pca2d)
!#                  Thermal load:      85 MTU/acre & 21 PWR (85)
!#                  Emplacement mode:  Center-in-drift
!#                  Drift diameter:    5.5 meters
!#                  Drift spacing:     22.5 meters
!#                  WP spacing:        18.92 meters
!#                  Initial heat output: 9.05 kW/package
!#                  WP diameter:       1.85 meters
!#                  Observation drift size: 4.5 meters in diameter
!#                                      15.90 m^2 in area
!#                                      600 meters long
!#
!#                  Distance from emplace.
!#                  drift crown to obser.
!#                  drift floor:      10 meters
!#                  Location of O.D.:  Mid-of-pillar (m)
!#                  Ventilation air temp.: Varied
!#                  Ventilation quantity: 10.0 m^3/s (10)
!#                  Coef. of convection: 1.8782 W/m^2-K
!#                  Modeling time period: 150 years
!#                  Ventilation segment: No. 1 (0 - 100 m) (1)
!#
!#   Code Version:  ANSYS Revision 5.2
!#
!#   Created By:    Yiming Sun
!#
!#   Last Modified: 02/09/97
!#
!*****
!
/COM,ANSYS MEDIA REV. 5.2
!
/FILNAM,pca2d85m101      ! Jobname to use for all subsequent files
/TITLE,2D Model (PCA;TL:85MTU/ac;AQ:10.0m^3/s;AT:26C;DOD:10m;SN:1)
/UNITS,SI
/SHOW
!
/NOPR
*ABB,SAVE_DB,SAVE
*ABB,RESUM_DB,RESUME
*ABB,QUIT,Fnc_/EXIT
*ABB,SHFR,./SHOW,FILE,,8
*ABB,SHFV,./SHOW,FILE,,1
*ABB,X11C,./SHOW,X11C,,8
*ABB,X11,./SHOW,X11,,1
*ABB,REPLOT,./REPLOT
*ABB,K1,./PNUM,KP,1
*ABB,K0,./PNUM,KP,0
*ABB,POWRGRPH,Fnc_/GRAPHICS
*ABB,ANSYSWEB,Fnc_HomePage
/GO
!
/FDELE,EMAT,DELE
/FDELE,ESAV,DELE
/FDELE,EROT,DELE
/FDELE,DSUB,DELE
/FDELE,TRI,DELE
/FDELE,OSAV,DELE
/FDELE,PAGE,DELE
!
/PREP7
!
!       Define element types
!
ET,1,PLANE55      !       4-node, 2-D thermal solid element
ET,2,LINK32       !       2-D conduction bar
R,1,1,0
ET,3,MATRIX50     !       Superelement for radiation
KEYOPT,3,1,1      !       Superelement behavior: radiation substructure
KEYOPT,3,6,0
!
!       Define material properties
!
!       Material number 1 (TCw unit)
MP,DENS,1,2169    !       Density (kg/m^3)
MP,KXX,1,5.014E7  !       Thermal conductivity (J/yr-m-C)
!
!       Material number 2 (PTn unit)
MP,DENS,2,1299    !       Density (kg/m^3)
MP,KXX,2,2.681E7  !       Thermal conductivity (J/yr-m-C)
!
!       Material number 3 (TSw1 unit)
MP,DENS,3,2163    !       Density (kg/m^3)
MP,KXX,3,5.046E7  !       Thermal conductivity (J/yr-m-C)
!
!       Material number 4 (TSw2 unit)

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MP,DENS,4,2274      ! Density (kg/m^3)
MP,KXX, 4,6.623E7   ! Thermal conductivity (J/yr-m-C)
MP,EMIS,4,0.9       ! Emissivity
!
! Material number 5 (TSw3 unit)
MP,DENS,5,2271      ! Density (kg/m^3)
MP,KXX, 5,4.037E7   ! Thermal conductivity (J/yr-m-C)
!
! Material number 6 (CHn1v unit)
MP,DENS,6,1972      ! Density (kg/m^3)
MP,KXX, 6,3.784E7   ! Thermal conductivity (J/yr-m-C)
!
! Material number 7 (CHn1z unit)
MP,DENS,7,1886      ! Density (kg/m^3)
MP,KXX, 7,4.037E7   ! Thermal conductivity (J/yr-m-C)
!
! Material number 8 (CHn2 unit)
MP,DENS,8,2070      ! Density (kg/m^3)
MP,KXX, 8,4.92E7    ! Thermal conductivity (J/yr-m-C)
!
! Material number 9 (Waste package)
MP,DENS,9,8131      ! Density (kg/m^3)
MP,KXX, 9,131.534E7 ! Thermal conductivity (J/yr-m-C)
MP,C, 9,487.901     ! Specific heat (J/kg-C)
MP,EMIS,9,0.8       ! Emissivity
!
! Material number 10 (link elements for radiation)
MP,EMIS,10,0.85     ! Emissivity
!
! Material number 11 (Radiation superelement element)
MP,EMIS,11,0.85     ! Emissivity
!
MPTEMP,1,25,94,95,114,115,250 ! Temperature table for temperature
! dependent specific heat (C)
! Specific heat (J/kg-C)
MPDATA,C,1,1,936.5,936.5,4322.2,4322.2,967.2,967.2 ! TCw unit
MPDATA,C,2,1,1715.6,1715.6,22564.3,22564.3,1172.9,1172.9 ! PTn unit
MPDATA,C,3,1,960.5,960.5,5670.6,5670.6,934.8,934.8 ! TSw1 unit
MPDATA,C,4,1,941.7,941.7,4608.0,4608.0,960.4,960.4 ! TSw2 unit
MPDATA,C,5,1,904.0,904.0,1990.0,1990.0,1124.4,1124.4 ! TSw3 unit
MPDATA,C,6,1,1300.8,1300.8,17935.1,17935.1,847.0,847.0 ! CHn1v unit
MPDATA,C,7,1,1416.2,1416.2,18762.1,18762.1,1210.8,1210.8 ! CHn1z unit
MPDATA,C,8,1,1231.2,1231.2,11998.2,11998.2,1330.6,1330.6 ! CHn2 unit
!
! Parameters for model generation
!
ORIG=0.0
X1=5.5
X2=11.25
DS=22.5
Y1=5.5
Y2=10.5
Y3=15
Y4=19.5
R1=2.75
RW=0.925
ROD=2.25
TSW2_UP=106.8
TSW2_LOW=-82.5
TSW1=236.9
PTN=275.0
TCW=311.0
TSW3=-98.3
CHN1V=-103.5
CHN1Z=-207.5
CHN2=-300.0
XOFF=33.75
YOFF=15.0
!
WPOFF,X2,0,0
CSYS,4
RECTNG,ORIG,X1,ORIG,Y1,
PCIRC,R1,,0,90,
ASBA,1,2
PCIRC,RW,,0,90,
ARSYM,Y,ALL,,,0,0
RECTNG,ORIG,X1,Y1,Y2,
RECTNG,ORIG,X1,Y2,Y3,
RECTNG,ORIG,X1,Y3,Y4,
RECTNG,ORIG,X1,Y4,TSW2_UP,
RECTNG,ORIG,X1,TSW2_UP,TSW1,
RECTNG,ORIG,X1,TSW1,PTN,
RECTNG,ORIG,X1,PTN,TCW,
RECTNG,ORIG,X1,-Y1,TSW2_LOW,
RECTNG,ORIG,X1,TSW2_LOW,TSW3,
RECTNG,ORIG,X1,TSW3,CHN1V,
RECTNG,ORIG,X1,CHN1V,CHN1Z,
RECTNG,ORIG,X1,CHN1Z,CHN2,
!
RECTNG, X1,X2, ORIG, Y1,
RECTNG, X1,X2, Y1, Y2,
RECTNG, X1,X2, Y2, Y3,
RECTNG, X1,X2, Y3, Y4,
RECTNG, X1,X2, Y4, TSW2_UP,
RECTNG, X1,X2, TSW2_UP, TSW1,
RECTNG, X1,X2, TSW1, PTN,
RECTNG, X1,X2, PTN, TCW,

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RECTNG, X1,X2, ORIG, -Y1,
RECTNG, X1,X2, -Y1,TSW2_LOW,
RECTNG, X1,X2,TSW2_LOW, TSW3,
RECTNG, X1,X2, TSW3, CHN1V,
RECTNG, X1,X2, CHN1V, CHN1Z,
RECTNG, X1,X2, CHN1Z, CHN2,
!
ARSYM,X,ALL,,,0,0
WPOFF,X2,0,0
ASEL,S,LOC,X,-X2,0,,1
ARSYM,X,ALL,,,0,0
ALLSEL
WPOFF,X2,0,0
ARSYM,X,ALL,,,0,0
WPOFF,-XOFF,YOFF,0
!
PCIRC,ROD, ,0,90,
PCIRC,ROD, ,0,-90,
!
ASBA,50,181
ASBA,49,182
WPOFF,0,-YOFF,0
AGLUE,ALL
/TRIAD,ROBOT
APLOT
SAVE
!
!           Meshing
!
TYPE,1,
MAT,9,
ESYS,0,
ESHAPE,2,0
MOPT,EXPND,1,
MOPT,TRANS,2,
MOPT,IESZ,0,
ESIZE,0.5,0,
AMESH,1,
AMESH,49
AMESH,181
AMESH,187
AMESH,182
AMESH,188
AMESH,184
AMESH,61
AMESH,185
AMESH,189
AMESH,186
AMESH,91
!
LCCAT,2,3
LCCAT,14,825
LCCAT,891,835
LCCAT,128,830
LCCAT,912,608
LCCAT,992,915
LCCAT,254,878
LCCAT,248,249
LCCAT,943,488
LCCAT,1005,948
LCCAT,374,938
LCCAT,368,369
LCCAT,769,845
LCCAT,841,894
!
TYPE,1,
MAT,4,
ESYS,0,
LSEL,S,LINE,,1044
LSEL,A,LINE,,724
!
LSEL,A,LINE,,5
LSEL,A,LINE,,1032
LSEL,A,LINE,,1034
LSEL,A,LINE,,1033
LSEL,A,LINE,,1036
LSEL,A,LINE,,1037
LSEL,A,LINE,,1035
LSEL,A,LINE,,251
LSEL,A,LINE,,1039
LSEL,A,LINE,,1040
LSEL,A,LINE,,1038
LSEL,A,LINE,,371
LESIZE,ALL,,10
!
LSEL,S,LINE,,1041,
LSEL,A,LINE,,1043,
LSEL,A,LINE,,1042,
LSEL,A,LINE,,127,
LSEL,A,LINE,,8,
LSEL,A,LINE,,9,
LSEL,A,LINE,,15,
LSEL,A,LINE,,247,
LSEL,A,LINE,,607,
LSEL,A,LINE,,250,
LSEL,A,LINE,,255,
LSEL,A,LINE,,367
LSEL,A,LINE,,487

```

! Mesh the waste package

! Concatenates lines

! Mesh the TSw2 unit

! Observation drift

! Emplacement drift

```
LSEL,A,LINE,,370
LSEL,A,LINE,,375
LESIZE,ALL,,5
!
LSEL,S,LINE,,845,
LSEL,A,LINE,,769,
LSEL,A,LINE,,841,
LSEL,A,LINE,,894,
LSEL,A,LINE,,830,
LSEL,A,LINE,,3,
LSEL,A,LINE,,2,
LSEL,A,LINE,,825,
LSEL,A,LINE,,14,
LSEL,A,LINE,,835,
LSEL,A,LINE,,891,
LSEL,A,LINE,,128,
LSEL,A,LINE,,249,
LSEL,A,LINE,,912,
LSEL,A,LINE,,608,
LSEL,A,LINE,,992,
LSEL,A,LINE,,915,
LSEL,A,LINE,,254,
LSEL,A,LINE,,878,
LSEL,A,LINE,,248,
LSEL,A,LINE,,369,
LSEL,A,LINE,,943,
LSEL,A,LINE,,488,
LSEL,A,LINE,,1005,
LSEL,A,LINE,,948,
LSEL,A,LINE,,374,
LSEL,A,LINE,,938,
LSEL,A,LINE,,368,
LSEL,A,LINE,,766
LESIZE,ALL,,5
!
LSEL,S,LINE,,738
LSEL,A,LINE,,764
LSEL,A,LINE,,821
LSEL,A,LINE,,795
LSEL,A,LINE,,823
LESIZE,ALL,,4
!
LSEL,S,LINE,,840
LSEL,A,LINE,,23
LSEL,A,LINE,,263
LSEL,A,LINE,,918
LSEL,A,LINE,,383
LSEL,A,LINE,,953
LESIZE,ALL,,5
!
ALLSEL
ESIZE,1,0,
AMESH,353,354,1,
AMESH,3
AMESH,344,346,1
AMESH,63
AMESH,347,349,1
AMESH,93
AMESH,350,352,1
ESIZE,1.5,0
AMESH,204
AMESH,271
AMESH,190
AMESH,233
AMESH,203
AMESH,258
AMESH,231
AMESH,318
AMESH,218
AMESH,293
AMESH,232
AMESH,331
!
AMESH,272
AMESH,235
AMESH,191
AMESH,239
AMESH,241
AMESH,193
AMESH,194
AMESH,234
AMESH,259
AMESH,238
AMESH,240
AMESH,260
AMESH,261
AMESH,206
AMESH,281
AMESH,208
AMESH,209
AMESH,283
AMESH,284
AMESH,319
AMESH,294
AMESH,320
AMESH,298
AMESH,321
AMESH,300
```

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AMESH,219
AMESH,295
AMESH,221
AMESH,299
AMESH,222
AMESH,301
AMESH,332
AMESH,334
AMESH,335
!
ESIZE,2,0
AMESH,205
AMESH,243
AMESH,195
AMESH,242
AMESH,262
AMESH,210
AMESH,285
AMESH,322
AMESH,302
AMESH,223
AMESH,303
AMESH,336
AMESH,273
AMESH,237
AMESH,192
AMESH,236
AMESH,266
AMESH,207
AMESH,282
AMESH,326
AMESH,296
AMESH,220
AMESH,297
AMESH,333
!
TYPE,1,           !      Mesh the TSwl unit
MAT,3,
ESYS,0,
ESIZE,3,0,0,
AMESH,274
AMESH,245
AMESH,196
AMESH,244
AMESH,263
AMESH,211
AMESH,286
AMESH,323
AMESH,304
AMESH,224
AMESH,305
AMESH,337
!
TYPE,1,           !      Mesh the PTn unit
MAT,2,
ESYS,0,
ESIZE,7.5,0,
AMESH,275
AMESH,247
AMESH,197
AMESH,246
AMESH,264
AMESH,212
AMESH,287
AMESH,324
AMESH,306
AMESH,225
AMESH,307
AMESH,338
!
TYPE,1,           !      Mesh the TCw unit
MAT,1,
ESYS,0,
ESIZE,15,0,
AMESH,276
AMESH,249
AMESH,198
AMESH,248
AMESH,265
AMESH,213
AMESH,288
AMESH,325
AMESH,308
AMESH,226
AMESH,309
AMESH,339
!
TYPE,1,           !      Mesh the TSw3 unit
MAT,5,
ESYS,0,
ESIZE,3,0,0,
AMESH,277
AMESH,250
AMESH,199
AMESH,251
AMESH,267
AMESH,214
AMESH,289
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AMESH,327
AMESH,311
AMESH,227
AMESH,310
AMESH,340
!
TYPE,1,                      !      Mesh the CHn1v unit
MAT,6,
ESYS,0,
ESIZE,3.0,0,
AMESH,278
AMESH,252
AMESH,200
AMESH,253
AMESH,268
AMESH,215
AMESH,290
AMESH,328
AMESH,313
AMESH,228
AMESH,312
AMESH,341
!
TYPE,1,                      !      Mesh the CHn1z unit
MAT,7,
ESYS,0,
ESIZE,7.5,0,
AMESH,279
AMESH,254
AMESH,201
AMESH,255
AMESH,269
AMESH,216
AMESH,291
AMESH,329
AMESH,315
AMESH,229
AMESH,314
AMESH,342
!
TYPE,1,                      !      Mesh the CHn2 unit
MAT,8,
ESYS,0,
ESIZE,15,0,
AMESH,280
AMESH,256
AMESH,202
AMESH,257
AMESH,270
AMESH,217
AMESH,292
AMESH,330
AMESH,317
AMESH,230
AMESH,316
AMESH,343
!
TYPE,2,                      !      Define link elements
MAT,10,
REAL,1,
ESYS,0,
LSEL,S,LINE,,1              !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
LSEL,A,LINE,,5              !      Drift wall
LSEL,A,LINE,,1033
LSEL,A,LINE,,1034
LSEL,A,LINE,,1032
LSEL,A,LINE,,1036
LSEL,A,LINE,,251
LSEL,A,LINE,,1035
LSEL,A,LINE,,1037
LSEL,A,LINE,,1039
LSEL,A,LINE,,371
LSEL,A,LINE,,1038
LSEL,A,LINE,,1040
NSLL,S,1
ESURF,ALL
PLOT
!
/AUX12                      !      Generate superelement for thermal
EMIS,2,0.85,                !      radiation calculation
STEF,1.7878,
GEOM,1,0,
SPACE,,
ESEL,S,TYPE,,2,2
NSLE,S
VTYPE,0,
MPRINT,0

```

```

WRITE,pca2d85m101      !      Save radiation matrices
FINISH
!
/PREP7
TYPE,3,
MAT,11,
REAL,1,
ESYS,0,
SE,pca2d85m101
!
ESEL,S,TYPE,,2,2
EDELE,ALL
ALLSEL
!
/SOLU
ANTYPE,TRANS          !      Solution phase
NROPT,AUTO             !      Transient analysis
TOFFST,273             !      Program chosen Newton-Raphson option
TINTP,0.005, , ,0.5,0.5,0.2 !      Specify the temperature offset: 273 C
!                      !      Use defaults of transient integration
!                      !      parameters
OUTPR,NSOL,5,          !      Solution printout at every 5 substeps
OUTRES,NSOL,5,         !      Solution data written to database
!                      !      at every 5 substeps
IC,ALL,TEMP,26,        !      Initial temperature at all nodes
NSEL,S,LOC,Y,311.0    !      Select all nodes on top surface
D,ALL,TEMP,18.7
NSEL,S,LOC,Y,-300.0   !
D,ALL,TEMP,32.53      !      Select all nodes on bottom surface
ALLSEL
SAVE
!
!      Load step number 1
TIMINT,OFF             !      Turn off transient effects at the
!                      !      first load step
TIME,1e-7
AUTOTS,1
DELTIM,1e-8,1e-8,1e-7,0
KBC,0
LSWRITE,1,
!
!      Load step number 2
TIMINT,ON              !      Turn on transient effects at the
!                      !      rest of load steps
TIME,0.5e-2
AUTOTS,1
DELTIM,0.5e-4,0.5e-4,0.5e-3,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,26
KBC,0
LSEL,S,LINE,,1         !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.5952e9,
ALLSEL
LSWRITE,2,
!
!      Load step number 3
TIME,1
AUTOTS,1
DELTIM,0.01,0.01,0.1,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,26
KBC,0
LSEL,S,LINE,,1         !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.5289e9,
ALLSEL
LSWRITE,3,
!
!      Load step number 4
TIME,5
AUTOTS,1
DELTIM,0.05,0.05,0.5,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift

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LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,26
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.3217e9,
ALLSEL
LSWRITE,4,
!
!          Load step number 5
TIME,10
AUTOTS,1
DELTIM,0.05,0.05,0.5,0
KBC,1
LSEL,S,LINE,,1044       !          Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,26
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.1169e9,
ALLSEL
LSWRITE,5,
!
!          Load step number 6
TIME,20
AUTOTS,1
DELTIM,0.1,0.1,0.75,0
KBC,1
LSEL,S,LINE,,1044       !          Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,26
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.7929e9,
ALLSEL
LSWRITE,6,
!
!          Load step number 7
TIME,30
AUTOTS,1
DELTIM,0.1,0.1,0.75,0
KBC,1
LSEL,S,LINE,,1044       !          Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,26
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.5401e9,
ALLSEL
LSWRITE,7,
!
!          Load step number 8
TIME,40
AUTOTS,1

```

```
DELTIM,0.15,0.15,0.75,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,26
KBC,0
LSEL,S,LINE,,1        !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.3400e9,
ALLSEL
LSWRITE,8,
!
!      Load step number 9
TIME,50
AUTOTS,1
DELTIM,0.15,0.15,0.75,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,26
KBC,0
LSEL,S,LINE,,1        !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.1779e9,
ALLSEL
LSWRITE,9,
!
!      Load step number 10
TIME,60
AUTOTS,1
DELTIM,0.15,0.15,1.0,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,26
KBC,0
LSEL,S,LINE,,1        !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.0477e9,
ALLSEL
LSWRITE,10,
!
!      Load step number 11
TIME,70
AUTOTS,1
DELTIM,0.15,0.15,1.0,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,26
KBC,0
LSEL,S,LINE,,1        !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,9.4197e8,
ALLSEL
LSWRITE,11,
!
!      Load step number 12
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TIME,80
AUTOTS,1
DELTIM,0.15,0.15,1.5,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,26
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,8.5514e8,
ALLSEL
LSWRITE,12,
!
!      Load step number 13
TIME,100
AUTOTS,1
DELTIM,0.15,0.15,2.5,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,26
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,7.2487e8,
ALLSEL
LSWRITE,13,
!
!      Load step number 14
TIME,150
AUTOTS,1
DELTIM,0.2,0.2,5,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,26
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,5.4619e8,
ALLSEL
LSWRITE,14,
!
ALLSEL
LSSOLVE,1,14,1,      !      Solve with 14 load steps
FINISH

```

```

/BATCH,LIST
!
!*****
!#
!#                               ANSYS INPUT
!#
!#      Filename:      pca2d85m102
!#
!#      Input File:    pca2d85m102.dat
!#
!#      Output File:   pca2d85m102.out
!#
!#      Description:   2D Analysis for temperature at performance
!#                    confirmation observation drift (pca2d)
!#                    Thermal load:      85 MTU/acre & 21 PWR (85)
!#                    Emplacement mode:  Center-in-drift
!#                    Drift diameter:    5.5 meters
!#                    Drift spacing:     22.5 meters
!#                    WP spacing:        18.92 meters
!#                    Initial heat output: 9.05 kW/package
!#                    WP diameter:       1.85 meters
!#                    Observation drift size: 4.5 meters in diameter
!#                                         15.90 m^2 in area
!#                                         600 meters long
!#
!#                    Distance from emplace.
!#                      drift crown to obser.
!#                      drift floor:     10 meters
!#                    Location of O.D.:  Mid-of-pillar (m)
!#                    Ventilation air temp.: Varied
!#                    Ventilation quantity: 10.0 m^3/s (10)
!#                    Coef. of convection: 1.8782 W/m^2-K
!#                    Modeling time period: 150 years
!#                    Ventilation segment: No. 2 (100 - 200 m) (2)
!#
!#      Code Version:  ANSYS Revision 5.2
!#
!#      Created By:    Yiming Sun
!#
!#      Last Modified: 02/10/97
!#
!*****
/COM,ANSYS MEDIA REV. 5.2
!
/FILNAM,pca2d85m102      !      Jobname to use for all subsequent files
/TITLE,2D Model (PCA;TL:85MTU/ac;AQ:10.0m^3/s;AT:26C;DOD:10m;SN:2)
/UNITS,SI
/SHOW
!
/NOPR
*ABB,SAVE_DB,SAVE
*ABB,RESUM_DB,RESUME
*ABB,QUIT,Fnc_/EXIT
*ABB,SHFR,/,SHOW,FILE,,,8
*ABB,SHFV,/,SHOW,FILE,,1
*ABB,X11C,/,SHOW,X11C,,,8
*ABB,X11,/,SHOW,X11,,1
*ABB,REPLOT,/,REPLOT
*ABB,K1,/,PNUM,KP,1
*ABB,K0,/,PNUM,KP,0
*ABB,POWRGRPH,Fnc_/GRAPHICS
*ABB,ANSYSWEB,Fnc_HomePage
/GO
!
/FDELE;EMAT,DELE
/FDELE;ESAV,DELE
/FDELE;EROT,DELE
/FDELE;DSUB,DELE
/FDELE;TRI,DELE
/FDELE;OSAV,DELE
/FDELE;PAGE,DELE
!
/PREP7
!
!      Define element types
!
ET,1,PLANE55      !      4-node, 2-D thermal solid element
ET,2,LINK32      !      2-D conduction bar
R,1,1,0
ET,3,MATRIX50    !      Superelement for radiation
KEYOPT,3,1,1     !      Superelement behavior: radiation substructure
KEYOPT,3,6,0
!
!      Define material properties
!
!      Material number 1 (TCw unit)
MP,DENS,1,2169    !      Density (kg/m^3)
MP,KXX,1,5.014E7 !      Thermal conductivity (J/yr-m-C)
!
!      Material number 2 (PTn unit)
MP,DENS,2,1299    !      Density (kg/m^3)
MP,KXX,2,2.681E7 !      Thermal conductivity (J/yr-m-C)
!
!      Material number 3 (TSw1 unit)
MP,DENS,3,2163    !      Density (kg/m^3)
MP,KXX,3,5.046E7 !      Thermal conductivity (J/yr-m-C)
!
!      Material number 4 (TSw2 unit)

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MP,DENS,4,2274      !      Density (kg/m^3)
MP,KXX, 4,6.623E7   !      Thermal conductivity (J/yr-m-C)
MP,EMIS,4,0.9       !      Emissivity
!
!      Material number 5 (TSw3 unit)
MP,DENS,5,2271      !      Density (kg/m^3)
MP,KXX, 5,4.037E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 6 (CHnlv unit)
MP,DENS,6,1972      !      Density (kg/m^3)
MP,KXX, 6,3.784E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 7 (CHnlz unit)
MP,DENS,7,1886      !      Density (kg/m^3)
MP,KXX, 7,4.037E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 8 (CHn2 unit)
MP,DENS,8,2070      !      Density (kg/m^3)
MP,KXX, 8,4.92E7    !      Thermal conductivity (J/yr-m-C)
!
!      Material number 9 (Waste package)
MP,DENS,9,8131      !      Density (kg/m^3)
MP,KXX, 9,131.534E7 !      Thermal conductivity (J/yr-m-C)
MP,C, 9,487.901     !      Specific heat (J/kg-C)
MP,EMIS,9,0.8       !      Emissivity
!
!      Material number 10 (link elements for radiation)
MP,EMIS,10,0.85     !      Emissivity
!
!      Material number 11 (Radiation superelement element)
MP,EMIS,11,0.85     !      Emissivity
!
MPTEMP,1,25,94,95,114,115,250 ! Temperature table for temperature
!                               dependent specific heat (C)
!      Specific heat (J/kg-C)
MPDATA,C,1,1,936.5,936.5,4322.2,4322.2,967.2,967.2 !      TCw unit
MPDATA,C,2,1,1715.6,1715.6,22564.3,22564.3,1172.9,1172.9 !      PTn unit
MPDATA,C,3,1,960.5,960.5,5670.6,5670.6,934.8,934.8 !      TSw1 unit
MPDATA,C,4,1,941.7,941.7,4608.0,4608.0,960.4,960.4 !      TSw2 unit
MPDATA,C,5,1,904.0,904.0,1990.0,1990.0,1124.4,1124.4 !      TSw3 unit
MPDATA,C,6,1,1300.8,1300.8,17935.1,17935.1,847.0,847.0 !      CHnlv unit
MPDATA,C,7,1,1416.2,1416.2,18762.1,18762.1,1210.8,1210.8 !      CHnlz unit
MPDATA,C,8,1,1231.2,1231.2,11998.2,11998.2,1330.6,1330.6 !      CHn2 unit
!
!      Parameters for model generation
!
ORIG=0.0
X1=5.5
X2=11.25
DS=22.5
Y1=5.5
Y2=10.5
Y3=15
Y4=19.5
R1=2.75
RW=0.925
ROD=2.25
TSW2_UP=106.8
TSW2_LOW=-82.5
TSW1=236.9
PTN=275.0
TCW=311.0
TSW3=-98.3
CHN1V=-103.5
CHN1Z=-207.5
CHN2=-300.0
XOFF=33.75
YOFF=15.0
!
WPOFF,X2,0,0
CSYS,4
RECTNG,ORIG,X1,ORIG,Y1,
PCIRC,R1,,0,90,
ASBA,1,2
PCIRC,RW,,0,90,
ARSYM,Y,ALL,,,0,0
RECTNG,ORIG,X1,Y1,Y2,
RECTNG,ORIG,X1,Y2,Y3,
RECTNG,ORIG,X1,Y3,Y4,
RECTNG,ORIG,X1,Y4,TSW2_UP,
RECTNG,ORIG,X1,TSW2_UP,TSW1,
RECTNG,ORIG,X1,TSW1,PTN,
RECTNG,ORIG,X1,PTN,TCW,
RECTNG,ORIG,X1,-Y1,TSW2_LOW,
RECTNG,ORIG,X1,TSW2_LOW,TSW3,
RECTNG,ORIG,X1,TSW3,CHN1V,
RECTNG,ORIG,X1,CHN1V,CHN1Z,
RECTNG,ORIG,X1,CHN1Z,CHN2,
!
RECTNG, X1,X2, ORIG, Y1,
RECTNG, X1,X2, Y1, Y2,
RECTNG, X1,X2, Y2, Y3,
RECTNG, X1,X2, Y3, Y4,
RECTNG, X1,X2, Y4, TSW2_UP,
RECTNG, X1,X2, TSW2_UP, TSW1,
RECTNG, X1,X2, TSW1, PTN,
RECTNG, X1,X2, PTN, TCW,

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```

RECTNG, X1,X2, ORIG, -Y1,
RECTNG, X1,X2, -Y1,TSW2_LOW,
RECTNG, X1,X2,TSW2_LOW, TSW3,
RECTNG, X1,X2, TSW3, CHN1V,
RECTNG, X1,X2, CHN1V, CHN1Z,
RECTNG, X1,X2, CHN1Z, CHN2,

```

```

!
ARSYM,X,ALL,,,0,0
WPOFF,X2,0,0
ASEL,S,LOC,X,-X2,0,,1
ARSYM,X,ALL,,,0,0
ALLSEL
WPOFF,X2,0,0
ARSYM,X,ALL,,,0,0
WPOFF,-XOFF,YOFF,0

```

```

!
PCIRC,ROD, ,0,90,
PCIRC,ROD, ,0,-90,

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```

!
ASBA,50,181
ASBA,49,182
WPOFF,0,-YOFF,0
AGLUE,ALL
/TRIAD,ROBOT
APLOT
SAVE

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```

!
! Meshing

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```

! TYPE,1, ! Mesh the waste package

```

```

MAT,9,
ESYS,0,
ESHAPE,2,0
MOPT,EXPND,1,
MOPT,TRANS,2,
MOPT,IESZ,0,
ESIZE,0.5,0,
AMESH,1,
AMESH,49
AMESH,181
AMESH,187
AMESH,182
AMESH,188
AMESH,184
AMESH,61
AMESH,185
AMESH,189
AMESH,186
AMESH,91

```

```

!
LCCAT,2,3 ! Concatenates lines
LCCAT,14,825
LCCAT,891,835
LCCAT,128,830
LCCAT,912,608
LCCAT,992,915
LCCAT,254,878
LCCAT,248,249
LCCAT,943,488
LCCAT,1005,948
LCCAT,374,938
LCCAT,368,369
LCCAT,769,845
LCCAT,841,894

```

```

! TYPE,1, ! Mesh the TSw2 unit

```

```

MAT,4,
ESYS,0,
LSEL,S,LINE,,1044 ! Observation drift
LSEL,A,LINE,,724

```

```

!
LSEL,A,LINE,,5 ! Emplacement drift

```

```

LSEL,A,LINE,,1032
LSEL,A,LINE,,1034
LSEL,A,LINE,,1033
LSEL,A,LINE,,1036
LSEL,A,LINE,,1037
LSEL,A,LINE,,1035
LSEL,A,LINE,,251
LSEL,A,LINE,,1039
LSEL,A,LINE,,1040
LSEL,A,LINE,,1038
LSEL,A,LINE,,371
LESIZE,ALL,,10
!
LSEL,S,LINE,,1041,
LSEL,A,LINE,,1043,
LSEL,A,LINE,,1042,
LSEL,A,LINE,,127,
LSEL,A,LINE,,8,
LSEL,A,LINE,,9,
LSEL,A,LINE,,15,
LSEL,A,LINE,,247,
LSEL,A,LINE,,607,
LSEL,A,LINE,,250,
LSEL,A,LINE,,255,
LSEL,A,LINE,,367
LSEL,A,LINE,,487

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```
LSEL,A,LINE,,370
LSEL,A,LINE,,375
LESIZE,ALL,,5
!
LSEL,S,LINE,,845,
LSEL,A,LINE,,769,
LSEL,A,LINE,,841,
LSEL,A,LINE,,894,
LSEL,A,LINE,,830,
LSEL,A,LINE,,3,
LSEL,A,LINE,,2,
LSEL,A,LINE,,825,
LSEL,A,LINE,,14,
LSEL,A,LINE,,835,
LSEL,A,LINE,,891,
LSEL,A,LINE,,128
LSEL,A,LINE,,249
LSEL,A,LINE,,912
LSEL,A,LINE,,608
LSEL,A,LINE,,992,
LSEL,A,LINE,,915
LSEL,A,LINE,,254
LSEL,A,LINE,,878
LSEL,A,LINE,,248
LSEL,A,LINE,,369
LSEL,A,LINE,,943
LSEL,A,LINE,,488
LSEL,A,LINE,,1005,
LSEL,A,LINE,,948
LSEL,A,LINE,,374
LSEL,A,LINE,,938
LSEL,A,LINE,,368
LSEL,A,LINE,,766
LESIZE,ALL,,5
!
LSEL,S,LINE,,738
LSEL,A,LINE,,764
LSEL,A,LINE,,821
LSEL,A,LINE,,795
LSEL,A,LINE,,823
LESIZE,ALL,,4
!
LSEL,S,LINE,,840
LSEL,A,LINE,,23
LSEL,A,LINE,,263
LSEL,A,LINE,,918
LSEL,A,LINE,,383
LSEL,A,LINE,,953
LESIZE,ALL,,5
!
ALLSEL
ESIZE,1,0,
AMESH,353,354,1,
AMESH,3
AMESH,344,346,1
AMESH,63
AMESH,347,349,1
AMESH,93
AMESH,350,352,1
ESIZE,1.5,0
AMESH,204
AMESH,271
AMESH,190
AMESH,233
AMESH,203
AMESH,258
AMESH,231
AMESH,318
AMESH,218
AMESH,293
AMESH,232
AMESH,331
!
AMESH,272
AMESH,235
AMESH,191
AMESH,239
AMESH,241
AMESH,193
AMESH,194
AMESH,234
AMESH,259
AMESH,238
AMESH,240
AMESH,260
AMESH,261
AMESH,206
AMESH,281
AMESH,208
AMESH,209
AMESH,283
AMESH,284
AMESH,319
AMESH,294
AMESH,320
AMESH,298
AMESH,321
AMESH,300
```

```
AMESH,219
AMESH,295
AMESH,221
AMESH,299
AMESH,222
AMESH,301
AMESH,332
AMESH,334
AMESH,335
!
ESIZE,2,0
AMESH,205
AMESH,243
AMESH,195
AMESH,242
AMESH,262
AMESH,210
AMESH,285
AMESH,322
AMESH,302
AMESH,223
AMESH,303
AMESH,336
AMESH,273
AMESH,237
AMESH,192
AMESH,236
AMESH,266
AMESH,207
AMESH,282
AMESH,326
AMESH,296
AMESH,220
AMESH,297
AMESH,333
!
TYPE,1,          !      Mesh the TSwl unit
MAT,3,
ESYS,0,
ESIZE,3.0,0,
AMESH,274
AMESH,245
AMESH,196
AMESH,244
AMESH,263
AMESH,211
AMESH,286
AMESH,323
AMESH,304
AMESH,224
AMESH,305
AMESH,337
!
TYPE,1,          !      Mesh the PTn unit
MAT,2,
ESYS,0,
ESIZE,7.5,0,
AMESH,275
AMESH,247
AMESH,197
AMESH,246
AMESH,264
AMESH,212
AMESH,287
AMESH,324
AMESH,306
AMESH,225
AMESH,307
AMESH,338
!
TYPE,1,          !      Mesh the TCw unit
MAT,1,
ESYS,0,
ESIZE,15,0,
AMESH,276
AMESH,249
AMESH,198
AMESH,248
AMESH,265
AMESH,213
AMESH,288
AMESH,325
AMESH,308
AMESH,226
AMESH,309
AMESH,339
!
TYPE,1,          !      Mesh the TSw3 unit
MAT,5,
ESYS,0,
ESIZE,3.0,0,
AMESH,277
AMESH,250
AMESH,199
AMESH,251
AMESH,267
AMESH,214
AMESH,289
```

```

AMESH,327
AMESH,311
AMESH,227
AMESH,310
AMESH,340
!
TYPE,1,          !      Mesh the CHn1v unit
MAT,6,
ESYS,0,
ESIZE,3.0,0,
AMESH,278
AMESH,252
AMESH,200
AMESH,253
AMESH,268
AMESH,215
AMESH,290
AMESH,328
AMESH,313
AMESH,228
AMESH,312
AMESH,341
!
TYPE,1,          !      Mesh the CHn1z unit
MAT,7,
ESYS,0,
ESIZE,7.5,0,
AMESH,279
AMESH,254
AMESH,201
AMESH,255
AMESH,269
AMESH,216
AMESH,291
AMESH,329
AMESH,315
AMESH,229
AMESH,314
AMESH,342
!
TYPE,1,          !      Mesh the CHn2 unit
MAT,8,
ESYS,0,
ESIZE,15,0,
AMESH,280
AMESH,256
AMESH,202
AMESH,257
AMESH,270
AMESH,217
AMESH,292
AMESH,330
AMESH,317
AMESH,230
AMESH,316
AMESH,343
!
TYPE,2,          !      Define link elements
MAT,10,
REAL,1,
ESYS,0,
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
LSEL,A,LINE,,5          !      Drift wall
LSEL,A,LINE,,1033
LSEL,A,LINE,,1034
LSEL,A,LINE,,1032
LSEL,A,LINE,,1036
LSEL,A,LINE,,251
LSEL,A,LINE,,1035
LSEL,A,LINE,,1037
LSEL,A,LINE,,1039
LSEL,A,LINE,,371
LSEL,A,LINE,,1038
LSEL,A,LINE,,1040
NSLL,S,1
ESURF,ALL
PLOT
!
/AUX12          !      Generate superelement for thermal
EMIS,2,0.85,    !      radiation calculation
STEF,1.7878,
GEOM,1,0,
SPACE,
ESEL,S,TYPE,,2,2
NSLE,S
VTYPE,0,
MPRINT,0

```

```

WRITE,pca2d85m102      !      Save radiation matrices
FINISH
!
/PREP7
TYPE,3,
MAT,11,
REAL,1,
ESYS,0,
SE,pca2d85m102
!
ESEL,S,TYPE,,2,2
EDELE,ALL
ALLSEL
!
/SOLU      !      Solution phase
ANTYPE,TRANS      !      Transient analysis
NROPT,AUTO      !      Program chosen Newton-Raphson option
TOFFST,273      !      Specify the temperature offset: 273 C
TINTP,0.005,,0.5,0.5,0.2      !      Use defaults of transient integration
!      parameters
OUTPR,NSOL,5,      !      Solution printout at every 5 substeps
OUTRES,NSOL,5,      !      Solution data written to database
!      at every 5 substeps
IC,ALL,TEMP,26,      !      Initial temperature at all nodes
NSEL,S,LOC,Y,311.0      !      Select all nodes on top surface
D,ALL,TEMP,18.7
NSEL,S,LOC,Y,-300.0      !      Select all nodes on bottom surface
D,ALL,TEMP,32.53
ALLSEL
SAVE
!
!      Load step number 1
TIMINT,OFF      !      Turn off transient effects at the
!      first load step
TIME,1e-7
AUTOTS,1
DELTIM,1e-8,1e-8,1e-7,0
KBC,0
LSWRITE,1,
!
TIMINT,ON      !      Turn on transient effects at the
!      rest of load steps
!
!      Load step number 2
TIME,0.5e-2
AUTOTS,1
DELTIM,0.5e-4,0.5e-4,0.5e-3,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,26
KBC,0
LSEL,S,LINE,,1      !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.5952e9,
ALLSEL
LSWRITE,2,
!
!      Load step number 3
TIME,1
AUTOTS,1
DELTIM,0.01,0.01,0.1,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,26.06
KBC,0
LSEL,S,LINE,,1      !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.5289e9,
ALLSEL
LSWRITE,3,
!
!      Load step number 4
TIME,5
AUTOTS,1
DELTIM,0.05,0.05,0.5,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift

```

```
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,27.00
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.3217e9,
ALLSEL
LSWRITE,4,
!
!          Load step number 5
TIME,10
AUTOTS,1
DELTIM,0.05,0.05,0.5,0
KBC,1
LSEL,S,LINE,,1044       !          Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,27.64
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.1169e9,
ALLSEL
LSWRITE,5,
!
!          Load step number 6
TIME,20
AUTOTS,1
DELTIM,0.1,0.1,0.75,0
KBC,1
LSEL,S,LINE,,1044       !          Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,28.22
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.7929e9,
ALLSEL
LSWRITE,6,
!
!          Load step number 7
TIME,30
AUTOTS,1
DELTIM,0.1,0.1,0.75,0
KBC,1
LSEL,S,LINE,,1044       !          Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,28.49
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.5401e9,
ALLSEL
LSWRITE,7,
!
!          Load step number 8
TIME,40
AUTOTS,1
```

```
DELTIM,0.15,0.15,0.75,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,28.65
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.3400e9,
ALLSEL
LSWRITE,8,
!
!      Load step number 9
TIME,50
AUTOTS,1
DELTIM,0.15,0.15,0.75,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,28.74
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.1779e9,
ALLSEL
LSWRITE,9,
!
!      Load step number 10
TIME,60
AUTOTS,1
DELTIM,0.15,0.15,1.0,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,28.79
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.0477e9,
ALLSEL
LSWRITE,10,
!
!      Load step number 11
TIME,70
AUTOTS,1
DELTIM,0.15,0.15,1.0,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,28.81
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,9.4197e8,
ALLSEL
LSWRITE,11,
!
!      Load step number 12
```

```
TIME,80
AUTOTS,1
DELTIM,0.15,0.15,1.5,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,28.81
KBC,0
LSEL,S,LINE,,1         !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,8.5514e8,
ALLSEL
LSWRITE,12,
!
!      Load step number 13
TIME,100
AUTOTS,1
DELTIM,0.15,0.15,2.5,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,28.79
KBC,0
LSEL,S,LINE,,1         !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,7.2487e8,
ALLSEL
LSWRITE,13,
!
!      Load step number 14
TIME,150
AUTOTS,1
DELTIM,0.2,0.2,5,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,28.71
KBC,0
LSEL,S,LINE,,1         !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,5.4619e8,
ALLSEL
LSWRITE,14,
!
ALLSEL
LSSOLVE,1,14,1,      !      Solve with 14 load steps
FINISH
```

```

/BATCH,LIST
!
!#####
!#
!#                               ANSYS INPUT
!#
!#   Filename:      pca2d85m103
!#
!#   Input File:    pca2d85m103.dat
!#
!#   Output File:   pca2d85m103.out
!#
!#   Description:   2D Analysis for temperature at performance
!#                  confirmation observation drift (pca2d)
!#                  Thermal load:      85 MTU/acre & 21 FWR (85)
!#                  Emplacement mode:  Center-in-drift
!#                  Drift diameter:    5.5 meters
!#                  Drift spacing:     22.5 meters
!#                  WP spacing:        18.92 meters
!#                  Initial heat output: 9.05 kW/package
!#                  WP diameter:       1.85 meters
!#                  Observation drift size: 4.5 meters in diameter
!#                                      15.90 m^2 in area
!#                                      600 meters long
!#
!#                  Distance from emplace.
!#                  drift crown to obser.
!#                  drift floor:      10 meters
!#                  Location of O.D.:  Mid-of-pillar (m)
!#                  Ventilation air temp.: Varied
!#                  Ventilation quantity: 10.0 m^3/s (10)
!#                  Coef. of convection: 1.8782 W/m^2-K
!#                  Modeling time period: 150 years
!#                  Ventilation segment: No. 3 (200 - 300 m) (3)
!#
!#   Code Version:  ANSYS Revision 5.2
!#
!#   Created By:    Yiming Sun
!#
!#   Last Modified: 02/11/97
!#
!#####
!
/COM,ANSYS MEDIA REV. 5.2
!
/FILNAM,pca2d85m103      !      Jobname to use for all subsequent files
/TITLE,2D Model (PCA;TL:85MTU/ac;AQ:10.0m^3/s;AT:26C;DOD:10m;SN:3)
/UNITS,SI
/SHOW
!
/NOFR
*ABB,SAVE_DB,SAVE
*ABB,RESUM_DB,RESUME
*ABB,QUIT,Fnc_/EXIT
*ABB,SHFR,./SHOW,FILE,,,8
*ABB,SHFV,./SHOW,FILE,,1
*ABB,X11C,./SHOW,X11C,,,8
*ABB,X11,./SHOW,X11,,1
*ABB,REPLOTT,./REPLOTT
*ABB,K1,./PNUM,KP,1
*ABB,KO,./PNUM,KP,0
*ABB,POWRGRPH,Fnc_/GRAPHICS
*ABB,ANSYSWEB,Fnc_HomePage
/GO
!
/FDELE,EMAT,DELE
/FDELE,ESAV,DELE
/FDELE,EROT,DELE
/FDELE,DSUB,DELE
/FDELE,TRI,DELE
/FDELE,OSAV,DELE
/FDELE,PAGE,DELE
!
/PREP7
!
!      Define element types
!
ET,1,PLANE55      !      4-node, 2-D thermal solid element
ET,2,LINK32      !      2-D conduction bar
R,1,1,0
ET,3,MATRIX50    !      Superelement for radiation
KEYOPT,3,1,1     !      Superelement behavior: radiation substructure
KEYOPT,3,6,0
!
!      Define material properties
!
!      Material number 1 (TCw unit)
MP,DENS,1,2169    !      Density (kg/m^3)
MP,KXX,1,5.014E7 !      Thermal conductivity (J/yr-m-C)
!
!      Material number 2 (PTn unit)
MP,DENS,2,1299    !      Density (kg/m^3)
MP,KXX,2,2.681E7 !      Thermal conductivity (J/yr-m-C)
!
!      Material number 3 (TSw1 unit)
MP,DENS,3,2163    !      Density (kg/m^3)
MP,KXX,3,5.046E7 !      Thermal conductivity (J/yr-m-C)
!
!      Material number 4 (TSw2 unit)

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MP,DENS,4,2274      !      Density (kg/m^3)
MP,KXX, 4,6.623E7   !      Thermal conductivity (J/yr-m-C)
MP,EMIS,4,0.9       !      Emissivity
!
!      Material number 5 (TSw3 unit)
MP,DENS,5,2271      !      Density (kg/m^3)
MP,KXX, 5,4.037E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 6 (CHn1v unit)
MP,DENS,6,1972      !      Density (kg/m^3)
MP,KXX, 6,3.784E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 7 (CHn1z unit)
MP,DENS,7,1886      !      Density (kg/m^3)
MP,KXX, 7,4.037E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 8 (CHn2 unit)
MP,DENS,8,2070      !      Density (kg/m^3)
MP,KXX, 8,4.92E7    !      Thermal conductivity (J/yr-m-C)
!
!      Material number 9 (Waste package)
MP,DENS,9,8131      !      Density (kg/m^3)
MP,KXX, 9,131.534E7 !      Thermal conductivity (J/yr-m-C)
MP,C, 9,487.901     !      Specific heat (J/kg-C)
MP,EMIS,9,0.8       !      Emissivity
!
!      Material number 10 (link elements for radiation)
MP,EMIS,10,0.85     !      Emissivity
!
!      Material number 11 (Radiation superelement element)
MP,EMIS,11,0.85     !      Emissivity
!
MPTEMP,1,25,94,95,114,115,250 ! Temperature table for temperature
!                               dependent specific heat (C)
!      Specific heat (J/kg-C)
MPDATA,C,1,1,936.5,936.5,4322.2,4322.2,967.2,967.2 !      TCw unit
MPDATA,C,2,1,1715.6,1715.6,22564.3,22564.3,1172.9,1172.9 !      PTn unit
MPDATA,C,3,1,960.5,960.5,5670.6,5670.6,934.8,934.8 !      TSw1 unit
MPDATA,C,4,1,941.7,941.7,4608.0,4608.0,960.4,960.4 !      TSw2 unit
MPDATA,C,5,1,904.0,904.0,1990.0,1990.0,1124.4,1124.4 !      TSw3 unit
MPDATA,C,6,1,1300.8,1300.8,17935.1,17935.1,847.0,847.0 !      CHn1v unit
MPDATA,C,7,1,1416.2,1416.2,18762.1,18762.1,1210.8,1210.8 !      CHn1z unit
MPDATA,C,8,1,1231.2,1231.2,11998.2,11998.2,1330.6,1330.6 !      CHn2 unit
!
!      Parameters for model generation
!
ORIG=0.0
X1=5.5
X2=11.25
DS=22.5
Y1=5.5
Y2=10.5
Y3=15
Y4=19.5
R1=2.75
RW=0.925
ROD=2.25
TSW2_UP=106.8
TSW2_LOW=-82.5
TSW1=236.9
PTN=275.0
TCW=311.0
TSW3=-98.3
CHN1V=-103.5
CHN1Z=-207.5
CHN2=-300.0
XOFF=33.75
YOFF=15.0
!
WPOFF,X2,0,0
CSYS,4
RECTNG,ORIG,X1,ORIG,Y1,
PCIRC,R1,,0,90,
ASBA,1,2
PCIRC,RW,,0,90,
ARSYM,Y,ALL,,,,0,0
RECTNG,ORIG,X1, Y1, Y2,
RECTNG,ORIG,X1, Y2, Y3,
RECTNG,ORIG,X1, Y3, Y4,
RECTNG,ORIG,X1, Y4, TSW2_UP,
RECTNG,ORIG,X1, TSW2_UP, TSW1,
RECTNG,ORIG,X1, TSW1, PTN,
RECTNG,ORIG,X1, PTN, TCW,
RECTNG,ORIG,X1, -Y1,TSW2_LOW,
RECTNG,ORIG,X1,TSW2_LOW, TSW3,
RECTNG,ORIG,X1, TSW3, CHN1V,
RECTNG,ORIG,X1, CHN1V, CHN1Z,
RECTNG,ORIG,X1, CHN1Z, CHN2,
!
RECTNG, X1,X2, ORIG, Y1,
RECTNG, X1,X2, Y1, Y2,
RECTNG, X1,X2, Y2, Y3,
RECTNG, X1,X2, Y3, Y4,
RECTNG, X1,X2, Y4, TSW2_UP,
RECTNG, X1,X2, TSW2_UP, TSW1,
RECTNG, X1,X2, TSW1, PTN,
RECTNG, X1,X2, PTN, TCW,

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RECTNG, X1,X2, ORIG, -Y1,
RECTNG, X1,X2, -Y1,TSW2_LOW,
RECTNG, X1,X2,TSW2_LOW, TSW3,
RECTNG, X1,X2, TSW3, CHN1V,
RECTNG, X1,X2, CHN1V, CHN1Z,
RECTNG, X1,X2, CHN1Z, CHN2,
!
ARSYM,X,ALL,,,0,0
WPOFF,X2,0,0
ASEL,S,LOC,X,-X2,0,,1
ARSYM,X,ALL,,,0,0
ALLSEL
WPOFF,X2,0,0
ARSYM,X,ALL,,,0,0
WPOFF,-XOFF,YOFF,0
!
PCIRC,ROD, ,0,90,
PCIRC,ROD, ,0,-90,
!
ASBA,50,181
ASBA,49,182
WPOFF,0,-YOFF,0
AGLUE,ALL
/TRIAD,RBOT
APLOT
SAVE
!
! Meshing
!
TYPE,1,
MAT,9,
ESYS,0,
ESHAPE,2,0
MOPT,EXPND,1,
MOPT,TRANS,2,
MOPT,IESZ,0,
ESIZE,0.5,0,
AMESH,1,
AMESH,49
AMESH,181
AMESH,187
AMESH,182
AMESH,188
AMESH,184
AMESH,61
AMESH,185
AMESH,189
AMESH,186
AMESH,91
!
LCCAT,2,3
LCCAT,14,825
LCCAT,891,835
LCCAT,128,830
LCCAT,912,608
LCCAT,992,915
LCCAT,254,878
LCCAT,248,249
LCCAT,943,488
LCCAT,1005,948
LCCAT,374,938
LCCAT,368,369
LCCAT,769,845
LCCAT,841,894
!
TYPE,1,
MAT,4,
ESYS,0,
LSEL,S,LINE,,1044
LSEL,A,LINE,,724
!
LSEL,A,LINE,,5
LSEL,A,LINE,,1032
LSEL,A,LINE,,1034
LSEL,A,LINE,,1033
LSEL,A,LINE,,1036
LSEL,A,LINE,,1037
LSEL,A,LINE,,1035
LSEL,A,LINE,,251
LSEL,A,LINE,,1039
LSEL,A,LINE,,1040
LSEL,A,LINE,,1038
LSEL,A,LINE,,371
LESIZE,ALL,,10
!
LSEL,S,LINE,,1041,
LSEL,A,LINE,,1043,
LSEL,A,LINE,,1042,
LSEL,A,LINE,,127,
LSEL,A,LINE,,8,
LSEL,A,LINE,,9,
LSEL,A,LINE,,15,
LSEL,A,LINE,,247,
LSEL,A,LINE,,607,
LSEL,A,LINE,,250,
LSEL,A,LINE,,255,
LSEL,A,LINE,,367
LSEL,A,LINE,,487

```

Mesh the waste package

Concatenates lines

Mesh the TSw2 unit

Observation drift

Emplacement drift

```
LSEL,A,LINE,,370
LSEL,A,LINE,,375
LESIZE,ALL,,5
!
LSEL,S,LINE,,845,
LSEL,A,LINE,,769,
LSEL,A,LINE,,841,
LSEL,A,LINE,,894,
LSEL,A,LINE,,830,
LSEL,A,LINE,,3,
LSEL,A,LINE,,2,
LSEL,A,LINE,,825,
LSEL,A,LINE,,14,
LSEL,A,LINE,,835,
LSEL,A,LINE,,891,
LSEL,A,LINE,,128
LSEL,A,LINE,,249
LSEL,A,LINE,,912
LSEL,A,LINE,,608
LSEL,A,LINE,,992,
LSEL,A,LINE,,915
LSEL,A,LINE,,254
LSEL,A,LINE,,878
LSEL,A,LINE,,248
LSEL,A,LINE,,369
LSEL,A,LINE,,943
LSEL,A,LINE,,488
LSEL,A,LINE,,1005,
LSEL,A,LINE,,948
LSEL,A,LINE,,374
LSEL,A,LINE,,938
LSEL,A,LINE,,368
LSEL,A,LINE,,766
LESIZE,ALL,,5
!
LSEL,S,LINE,,738
LSEL,A,LINE,,764
LSEL,A,LINE,,821
LSEL,A,LINE,,795
LSEL,A,LINE,,823
LESIZE,ALL,,4
!
LSEL,S,LINE,,840
LSEL,A,LINE,,23
LSEL,A,LINE,,263
LSEL,A,LINE,,918
LSEL,A,LINE,,383
LSEL,A,LINE,,953
LESIZE,ALL,,5
!
ALLSEL
ESIZE,1,0,
AMESH,353,354,1,
AMESH,3
AMESH,344,346,1
AMESH,63
AMESH,347,349,1
AMESH,93
AMESH,350,352,1
ESIZE,1.5,0
AMESH,204
AMESH,271
AMESH,190
AMESH,233
AMESH,203
AMESH,258
AMESH,231
AMESH,318
AMESH,218
AMESH,293
AMESH,232
AMESH,331
!
AMESH,272
AMESH,235
AMESH,191
AMESH,239
AMESH,241
AMESH,193
AMESH,194
AMESH,234
AMESH,259
AMESH,238
AMESH,240
AMESH,260
AMESH,261
AMESH,206
AMESH,281
AMESH,208
AMESH,209
AMESH,283
AMESH,284
AMESH,319
AMESH,294
AMESH,320
AMESH,298
AMESH,321
AMESH,300
```

```
AMESH,219
AMESH,295
AMESH,221
AMESH,299
AMESH,222
AMESH,301
AMESH,332
AMESH,334
AMESH,335
!
ESIZE,2,0
AMESH,205
AMESH,243
AMESH,195
AMESH,242
AMESH,262
AMESH,210
AMESH,285
AMESH,322
AMESH,302
AMESH,223
AMESH,303
AMESH,336
AMESH,273
AMESH,237
AMESH,192
AMESH,236
AMESH,266
AMESH,207
AMESH,282
AMESH,326
AMESH,296
AMESH,220
AMESH,297
AMESH,333
!
TYPE,1,           !      Mesh the TSw1 unit
MAT,3,
ESYS,0,
ESIZE,3.0,0,
AMESH,274
AMESH,245
AMESH,196
AMESH,244
AMESH,263
AMESH,211
AMESH,286
AMESH,323
AMESH,304
AMESH,224
AMESH,305
AMESH,337
!
TYPE,1,           !      Mesh the PTn unit
MAT,2,
ESYS,0,
ESIZE,7.5,0,
AMESH,275
AMESH,247
AMESH,197
AMESH,246
AMESH,264
AMESH,212
AMESH,287
AMESH,324
AMESH,306
AMESH,225
AMESH,307
AMESH,338
!
TYPE,1,           !      Mesh the TCw unit
MAT,1,
ESYS,0,
ESIZE,15,0,
AMESH,276
AMESH,249
AMESH,198
AMESH,248
AMESH,265
AMESH,213
AMESH,288
AMESH,325
AMESH,308
AMESH,226
AMESH,309
AMESH,339
!
TYPE,1,           !      Mesh the TSw3 unit
MAT,5,
ESYS,0,
ESIZE,3.0,0,
AMESH,277
AMESH,250
AMESH,199
AMESH,251
AMESH,267
AMESH,214
AMESH,289
```

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AMESH,327
AMESH,311
AMESH,227
AMESH,310
AMESH,340
!
TYPE,1,          !      Mesh the CHn1v unit
MAT,6,
ESYS,0,
ESIZE,3.0,0,
AMESH,278
AMESH,252
AMESH,200
AMESH,253
AMESH,268
AMESH,215
AMESH,290
AMESH,328
AMESH,313
AMESH,228
AMESH,312
AMESH,341
!
TYPE,1,          !      Mesh the CHn1z unit
MAT,7,
ESYS,0,
ESIZE,7.5,0,
AMESH,279
AMESH,254
AMESH,201
AMESH,255
AMESH,269
AMESH,216
AMESH,291
AMESH,329
AMESH,315
AMESH,229
AMESH,314
AMESH,342
!
TYPE,1,          !      Mesh the CHn2 unit
MAT,8,
ESYS,0,
ESIZE,15,0,
AMESH,280
AMESH,256
AMESH,202
AMESH,257
AMESH,270
AMESH,217
AMESH,292
AMESH,330
AMESH,317
AMESH,230
AMESH,316
AMESH,343
!
TYPE,2,          !      Define link elements
MAT,10,
REAL,1,
ESYS,0,
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
LSEL,A,LINE,,5          !      Drift wall
LSEL,A,LINE,,1033
LSEL,A,LINE,,1034
LSEL,A,LINE,,1032
LSEL,A,LINE,,1036
LSEL,A,LINE,,251
LSEL,A,LINE,,1035
LSEL,A,LINE,,1037
LSEL,A,LINE,,1039
LSEL,A,LINE,,371
LSEL,A,LINE,,1038
LSEL,A,LINE,,1040
NSLL,S,1
ESURF,ALL
PLOT
!
/AUX12          !      Generate superelement for thermal
EMIS,2,0.85,    !      radiation calculation
STEF,1.7878,
GEOM,1,0,
SPACE,,
ESEL,S,TYPE,,2.2
NSLE,S
VTYPE,0,
MPRINT,0

```

```

WRITE,pca2d85m103          !      Save radiation matrices
FINISH
!
/PREP7
TYPE,3,
MAT,11,
REAL,1,
ESYS,0,
SE,pca2d85m103
!
ESEL,S,TYPE,,2,2
EDELE,ALL
ALLSEL
!
/SOLU                      !      Solution phase
ANTYPE,TRANS               !      Transient analysis
NROPT,AUTO                 !      Program chosen Newton-Raphson option
TOFFST,273                !      Specify the temperature offset: 273 C
TINTP,0.005,,0.5,0.5,0.2 !      Use defaults of transient integration
                             parameters
OUTPR,NSOL,5              !      Solution printout at every 5 substeps
OUTRES,NSOL,5             !      Solution data written to database
                             at every 5 substeps
IC,ALL,TEMP,26            !      Initial temperature at all nodes
NSEL,S,LOC,Y,311.0        !      Select all nodes on top surface
D,ALL,TEMP,18.7
NSEL,S,LOC,Y,-300.0       !
D,ALL,TEMP,32.53         !      Select all nodes on bottom surface
ALLSEL
SAVE
!
!      Load step number 1
TIMINT,OFF                !      Turn off transient effects at the
                             first load step
TIME,1e-7
AUTOTS,1
DELTIM,1e-8,1e-8,1e-7,0
KBC,0
LSWRITE,1,
!
TIMINT,ON                 !      Turn on transient effects at the
                             rest of load steps
!      Load step number 2
TIME,0.5e-2
AUTOTS,1
DELTIM,0.5e-4,0.5e-4,0.5e-3,0
KBC,1
LSEL,S,LINE,,1044         !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,26
KBC,0
LSEL,S,LINE,,1           !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.5952e9,
ALLSEL
LSWRITE,2,
!
!      Load step number 3
TIME,1
AUTOTS,1
DELTIM,0.01,0.01,0.1,0
KBC,1
LSEL,S,LINE,,1044         !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,26.12
KBC,0
LSEL,S,LINE,,1           !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.5289e9,
ALLSEL
LSWRITE,3,
!
!      Load step number 4
TIME,5
AUTOTS,1
DELTIM,0.05,0.05,0.5,0
KBC,1
LSEL,S,LINE,,1044         !      Observation drift

```

```
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,27.95
KBC,0
LSEL,S,LINE,,1      !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.3217e9,
ALLSEL
LSWRITE,4,
!
!      Load step number 5
TIME,10
AUTOTS,1
DELTIM,0.05,0.05,0.5,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,29.21
KBC,0
LSEL,S,LINE,,1      !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.1169e9,
ALLSEL
LSWRITE,5,
!
!      Load step number 6
TIME,20
AUTOTS,1
DELTIM,0.1,0.1,0.75,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,30.36
KBC,0
LSEL,S,LINE,,1      !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.7929e9,
ALLSEL
LSWRITE,6,
!
!      Load step number 7
TIME,30
AUTOTS,1
DELTIM,0.1,0.1,0.75,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,30.90
KBC,0
LSEL,S,LINE,,1      !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.5401e9,
ALLSEL
LSWRITE,7,
!
!      Load step number 8
TIME,40
AUTOTS,1
```

```
DELTIM,0.15,0.15,0.75,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,31.21
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.3400e9,
ALLSEL
LSWRITE,8,
!
!      Load step number 9
TIME,50
AUTOTS,1
DELTIM,0.15,0.15,0.75,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,31.39
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.1779e9,
ALLSEL
LSWRITE,9,
!
!      Load step number 10
TIME,60
AUTOTS,1
DELTIM,0.15,0.15,1.0,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,31.49
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.0477e9,
ALLSEL
LSWRITE,10,
!
!      Load step number 11
TIME,70
AUTOTS,1
DELTIM,0.15,0.15,1.0,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,31.53
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,9.4197e8,
ALLSEL
LSWRITE,11,
!
!      Load step number 12
```



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TIME,80
AUTOTS,1
DELTIM,0.15,0.15,1.5,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,31.54
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,8.5514e8,
ALLSEL
LSWRITE,12,
!
!      Load step number 13
TIME,100
AUTOTS,1
DELTIM,0.15,0.15,2.5,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,31.50
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,7.2487e8,
ALLSEL
LSWRITE,13,
!
!      Load step number 14
TIME,150
AUTOTS,1
DELTIM,0.2,0.2,5,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,31.35
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,5.4619e8,
ALLSEL
LSWRITE,14,
!
ALLSEL
LSSOLVE,1,14,1,           !      Solve with 14 load steps
FINISH

```

```

/BATCH,LIST
!
!#####
!#
!#                               ANSYS INPUT
!#
!#   Filename:      pca2d85m104
!#
!#   Input File:    pca2d85m104.dat
!#
!#   Output File:   pca2d85m104.out
!#
!#   Description:   2D Analysis for temperature at performance
!#                  confirmation observation drift (pca2d)
!#                  Thermal load:      85 MTU/acre & 21 PWR (85)
!#                  Emplacement mode:  Center-in-drift
!#                  Drift diameter:    5.5 meters
!#                  Drift spacing:     22.5 meters
!#                  WP spacing:        18.92 meters
!#                  Initial heat output: 9.05 kW/package
!#                  WP diameter:       1.85 meters
!#                  Observation drift size: 4.5 meters in diameter
!#                                      15.90 m^2 in area
!#                                      600 meters long
!#
!#                  Distance from emplace.
!#                  drift crown to obser.
!#                  drift floor:      10 meters
!#                  Location of O.D.:  Mid-of-pillar (m)
!#                  Ventilation air temp.: Varied
!#                  Ventilation quantity: 10.0 m^3/s (10)
!#                  Coef. of convection: 1.8782 W/m^2-K
!#                  Modeling time period: 150 years
!#                  Ventilation segment: No. 4 (300 - 400 m) (4)
!#
!#   Code Version:  ANSYS Revision 5.2
!#
!#   Created By:    Yiming Sun
!#
!#   Last Modified: 02/12/97
!#
!#####
!
/COM,ANSYS MEDIA REV. 5.2
!
/FILNAM,pca2d85m104      ! Jobname to use for all subsequent files
/TITLE,2D Model (PCA;TL:85MTU/ac;AQ:10.0m^3/s;AT:26C;DOD:10m;SN:4)
/UNITS,SI
/SHOW
!
/NOPR
*ABB,SAVE_DB,SAVE
*ABB,RESUM_DB,RESUME
*ABB,QUIT,Fnc_/EXIT
*ABB,SHFR,./SHOW,FILE,,8
*ABB,SHFV,./SHOW,FILE,,1
*ABB,X11C,./SHOW,X11C,,8
*ABB,X11,./SHOW,X11,,1
*ABB,REPLLOT,./REPLLOT
*ABB,K1,./PNUM,KP,1
*ABB,K0,./PNUM,KP,0
*ABB,POWERGRPH,Fnc_/GRAPHICS
*ABB,ANSYSWEB,Fnc_HomePage
/GO
!
/FDELE,EMAT,DELE
/FDELE,ESAV,DELE
/FDELE,EROT,DELE
/FDELE,DSUB,DELE
/FDELE,TRI,DELE
/FDELE,OSAV,DELE
/FDELE,PAGE,DELE
!
/PREP7
!
!      Define element types
!
ET,1,PLANE55      ! 4-node, 2-D thermal solid element
ET,2,LINK32      ! 2-D conduction bar
R,1,1,0
ET,3,MATRIX50    ! Superelement for radiation
KEYOPT,3,1,1     ! Superelement behavior: radiation substructure
KEYOPT,3,6,0
!
!      Define material properties
!
!      Material number 1 (TCw unit)
MP,DENS,1,2169    ! Density (kg/m^3)
MP,KXX,1,5.014E7  ! Thermal conductivity (J/yr-m-C)
!
!      Material number 2 (PTn unit)
MP,DENS,2,1299    ! Density (kg/m^3)
MP,KXX,2,2.681E7  ! Thermal conductivity (J/yr-m-C)
!
!      Material number 3 (TSw1 unit)
MP,DENS,3,2163    ! Density (kg/m^3)
MP,KXX,3,5.046E7  ! Thermal conductivity (J/yr-m-C)
!
!      Material number 4 (TSw2 unit)

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MP,DENS,4,2274      !      Density (kg/m^3)
MP,KXX, 4,6.623E7   !      Thermal conductivity (J/yr-m-C)
MP,EMIS,4,0.9       !      Emissivity
!
!      Material number 5 (TSw3 unit)
MP,DENS,5,2271      !      Density (kg/m^3)
MP,KXX, 5,4.037E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 6 (CHn1v unit)
MP,DENS,6,1972      !      Density (kg/m^3)
MP,KXX, 6,3.784E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 7 (CHn1z unit)
MP,DENS,7,1886      !      Density (kg/m^3)
MP,KXX, 7,4.037E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 8 (CHn2 unit)
MP,DENS,8,2070      !      Density (kg/m^3)
MP,KXX, 8,4.92E7    !      Thermal conductivity (J/yr-m-C)
!
!      Material number 9 (Waste package)
MP,DENS,9,8131      !      Density (kg/m^3)
MP,KXX, 9,131.534E7 !      Thermal conductivity (J/yr-m-C)
MP,C, 9,487.901     !      Specific heat (J/kg-C)
MP,EMIS,9,0.8       !      Emissivity
!
!      Material number 10 (link elements for radiation)
MP,EMIS,10,0.85     !      Emissivity
!
!      Material number 11 (Radiation superelement element)
MP,EMIS,11,0.85     !      Emissivity
!
!      Temperature table for temperature
!      dependent specific heat (C)
!      Specific heat (J/kg-C)
MPDATA,C,1,1,936.5,936.5,4322.2,4322.2,967.2,967.2      !      TCw unit
MPDATA,C,2,1,1715.6,1715.6,22564.3,22564.3,1172.9,1172.9 !      PTn unit
MPDATA,C,3,1,960.5,960.5,5670.6,5670.6,934.8,934.8      !      TSw1 unit
MPDATA,C,4,1,941.7,941.7,4608.0,4608.0,960.4,960.4      !      TSw2 unit
MPDATA,C,5,1,904.0,904.0,1990.0,1990.0,1124.4,1124.4    !      TSw3 unit
MPDATA,C,6,1,1300.8,1300.8,17935.1,17935.1,847.0,847.0  !      CHn1v unit
MPDATA,C,7,1,1416.2,1416.2,18762.1,18762.1,1210.8,1210.8 !      CHn1z unit
MPDATA,C,8,1,1231.2,1231.2,11998.2,11998.2,1330.6,1330.6 !      CHn2 unit
!
!      Parameters for model generation
!
ORIG=0.0
X1=5.5
X2=11.25
DS=22.5
Y1=5.5
Y2=10.5
Y3=15
Y4=19.5
R1=2.75
RW=0.925
ROD=2.25
TSW2_UP=106.8
TSW2_LOW=-82.5
TSW1=236.9
PTN=275.0
TCW=311.0
TSW3=-98.3
CHN1V=-103.5
CHN1Z=-207.5
CHN2=-300.0
XOFF=33.75
YOFF=15.0
!
WPOFF,X2,0,0
CSYS,4
RECTNG,ORIG,X1,ORIG,Y1,
PCIRC,R1,,0,90,
ASBA,1,2
PCIRC,RW,,0,90,
ARSYM,Y,ALL,,,0,0
RECTNG,ORIG,X1,      Y1,      Y2,
RECTNG,ORIG,X1,      Y2,      Y3,
RECTNG,ORIG,X1,      Y3,      Y4,
RECTNG,ORIG,X1,      Y4,      TSW2_UP,
RECTNG,ORIG,X1,      TSW2_UP,      TSW1,
RECTNG,ORIG,X1,      TSW1,      PTN,
RECTNG,ORIG,X1,      PTN,      TCW,
RECTNG,ORIG,X1,      -Y1,TSW2_LOW,
RECTNG,ORIG,X1,TSW2_LOW,      TSW3,
RECTNG,ORIG,X1,      TSW3,      CHN1V,
RECTNG,ORIG,X1,      CHN1V,      CHN1Z,
RECTNG,ORIG,X1,      CHN1Z,      CHN2,
!
RECTNG, X1,X2,      ORIG,      Y1,
RECTNG, X1,X2,      Y1,      Y2,
RECTNG, X1,X2,      Y2,      Y3,
RECTNG, X1,X2,      Y3,      Y4,
RECTNG, X1,X2,      Y4,      TSW2_UP,
RECTNG, X1,X2,      TSW2_UP,      TSW1,
RECTNG, X1,X2,      TSW1,      PTN,
RECTNG, X1,X2,      PTN,      TCW,

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RECTNG, X1,X2, ORIG, -Y1,
RECTNG, X1,X2, -Y1, TSW2_LOW,
RECTNG, X1,X2, TSW2_LOW, TSW3,
RECTNG, X1,X2, TSW3, CHN1V,
RECTNG, X1,X2, CHN1V, CHN1Z,
RECTNG, X1,X2, CHN1Z, CHN2,
!
ARSYM,X,ALL,,,0,0
WPOFF,X2,0,0
ASEL,S,LOC,X,-X2,0,,1
ARSYM,X,ALL,,,0,0
ALLSEL
WPOFF,X2,0,0
ARSYM,X,ALL,,,0,0
WPOFF,-XOFF,YOFF,0
!
PCIRC,ROD, ,0,90,
PCIRC,ROD, ,0,-90,
!
ASBA,50,181
ASBA,49,182
WPOFF,0,-YOFF,0
AGLUE,ALL
/TRIAD,ROBOT
APLOT
SAVE
!
!           Meshing
!
TYPE,1,                               !           Mesh the waste package
MAT,9,
ESYS,0,
ESHAPE,2,0
MOPT,EXPND,1,
MOPT,TRANS,2,
MOPT,IESZ,0,
ESIZE,0.5,0,
AMESH,1,
AMESH,49
AMESH,181
AMESH,187
AMESH,182
AMESH,188
AMESH,184
AMESH,61
AMESH,185
AMESH,189
AMESH,186
AMESH,91
!
LCCAT,2,3                               !           Concatenates lines
LCCAT,14,825
LCCAT,891,835
LCCAT,128,830
LCCAT,912,608
LCCAT,992,915
LCCAT,254,878
LCCAT,248,249
LCCAT,943,488
LCCAT,1005,948
LCCAT,374,938
LCCAT,368,369
LCCAT,769,845
LCCAT,841,894
!
TYPE,1,                               !           Mesh the TSw2 unit
MAT,4,
ESYS,0,
LSEL,S,LINE,,1044                       !           Observation drift
LSEL,A,LINE,,724
!
LSEL,A,LINE,,5                           !           Emplacement drift
LSEL,A,LINE,,1032
LSEL,A,LINE,,1034
LSEL,A,LINE,,1033
LSEL,A,LINE,,1036
LSEL,A,LINE,,1037
LSEL,A,LINE,,1035
LSEL,A,LINE,,251
LSEL,A,LINE,,1039
LSEL,A,LINE,,1040
LSEL,A,LINE,,1038
LSEL,A,LINE,,371
LESIZE,ALL,,10
!
LSEL,S,LINE,,1041,
LSEL,A,LINE,,1043,
LSEL,A,LINE,,1042,
LSEL,A,LINE,,127,
LSEL,A,LINE,,8,
LSEL,A,LINE,,9,
LSEL,A,LINE,,15,
LSEL,A,LINE,,247,
LSEL,A,LINE,,607,
LSEL,A,LINE,,250,
LSEL,A,LINE,,255,
LSEL,A,LINE,,367
LSEL,A,LINE,,487

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LSEL,A,LINE,,370
LSEL,A,LINE,,375
LESIZE,ALL,,5
!
LSEL,S,LINE,,845,
LSEL,A,LINE,,769,
LSEL,A,LINE,,841,
LSEL,A,LINE,,894,
LSEL,A,LINE,,830,
LSEL,A,LINE,,3,
LSEL,A,LINE,,2,
LSEL,A,LINE,,825,
LSEL,A,LINE,,14,
LSEL,A,LINE,,835,
LSEL,A,LINE,,891,
LSEL,A,LINE,,128
LSEL,A,LINE,,249
LSEL,A,LINE,,912
LSEL,A,LINE,,608
LSEL,A,LINE,,992,
LSEL,A,LINE,,915
LSEL,A,LINE,,254
LSEL,A,LINE,,878
LSEL,A,LINE,,248
LSEL,A,LINE,,369
LSEL,A,LINE,,943
LSEL,A,LINE,,488
LSEL,A,LINE,,1005,
LSEL,A,LINE,,948
LSEL,A,LINE,,374
LSEL,A,LINE,,938
LSEL,A,LINE,,368
LSEL,A,LINE,,766
LESIZE,ALL,,5
!
LSEL,S,LINE,,738
LSEL,A,LINE,,764
LSEL,A,LINE,,821
LSEL,A,LINE,,795
LSEL,A,LINE,,823
LESIZE,ALL,,4
!
LSEL,S,LINE,,840
LSEL,A,LINE,,23
LSEL,A,LINE,,263
LSEL,A,LINE,,918
LSEL,A,LINE,,383
LSEL,A,LINE,,953
LESIZE,ALL,,5
!
ALLSEL
ESIZE,1,0,
AMESH,353,354,1,
AMESH,3
AMESH,344,346,1
AMESH,63
AMESH,347,349,1
AMESH,93
AMESH,350,352,1
ESIZE,1.5,0
AMESH,204
AMESH,271
AMESH,190
AMESH,233
AMESH,203
AMESH,258
AMESH,231
AMESH,318
AMESH,218
AMESH,293
AMESH,232
AMESH,331
!
AMESH,272
AMESH,235
AMESH,191
AMESH,239
AMESH,241
AMESH,193
AMESH,194
AMESH,234
AMESH,259
AMESH,238
AMESH,240
AMESH,260
AMESH,261
AMESH,206
AMESH,281
AMESH,208
AMESH,209
AMESH,283
AMESH,284
AMESH,319
AMESH,294
AMESH,320
AMESH,298
AMESH,321
AMESH,300
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AMESH,219
AMESH,295
AMESH,221
AMESH,299
AMESH,222
AMESH,301
AMESH,332
AMESH,334
AMESH,335
!
ESIZE,2,0
AMESH,205
AMESH,243
AMESH,195
AMESH,242
AMESH,262
AMESH,210
AMESH,285
AMESH,322
AMESH,302
AMESH,223
AMESH,303
AMESH,336
AMESH,273
AMESH,237
AMESH,192
AMESH,236
AMESH,266
AMESH,207
AMESH,282
AMESH,326
AMESH,296
AMESH,220
AMESH,297
AMESH,333
!
TYPE,1,                                !      Mesh the TSw1 unit
MAT,3,
ESYS,0,
ESIZE,3,0,0,
AMESH,274
AMESH,245
AMESH,196
AMESH,244
AMESH,263
AMESH,211
AMESH,286
AMESH,323
AMESH,304
AMESH,224
AMESH,305
AMESH,337
!
TYPE,1,                                !      Mesh the PTn unit
MAT,2,
ESYS,0,
ESIZE,7,5,0,
AMESH,275
AMESH,247
AMESH,197
AMESH,246
AMESH,264
AMESH,212
AMESH,287
AMESH,324
AMESH,306
AMESH,225
AMESH,307
AMESH,338
!
TYPE,1,                                !      Mesh the TCw unit
MAT,1,
ESYS,0,
ESIZE,15,0,
AMESH,276
AMESH,249
AMESH,198
AMESH,248
AMESH,265
AMESH,213
AMESH,288
AMESH,325
AMESH,308
AMESH,226
AMESH,309
AMESH,339
!
TYPE,1,                                !      Mesh the TSw3 unit
MAT,5,
ESYS,0,
ESIZE,3,0,0,
AMESH,277
AMESH,250
AMESH,199
AMESH,251
AMESH,267
AMESH,214
AMESH,289
```

```

AMESH,327
AMESH,311
AMESH,227
AMESH,310
AMESH,340
!
TYPE,1,                      !      Mesh the CHn1v unit
MAT,6,
ESYS,0,
ESIZE,3.0,0,
AMESH,278
AMESH,252
AMESH,200
AMESH,253
AMESH,268
AMESH,215
AMESH,290
AMESH,328
AMESH,313
AMESH,228
AMESH,312
AMESH,341
!
TYPE,1,                      !      Mesh the CHn1z unit
MAT,7,
ESYS,0,
ESIZE,7.5,0,
AMESH,279
AMESH,254
AMESH,201
AMESH,255
AMESH,269
AMESH,216
AMESH,291
AMESH,329
AMESH,315
AMESH,229
AMESH,314
AMESH,342
!
TYPE,1,                      !      Mesh the CHn2 unit
MAT,8,
ESYS,0,
ESIZE,15,0,
AMESH,280
AMESH,256
AMESH,202
AMESH,257
AMESH,270
AMESH,217
AMESH,292
AMESH,330
AMESH,317
AMESH,230
AMESH,316
AMESH,343
!
TYPE,2,                      !      Define link elements
MAT,10,
REAL,1,
ESYS,0,
LSEL,S,LINE,,1              !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
LSEL,A,LINE,,5              !      Drift wall
LSEL,A,LINE,,1033
LSEL,A,LINE,,1034
LSEL,A,LINE,,1032
LSEL,A,LINE,,1036
LSEL,A,LINE,,251
LSEL,A,LINE,,1035
LSEL,A,LINE,,1037
LSEL,A,LINE,,1039
LSEL,A,LINE,,371
LSEL,A,LINE,,1038
LSEL,A,LINE,,1040
NSLL,S,1
ESURF,ALL
PLOT
!
/AUX12                      !      Generate superelement for thermal
EMIS,2,0.85,                !      radiation calculation
STEF,1.7878,
GEOM,1,0,
SPACE, ,
ESEL,S,TYPE,,2,2
NSLE,S
VTYPE,0, ,
MPRINT,0

```

```

WRITE,pca2d85m104      !      Save radiation matrices
FINISH
!
/PREP7
TYPE,3,
MAT,11,
REAL,1,
ESYS,0,
SE,pca2d85m104
!
ESEL,S,TYPE,,2,2
EDELE,ALL
ALLSEL
!
/SOLU
ANTYPE,TRANS           !      Solution phase
NROPT,AUTO              !      Transient analysis
TOFFST,273              !      Programchosen Newton-Raphson option
TINTP,0.005, , ,0.5,0.5,0.2 !      Specify the temperature offset: 273 C
!      Use defaults of transient integration
!      parameters
OUTPR,NSOL,5,           !      Solution printout at every 5 substeps
OUTRES,NSOL,5,          !      Solution data written to database
!      at every 5 substeps
IC,ALL,TEMP,26,         !      Initial temperature at all nodes
NSEL,S,LOC,Y,311.0      !      Select all nodes on top surface
D,ALL,TEMP,18.7
NSEL,S,LOC,Y,-300.0     !
D,ALL,TEMP,32.53        !      Select all nodes on bottom surface
ALLSEL
SAVE
!
!      Load step number 1
TIMINT,OFF              !      Turn off transient effects at the
!      first load step
TIME,1e-7
AUTOTS,1
DELTIM,1e-8,1e-8,1e-7,0
KBC,0
LSWRITE,1,
!
TIMINT,ON               !      Turn on transient effects at the
!      rest of load steps
!      Load step number 2
TIME,0.5e-2
AUTOTS,1
DELTIM,0.5e-4,0.5e-4,0.5e-3,0
KBC,1
LSEL,S,LINE,,1044       !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,26
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.5952e9,
ALLSEL
LSWRITE,2,
!
!      Load step number 3
TIME,1
AUTOTS,1
DELTIM,0.01,0.01,0.1,0
KBC,1
LSEL,S,LINE,,1044       !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,26.18
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.5289e9,
ALLSEL
LSWRITE,3,
!
!      Load step number 4
TIME,5
AUTOTS,1
DELTIM,0.05,0.05,0.5,0
KBC,1
LSEL,S,LINE,,1044       !      Observation drift

```



```
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,28.85
KBC,0
LSEL,S,LINE,,1                !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.3217e9,
ALLSEL
LSWRITE,4,
!
!          Load step number 5
TIME,10
AUTOTS,1
DELTIM,0.05,0.05,0.5,0
KBC,1
LSEL,S,LINE,,1044            !          Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,30.71
KBC,0
LSEL,S,LINE,,1                !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.1169e9,
ALLSEL
LSWRITE,5,
!
!          Load step number 6
TIME,20
AUTOTS,1
DELTIM,0.1,0.1,0.75,0
KBC,1
LSEL,S,LINE,,1044            !          Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,32.42
KBC,0
LSEL,S,LINE,,1                !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.7929e9,
ALLSEL
LSWRITE,6,
!
!          Load step number 7
TIME,30
AUTOTS,1
DELTIM,0.1,0.1,0.75,0
KBC,1
LSEL,S,LINE,,1044            !          Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,33.22
KBC,0
LSEL,S,LINE,,1                !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.5401e9,
ALLSEL
LSWRITE,7,
!
!          Load step number 8
TIME,40
AUTOTS,1
```

```
DELTIM,0.15,0.15,0.75,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,33.68
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.3400e9,
ALLSEL
LSWRITE,8,
!
!      Load step number 9
TIME,50
AUTOTS,1
DELTIM,0.15,0.15,0.75,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,33.95
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.1779e9,
ALLSEL
LSWRITE,9,
!
!      Load step number 10
TIME,60
AUTOTS,1
DELTIM,0.15,0.15,1.0,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,34.10
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.0477e9,
ALLSEL
LSWRITE,10,
!
!      Load step number 11
TIME,70
AUTOTS,1
DELTIM,0.15,0.15,1.0,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,34.17
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,9.4197e8,
ALLSEL
LSWRITE,11,
!
!      Load step number 12
```

```
TIME,80
AUTOTS,1
DELTIM,0.15,0.15,1.5,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,34.18
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,8.5514e8,
ALLSEL
LSWRITE,12,
!
!      Load step number 13
TIME,100
AUTOTS,1
DELTIM,0.15,0.15,2.5,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,34.13
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,7.2487e8,
ALLSEL
LSWRITE,13,
!
!      Load step number 14
TIME,150
AUTOTS,1
DELTIM,0.2,0.2,5,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,33.91
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,5.4619e8,
ALLSEL
LSWRITE,14,
!
ALLSEL
LSSOLVE,1,14,1,      !      Solve with 14 load steps
FINISH
```

```
BATCH,LIST
!#####
!#
!#                               ANSYS INPUT
!#
!#   Filename:          pca2d85m105
!#
!#   Input File:        pca2d85m105.dat
!#
!#   Output File:       pca2d85m105.out
!#
!#   Description:       2D Analysis for temperature at performance
!#                       confirmation observation drift (pca2d)
!#                       Thermal load:           85 MTU/acre & 21 PWR (85)
!#                       Emplacement mode:       Center-in-drift      #
!#                       Drift diameter:         5.5 meters            #
!#                       Drift spacing:          22.5 meters
!#                       WP spacing:             18.92 meters
!#                       Initial heat output:    9.05 kW/package
!#                       WP diameter:           1.85 meters
!#                       Observation drift size: 4.5 meters in diameter
!#                                               15.90 m^2 in area
!#                                               600 meters long
!#
!#                       Distance from emplace.
!#                           drift crown to obser.
!#                           drift floor:        10 meters
!#                       Location of O.D.:       Mid-of-pillar (m)
!#                       Ventilation air temp.:  Varied
!#                       Ventilation quantity:   10.0 m^3/s (10)
!#                       Coef. of convection:    1.8782 W/m^2-K
!#                       Modeling time period:   150 years
!#                       Ventilation segment:     No. 5 (400 - 500 m) (5)
!#
!#   Code Version:      ANSYS Revision 5.2
!#
!#   Created By:        Yiming Sun
!#
!#   Last Modified:     02/13/97
!#
!#####
!/COM,ANSYS MEDIA REV. 5.2
!
!/FILNAM,pca2d85m105      ! Jobname to use for all subsequent files
!/TITLE,2D Model (PCA;TL:85MTU/ac;AQ:10.0m^3/s;AT:26C;DOD:10m;SN:5)
!/UNITS,SI
!/SHOW
!
!/NOPR
!*ABB,SAVE_DB ,SAVE
!*ABB,RESUM_DB,RESUME
!*ABB,QUIT ,Fnc_/EXIT
!*ABB,SHFR ,/SHOW,FILE,,8
!*ABB,SHFV ,/SHOW,FILE,,1
!*ABB,X11C ,/SHOW,X11C,,8
!*ABB,X11 ,/SHOW,X11,,1
!*ABB,REPLOT ,/REPLOT
!*ABB,K1 ,/PNUM,KP,1
!*ABB,K0 ,/PNUM,KP,0
!*ABB,POWGRPH,Fnc_/GRAPHICS
!*ABB,ANSYSWEB,Fnc_HomePage
!/GO
!
!/FDELE,EMAT,DELE
!/FDELE,ESAV,DELE
!/FDELE,EROT,DELE
!/FDELE,DSUB,DELE
!/FDELE,TRI,DELE
!/FDELE,OSAV,DELE
!/FDELE,PAGE,DELE
!
!/PREP7
!
! Define element types
!
ET,1,PLANE55      ! 4-node, 2-D thermal solid element
ET,2,LINK32      ! 2-D conduction bar
R,1,1.0
ET,3,MATRIX50    ! Superelement for radiation
KEYOPT,3,1,1    ! Superelement behavior: radiation substructure
KEYOPT,3,6,0    !
!
! Define material properties
!
! Material number 1 (TCw unit)
MP,DENS,1,2169    ! Density (kg/m^3)
MP,KXX,1,1.5.014E7 ! Thermal conductivity (J/yr-m-C)
!
! Material number 2 (PTn unit)
MP,DENS,2,1299    ! Density (kg/m^3)
MP,KXX,2,2.2.681E7 ! Thermal conductivity (J/yr-m-C)
!
! Material number 3 (TSwl unit)
MP,DENS,3,2163    ! Density (kg/m^3)
MP,KXX,3,3.5.046E7 ! Thermal conductivity (J/yr-m-C)
!
! Material number 4 (TSw2 unit)
```

```

MP,DENS,4,2274      !      Density (kg/m^3)
MP,KXX, 4,6.623E7   !      Thermal conductivity (J/yr-m-C)
MP,EMIS,4,0.9       !      Emissivity
!
!      Material number 5 (TSw3 unit)
MP,DENS,5,2271      !      Density (kg/m^3)
MP,KXX, 5,4.037E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 6 (CHn1v unit)
MP,DENS,6,1972      !      Density (kg/m^3)
MP,KXX, 6,3.784E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 7 (CHn1z unit)
MP,DENS,7,1886      !      Density (kg/m^3)
MP,KXX, 7,4.037E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 8 (CHn2 unit)
MP,DENS,8,2070      !      Density (kg/m^3)
MP,KXX, 8,4.92E7    !      Thermal conductivity (J/yr-m-C)
!
!      Material number 9 (Waste package)
MP,DENS,9,8131      !      Density (kg/m^3)
MP,KXX, 9,131.534E7 !      Thermal conductivity (J/yr-m-C)
MP,C, 9,487.901     !      Specific heat (J/kg-C)
MP,EMIS,9,0.8       !      Emissivity
!
!      Material number 10 (link elements for radiation)
MP,EMIS,10,0.85     !      Emissivity
!
!      Material number 11 (Radiation superelement element)
MP,EMIS,11,0.85     !      Emissivity
!
MPTEMP,1,25,94,95,114,115,250 ! Temperature table for temperature
! dependent specific heat (C)
!      Specific heat (J/kg-C)
MPDATA,C,1,1,936.5,936.5,4322.2,4322.2,967.2,967.2 ! TCw unit
MPDATA,C,2,1,1715.6,1715.6,22564.3,22564.3,1172.9,1172.9 ! PTn unit
MPDATA,C,3,1,960.5,960.5,5670.6,5670.6,934.8,934.8 ! TSw1 unit
MPDATA,C,4,1,941.7,941.7,4608.0,4608.0,960.4,960.4 ! TSw2 unit
MPDATA,C,5,1,904.0,904.0,1990.0,1990.0,1124.4,1124.4 ! TSw3 unit
MPDATA,C,6,1,1300.8,1300.8,17935.1,17935.1,847.0,847.0 ! CHn1v unit
MPDATA,C,7,1,1416.2,1416.2,18762.1,18762.1,1210.8,1210.8 ! CHn1z unit
MPDATA,C,8,1,1231.2,1231.2,11998.2,11998.2,1330.6,1330.6 ! CHn2 unit
!
!      Parameters for model generation
!
ORIG=0.0
X1=5.5
X2=11.25
DS=22.5
Y1=5.5
Y2=10.5
Y3=15
Y4=19.5
R1=2.75
RW=0.925
ROD=2.25
TSW2_UP=106.8
TSW2_LOW=-82.5
TSW1=236.9
PTN=275.0
TCW=311.0
TSW3=-98.3
CHN1V=-103.5
CHN1Z=-207.5
CHN2=-300.0
XOFF=33.75
YOFF=15.0
!
WPOFF,X2,0,0
CSYS,4
RECTNG,ORIG,X1,ORIG,Y1,
PCIRC,R1,,0,90,
ASBA,1,2
PCIRC,RW,,0,90,
ARSYM,Y,ALL,,,0,0
RECTNG,ORIG,X1, Y1, Y2,
RECTNG,ORIG,X1, Y2, Y3,
RECTNG,ORIG,X1, Y3, Y4,
RECTNG,ORIG,X1, Y4, TSW2_UP,
RECTNG,ORIG,X1, TSW2_UP, TSW1,
RECTNG,ORIG,X1, TSW1, PTN,
RECTNG,ORIG,X1, PTN, TCW,
RECTNG,ORIG,X1, -Y1, TSW2_LOW,
RECTNG,ORIG,X1, TSW2_LOW, TSW3,
RECTNG,ORIG,X1, TSW3, CHN1V,
RECTNG,ORIG,X1, CHN1V, CHN1Z,
RECTNG,ORIG,X1, CHN1Z, CHN2,
!
RECTNG, X1,X2, ORIG, Y1,
RECTNG, X1,X2, Y1, Y2,
RECTNG, X1,X2, Y2, Y3,
RECTNG, X1,X2, Y3, Y4,
RECTNG, X1,X2, Y4, TSW2_UP,
RECTNG, X1,X2, TSW2_UP, TSW1,
RECTNG, X1,X2, TSW1, PTN,
RECTNG, X1,X2, PTN, TCW,

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RECTNG, X1,X2, ORIG, -Y1,
RECTNG, X1,X2, -Y1,TSW2_LOW,
RECTNG, X1,X2,TSW2_LOW, TSW3,
RECTNG, X1,X2, TSW3, CHN1V,
RECTNG, X1,X2, CHN1V, CHN1Z,
RECTNG, X1,X2, CHN1Z, CHN2,
!
ARSYM,X,ALL,,,0,0
WPOFF,X2,0,0
ASEL,S,LOC,X,-X2,0,,1
ARSYM,X,ALL,,,0,0
ALLSEL
WPOFF,X2,0,0
ARSYM,X,ALL,,,0,0
WPOFF,-XOFF,YOFF,0
!
PCIRC,ROD, ,0,90,
PCIRC,ROD, ,0,-90,
!
ASBA,50,181
ASBA,49,182
WPOFF,0,-YOFF,0
AGLUE,ALL
/TRIAD,RBOT
APLOT
SAVE
!
!           Meshing
!
TYPE,1,
MAT,9,
ESYS,0,
ESHAPE,2,0
MOPT,EXPND,1,
MOPT,TRANS,2,
MOPT,IESZ,0,
ESIZE,0.5,0,
AMESH,1,
AMESH,49
AMESH,181
AMESH,187
AMESH,182
AMESH,188
AMESH,184
AMESH,61
AMESH,185
AMESH,189
AMESH,186
AMESH,91
!
LCCAT,2,3
LCCAT,14,825
LCCAT,891,835
LCCAT,128,830
LCCAT,912,608
LCCAT,992,915
LCCAT,254,878
LCCAT,248,249
LCCAT,943,488
LCCAT,1005,948
LCCAT,374,938
LCCAT,368,369
LCCAT,769,845
LCCAT,841,894
!
TYPE,1,
MAT,4,
ESYS,0,
LSEL,S,LINE,,1044
LSEL,A,LINE,,724
!
LSEL,A,LINE,,5
LSEL,A,LINE,,1032
LSEL,A,LINE,,1034
LSEL,A,LINE,,1033
LSEL,A,LINE,,1036
LSEL,A,LINE,,1037
LSEL,A,LINE,,1035
LSEL,A,LINE,,251
LSEL,A,LINE,,1039
LSEL,A,LINE,,1040
LSEL,A,LINE,,1038
LSEL,A,LINE,,371
LESIZE,ALL,,,10
!
LSEL,S,LINE,,1041,
LSEL,A,LINE,,1043,
LSEL,A,LINE,,1042,
LSEL,A,LINE,,127,
LSEL,A,LINE,,8,
LSEL,A,LINE,,9,
LSEL,A,LINE,,15,
LSEL,A,LINE,,247,
LSEL,A,LINE,,607,
LSEL,A,LINE,,250,
LSEL,A,LINE,,255,
LSEL,A,LINE,,367
LSEL,A,LINE,,487

```

Mesh the waste package

Concatenates lines

Mesh the TSw2 unit

Observation drift

Emplacement drift

```
LSEL,A,LINE,,370
LSEL,A,LINE,,375
LESIZE,ALL,,5
!
LSEL,S,LINE,,845,
LSEL,A,LINE,,769,
LSEL,A,LINE,,841,
LSEL,A,LINE,,894,
LSEL,A,LINE,,830,
LSEL,A,LINE,,3,
LSEL,A,LINE,,2,
LSEL,A,LINE,,825,
LSEL,A,LINE,,14,
LSEL,A,LINE,,835,
LSEL,A,LINE,,891,
LSEL,A,LINE,,128,
LSEL,A,LINE,,249,
LSEL,A,LINE,,912,
LSEL,A,LINE,,608,
LSEL,A,LINE,,992,
LSEL,A,LINE,,915,
LSEL,A,LINE,,254,
LSEL,A,LINE,,878,
LSEL,A,LINE,,248,
LSEL,A,LINE,,369,
LSEL,A,LINE,,943,
LSEL,A,LINE,,488,
LSEL,A,LINE,,1005,
LSEL,A,LINE,,948,
LSEL,A,LINE,,374,
LSEL,A,LINE,,938,
LSEL,A,LINE,,368,
LSEL,A,LINE,,766,
LESIZE,ALL,,5
!
LSEL,S,LINE,,738
LSEL,A,LINE,,764
LSEL,A,LINE,,821
LSEL,A,LINE,,795
LSEL,A,LINE,,823
LESIZE,ALL,,4
!
LSEL,S,LINE,,840
LSEL,A,LINE,,23
LSEL,A,LINE,,263
LSEL,A,LINE,,918
LSEL,A,LINE,,383
LSEL,A,LINE,,953
LESIZE,ALL,,5
!
ALLSEL
ESIZE,1,0,
AMESH,353,354,1,
AMESH,3
AMESH,344,346,1
AMESH,63
AMESH,347,349,1
AMESH,93
AMESH,350,352,1
ESIZE,1.5,0
AMESH,204
AMESH,271
AMESH,190
AMESH,233
AMESH,203
AMESH,258
AMESH,231
AMESH,318
AMESH,218
AMESH,293
AMESH,232
AMESH,331
!
AMESH,272
AMESH,235
AMESH,191
AMESH,239
AMESH,241
AMESH,193
AMESH,194
AMESH,234
AMESH,259
AMESH,238
AMESH,240
AMESH,260
AMESH,261
AMESH,206
AMESH,281
AMESH,208
AMESH,209
AMESH,283
AMESH,284
AMESH,319
AMESH,294
AMESH,320
AMESH,298
AMESH,321
AMESH,300
```

```
AMESH,219
AMESH,295
AMESH,221
AMESH,299
AMESH,222
AMESH,301
AMESH,332
AMESH,334
AMESH,335
!
ESIZE,2,0
AMESH,205
AMESH,243
AMESH,195
AMESH,242
AMESH,262
AMESH,210
AMESH,285
AMESH,322
AMESH,302
AMESH,223
AMESH,303
AMESH,336
AMESH,273
AMESH,237
AMESH,192
AMESH,236
AMESH,266
AMESH,207
AMESH,282
AMESH,326
AMESH,296
AMESH,220
AMESH,297
AMESH,333
!
TYPE,1,                      !      Mesh the TSwt unit
MAT,3,
ESYS,0,
ESIZE,3,0,0,
AMESH,274
AMESH,245
AMESH,196
AMESH,244
AMESH,263
AMESH,211
AMESH,286
AMESH,323
AMESH,304
AMESH,224
AMESH,305
AMESH,337
!
TYPE,1,                      !      Mesh the PTn unit
MAT,2,
ESYS,0,
ESIZE,7,5,0,
AMESH,275
AMESH,247
AMESH,197
AMESH,246
AMESH,264
AMESH,212
AMESH,287
AMESH,324
AMESH,306
AMESH,225
AMESH,307
AMESH,338
!
TYPE,1,                      !      Mesh the TCw unit
MAT,1,
ESYS,0,
ESIZE,15,0,
AMESH,276
AMESH,249
AMESH,198
AMESH,248
AMESH,265
AMESH,213
AMESH,288
AMESH,325
AMESH,308
AMESH,226
AMESH,309
AMESH,339
!
TYPE,1,                      !      Mesh the TSwt unit
MAT,5,
ESYS,0,
ESIZE,3,0,0,
AMESH,277
AMESH,250
AMESH,199
AMESH,251
AMESH,267
AMESH,214
AMESH,289
```



```

AMESH,327
AMESH,311
AMESH,227
AMESH,310
AMESH,340
!
TYPE,1,                                !      Mesh the CHn1v unit
MAT,6,
ESYS,0,
ESIZE,3.0,0,
AMESH,278
AMESH,252
AMESH,200
AMESH,253
AMESH,268
AMESH,215
AMESH,290
AMESH,328
AMESH,313
AMESH,228
AMESH,312
AMESH,341
!
TYPE,1,                                !      Mesh the CHn1z unit
MAT,7,
ESYS,0,
ESIZE,7.5,0,
AMESH,279
AMESH,254
AMESH,201
AMESH,255
AMESH,269
AMESH,216
AMESH,291
AMESH,329
AMESH,315
AMESH,229
AMESH,314
AMESH,342
!
TYPE,1,                                !      Mesh the CHn2 unit
MAT,8,
ESYS,0,
ESIZE,15,0,
AMESH,280
AMESH,256
AMESH,202
AMESH,257
AMESH,270
AMESH,217
AMESH,292
AMESH,330
AMESH,317
AMESH,230
AMESH,316
AMESH,343
!
TYPE,2,                                !      Define link elements
MAT,10,
REAL,1,
ESYS,0,
LSEL,S,LINE,,1                        !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
LSEL,A,LINE,,5                        !      Drift wall
LSEL,A,LINE,,1033
LSEL,A,LINE,,1034
LSEL,A,LINE,,1032
LSEL,A,LINE,,1036
LSEL,A,LINE,,251
LSEL,A,LINE,,1035
LSEL,A,LINE,,1037
LSEL,A,LINE,,1039
LSEL,A,LINE,,371
LSEL,A,LINE,,1038
LSEL,A,LINE,,1040
NSLL,S,1
ESURF,ALL
PLOT
!
/AUX12                                !      Generate superelement for thermal
EMIS,2,0.85,                          !      radiation calculation
STEF,1.7878,
GEOM,1,0,
SPACE,,
ESEL,S,TYPE,,2,2
NSLE,S
VTYPE,0,
MPRINT,0

```

```

WRITE,pca2d85m105      !      Save radiation matrices
FINISH
!
/PREP7
TYPE,3,
MAT,11,
REAL,1,
ESYS,0,
SE,pca2d85m105
!
ESEL,S,TYPE,,2,2
EDELE,ALL
ALLSEL
!
/SOLU                  !      Solution phase
ANTYPE,TRANS           !      Transient analysis
NROPT,AUTO             !      Program chosen Newton-Raphson option
TOFST,273              !      Specify the temperature offset: 273 C
TINTP,0.005,,0.5,0.5,0.2 !      Use defaults of transient integration
!                      parameters
OUTPR,NSOL,5,          !      Solution printout at every 5 substeps
OUTRES,NSOL,5,         !      Solution data written to database
!                      at every 5 substeps
IC,ALL,TEMP,26,        !      Initial temperature at all nodes
NSEL,S,LOC,Y,311.0     !      Select all nodes on top surface
D,ALL,TEMP,18.7
NSEL,S,LOC,Y,-300.0    !      Select all nodes on bottom surface
D,ALL,TEMP,32.53
ALLSEL
SAVE
!
!      Load step number 1
TIMINT,OFF             !      Turn off transient effects at the
!                      first load step
TIME,1e-7
AUTOTS,1
DELTIM,1e-8,1e-8,1e-7,0
KBC,0
LSWRITE,1,
!
TIMINT,ON              !      Turn on transient effects at the
!                      rest of load steps
!      Load step number 2
TIME,0.5e-2
AUTOTS,1
DELTIM,0.5e-4,0.5e-4,0.5e-3,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,26
KBC,0
LSEL,S,LINE,,1         !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.5952e9,
ALLSEL
LSWRITE,2,
!
!      Load step number 3
TIME,1
AUTOTS,1
DELTIM,0.01,0.01,0.1,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,26.23
KBC,0
LSEL,S,LINE,,1         !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.5289e9,
ALLSEL
LSWRITE,3,
!
!      Load step number 4
TIME,5
AUTOTS,1
DELTIM,0.05,0.05,0.5,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift

```

```
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,29.71
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.3217e9,
ALLSEL
LSWRITE,4,
!
!          Load step number 5
TIME,10
AUTOTS,1
DELTIM,0.05,0.05,0.5,0
KBC,1
LSEL,S,LINE,,1044       !          Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,32.15
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.1169e9,
ALLSEL
LSWRITE,5,
!
!          Load step number 6
TIME,20
AUTOTS,1
DELTIM,0.1,0.1,0.75,0
KBC,1
LSEL,S,LINE,,1044       !          Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,34.40
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.7929e9,
ALLSEL
LSWRITE,6,
!
!          Load step number 7
TIME,30
AUTOTS,1
DELTIM,0.1,0.1,0.75,0
KBC,1
LSEL,S,LINE,,1044       !          Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,35.46
KBC,0
LSEL,S,LINE,,1          !          WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.5401e9,
ALLSEL
LSWRITE,7,
!
!          Load step number 8
TIME,40
AUTOTS,1
```

```
DELTIM,0.15,0.15,0.75,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,36.07
KBC,0
LSEL,S,LINE,,1         !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.3400e9,
ALLSEL
LSWRITE,8,
!
!      Load step number 9
TIME,50
AUTOTS,1
DELTIM,0.15,0.15,0.75,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,36.42
KBC,0
LSEL,S,LINE,,1         !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.1779e9,
ALLSEL
LSWRITE,9,
!
!      Load step number 10
TIME,60
AUTOTS,1
DELTIM,0.15,0.15,1.0,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,36.63
KBC,0
LSEL,S,LINE,,1         !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.0477e9,
ALLSEL
LSWRITE,10,
!
!      Load step number 11
TIME,70
AUTOTS,1
DELTIM,0.15,0.15,1.0,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,36.72
KBC,0
LSEL,S,LINE,,1         !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,9.4197e8,
ALLSEL
LSWRITE,11,
!
!      Load step number 12
```

```
TIME,80
AUTOTS,1
DELTIM,0.15,0.15,1.5,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,36.74
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,8.5514e8,
ALLSEL
LSWRITE,12,
!
!      Load step number 13
TIME,100
AUTOTS,1
DELTIM,0.15,0.15,2.5,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,36.69
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,7.2487e8,
ALLSEL
LSWRITE,13,
!
!      Load step number 14
TIME,150
AUTOTS,1
DELTIM,0.2,0.2,5,0
KBC,1
LSEL,S,LINE,,1044          !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,36.40
KBC,0
LSEL,S,LINE,,1             !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,5.4619e8,
ALLSEL
LSWRITE,14,
!
ALLSEL
LSSOLVE,1,14,1,          !      Solve with 14 load steps
FINISH
```

```

/BATCH,LIST
!#####
!#
!# ANSYS INPUT
!#
!# Filename:          pca2d85m106
!#
!# Input File:       pca2d85m106.dat
!#
!# Output File:      pca2d85m106.out
!#
!# Description:      2D Analysis for temperature at performance
!#                    confirmation observation drift (pca2d)
!# Thermal load:     85 MTU/acre & 21 PWR (85)
!# Emplacement mode: Center-in-drift #
!# Drift diameter:   5.5 meters #
!# Drift spacing:    22.5 meters
!# WP spacing:       18.92 meters
!# Initial heat output: 9.05 kW/package
!# WP diameter:      1.85 meters
!# Observation drift size: 4.5 meters in diameter
!#                   15.90 m^2 in area
!#                   600 meters long
!#
!# Distance from emplace.
!#   drift crown to obser.
!#   drift floor:    10 meters
!# Location of O.D.: Mid-of-pillar (m)
!# Ventilation air temp.: Varied
!# Ventilation quantity: 10.0 m^3/s (10)
!# Coef. of convection: 1.8782 W/m^2-K
!# Modeling time period: 150 years
!# Ventilation segment: No. 6 (500 - 600 m) (6)
!#
!# Code Version:     ANSYS Revision 5.2
!#
!# Created By:       Yiming Sun
!#
!# Last Modified:    02/15/97
!#
!#####
!/COM,ANSYS MEDIA REV. 5.2
!/FILNAM,pca2d85m106 ! Jobname to use for all subsequent files
!/TITLE,2D Model (PCA;TL:85MTU/ac;AQ:10.0m^3/s;AT:26C;DOD:10m;SN:6)
!/UNITS,SI
!/SHOW
!/NOPR
!*ABB,SAVE_DB ,SAVE
!*ABB,RESUM_DB,RESUME
!*ABB,QUIT ,Fnc_/EXIT
!*ABB,SHFR ,/SHOW,FILE,,,8
!*ABB,SHFV ,/SHOW,FILE,,1
!*ABB,X11C ,/SHOW,X11C,,,8
!*ABB,X11 ,/SHOW,X11,,1
!*ABB,REPLOTT,/REPLOT
!*ABB,K1 ,/PNUM,KP,1
!*ABB,K0 ,/PNUM,KP,0
!*ABB,POWGRPH,Fnc_/GRAPHICS
!*ABB,ANSYSWEB,Fnc_HomePage
!/GO
!/
!/FDELE,EMAT,DELE
!/FDELE,ESAV,DELE
!/FDELE,EROT,DELE
!/FDELE,DSUB,DELE
!/FDELE,TRI,DELE
!/FDELE,OSAV,DELE
!/FDELE,PAGE,DELE
!/
!/PREP7
!/
! Define element types
!
! ET,1,PLANE55 ! 4-node, 2-D thermal solid element
! ET,2,LINK32 ! 2-D conduction bar
! R,1,1.0
! ET,3,MATRIX50 ! Superelement for radiation
! KEYOPT,3,1,1 ! Superelement behavior: radiation substructure
! KEYOPT,3,6,0 !
!
! Define material properties
!
! Material number 1 (TCw unit)
! MP,DENS,1,2169 ! Density (kg/m^3)
! MP,KXX,1,5.014E7 ! Thermal conductivity (J/yr-m-C)
!
! Material number 2 (PTn unit)
! MP,DENS,2,1299 ! Density (kg/m^3)
! MP,KXX,2,2.681E7 ! Thermal conductivity (J/yr-m-C)
!
! Material number 3 (TSwl unit)
! MP,DENS,3,2163 ! Density (kg/m^3)
! MP,KXX,3,5.046E7 ! Thermal conductivity (J/yr-m-C)
!
! Material number 4 (TSw2 unit)

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```

MP,DENS,4,2274      !      Density (kg/m^3)
MP,KXX, 4,6.623E7   !      Thermal conductivity (J/yr-m-C)
MP,EMIS,4,0.9       !      Emissivity
!
!      Material number 5 (TSw3 unit)
MP,DENS,5,2271      !      Density (kg/m^3)
MP,KXX, 5,4.037E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 6 (CHNlv unit)
MP,DENS,6,1972      !      Density (kg/m^3)
MP,KXX, 6,3.784E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 7 (CHNlz unit)
MP,DENS,7,1886      !      Density (kg/m^3)
MP,KXX, 7,4.037E7   !      Thermal conductivity (J/yr-m-C)
!
!      Material number 8 (CHn2 unit)
MP,DENS,8,2070      !      Density (kg/m^3)
MP,KXX, 8,4.92E7    !      Thermal conductivity (J/yr-m-C)
!
!      Material number 9 (Waste package)
MP,DENS,9,8131      !      Density (kg/m^3)
MP,KXX, 9,131.534E7 !      Thermal conductivity (J/yr-m-C)
MP,C, 9,487.901     !      Specific heat (J/kg-C)
MP,EMIS,9,0.8       !      Emissivity
!
!      Material number 10 (link elements for radiation)
MP,EMIS,10,0.85     !      Emissivity
!
!      Material number 11 (Radiation superelement element)
MP,EMIS,11,0.85     !      Emissivity
!
MPTEMP,1,25,94,95,114,115,250 !      Temperature table for temperature
!                                     dependent specific heat (C)
!      Specific heat (J/kg-C)
MPDATA,C,1,1,936.5,936.5,4322.2,4322.2,967.2,967.2 !      TCw unit
MPDATA,C,2,1,1715.6,1715.6,22564.3,22564.3,1172.9,1172.9 !      PTn unit
MPDATA,C,3,1,960.5,960.5,5670.6,5670.6,934.8,934.8 !      TSw1 unit
MPDATA,C,4,1,941.7,941.7,4608.0,4608.0,960.4,960.4 !      TSw2 unit
MPDATA,C,5,1,904.0,904.0,1990.0,1990.0,1124.4,1124.4 !      TSw3 unit
MPDATA,C,6,1,1300.8,1300.8,17935.1,17935.1,847.0,847.0 !      CHNlv unit
MPDATA,C,7,1,1416.2,1416.2,18762.1,18762.1,1210.8,1210.8 !      CHNlz unit
MPDATA,C,8,1,1231.2,1231.2,11998.2,11998.2,1330.6,1330.6 !      CHN2 unit
!
!      Parameters for model generation
!
ORIG=0.0
X1=5.5
X2=11.25
DS=22.5
Y1=5.5
Y2=10.5
Y3=15
Y4=19.5
R1=2.75
RW=0.925
ROD=2.25
TSW2_UP=106.8
TSW2_LOW=-82.5
TSW1=236.9
PTN=275.0
TCW=311.0
TSW3=-98.3
CHN1V=-103.5
CHN1Z=-207.5
CHN2=-300.0
XOFF=33.75
YOFF=15.0
!
WPOFF,X2,0,0
CSYS,4
RECTNG,ORIG,X1,ORIG,Y1,
PCIRC,R1,,0,90,
ASBA,1,2
PCIRC,RW,,0,90,
ARSYM,Y,ALL,,,0,0
RECTNG,ORIG,X1,Y1,Y2,
RECTNG,ORIG,X1,Y2,Y3,
RECTNG,ORIG,X1,Y3,Y4,
RECTNG,ORIG,X1,Y4,TSW2_UP,
RECTNG,ORIG,X1,TSW2_UP,TSW1,
RECTNG,ORIG,X1,TSW1,PTN,
RECTNG,ORIG,X1,PTN,TCW,
RECTNG,ORIG,X1,-Y1,TSW2_LOW,
RECTNG,ORIG,X1,TSW2_LOW,TSW3,
RECTNG,ORIG,X1,TSW3,CHN1V,
RECTNG,ORIG,X1,CHN1V,CHN1Z,
RECTNG,ORIG,X1,CHN1Z,CHN2,
!
RECTNG, X1,X2, ORIG, Y1,
RECTNG, X1,X2, Y1, Y2,
RECTNG, X1,X2, Y2, Y3,
RECTNG, X1,X2, Y3, Y4,
RECTNG, X1,X2, Y4, TSW2_UP,
RECTNG, X1,X2, TSW2_UP, TSW1,
RECTNG, X1,X2, TSW1, PTN,
RECTNG, X1,X2, PTN, TCW,

```

```

RECTNG, X1,X2, ORIG, -Y1,
RECTNG, X1,X2, -Y1,TSW2_LOW,
RECTNG, X1,X2,TSW2_LOW, TSW3,
RECTNG, X1,X2, TSW3, CHN1V,
RECTNG, X1,X2, CHN1V, CHN1Z,
RECTNG, X1,X2, CHN1Z, CHN2,

```

```

!
ARSYM,X,ALL,,,0,0
WPOFF,X2,0,0
ASEL,S,LOC,X,-X2,0,,1
ARSYM,X,ALL,,,0,0
ALLSEL
WPOFF,X2,0,0
ARSYM,X,ALL,,,0,0
WPOFF,-XOFF,YOFF,0

```

```

!
PCIRC,ROD, ,0,90,
PCIRC,ROD, ,0,-90,

```

```

!
ASBA,50,181
ASBA,49,182
WPOFF,0,-YOFF,0
AGLUE,ALL
/TRIAD,RBOT
APLOT
SAVE

```

```

!
! Meshing
!

```

```

TYPE,1, ! Mesh the waste package

```

```

MAT,9,
ESYS,0,
ESHAPE,2,0
MOPT,EXPND,1,
MOPT,TRANS,2,
MOPT,IESZ,0,
ESIZE,0.5,0,
AMESH,1,
AMESH,49
AMESH,181
AMESH,187
AMESH,182
AMESH,188
AMESH,184
AMESH,61
AMESH,185
AMESH,189
AMESH,186
AMESH,91

```

```

!
LCCAT,2,3 ! Concatenates lines
LCCAT,14,825
LCCAT,891,835
LCCAT,128,830
LCCAT,912,608
LCCAT,992,915
LCCAT,254,878
LCCAT,248,249
LCCAT,943,488
LCCAT,1005,948
LCCAT,374,938
LCCAT,368,369
LCCAT,769,845
LCCAT,841,894

```

```

!
TYPE,1, ! Mesh the TSw2 unit

```

```

MAT,4,
ESYS,0,
LSEL,S,LINE,,1044 ! Observation drift
LSEL,A,LINE,,724

```

```

!
LSEL,A,LINE,,5 ! Emplacement drift

```

```

LSEL,A,LINE,,1032
LSEL,A,LINE,,1034
LSEL,A,LINE,,1033
LSEL,A,LINE,,1036
LSEL,A,LINE,,1037
LSEL,A,LINE,,1035
LSEL,A,LINE,,251
LSEL,A,LINE,,1039
LSEL,A,LINE,,1040
LSEL,A,LINE,,1038
LSEL,A,LINE,,371
LESIZE,ALL,,10

```

```

!
LSEL,S,LINE,,1041,
LSEL,A,LINE,,1043,
LSEL,A,LINE,,1042,
LSEL,A,LINE,,127,
LSEL,A,LINE,,8,
LSEL,A,LINE,,9,
LSEL,A,LINE,,15,
LSEL,A,LINE,,247,
LSEL,A,LINE,,607,
LSEL,A,LINE,,250,
LSEL,A,LINE,,255,
LSEL,A,LINE,,367
LSEL,A,LINE,,487

```



```
LSEL,A,LINE,,370
LSEL,A,LINE,,375
LESIZE,ALL,,5
!
LSEL,S,LINE,,845,
LSEL,A,LINE,,769,
LSEL,A,LINE,,841,
LSEL,A,LINE,,894,
LSEL,A,LINE,,830,
LSEL,A,LINE,,3,
LSEL,A,LINE,,2,
LSEL,A,LINE,,825,
LSEL,A,LINE,,14,
LSEL,A,LINE,,835,
LSEL,A,LINE,,891,
LSEL,A,LINE,,128,
LSEL,A,LINE,,249,
LSEL,A,LINE,,912,
LSEL,A,LINE,,608,
LSEL,A,LINE,,992,
LSEL,A,LINE,,915,
LSEL,A,LINE,,254,
LSEL,A,LINE,,878,
LSEL,A,LINE,,248,
LSEL,A,LINE,,369,
LSEL,A,LINE,,943,
LSEL,A,LINE,,488,
LSEL,A,LINE,,1005,
LSEL,A,LINE,,948,
LSEL,A,LINE,,374,
LSEL,A,LINE,,938,
LSEL,A,LINE,,368,
LSEL,A,LINE,,766
LESIZE,ALL,,5
!
LSEL,S,LINE,,738
LSEL,A,LINE,,764
LSEL,A,LINE,,821
LSEL,A,LINE,,795
LSEL,A,LINE,,823
LESIZE,ALL,,4
!
LSEL,S,LINE,,840
LSEL,A,LINE,,23
LSEL,A,LINE,,263
LSEL,A,LINE,,918
LSEL,A,LINE,,383
LSEL,A,LINE,,953
LESIZE,ALL,,5
!
ALLSEL
ESIZE,1,0,
AMESH,353,354,1,
AMESH,3
AMESH,344,346,1
AMESH,63
AMESH,347,349,1
AMESH,93
AMESH,350,352,1
ESIZE,1.5,0
AMESH,204
AMESH,271
AMESH,190
AMESH,233
AMESH,203
AMESH,258
AMESH,231
AMESH,318
AMESH,218
AMESH,293
AMESH,232
AMESH,331
!
AMESH,272
AMESH,235
AMESH,191
AMESH,239
AMESH,241
AMESH,193
AMESH,194
AMESH,234
AMESH,259
AMESH,238
AMESH,240
AMESH,260
AMESH,261
AMESH,206
AMESH,281
AMESH,208
AMESH,209
AMESH,283
AMESH,284
AMESH,319
AMESH,294
AMESH,320
AMESH,298
AMESH,321
AMESH,300
```

```
AMESH,219
AMESH,295
AMESH,221
AMESH,299
AMESH,222
AMESH,301
AMESH,332
AMESH,334
AMESH,335
!
ESIZE,2,0
AMESH,205
AMESH,243
AMESH,195
AMESH,242
AMESH,262
AMESH,210
AMESH,285
AMESH,322
AMESH,302
AMESH,223
AMESH,303
AMESH,336
AMESH,273
AMESH,237
AMESH,192
AMESH,236
AMESH,266
AMESH,207
AMESH,282
AMESH,326
AMESH,296
AMESH,220
AMESH,297
AMESH,333
!
TYPE,1,          !      Mesh the TSw1 unit
MAT,3,
ESYS,0,
ESIZE,3.0,0,
AMESH,274
AMESH,245
AMESH,196
AMESH,244
AMESH,263
AMESH,211
AMESH,286
AMESH,323
AMESH,304
AMESH,224
AMESH,305
AMESH,337
!
TYPE,1,          !      Mesh the PTn unit
MAT,2,
ESYS,0,
ESIZE,7.5,0,
AMESH,275
AMESH,247
AMESH,197
AMESH,246
AMESH,264
AMESH,212
AMESH,287
AMESH,324
AMESH,306
AMESH,225
AMESH,307
AMESH,338
!
TYPE,1,          !      Mesh the TCw unit
MAT,1,
ESYS,0,
ESIZE,15,0,
AMESH,276
AMESH,249
AMESH,198
AMESH,248
AMESH,265
AMESH,213
AMESH,288
AMESH,325
AMESH,308
AMESH,226
AMESH,309
AMESH,339
!
TYPE,1,          !      Mesh the TSw3 unit
MAT,5,
ESYS,0,
ESIZE,3.0,0,
AMESH,277
AMESH,250
AMESH,199
AMESH,251
AMESH,267
AMESH,214
AMESH,289
```

```

AMESH,327
AMESH,311
AMESH,227
AMESH,310
AMESH,340
!
TYPE,1,                                !      Mesh the CHn1v unit
MAT,6,
ESYS,0,
ESIZE,3.0,0,
AMESH,278
AMESH,252
AMESH,200
AMESH,253
AMESH,268
AMESH,215
AMESH,290
AMESH,328
AMESH,313
AMESH,228
AMESH,312
AMESH,341
!
TYPE,1,                                !      Mesh the CHn1z unit
MAT,7,
ESYS,0,
ESIZE,7.5,0,
AMESH,279
AMESH,254
AMESH,201
AMESH,255
AMESH,269
AMESH,216
AMESH,291
AMESH,329
AMESH,315
AMESH,229
AMESH,314
AMESH,342
!
TYPE,1,                                !      Mesh the CHn2 unit
MAT,8,
ESYS,0,
ESIZE,15,0,
AMESH,280
AMESH,256
AMESH,202
AMESH,257
AMESH,270
AMESH,217
AMESH,292
AMESH,330
AMESH,317
AMESH,230
AMESH,316
AMESH,343
!
TYPE,2,                                !      Define link elements
MAT,10,
REAL,1,
ESYS,0,
LSEL,S,LINE,,1                        !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
LSEL,A,LINE,,5                        !      Drift wall
LSEL,A,LINE,,1033
LSEL,A,LINE,,1034
LSEL,A,LINE,,1032
LSEL,A,LINE,,1036
LSEL,A,LINE,,251
LSEL,A,LINE,,1035
LSEL,A,LINE,,1037
LSEL,A,LINE,,1039
LSEL,A,LINE,,371
LSEL,A,LINE,,1038
LSEL,A,LINE,,1040
NSLL,S,1
ESURF,ALL
PLOT
!
/AUX12                                !      Generate superelement for thermal
EMIS,2,0.85,                          !      radiation calculation
STEF,1.7878,
GEOM,1,0,
SPACE,,
ESEL,S,TYPE,,2,2
NSLE,S
VTYPE,0,
MPRINT,0

```

```

WRITE,pca2d85m106          !      Save radiation matrices
FINISH
!
/PREP7
TYPE,3,
MAT,11,
REAL,1,
ESYS,0,
SE,pca2d85m106
!
ESEL,S,TYPE,,2,2
EDEL,E,ALL
ALLSEL
!
/SOLU          !      Solution phase
ANTYPE,TRANS  !      Transient analysis
NROPT,AUTO    !      Program chosen Newton-Raphson option
TOFFST,273    !      Specify the temperature offset: 273 C
TINTP,0.005, , ,0.5,0.5,0.2 !      Use defaults of transient integration
!      parameters
OUTPR,NSOL,5, !      Solution printout at every 5 substeps
OUTRES,NSOL,5, !      Solution data written to database
!      at every 5 substeps
IC,ALL,TEMP,26, !      Initial temperature at all nodes
NSEL,S,LOC,Y,311.0 !      Select all nodes on top surface
D,ALL,TEMP,18.7
NSEL,S,LOC,Y,-300.0 !      Select all nodes on bottom surface
D,ALL,TEMP,32.53
ALLSEL
SAVE
!
!      Load step number 1
TIMINT,OFF      !      Turn off transient effects at the
!      first load step
TIME,1e-7
AUTOTS,1
DELTIM,1e-8,1e-8,1e-7,0
KBC,0
LSWRITE,1,
!
TIMINT,ON      !      Turn on transient effects at the
!      rest of load steps
!      Load step number 2
TIME,0.5e-2
AUTOTS,1
DELTIM,0.5e-4,0.5e-4,0.5e-3,0
KBC,1
LSEL,S,LINE,,1044 !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,26
KBC,0
LSEL,S,LINE,,1 !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.5952e9,
ALLSEL
LSWRITE,2,
!
!      Load step number 3
TIME,1
AUTOTS,1
DELTIM,0.01,0.01,0.1,0
KBC,1
LSEL,S,LINE,,1044 !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,26.28
KBC,0
LSEL,S,LINE,,1 !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.5289e9,
ALLSEL
LSWRITE,3,
!
!      Load step number 4
TIME,5
AUTOTS,1
DELTIM,0.05,0.05,0.5,0
KBC,1
LSEL,S,LINE,,1044 !      Observation drift

```

```
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,30.52
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.3217e9,
ALLSEL
LSWRITE,4,
!
!      Load step number 5
TIME,10
AUTOTS,1
DELTIM,0.05,0.05,0.5,0
KBC,1
LSEL,S,LINE,,1044       !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,33.52
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,2.1169e9,
ALLSEL
LSWRITE,5,
!
!      Load step number 6
TIME,20
AUTOTS,1
DELTIM,0.1,0.1,0.75,0
KBC,1
LSEL,S,LINE,,1044       !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,36.30
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.7929e9,
ALLSEL
LSWRITE,6,
!
!      Load step number 7
TIME,30
AUTOTS,1
DELTIM,0.1,0.1,0.75,0
KBC,1
LSEL,S,LINE,,1044       !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,37.62
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.5401e9,
ALLSEL
LSWRITE,7,
!
!      Load step number 8
TIME,40
AUTOTS,1
```

```
DELTIM,0.15,0.15,0.75,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,38.37
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.3400e9,
ALLSEL
LSWRITE,8,
!
!      Load step number 9
TIME,50
AUTOTS,1
DELTIM,0.15,0.15,0.75,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,38.81
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.1779e9,
ALLSEL
LSWRITE,9,
!
!      Load step number 10
TIME,60
AUTOTS,1
DELTIM,0.15,0.15,1.0,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,39.08
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,1.0477e9,
ALLSEL
LSWRITE,10,
!
!      Load step number 11
TIME,70
AUTOTS,1
DELTIM,0.15,0.15,1.0,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,39.19
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,9.4197e8,
ALLSEL
LSWRITE,11,
!
!      Load step number 12
```

```
TIME,80
AUTOTS,1
DELTIM,0.15,0.15,1.5,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,39.23
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,8.5514e8,
ALLSEL
LSWRITE,12,
!
!      Load step number 13
TIME,100
AUTOTS,1
DELTIM,0.15,0.15,2.5,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,39.17
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,7.2487e8,
ALLSEL
LSWRITE,13,
!
!      Load step number 14
TIME,150
AUTOTS,1
DELTIM,0.2,0.2,5,0
KBC,1
LSEL,S,LINE,,1044      !      Observation drift
LSEL,A,LINE,,724
SFL,ALL,CONV,5.9231e7,,38.83
KBC,0
LSEL,S,LINE,,1          !      WP
LSEL,A,LINE,,722
LSEL,A,LINE,,735
LSEL,A,LINE,,194
LSEL,A,LINE,,725
LSEL,A,LINE,,736
LSEL,A,LINE,,729
LSEL,A,LINE,,241
LSEL,A,LINE,,731
LSEL,A,LINE,,737
LSEL,A,LINE,,733
LSEL,A,LINE,,361
SFL,ALL,HFLUX,5.4619e8,
ALLSEL
LSWRITE,14,
!
ALLSEL
LSSOLVE,1,14,1,      !      Solve with 14 load steps
FINISH
```