Appendix G

NUCLEAR WASTE MANAGEMENT PROGRAM Sandia National Laboratories	**User's Manual Criteria Form**	Form Number: NP 19-1-6 Page 1 of 1

Does the user's manual contain as appropriate:

1. **Software Name:** DRSPALL
2. **Software Version:** 1.00
3. **Document Version:** 1.00
4. **ERMS #:** 524780

Prior to sign-off of the User's Manual, all items shall be appropriately addressed by the code sponsor so that "**Yes**" or "**N/A**" may be checked. Include this form as part of the User's Manual.

5. A statement(s) of functional requirements (consistent with those in the RD) and system limitations? ☑ Yes

6. An explanation of the mathematical model and numerical models, where applicable as based on code functionality? ☑ Yes ☐ N/A

7. Physical and mathematical assumptions, where applicable as based on code functionality? ☐ Yes ☑ N/A

8. The capabilities and limitations inherent in the software? ☑ Yes

9. Instructions that describe the user's interaction with the software? ☑ Yes

10. The identification of input parameters, formats, and valid ranges? ☑ Yes

11. Messages initiated as a result of improper input and how the user can respond? ☑ Yes

12. The identification and description of output specifications and formats? ☑ Yes

13. A description of any required training necessary to use the software? ☑ Yes

14. The identification of components of the code that were not tested? ☑ Yes

15. DAVID LORD — **Code Team/Sponsor** (*print*) | Signature: David P. Lord | Date: 10/2/2003

16. JW GARNER — **Technical Reviewer** (*print*) | Signature: JW Garner | Date: 10/2/03

17. David Kessel — **Responsible Manager** (*print*) | Signature: David Kessel | Date: 10/2/03

18. Jennifer Long — **SCM Coordinator** (*print*) | Signature: Jennifer Long | Date: 10/6/03

Key for check boxes above:

Check **Yes** for each item reviewed and found acceptable
Check **N/A** for items not applicable, where applicable as based on code functionality

WIPP PA

USER'S MANUAL

for

DRSPALL Version 1.00

Document Version 1.00

ERMS# 524780

October 2003

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0   INTRODUCTION

This document serves as a User's Manual for the DRSPALL program as used in the Waste Isolation Pilot Plant (WIPP) Performance Assessment (PA) calculation. As such, it describes the purpose and function of the DRSPALL program and the user's interaction with it.

1.1   Software Identifier

Code Name: DRSPALL
Version: 1.00
WIPP Prefix: DRS
Platform: Compaq Fortran on OpenVMS V7.3-1 Alpha

1.2   Points of Contact

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1.3   Code Overview

DRSPALL is written to calculate the volume of WIPP solid waste subject to material failure and transport to the surface as a result of an inadvertent drilling intrusion. The code calculates coupled repository and wellbore transient multi-phase compressible fluid flow before, during, and after the drilling intrusion process. Mathematical models are included for bit penetration, multi-phase (mud, salt, waste, and gas) fluid flow in the well, fluid expulsion at the surface, coupling of the well and the drilled repository, repository spalling (tensile) failure, fluidized bed

transport of failed waste, and repository internal gas flow. The wellbore model is one-dimensional with linear flow, while the repository model is one-dimensional with either spherical or cylindrical flow.

2.0 FUNCTIONAL REQUIREMENTS

The requirements for DRSPALL are listed in the *WIPP PA Requirements Document for DRSPALL Version 1.00*. The additional functionality to be tested and the functionality not tested are listed in the *WIPP PA Verification and Validation Plan and Validation Document for DRSPALL Version 1.00*. The requirements and functionality are repeated here for the reader's convenience.

2.1 Functional Requirements

In general DRSPALL shall calculate the volume of WIPP waste subject to material failure and transport to the surface as a result of an inadvertent drilling intrusion into the repository. More specifically DRSPALL will calculate the following:

R.1 Compressible, viscous, isothermal, multiphase mixture flow (mud, salt, waste, repository gas) in the wellbore using one dimensional linear geometry and assuming a Newtonian fluid. Either laminar or turbulent flow shall be modeled depending on wellbore and fluid properties.

R.2 Repository gas flow as single-phase Darcy porous flow using either one dimensional cylindrical or spherical geometry

R.3 Coupling of the wellbore and the repository flow models prior to and after penetration

R.4 Spalling (tensile) failure of the homogeneous waste material using an effective stress law with seepage forces

R.5 Fluidized bed transport of failed (disaggregated) waste material.

R.6 Mixture expulsion at the surface

2.2 External Interface Requirements

R.7 DRSPALL shall read an input control file, which may be pre-generated using a text processor. It will contain numerical control parameters and, optionally, material properties and problem geometry.

R.8 Properties and non-numerical control parameters will, optionally, be read from a CDB.

R.9 Grid, properties, parameters and spatial and time dependent results will be written to an output CDB.

2.3   Additional Functionality To Be Tested

No additional functionality will be tested.

2.4   Functionality Not Tested

All functionality represented by requirements will be tested.

3.0 REQUIRED USER TRAINING AND/OR BACKGROUND

To exercise DRSPALL, users should have basic knowledge of OpenVMS and Digital Command Language, and access to the WIPP cluster of Compaq Alpha computers with the OpenVMS operating system or their functional equivalents.

Because DRSPALL manipulates a CAMDAT database, users should have an understanding of the CAMDAT terminology and contents. For a detailed description of the CAMDAT database, refer to Chapter 7 of the *WIPP PA User's Manual for CAMDAT_LIB Version 1.22.*

It is highly recommended that the new user read the *WIPP PA Design Document for DRSPALL Version 1.10* before setting up and executing DRSPALL. DRSPALL's conceptual and mathematical models rely on the conservation of wellbore surface area to equivalence the two-dimensional real-world problem to the 1-dimensional cylindrical or spherical model geometry. Understanding these concepts as well as the WIPP PA specific application is essential for proper execution of the code.

4.0   THEORETICAL BASIS

The theoretical basis for DRSPALL is explained in detail in the *WIPP PA Design Document for DRSPALL Version 1.00*.

5.0   MATHEMATICAL MODEL

The mathematical model for DRSPALL is explained in detail in the *WIPP PA Design Document for DRSPALL Version 1.00*.

6.0 CAPABILITIES AND LIMITATIONS OF THE SOFTWARE

DRSPALL (from Direct Release Spall) is written to calculate the volume of WIPP solid waste subject to material failure and transport to the surface as a result of an inadvertent drilling intrusion. The code calculates coupled repository and wellbore transient mixed-phase compressible fluid flow before, during, and after the drilling intrusion process. Mathematical models are included of bit penetration, mixed-phase (mud, salt, waste, and gas) fluid flow in the well, fluid expulsion at the surface, coupling of the well and the drilled repository, repository spalling (tensile) failure, fluidized bed transport of failed waste, and repository internal gas flow. The wellbore model is one-dimensional with linear flow, while the repository model is one-dimensional with either spherical or cylindrical radial flow. Flow in the well is treated as a compressible, viscous, multi-phase mixture of mud, gas, salt, and possibly waste solids. Flow in the repository is treated as viscous, compressible single-phase gas flow in a porous solid

DRSPALL was developed specifically for calculating the volume of WIPP solid waste subject to material failure and transport to the surface as a result of an inadvertent drilling intrusion. Therefore, many input parameters have been bounded to ranges established for WIPP specific materials, WIPP repository geometry and standard drilling practices in the Delaware basin and are documented in the *Parameter Justification Report* (Hansen, et al., 2003). Specific parameters and ranges are tabulated in Section 8.0, Table 8-1.

7.0 USER INTERACTIONS WITH THE SOFTWARE

DRSPALL executes on a Compaq Alpha under OpenVMS. To execute DRSPALL, type DRSPALL at the OpenVMS system "$" prompt and press the carriage-return key. The names of four files and one text string will be requested sequentially by DRSPALL. Alternately, the user may append the names of the files and the text string (in order) to the DRSPALL command line before pressing the carriage-return key. The required information is as follows:

1. The input control file. This required file sets the values for the problem specification parameters. If an input CAMDAT file is specified, the parameters may be read from CAMDAT properties specified in the input control file. The input control file is described in Section 8.1.

2. The output diagnostics file. This file contains a listing of the input control file and the input problem specification parameters. The output diagnostics file is described in Section 10.1.

3. An optional input CAMDAT file. This file contains certain problem specification parameters, defined as properties and referenced by the input control file. If the user enters "CANCEL", all input must come from the input control file. The input CAMDAT file is described in Section 8.2.

4. An output CAMDAT file. This file contains the results of the DRSPALL execution. The output CAMDAT file is described in Section 10.2.

8.0 DESCRIPTION OF INPUT FILES

DRSPALL inputs a set of problem specification parameters from the input control file. The format of the input control file is described in Section 8.1. If an input CAMDAT file is specified as described in Section 7.0, the input control file may reference values from the input CAMDAT file. The format of the input CAMDAT file is described in Section 8.2.

The DRSPALL input parameters are listed in **Table 8-1**, along with their default values, units, and range. The input parameters should be self-explanatory. More information is available in the *WIPP PA Design Document for DRSPALL Version 1.00*. The parameters are grouped into categories (e.g., Repository, Waste). All numeric parameters are double-precision real numbers, unless otherwise noted.

The input parameters are listed twice in the output diagnostics file, described in Section 10.1. The first listing is a direct echo of the input control file. The second listing writes the values that are being used by DRSPALL. If there is an error in the input parameters, it will be reflected in the second listing.

Table 8-1 DRSPALL Input Parameters

Category and Parameters	Units	CAMDAT*	Default	Range
REPOSITORY				
Land elevation	m	YES	1037.3	900.0 – 1100.0
Repository top	m	YES	385.31	300.0 – 500.0
Repository thickness	m	YES	0.0	0.0 – calculated internally 1.0 – 2.0 use specified value
DRZ[#] thickness	m	YES	0.85	0.1 – 1.0
DRZ permeability	m^2	YES	1.0e-15	1.0e-21 – 1.0e-12; < DDZ Permeability
Outer radius	m	YES	19.2	10.0 – 50.0; > 0.5 * Bit Diameter
Initial gas pressure	Pa	YES	14.5e6	6.0e6 – 15.0e6; ≤ far-field in-situ stress
Far-field In-Situ Stress	Pa	YES	14.8e6	14.0e6 – 15.0e6
WASTE				
Repository initial porosity	–	YES	0.575	0.20 – 0.85
Repository initial permeability	m^2	YES	1.7e-13	1.0e-17 – 1.0e-12
Forchheimer beta	–	YES	1.15e-6	1.0e-12 – 1.0e-4
Biot beta	–	YES	1.0	0.5 – 1.0
Poisson's ratio	–	YES	0.35	0.2 – 0.4
Cohesion	Pa	YES	1.23e5	1.0e4 – 1.0e7
Friction angle	deg	YES	45.0	30.0 – 60.0
Tensile strength	Pa	YES	6895.0	6.89e3 – 6.91e6
Characteristic failure length	–	YES	0.02	0.0 – 0.1
Particle diameter	m	YES	0.001	0.001 – 0.01; < Bit Diameter
Gas viscosity	Pa-s	YES	10.0e-6	1.0e-6 – 1.0e-4
MUD				
Initial mud density	kg/m^3	YES	1210.0	1000.0 – 1500.0
Mud viscosity	Pa-s	YES	0.01	1.0e-4 – 1.0e-1
Wall roughness pipe	m	YES	0.5e-5	1.0e-14 – 1.0e-2
Wall roughness annulus	m	YES	0.5e-5	1.0e-14 – 1.0e-2
Max mud solids vol. Fraction	–	YES	0.6	0.5 – 0.8
Mud solids viscosity exponent	–	YES	-1.8	-2.0 – -1.2
WELLBORE/DRILLING				
Bit diameter	m	YES	0.3112	0.25 – 1.32
Pipe diameter	m	YES	0.1143	0.1 – 0.15; < Bit Diameter
Collar diameter	m	YES	0.2032	0.15 – 0.25; > Pipe Diameter, < Bit Diameter
Pipe inside diameter	m	YES	0.1005	0.08 – 0.13; < Pipe Diameter
Collar length	m	YES	182.9	0.0 – 250.0

Category and Parameters	Units	CAMDAT*	Default	Range
Exit pipe length	m	YES	15.24	0 – 25.0
Exit pipe diameter	m	YES	0.0508	0.0254 – 0.3048
Drilling rate	m/s	YES	0.005	0.0 – 0.01
Initial bit height above repository	m	YES	0.15	0.01 – 1.0
Mud pumping rate	m^3/s	YES	0.021443	0.001 – 0.1
Maximum pump pressure	Pa	YES	27.5e6	1.0e5 – 100.0e6
DDZ$^\#$ thickness	m	YES	0.15	0.1 – 0.3
DDZ permeability	m^2	YES	1.0e-14	1.0e-21 – 1.0e-12; > DRZ Permeability
Stop drilling exit volume rate	m^3/s	YES	1000.0	0.05 – 2000.0
Stop pumping exit volume rate	m^3/s	YES	1000.0	1.0 – 2000.0
Stop drilling time	s	YES	1000.0	≥0
COMPUTATIONAL				
Spherical / Cylindrical	–	NO	S	S or C (Spherical or Cylindrical)
Allow fluidization	–	NO	Y	Y or N or A (Yes, No or Always)
Maximum run time	s	NR	900.0	> 0
Repository zone size	m	NR	0.002	>0
Region of constant zone size, zone Growth Rate	m, –	NO	0.5, 1.01	>0.0, ≥ 1.0
Wellbore zone size	m	NR	2.0	>0
Wellbore zone growth rate	–	NR	1.01	≥ 1.0
First wellbore zone	–	NR	2	1 – model inside pipe >1 – model annulus only
Well stability factor	–	NR	0.1	<1.0
Repository stability factor	–	NR	5.0	>0.0
Mass diffusion factor	–	NR	0.02	0 – 0.05 (0.002 recommended)
Momentum diffusion factor	–	NR	0.002	0 – 0.05
VALIDATION	Optional Category to run validation tests described in the *WIPP PA Verification and Validation Plan and Validation Document for DRSPALL Version 1.00*			
Validation Test Case	–	NR	0.0	testcase. subcase (see VVP/VD)
PARAMETERS AND CONSTANTS		Optional Category		
Pi	–	YES	3.14159263589 793	–
Atmospheric Pressure	Pa	YES	101300.0	–
Gravity	m/s^2	YES	9.8067	–
Gas Constant	J/kg K	YES	4124.0	–
Repository Temperature	K	YES	300.0	–
Water Compressibility	1/Pa	YES	3.1e-10	–
Waste Density	kg/m^3	YES	2650.0	–
Salt Density	kg/m^3	YES	2201.0	–
Shape Factor	–	YES	1.0	-0 < x ≤1.0
Tensile Velocity	m/s	YES	1000.0	–

Category and Parameters	Units	CAMDAT*	Default	Range
Bit Nozzle Number	–	YES	3.0	–
Bit Nozzle Diameter	m	YES	0.011112	–
Choke Efficiency	–	YES	0.9	-.0 < x ≤ 1.0
Optional Parameters – highlighted characters must be specified in text field				
INITIAL CAVITY RADIUS	m	YES	0.0	=0 – calculated internally >0.0 – use specified value
MINIMUM CHARacteristic Velocity for Fluidization	m/s	YES	1.0e-6	>0
MINIMUM NUMBer of zones per Characteristic Length	–	YES	5	1≤ n ≤10

DRZ – Disturbed Rock Zone; DDZ – Drill Damage Zone

* NO – can not be read from CAMDAT file; NR – not recommended to read from CAMDAT file; YES – can be read from CAMDAT file

8.1   The Input Control File

The input control file is an ASCII text file that defines the problem specification parameters. An example of an input control file is shown in **Figure 8-1**.

The parameters are grouped in categories in **Table 8-1** and in the input control file. In **Table 8-1**, the category name appears as a shaded row, with the parameters listed under the category. In the input control file, the category name *must* be followed by a record for each parameter within the category, in order. The categories themselves may appear in the input control file in any order, but the parameters within the category must appear in the order listed in **Table 8-1**. Optional categories are noted in the table; all other categories are required. Comment records may appear outside of the category definitions.

The start of the category is recognized by the first few letters of the category name. The bold letters of the category name in **Table 8-1** are enough to identify the category. All letters are converted to uppercase before any parsing is done, and leading blanks are ignored.

A record for each parameter within the category must follow, in the order listed in **Table 8-1**, directly after the category name. The parameter records are in free-format, as follows:

text : value

Any text before the colon is ignored. The text usually includes the parameter name for readability. (An equal sign, "=", may be substituted for the colon.)

The *value* field for a single numeric parameter may be one of the following:

Blank or "DEFAULT" (case is unimportant and leading spaces are ignored) to assign the default value to the parameter. The default values are listed in **Table 8-1**.

A specific value to assign to the parameter, in any valid FORTRAN format for a double-precision real number.

The material name and property name of the CAMDAT property that contains the value of the parameter. The material name and property name may be separated by a comma, a colon, an equal sign, or blanks. See Section 8.1 for more information on the input CAMDAT file. If the property is not present on the input CAMDAT file, the parameter is assigned its default value. This option is only available if an input CAMDAT file has been specified as described in Section 7.0 and if the parameter has "Yes" in the CAMDAT column in **Table 8-1**.

For a text parameter (e.g., Spherical/Cylindrical), the first non-blank character (case is unimportant) after the colon must be an allowable value for the text parameter, as listed in **Table 8-1**.

The *value* field for a parameter that expects two values (e.g., Repository radius, Growth) should contain the two values in any valid FORTRAN format for a double-precision real number or integer, as appropriate. The two values should be separated by a comma or blank(s).

Note that although the text in a parameter record is not processed in any way, the parameter records are also read when the parser is searching for the start of a category. Thus, if the first characters of the text of a parameter record are the same as the first few letters of any category name (case is unimportant and leading blanks are ignored), that category name must appear before the parameter record. For example, in the input control file shown in **Figure 8-1**, *the text "Repository" appears as the first word in several parameter records. This would conflict with the category name "REPOSITORY" if this category appeared later in the file.*

Comment lines may appear outside of the category definitions. That is, a comment record may not be inserted between the start of the category and the end of the parameter records for that category. It is suggested that the comment lines begin with a special character such as "!" to avoid problems with parsing.

Figure 8-1 Example DRSPALL Input Control File

REPOSITORY

Land Elevation	(m):	DRSPALL SURFELEV
Repository top	(m):	DRSPALL REPOSTOP
Total Thickness	(m):	0.0
DRZ Thickness	(m):	DRSPALL DRZTCK
DRZ Permeability	(m^2):	DRSPALL DRZPERM
Outer Radius	(m):	1.9200E+01
Initial Gas Pressure	(m):	DRSPALL REPIPRES
Far-Field In-Situ Stress	(m):	DRSPALL FFSTRESS

WASTE

Porosity	(-):	DRSPALL REPIPOR
Permeability	(m^2):	DRSPALL REPIPERM
Forch Beta	(-):	DRSPALL FRCHBETA
Biot Beta	(-):	DRSPALL BIOTBETA
Poisoson Ratio	(-):	DRSPALL POISRAT
Cohesion	(Pa):	DRSPALL COHESION
Friction Angle	(deg):	DRSPALL FRICTANG
Tensile Strength	(Pa):	DRSPALL TENSLSTR
Lt	(m):	0.02
Particle Diameter	(m):	DRSPALL PARTDIAM
Gas Viscosity	(Pa-s):	DRSPALL GASVISCO

MUD

Density	(kg/m^3):	DRSPALL INITMDEN
Viscosity	(Pa-s):	DRSPALL MUDVISCO
Wall Roughness Pipe	(m):	DRSPALL PIPEROUG
Wall Roughness Annulus	(m):	DRSPALL ANNUROUG
Max Solids Vol. Frac.	(Pa-s):	DRSPALL MUDSOLMX
Solids Viscosity Exp.	(Pa-s):	DRSPALL MUDSOLVE

WELLBORE/DRILLING

Bit Diameter	(m):	DRSPALL BITDIAM
Pipe Diameter	(m):	DRSPALL PIPEDIAM
Collar Diameter	(m):	DRSPALL COLRDIAM
Pipe Inside Diameter	(m):	DRSPALL PIPEID
Collar Length	(m):	DRSPALL COLRLNGT
Exit pipe Length	(m):	DRSPALL EXITPLEN
Exit Pipe Diameter	(m):	DRSPALL EXITPDIA
Drilling Rate	(m/s):	DRSPALL DRILRATE
Bit Above Repository (init.)	(m):	DRSPALL INITBAR
Mud Pump Rate	(m^3/s):	DRSPALL MUDPRATE
Max Pump Pressure	(Pa):	27.5d6
DDZ Thickness	(m):	DRSPALL DDZTHICK
DDZ Permeability	(m^2):	DRSPALL DDZPERM
Stop Drill Exit Vol Rate	(m^3/s):	DRSPALL STPDVOLR
Stop Pump Exit Vol Rate	(m^3/s):	DRSPALL STPPVOLR
Stop Drilling Time	(s):	DRSPALL STPDTIME

COMPUTATIONAL

Spherical/Cylindrical	(S/C):	S
Allow Fluidization	(Y/N):	Y
Max Run Time	(s):	1.0
Respository Cell Length	(m):	0.002
radius, Growth rate	(m,-):	0.5, 1.01
Wellbore Cell Length	(m):	1.0
wellbore Zone Growth Rate	(-):	1.01

```
    First wellbore Zone                  (-):  10
    Well Stability factor                (-):  0.02
    Repository Stability factor          (-):  5.0
    Mass Diffusion factor                (-):  0.002
    Momentum Diffusion factor            (-):  0.002


VALIDATION
    Validation Test Case                 (-):  4.2


PARAMETERS
    Pi                        .          (-):  REFCON    PI
    Atmospheric Pressure                (Pa):  1.0170E+05
    Gravity                        (m/s^2):  REFCON    GRAVACC
    Gas Constant                (J/kg K):  BLOWOUT   RGAS
    Repository Temperature          (K):  BLOWOUT   TREPO
    Water Compressibility       (1/Pa):  12.4e-10
    Waste Density              (kg/m^3):  BLOWOUT   RHOS
    Salt Density               (kg/m^3):  2.1800E+3
    Shape Factor                     (-):  DRSPALL SHAPEFAC
    Tensile Velocity               (m/s):  DEFAULT
    Bit Nozzle Number                (-):  DEFAULT
    Bit Nozzle Diameter              (m):  DEFAULT
    Choke Efficiency                 (-):  DEFAULT


    !Optional parameters
    Initial Cavity Radius            (m):  0.0
    Minimum Characteristic vel     (m/s):  1e-6
    Minimum Number of zones per Lt (-):  5
```

8.2   The Input CAMDAT File

The input CAMDAT file is a binary, sequential file used by many WIPP codes. A detailed description of the CAMDAT file format is given in Chapter 7 of the *WIPP PA User's Manual for CAMDAT_LIB Version 1.22*. The input CAMDAT file is optional, and is only available if it has been specified as described in Section 7.0.

The input control file may reference specific property values on the input CAMDAT file. A property is a single value that is associated with a material. ("Material" and "element block" are synonymous.) Both the material and the property are referenced by name. Properties may be assigned to the CAMDAT file with the MATSET program, described in the *WIPP PA User's Manual for MATSET Version 9.10*. DRSPALL limits the number of materials on the input CAMDAT file to 200.

The value of any property referenced by the input control file is printed to the output diagnostics file. If the referenced property does not exist on the input CAMDAT file, a message to that effect is printed to the output diagnostics file and the property is assigned its default value.

9.0 ERROR MESSAGES

The error messages that DRSPALL may generate are listed below, along with the cause of the error, and suggested action. The error messages are divided into three sections based on when the error may occur: while the user is specifying the file names, while reading the input control file, and during the simulation execution.

Unless otherwise noted, error messages are written to the output diagnostics file, described in Section 10.1. The messages below are of the following type:

- Fatal errors cause the program to abort. Fatal error messages are written to the diagnostics file and to the screen, although the messages may differ slightly.

- Other errors indicate problems that should be addressed. These errors usually lead to a fatal error later in processing.

- Warnings indicate possible problems. They do not cause the program to abort.

- Information-only messages are not errors, and thus only a few of these messages are listed below. The messages listed below are those that may be confused with error messages or those that provide information that may be especially useful in detecting problems.

9.1 File Assignment Errors

The errors in this section concern the DRSPALL input/output files that the user specifies at the start of execution. See Section 7.0 for information on specifying files.

FATAL ERROR – Incorrect file assignments

> This fatal error occurs when the user does not specify the files correctly. Common causes are specifying an input file that does not exist or not specifying a required file.

ERROR: must specify CDB or test output

> This fatal error occurs when the user does not specify either the output text files or the output CAMDAT file.

FATAL ERROR – PROBLEM WITH INPUT CDB

> This fatal error occurs when an input CAMDAT file is specified, but it is not a valid CAMDAT file.

9.2   Input Control File Errors

The errors in this section may occur while DRSPALL is processing the input control file. See Section 8.0 for information on the input control file and the input CAMDAT file. Although DRSPALL checks for errors as the input control file is read, the user must take care to correctly define the parameters. In particular, missing or misplaced parameter records or values in an invalid FORTRAN format may cause DRSPALL to abort without an explicit error message. The output diagnostics file, described in Section 10.1, contains a listing of all the parameters that were set by the input control file, including all the parameters read from the CAMDAT file. If the user suspects that there are problems with the input parameters, this file should be examined.

FATAL ERROR – IN DBIELBK

This fatal error indicates that the input CAMDAT file is invalid. One possible cause is that a CAMDAT property is requested, but no input CAMDAT file is specified.

FATAL ERROR – OVER 200 EL BLKS IN DBVALUE

This fatal error occurs if the input CAMDAT file contains more than 200 materials (element blocks). This is a hard-coded limit in DRSPALL.

FATAL ERROR – OVER 50 PROPERTIES IN DBVALUE

This fatal error occurs if over 50 properties are requested from the input CAMDAT file. No more than 50 input parameters in the input control file may reference a CAMDAT property. This error should never occur because there are less than 50 input parameters that allow CAMDAT properties as values.

ERROR: Unable to find Keyword *category*
Screen message: **ERROR: Unable to find Keyword**

This fatal error occurs when the input control file does not contain the category name indicated by *category* (REPOSITORY, WASTE, MUD, WELL, COMPUTATIONAL).

Default parameter values will be used

This information-only message indicates that the input control file does not contain the Parameters and Constants category, and that the default parameters will be used for this category.

ERROR: Could not find property *varname*
Screen message: **ERROR: Could not find property**

The fatal error occurs when the *varname* parameter record indicates that its value is a CAMDAT property, but the record contains a material name, but no property name. Note that the parameter name as indicated in this document may not exactly match *varname*.

ERROR: Could not find data on input record for *varname*
Screen message: **ERROR: Could not find data on input record**

The fatal error occurs when the *varname* parameter record does not contain a ":" (or "=")
and a value. Note that the parameter name as indicated in this document may not exactly
match *varname*.

ERROR: Could not find delimiter for variable=*varname*
Screen message: **ERROR: Could not find delimiter for variable**

This fatal error occurs when the *varname* text parameter record does not contain a ":" or
"=" to delimit the expected text value. Note that the parameter name as indicated in this
document may not exactly match *varname*.

FROM CDB, *material property* : *value*

This information-only message indicates that the indicated *value* was read from the
CAMDAT property. The property was requested by listing *material* and *property* as the
value on a parameter record.

PROPNAM *property* NOT FOUND!! SET TO DEFAULT: *value*

This information-only message indicates that the indicated CAMDAT property was not
found on the input CAMDAT file. The property was requested by listing the material and
property as the value on a parameter record. The material or property may not be defined
on the CAMDAT file, or the property may not be defined in the indicated material. If the
property was not found, the parameter is set to the default *value* shown. This message
does not cause DRSPALL to abort, but it may indicate a problem with the input
CAMDAT file or the input control file.

ERROR: *varname=value* Outside parameter bounds, (*minval,maxval*)

This error occurs when the *varname* input parameter is outside the proscribed range. The
value for the parameter, as indicated by the input control file, is listed. The range for the
input parameter is listed in **Table 8-1**, but the *minval* to *maxval* range is the range
checked by DRSPALL. Note that the parameter name as indicated in this document may
not exactly match *varname*. Also note that some ranges listed in the table may not be
checked by DRSPALL. This error will trigger a fatal error once the ranges of all input
parameters are checked.

ERROR: Parameter Bounds Exceeded

This fatal error occurs if the range of any input parameter is outside its bounds. If this
occurs, an error message identifying the parameter(s) will precede this error message in
the output diagnostics file.

9.3 Execution Errors

The errors in this section may occur after DRSPALL has processed the input control file. Since the simulation is controlled by the input parameters, the user should inspect the input parameters if the simulation does not proceed as expected. The output diagnostics file, described in Section 10.1, contains a listing of all the input parameters.

FATAL ERROR – PROBLEM WITH OUTPUT CDB
FATAL ERROR – PROBLEM WITH DBOQAREC
FATAL ERROR – PROBLEM WITH DBOHEAD

> These fatal errors occur when the output CAMDAT file cannot be opened or written. This may occur when the user does not have write access or the disk is full.

WARN: wellgasvol=', wellgasVol(i)

> This warning message is printed when the well gas volume is less than zero.

WARNING: Viscous choking(1 or 2) at *i*

> This warning message is printed when

> (1) The well solids fraction is greater than maximum allowed, or

> (2) The viscous term is greater than the acceleration a term, usually due to oscillation in the velocity flow.

10.0 DESCRIPTION OF OUTPUT FILES

10.1 The Output Diagnostics File

The output diagnostics file contains a listing of the input control file, followed by a listing of the actual parameter values as they will be used by DRSPALL. It also lists the value of any CAMDAT property that was read from the input CAMDAT file. If the user suspects that there are problems with the input parameters, this file should be examined. The user should examine the listing of the actual parameter values, rather than the listing of the input control file.

10.2 The Output CAMDAT File

The output CAMDAT file is a binary, sequential file used by many WIPP codes. A detailed description of the CAMDAT file format is given in Chapter 7 of the *WIPP PA User's Manual for CAMDAT_LIB Version 1.22*. This document only mentions the CAMDAT entities that are specific to the DRSPALL program.

10.2.1 Output CAMDAT Materials and Mesh

DRSPALL defines a mesh on the output CAMDAT file. The mesh consists of a set of elements. Each element must be contained within a named material. ("Material" and "element block" are synonymous.) DRSPALL defines three materials that contain elements: the repository, the wellbore inside the drill pipe, and the wellbore outside the drill pipe. If a material does not contain any elements, that material may only be used to contain property values. The output CAMDAT file generated by DRSPALL copies zero-element materials (with their properties) from the input CAMDAT file, if one is specified. DRSPALL adds one 0-element material (DATAUSED) that contains the parameters as read by DRSPALL.

Table 10-1 describes the materials, with their elements, that DRSPALL defines on the output CAMDAT file.

Table 10-1 CAMDAT Materials and Elements

Material Name	Description of Material and its Elements
DATAUSED	Contains properties with parameters as read by DRSPALL.
REPOS	Contains an element for each repository cell.
DOWN_WB	Contains an element for each wellbore cell inside the drill pipe.
UP_WB	Contains an element for each wellbore cell in the annulus outside the drill pipe.
xxxxxx	Contains properties copied from input CDB where the material names *xxxxxx* are defined on the input CDB

10.2.2 Output CAMDAT Properties

Table 10-2 describes the properties that DRSPALL writes to the output CAMDAT file. The properties are all contained within the DRSPALL material. The values of the properties are copied from the appropriate DRSPALL input parameter.

If an input CAMDAT file is specified (as described in Section 7.0), the properties from the input CAMDAT file will be copied to the output CAMDAT file. All input parameters used by DRSPALL are echoed to material block DATAUSED. Input properties values contained in input material blocks remain unchanged.

Table 10-2 CAMDAT Output Properties

Property Name	DRSPALL input parameter
SURFELEV	Land elevation
REPOSTOP	Repository top
REPOSTCK	Total thickness
DRZTCK	DRZ thickness
DRZPERM	DRZ permeability
REPOTRAD	Outer radius
REPIPRES	Initial gas pressure
FFPORPRS	Far-field Pore Pressure
FFSTRESS	Far-field In-Situ Stress
REPIPOR	Repository initial porosity
REPIPERM	Repository initial permeability
FRCHBETA	Forchheimer beta
BIOTBETA	Biot beta
POISSRAT	Poisson's ratio
COHESION	Cohesion
FRICTANG	Friction angle
TENSLSTR	Tensile strength
CHARLEN	Characteristic failure length
PARTDIAM	Particle diameter
GASBSDEN	Gas base density
GASVISCO	Gas viscosity
INITMDEN	Initial mud density
MUDVISCO	Mud viscosity
PIPEROUG	Pipe roughness
ANNUROUG	Annulus roughness
MUDSOLMX	Max mud solids vol. Fraction
MUDSOLVE	Mud solids viscosity exponent
BITDIAM	Bit diameter
PIPEDIAM	Pipe diameter
COLRDIAM	Collar diameter

Property Name	DRSPALL input parameter
PIPEID	Pipe inside diameter
COLRLNGT	Collar length
EXITPLEN	Exit pipe length
EXITPDIA	Exit pipe diameter
DRILRATE	Drilling rate
BITABOV	Initial bit above repository
MUDPRATE	Mud pump rate
MAXPPRES	Mud pump pressure
DDZTHICK	DDZ thickness
DDZPERM	DDZ permeability
STPDVOLR	Stop drilling exit volume rate
STPPVOLR	Stop pumping exit volume rate
STPDTIME	Stop drilling time
REPODR	Initial repository cell length
REPODDR	Repository cell growth rate
WELLDZ	Initial wellbore cell length
WELLDDZ	Well cell growth Rate
GEOMEXP	Geometry exponent
ALLOWFLD	Fluidization flag
WELLSTAB	Well stability factor
REPOSTAB	Repository stability factor
MASSDIFF	Mass diffusion factor
MOMDIFF	Momentum diffusion factor
VALIDTC	Validation test case flag
PI	Pi
REFPRES	Atmospheric pressure
GRAVACC	Gravity
RGAS	Gas constant
TREPO	Repository temperature
H2OCOMP	Water compressibility
WASTDENS	Waste density
SALTDENS	Salt density
SHAPFAC	Shape factor
TENSVEL	Tensile velocity
BITNZNO	Bit nozzle number
BITNZDIA	Bit nozzle diameter
CHOKEFF	Choke efficiency
CAVRAD0	Initial cavity radius
MINCHVEL	Minimum characteristic velocity
MINNUMLT	Minimum number of zones per characteristic length

10.2.3 Output CAMDAT Time Steps and Variables

DRSPALL outputs information to the output CAMDAT file at sequential "time steps". Each time step contains the simulation time, in seconds, and the history variables defined by DRSPALL. A history variable has a single value for each time. Certain time steps may contain the element variables defined by DRSPALL, as well as the history variables. An element variable has a value for each element.

The time at which each time step is output is determined by DRSPALL. DRSPALL outputs a new time step when a certain period of time has passed, and when wellbore interface velocity changes by more than 20% .

Table 10-3 describes the history variables that DRSPALL writes to the output CAMDAT file.

Table 10-3 CAMDAT History Variables

	History Variable Name	Description
1	PUMPRS	Pump pressure
2	BOTPRS	Well bottom pressure
3	CAVPRS	Cavity pressure
4	DRILLRAD	Equivalent Drilled radius
5	CAVRAD	Equivalent Cavity radius
6	TENSRAD	Equivalent Tensile radius
7	CUTRAD	Maximum Equivalent Cuttings radius (constant)
8	WBSUPVEL	Waste boundary pore velocity
9	FLUIDVEL	Fluidization velocity
10	MUDEJVEL	Mud ejection velocity
11	WASWELL	Waste in Well
12	WASEJCT	Waste ejected at surface
13	CUTMASMX	Maximum Cuttings mass
14	GASINJ	Gas injected into well
15	WELLGAS	Gas in Well
16	GASEJCT	Gas ejected at surface
17	GASPOSN	Gas position in well
18	WASPOSN	Waste position in well
19	CPUTIME	CPU time
20	RUNSTEP	Run step index
21	VOLSTORE	Volume failed/drilled material in storage(released from repository but not in well)
22	GASTORE	Gas mass in temporary storage
23	WASTORE	Waste mass in temporary storage
24	WASINJ	Waste injected into well

	History Variable Name	Description
25	GASCAV	Cavity gas mass
26	SWELLGAS	Sum of well gas mass/cell
27	SREPOGAS	Sum repository gas mass/cell
28	GASTOTAL	(16)+(22)+(25)+(26)+(27)
29	GASFROMW	Total gas from waste
30	CUTMASS	Mass of cuttings
31	SPLMASS	Mass of spalled material
32	TOTMASS	Total mass of material removed
33	CUTVOLEQ	Equivalent uncompacted cuttings volume
34	SPLVOLEQ	Equivalent uncompacted spall volume
35	TOTVOLEQ	Equivalent uncompacted total volume
36	CUTRUVOL	True cuttings volume
37	CUTRUMAS	True cutting mass
38	PUMPRATE	Mud pump rate
39	SHEARRAD	Maximum radius of shear failure
40	NOZLVEL	Nozzle fluid velocity
41	WBUPVEL	Fluid velocity near well bottom
42	FLUIDTIM	Characteristic fluidization time
43	SWELLWAS	Sum well waste mass /cell
44	WASFROMR	Total waste mass from repository
45	WASTOTAL	Total waste in system (removed from repository)
46	PITGAIN	Pitgain $= \Sigma (\Delta m \, \rho - R_p \, \Delta t)$, Δm = ejected mud mass; ρ mud density; R_p= mud pump rate; Δt = time increment
47	MUDEJCT	Accumulated mud mass ejected at surface
48	SPLVOL2	Incremental equivalent uncompacted spalled volume
49	SPLMAS2	Incremental equivalent spalled mass
50	BEDDEPTH	Bed depth TENSRAD-CAVRAD
51	FORCHRAT	Forchheimer test ratio

Table 10-4 describes the element variables that DRSPALL writes to the output CAMDAT file. Each element variable is only defined for certain materials, as indicated in the "Where Variable Defined" column in the table. (The materials and elements are described in 10.2.1). Variables defined for the "Repository" are only valid for the elements in the REPOS material; variables defined for the "Wellbore" are only valid for the elements in the DOWN_WP and UP_WB materials.

Table 10-4 CAMDAT Element Variables

	Element Variable Name	Where Variable Defined	Description
1	POREPRS	Repository	Repository pressure
2	RADEFSTR	Repository	Radial effective stress
3	TANEFSTR	Repository	Tangential effective stress
4	POREVEL	Repository	Pore velocity
5	RADELSTR	Repository	Radial elastic stress
6	TANELSTR	Repository	Tangential elastic stress
7	RADSPSTR	Repository	Radial seepage stress
8	TANSPSTR	Repository	Tangential seepage stress
9	FLUDSTRT	Repository	Fluidization start time
10	FLUDSTOP	Repository	Fluidization stop time
11	FAILSTRT	Repository	Failure start time
12	SUPRVEL	Repository	Superficial velocity
13	WELLPRS	Wellbore	Pressure
14	WELLVEL	Wellbore	Mixture velocity
15	WELLGSMS	Wellbore	Gas mass
16	WELLWSMS	Wellbore	Waste mass
17	WELLRHO	Wellbore	Mixture density
18	WELLWSVF	Wellbore	Waste volume fraction
19	WELLGSVF	Wellbore	Gas volume fraction
20	WELLSAVF	Wellbore	Salt volume fraction
21	WELLWSMF	Wellbore	Waste mass fraction
22	WELLGSMF	Wellbore	Gas mass fraction
23	WELLMDMF	Wellbore	Mud mass fraction
24	WELLVOL	Wellbore	Cell volume
25	COORD	Repository, Wellbore	Repository and well coordinate positions (center of cell)

11.0 REFERENCES

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