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Management & Operating Contractor

Validation Test Report for the CRWMS Analysis and Logistics Visually Interactive Model Version 3.0

Revision 0

10074-VTR-3.0-00

July, 2000

Prepared for:

U.S. Department of Energy
Office of Civilian Radioactive Waste Management
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DISCLAIMER

Civilian Radioactive Waste Management System
Management & Operating Contractor

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EXECUTIVE SUMMARY

This report describes the tests performed to validate the *CRWMS Analysis and Logistics Visually Interactive Model* (CALVIN) Version 3.0 (V3.0) computer code (STN: 10074-3.0-00). To validate the code, a series of test cases was developed in the CALVIN V3.0 Validation Test Plan (CRWMS M&O 1999a) that exercises the principal calculation models and options of CALVIN V3.0. Twenty-five test cases were developed: 18 logistics test cases and 7 cost test cases. These cases test the features of CALVIN in a sequential manner, so that the validation of each test case is used to demonstrate the accuracy of the input to subsequent calculations. Where necessary, the test cases utilize reduced-size data tables to make the hand calculations used to verify the results more tractable, while still adequately testing the code's capabilities. Acceptance criteria were established for the logistics and cost test cases in the Validation Test Plan (CRWMS M&O 1999a).

The Logistics test cases were developed to test the following CALVIN calculation models:

- Spent nuclear fuel (SNF) heat and reactivity calculations
- Options for altering reactor life
- Adjustment of commercial SNF (CSNF) acceptance rates for fiscal year calculations and mid-year acceptance start
- Fuel selection, transportation cask loading, and shipping to the Monitored Geologic Repository (MGR)
- Transportation cask shipping to and storage at an Interim Storage Facility (ISF)
- Reactor pool allocation options
- Disposal options at the MGR.

Two types of cost test cases were developed: cases to validate the detailed transportation costs, and cases to validate the costs associated with the Civilian Radioactive Waste Management System (CRWMS) Management and Operating Contractor (M&O) and Regional Servicing Contractors (RSCs).

For each test case, values calculated using Microsoft Excel 97 worksheets were compared to CALVIN V3.0 scenarios with the same input data and assumptions. All of the test case results compare with the CALVIN V3.0 results within the bounds of the acceptance criteria. Therefore, it is concluded that the CALVIN V3.0 calculation models and options tested in this report are validated.

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TABLES

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ACRONYMS AND ABBRVIATIONS

ACRONYMS

BWR	Boiling Water Reactor
CALVIN	CRWMS Analysis and Logistics Visually Interactive Model
CD	Compact Disk
CSNF	Commercial Spent Nuclear Fuel
DOE SNF	Department of Energy-Owned Spent Nuclear Fuel
HH	Heavy Haul
HLW	High-Level Radioactive Waste
ISF	Interim Storage Facility
ISFSI	Interim Spent Fuel Storage Installation
M&O	Management and Operating Contractor
MGR	Monitored Geologic Repository
MOX	Mixed Oxide
OCRWM	Office of Civilian Radioactive Waste Management
OFF	Oldest Fuel First
PWR	Pressurized Water Reactor
QARD	Quality Assurance and Requirements Description
RSC	Regional Servicing Contractor
RTDA	Reference Transportation Data and Assumptions
SS	Stainless Steel
TSLCC	Total System Life Cycle Cost
WAST	Waste Acceptance, Storage, and Transportation
WP	Waste Package
YFF	Youngest Fuel First

ABBREVIATIONS

GWD/MT	Gigawatt-Days per Metric Ton
k_∞	K - Infinity
k_{eff}	K - Effective
MWD/MT	Megawatt-Days per Metric Ton
MTHM	Metric Tons of Heavy Metal
MTU	Metric Tons of Uranium

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1. INTRODUCTION

1.1 PURPOSE AND SCOPE

The purpose of this report is to describe the tests performed to validate the *CRWMS Analysis and Logistics Visually Interactive Model* (CALVIN) Version 3.0 (V3.0) computer code (STN: 10074-3.0-00). CALVIN V3.0 was developed internally by the CRWMS Management and Operating Contractor (M&O); consequently, there are no test cases provided by a "supplier." To validate the code, a series of test cases was developed in the *Validation Test Plan for the CRWMS Analysis and Logistics Visually Interactive Model* (CRWMS M&O 1999a) that exercises the principal calculation models and options of CALVIN V3.0. Two general types of test cases have been developed: logistics test cases and cost test cases. These cases test the features of CALVIN in a sequential manner, so that the validation of each test case is used to demonstrate the accuracy of the input to subsequent calculations. Where necessary, the test cases utilize reduced-size data tables to make the hand calculations used to verify the results more tractable, while still adequately testing the code's capabilities.

Acceptance criteria were established for the logistics and cost test cases in the Validation Test Plan (CRWMS M&O 1999a). For logistics results of an integer nature (e.g., number of casks shipped by site per year), the test case and validation results must agree exactly. For heat and criticality calculations and all cost calculations, agreement must be within 1 percent.

A full description of CALVIN V3.0 can be found in the *CALVIN Version 3.0 User Manual* (CRWMS M&O 2000).

1.2 DOCUMENT STRUCTURE

This report is structured as follows:

Section 1 - Introduction and Scope.

Section 2 - Description of Validation Test Cases. This section describes each test case, including the input data used in the CALVIN runs and the validation calculations performed.

Section 3 - Results of Validation Calculations. This section describes the results of the validation calculations for each test case, including a comparison to the CALVIN V3.0 results.

Section 4 - Conclusions.

Section 5 - References.

1.3 QUALITY ASSURANCE

In accordance with the Validation Test Plan (CRWMS M&O 1999a), the requirements of the OCRWM *Quality Assurance Requirements and Description* (QARD) (DOE 2000) have been determined not to apply to this report. However, this document was developed in accordance with the process described in AP-SI.1Q, Revision 2, ICN 4, *Software Management*.

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2. DESCRIPTION OF VALIDATION TEST CASES

2.1 LOGISTICS TEST CASES

Logistics test cases were developed to test the following CALVIN calculations:

- SNF heat and reactivity calculations
- Options for altering reactor life
- Adjustment of CSNF acceptance rates for fiscal year calculations and mid-year acceptance start
- Fuel selection, transportation cask loading, and shipping to the MGR
- Transportation cask shipping to and storage at an ISF
- Reactor pool allocation options
- Disposal options at the MGR.

2.1.1 SNF Heat and Reactivity Calculations

CALVIN heat and reactivity calculations for CSNF were validated separately from the other logistics calculations, since they are used every time a transportation cask or waste package is loaded. The heat calculation (Test Case 1) was validated by accessing the Visual Basic coding of CALVIN V3.0, and using the Debug feature to set a "break point" at the location in the code where the heat calculation is performed. The code was then executed from Visual Basic, and the "Immediate Window" was used to manually input combinations of enrichment, burnup, and age for each fuel type (pressurized water reactor [PWR], boiling water reactor [BWR], PWR with stainless steel [SS] cladding, BWR with SS cladding, and PWR mixed oxide [MOX]). A "Debug.print" statement was temporarily added to the code to print out the results in the "Immediate Window" on the screen. These results were then validated by manual calculations. The temporary modifications made to the CALVIN V3.0 coding are shown in Appendix A. Table 2-1 shows the input values used for the heat calculation validation (Test Case 1).

Table 2-1. Test Case 1 Validation Inputs

Fuel Type	Burnup (GWD/MT)	Enrichment (%)	Age (years)
BWR	11	3.4	10
BWR	35	4.2	8

Table 2-1. Test Case 1 Validation Inputs (Continued)

Fuel Type	Burnup (GWD/MT)	Enrichment (%)	Age (years)
BWR	0.1	1.2	3.5
PWR	42	4.7	12
PWR	70	5.3	29
PWR	1.3	2.9	125
BWR-SS	32	3.1	17
PWR-SS	18	3.7	33
PWR-MOX	57	4.8	15
PWR-MOX	46	4.3	23

The transportation cask burnup-enrichment (B-E) curve calculation (Test Case 2) was validated by selecting three of the B-E curves included in the "B-E Curve" database table, calculating the burnup as a function of enrichment by hand, and comparing the results to those calculated by CAVLIN V3.0. As in the previous case, a "Debug.print" statement was temporarily added to the code to print out the results in the "Immediate Window" on the screen, and break points were added to the code to allow the input of the test data. The temporary modifications made to the CALVIN V3.0 coding are shown in Appendix A. Table 2-2 shows the input enrichment values for the validation calculations (Test Case 2).

Table 2-2. Test Case 2 Validation Input Values

Curve Number	Enrichment (%)
1	2.9
1	3.33
1	4.3
1	4.85
2	1.5[a]
2	3.45
2	3.8
2	4.3
2	4.95
5	2.45
5	3.35
5	3.8
5	4.62
5	6.0[a]

[a] These values are beyond the range of the B-E curve, and it is expected that CALVIN will skip the B-E calculation in these cases.

A similar approach was taken for the criticality calculations (Test Case 3). The temporary modifications made to the CALVIN V3.0 coding are shown in Appendix A. Since CALVIN V3.0 will calculate either "k_∞" or "k_{eff}" for a cask, depending on the values of the coefficients in the "K-Coeff" database table, both types of calculations were performed. Table 2-3 shows the input values used in the criticality validation. The last two cases are set up to test the burnup lower limit (5 GWD/MT) and the age upper limit (40 years) in the k_∞ calculation "K-Coeff" database table. CALVIN V3.0 should set the 4 GWD/MT value to 5 and the 50 years to 40 before it calculates k_∞. The constants for the criticality equation were then copied from the "K-Coeff" database table into an EXCEL file, and the values of k_∞ and k_{eff} were calculated manually. Note that the criticality equation was copied from Appendix A of the CALVIN Version 3.0 User Manual (CRWMS M&O 2000).

Table 2-3. Test Case 3 Validation Input Values

Fuel Type	Curve Number	Criticality Coeff	Burnup (GWD/MT)	Enrichment (%)	Age (Years)
BWR	1001	k_∞	45	4.1	25
PWR	1002	k_∞	30	3.5	10
BWR	1003	k_{eff}	38	3.8	15
PWR	1004	k_{eff}	46	4.5	7
BWR	1001	k_∞	4	3.5	10
PWR	1002	k_∞	40	4.0	50

2.1.2 Options for Altering Reactor Life

Test Cases 4 and 5 were designed to test the early reactor shutdown and maximum reactor life options on the "Utility Options" screen. These test cases utilize a simplified database with a limited number of reactor sites/pools and limited fuel source data.

Table 2-4 shows the reactor sites used in Test Cases 4 and 5. Table 2-5 shows the reactor pool data, and Table 2-6 shows the CSNF fuel data. Table 2-7 shows the data for the transportation, storage, and disposal casks, and Table 2-8 shows the modal assumptions for the pools and storage/disposal sites. Tables 2-4 through 2-7 were extracted from data tables "RX_INFO_VTP," "POOL_INFO_VTP," "Fuel VTP," and "CASK_VTP" in the "Work99VTP" database. However, only the data pertaining to the validation calculations is shown in each table below (for example, some fields in the data tables are not currently used by CALVIN).

Table 2-4. Test Cases 4 - 5 Reactor Data

CALVIN Rx No.	EIA No.	Reactor Name	SNF Length (in.)	Fuel Design Type	Reactor Type	Fuel Type[a]	Preferred Pool
4	1601	BEAVER VALLEY 1	168.8	WE-17	PWR	1	5
27	1701	CRYSTAL RVR 3	173.5	B&W-15	PWR	1	25
118	1803	TURKEY PT 3	166.9	WE-15	PWR	1	104
139	7001	SAVANNAH RIV-HLW	0	NA	HLW	2	125
156	7007	Group 1-Hanford	180	NA	DOE	3	150

[a] Fuel Type = 0 (BWR); 1 (PWR); 2 High-Level Waste (HLW); 3 U.S. Department of Energy (DOE) SNF

Table 2-5. Test Cases 4 - 5 Pool Data

CALVIN Pool	EIA No.	E/W[a]	Pool Name	Capacity	Full Core Reserve	Site ID	Utility ID	Type[b]	Main Pool
5	1601	E	BEAVER VALLEY 1	1615	157	1	16	1	5
25	1701	E	CRYSTAL RVR 3	1357	177	2	17	1	25
104	1803	E	TURKEY PT 3	435	157	3	18	1	104
125	7001	E	SRS-HLW	9999	0	6	70	2	125
127	7050	W	ISF1-Bare B	9999	0	4	70	0	127
128	7051	W	ISF1-Bare P	9999	0	4	70	1	128
129	7052	W	ISF1-HLW	9999	0	4	70	2	129
130	7052	W	ISF1-DOE	9999	0	4	70	3	130
131	7054	W	MGR1-Bare B	9999	0	5	70	0	131
132	7055	W	MGR1-Bare P	9999	0	5	70	1	132
133	7056	W	MGR1-HLW	9999	0	5	70	2	133
134	7057	W	MGR1-DOE	9999	0	5	70	3	134
150	7007	W	Group 1-Hanford	9999	0	7	70	3	150

[a] E = eastern U.S.; W = western U.S.
[b] Type = 0 (BWR); 1 (PWR); 2 (HLW); 3 (DOE SNF)

Table 2-6. Test Cases 4 - 5 Fuel Data

Batch ID	CALVIN Rx ID	MTU	No. Assm.	Burnup (MWD/MT)	Enrichment (%)	Discharge Date	Pool ID	Dry Year
1	27	30.147	65	28745	2.834	9/28/86	1701	1997
2	4	24.373	53	27891	2.605	12/26/86	1601	1997

Table 2-6. Test Cases 4 - 5 Fuel Data (Continued)

Batch ID	CALVIN Rx ID	MTU	No. Assm.	Burnup (MWD/MT)	Enrichment (%)	Discharge Date	Pool ID	Dry Year
3	118	27.931	61	37000	3.404	3/15/87	1803	0
4	4	33.707	73	32000	3.248	12/11/87	1601	1997
5	27	33.836	73	39000	3.495	3/14/90	1701	0
6	118	23.972	52	46000	3.4	4/4/94	1803	0
7	27	33.382	72	45000	3.94	2/29/96	1701	0
8	118	24.894	54	53000	4	9/15/98	1803	0
9	4	29.691	64	47000	3.73	3/7/02	1601	0
10	118	20.745	45	52520	4	4/15/03	1803	0
11	27	30.136	65	46000	4.2	3/1/04	1701	0
12	118	21.206	46	54111	4	10/21/07	1803	0
13	4	28.299	61	48000	3.73	2/4/08	1601	0
14	27	28.282	61	47000	4.2	3/2/10	1701	0
15	118	19.394	42	52231	4.24	10/15/10	1803	0
16	4	28.299	61	49000	3.73	1/19/11	1601	0
17	4	72.848	157	48611	3.73	1/29/12	1601	0
18	118	72.377	157	49380	4	7/19/12	1803	0
19	27	82.062	177	47911	3.94	12/3/12	1701	0

Table 2-7. Test Cases 4-5 Cask Parameters

Cask No.	Cask Name	Base Cask	Base Cask Name	Mode	Type	Use Can Line	Dry Ovpk	Tran Ovpk	Disp Ovpk	Capacity	Codisposable	B-E Curve
1	B-T-9/9-SP	1	B-LWT-GA9	T	B	FALSE	0	0	0	9	0	
2	B-T-9/7-SP	1	N/A	T	B	FALSE	0	0	0	7	0	
3	B-T-9/5-SP	1	N/A	T	B	FALSE	0	0	0	5	0	
4	B-T-9/4-SP	1	N/A	T	B	FALSE	0	0	0	4	0	
5	B-T-9/2-SP	1	N/A	T	B	FALSE	0	0	0	2	0	
6	P-T-4/4-SP	6	P-LWT-GA4	T	P	FALSE	0	0	0	4	0	
7	P-T-4/3-SP	6	N/A	T	P	FALSE	0	0	0	3	0	
8	P-T-4/2-SP	6	N/A	T	P	FALSE	0	0	0	2	0	
12	P-T-1-SP	12	P-LWT-NAC	T	P	FALSE	0	0	0	1	0	
21	B-R-68-SP	21	Large Rail	R	B	FALSE	0	0	0	68	0	
22	P-R-24-SP	21	N/A	R	P	FALSE	0	0	0	24	0	
23	B-R-44-SP	23	Medium Rail	R	B	FALSE	0	0	0	44	0	
24	P-R-21-SP	23	N/A	R	P	FALSE	0	0	0	21	0	
25	B-R-32-SP	25	Small Rail	R	B	FALSE	0	0	0	32	0	
26	P-R-12-SP	25	N/A	R	P	FALSE	0	0	0	12	0	
27	B-R-32-SP-HH	27	Med HH Rail	R	B	FALSE	0	0	0	32	0	
28	P-R-12-SP-HH	27	N/A	R	P	FALSE	0	0	0	12	0	
35	H-R-5-SP	35	HLW-Rail	R	H	TRUE	0	0	0	5	0	
37	D-R-4-SP-Grp1	37	DOE Rail-4 Can	R	X	TRUE	0	0	0	4	0	
106	B-S-NUH68-SP	106	N/A	S	B	FALSE	0	0	0	68	0	
107	P-S-NUH24-SP	107	N/A	S	P	FALSE	0	0	0	24	0	
200	B-C-68-ST	200	N/A	M	B	FALSE	201	202	0	68	0	
201	B-S-68-OV	201	N/A	S	B	FALSE	0	0	0	68	0	
202	B-R-68-OV	21	N/A	R	B	FALSE	0	0	0	68	0	
203	P-C-24-ST	203	N/A	M	P	FALSE	204	205	0	24	0	
204	P-S-24-OV	204	N/A	S	P	FALSE	0	0	0	24	0	
205	P-R-24-OV	21	N/A	R	P	FALSE	0	0	0	24	0	
311	H-E-5-CO	311	N/A	S	H	TRUE	0	0	0	5	313	0
313	D-E-1-CO	313	N/A	S	X	TRUE	0	0	0	1	311	0
319	D-E-4-SP-Grp1	319	N/A	S	X	TRUE	0	0	0	4	0	
342	H-E-5-SP	342	N/A	S	H	TRUE	0	0	0	5	0	
350	B-E-44-SP-K1.0NH	350	N/A	S	B	FALSE	0	0	0	44	0	1003
351	P-E-21-SP-K1.0NH	351	N/A	S	P	FALSE	0	0	0	21	0	1004
352	B-E-44-SP-K1.37NH	352	N/A	S	B	FALSE	0	0	0	44	0	1003
353	P-E-21-SP-K1.13NH	353	N/A	S	P	FALSE	0	0	0	21	0	1004

Table 2-7. Test Cases 4 - 5 Cask Parameters (Continued)

Cask No.	Cask Name	Cask heat (w)	Assem heat (w)	Cavity Length (in)	Loaded Weight (lb)	Empty Weight (lb)	RX Outer (min)	RX Inner (min)	ISF Outer (min)	ISF Inner (min)	ISF Cell (min)	MGR Outer (min)
1	B-T-9/9-SP	2121	235	200	53666	47321	1488	0	1248	0	600	1193
2	B-T-9/7-SP	2121	303	200	53666	47321	1488	0	1248	0	600	1193
3	B-T-9/5-SP	2030	406	200	53666	47321	1488	0	1248	0	600	1193
4	B-T-9/4-SP	2121	530	200	53666	47321	1488	0	1248	0	600	1193
5	B-T-9/2-SP	1460	730	200	53666	47321	1488	0	1248	0	600	1193
6	P-T-4/4-SP	2468	617	200	53661	47901	1488	0	1248	0	600	1193
7	P-T-4/3-SP	2220	740	200	53661	47901	1488	0	1248	0	600	1193
8	P-T-4/2-SP	2468	1234	200	53661	47901	1488	0	1248	0	600	1193
12	P-T-1-SP	2500	2500	200	51200	49730	1488	0	1248	0	600	1193
21	B-R-68-SP	16184	238	200	250000	202400	2259	0	1698	0	1560	1234
22	P-R-24-SP	16944	706	200	250000	209680	2259	0	1698	0	1560	1234
23	B-R-44-SP	20500	466	200	200000	169200	2259	0	1698	0	1560	1234
24	P-R-21-SP	21000	1000	200	200000	164720	2259	0	1698	0	1560	1234
25	B-R-32-SP	14912	466	200	150000	127600	2259	0	1698	0	1560	1234
26	P-R-12-SP	12000	1000	200	150000	129840	2259	0	1698	0	1560	1234
27	B-R-32-SP-HH	76800	2400	200	200000	177600	2259	0	1698	0	1560	1234
28	P-R-12-SP-HH	72000	6000	200	200000	179840	2259	0	1698	0	1560	1234
35	H-R-5-SP			200	229160	205160	930	0	0	0	0	855
37	D-R-4-SP-Grp1	0	0	0	200000	200000	2259	0	1698	0	1560	1234
106	B-S-NUH68-SP			200	0	0	3585	0	0	0	0	1
107	P-S-NUH24-SP			200	0	0	3585	0	0	0	0	1
200	B-C-68-ST	0		200	0	0	1944	663	0	0	0	1
201	B-S-68-OV	16184		200	0	0	642	0	0	0	0	1
202	B-R-68-OV	16184	238	200	244000	201200	642	0	1932	0	1794	1273
203	P-C-24-ST	0		200	0	0	1944	663	0	0	0	1
204	P-S-24-OV	16944		200	0	0	642	0	0	0	0	1
205	P-R-24-OV	16944	706	200	238800	199000	642	0	1932	0	1794	1273
311	H-E-5-CO	0	0	200	0	0	930	0	0	0	0	855
313	D-E-1-CO	0	0	180	0	0	930	0	0	0	0	0
319	D-E-4-SP-Grp1	0	0	180	0	0	0	0	0	0	0	1234
342	H-E-5-SP	0	0	200	0	0	930	0	0	0	0	855
350	B-E-44-SP-K1.0NH	17600		200	0	0	0	0	0	0	0	1234
351	P-E-21-SP-K1.0NH	17850		200	0	0	0	0	0	0	0	1234
352	B-E-44-SP-K1.37NH	17600		200	0	0	0	0	0	0	0	1234
353	P-E-21-SP-K1.13NH	17850		200	0	0	0	0	0	0	0	1234

Table 2-7. Test Cases 4 - 5 Cask Parameters (Continued)

Cask No.	Cask Name	MGR Inner (min)	MGR Cell (min)	Cask Life (yr)	Utilization (d/yr)	Cost ($M)	Maint Cost ($M/yr)	Repl Cost ($M)	Reusable	K_Inf	OWT FLAG	MOX	Min Drift Length (m)
1	B-T-9/9-SP	1	600	25	300	2.2	0.087	0.57	TRUE	0	FALSE	FALSE	
2	B-T-9/7-SP	1	600	25	300	2.2	0.087	0.57	TRUE	0	FALSE	FALSE	
3	B-T-9/5-SP	1	600	25	300	2.2	0.087	0.57	TRUE	0	FALSE	FALSE	
4	B-T-9/4-SP	1	600	25	300	2.2	0.087	0.57	TRUE	0	FALSE	FALSE	
5	B-T-9/2-SP	1	600	25	300	2.2	0.087	0.57	TRUE	0	FALSE	FALSE	
6	P-T-4/4-SP	1	600	25	300	2.1	0.087	0.4	TRUE	0	FALSE	FALSE	
7	P-T-4/3-SP	1	600	25	300	2.1	0.087	0.4	TRUE	0	FALSE	FALSE	
8	P-T-4/2-SP	1	600	25	300	2.1	0.087	0.4	TRUE	0	FALSE	FALSE	
12	P-T-1-SP	1	600	25	300	1.2	0.087	0.21	TRUE	0	FALSE	FALSE	
21	B-R-68-SP	1	1096	25	270	3.3	0.087	0.51	TRUE	0	FALSE	FALSE	
22	P-R-24-SP	1	1096	25	270	3.3	0.087	0.51	TRUE	0	FALSE	FALSE	
23	B-R-44-SP	1	1096	25	270	2.9	0.083	0.43	TRUE	0	FALSE	FALSE	
24	P-R-21-SP	1	1096	25	270	2.9	0.083	0.43	TRUE	0	FALSE	FALSE	
25	B-R-32-SP	1	1096	25	270	2.8	0.083	0.13	TRUE	0	FALSE	FALSE	
26	P-R-12-SP	1	1096	25	270	2.8	0.083	0.13	TRUE	0	FALSE	FALSE	
27	B-R-32-SP-HH	1	1096	25	270	2.9	0.083	0.13	TRUE	0	FALSE	FALSE	
28	P-R-12-SP-HH	1	1096	25	270	2.9	0.083	0.13	TRUE	0	FALSE	FALSE	
35	H-R-5-SP	1	423	40	255	3.5	0.087	0.35	TRUE	0	FALSE	FALSE	
37	D-R-4-SP-Grp1	1	1096	25	270	4.4	0.087	0.53	TRUE	0	FALSE	FALSE	
106	B-S-NUH68-SP	1	1	25	365	0.45	0	0	FALSE	0	FALSE	FALSE	
107	P-S-NUH24-SP	1	1	25	365	0.4	0	0	FALSE	0	FALSE	FALSE	
200	B-C-68-ST	1	1	25	365	0.6	0		FALSE	0	FALSE	FALSE	
201	B-S-68-OV	1	1	25	365	0.3			TRUE	0	FALSE	FALSE	
202	B-R-68-OV	1	1136	25	270	2.8	0.087	0	TRUE	0	FALSE	FALSE	
203	P-C-24-ST	1	1	25	365	0.5			FALSE	0	FALSE	FALSE	
204	P-S-24-OV	1	1	25	365	0.3			TRUE	0	FALSE	FALSE	
205	P-R-24-OV	1	1136	25	270	2.8	0.087	0	TRUE	0	FALSE	FALSE	
311	H-E-5-CO	1	423	25	365	0		0	FALSE	0	FALSE	FALSE	5.085
313	D-E-1-CO	1	0	25	365	0.29		0	FALSE	0	FALSE	FALSE	5.085
319	D-E-4-SP-Grp1	1	1096	25	365	0.3061858		0	FALSE	0	FALSE	FALSE	5.085
342	H-E-5-SP	1	423	25	365	0.2862745			FALSE	0	FALSE	FALSE	3.89
350	B-E-44-SP-K1.0NH	1	1096	25	365	0.3088235			FALSE	1	FALSE	FALSE	5.435
351	P-E-21-SP-K1.0NH	1	1096	25	365	0.3339978			FALSE	1	FALSE	FALSE	5.435
352	B-E-44-SP-K1.37NH	1	1096	25	365	0.4696078			FALSE	1.37	FALSE	FALSE	5.435
353	P-E-21-SP-K1.13NH	1	1096	25	365	0.3844729			FALSE	1.13	FALSE	FALSE	5.435

Table 2-8. Test Cases 4 - 5 Modal Assumptions

Pool No	Pool Name	Modal	Modal No	Priority 0 Cask	Priority 1 Cask	Priority 2 Cask	Priority 3 Cask
Transportation Modals							
1601	BEAVER VALLEY 1	P-125-R	8	P-R-24-SP	P-R-12-SP-HH	N/A	N/A
1701	CRYSTAL RVR 3	P-LWT	2	P-T-4/4-SP	P-T-4/3-SP	P-T-4/2-SP	P-T-1-SP
1803	TURKEY PT 3	P-100-R	6	P-R-21-SP	P-R-12-SP-HH	N/A	N/A
7001	SRS-HLW	HLW	21	H-R-5-SP	N/A	N/A	N/A
7050	ISF1-Bare B	B-ISF	3	B-R-68-SP	B-R-32-SP-HH	N/A	N/A
7051	ISF1-Bare P	P-ISF	4	P-R-24-SP	P-R-12-SP-HH	N/A	N/A
7007	Group 1-Hanford	Group 1	27	D-R-4-SP-Grp1	N/A	N/A	N/A
Dry/Emplace Modals							
1601	BEAVER VALLEY 1	P-125	8	P-C-24-ST	N/A	N/A	N/A
1701	CRYSTAL RVR 3	P-LWT	2	P-C-24-ST	N/A	N/A	N/A
1803	TURKEY PT 3	P-100	6	P-C-24-ST	N/A	N/A	N/A
7050	ISF1-Bare B	B-ISF	40	B-S-NUH68-SP	N/A	N/A	N/A
7051	ISF1-Bare P	P-ISF	41	P-S-NUH24-SP	N/A	N/A	N/A
7054	MGR1-Bare B	B-MGR	44	B-E-44-SP-K1.0NH	B-E-44-SP-K1.37NH	N/A	N/A
7055	MGR1-Bare P	P-MGR	45	P-E-21-SP-K1.0NH	P-E-21-SP-K1.13NH	N/A	N/A
7056	MGR1-HLW	H-MGR	46	H-E-5-SP	N/A	N/A	N/A
7057	MGR1-DOE	D-MGR	47	D-E-4-SP-Grp1	N/A	N/A	N/A

Table 2-9 shows the acceptance rates for CSNF, HLW, and DOE SNF assumed in Test Cases 4 and 5. Table 2-10 shows the remaining input assumptions. Note that the RSC options are not shown, since no RSC cost calculations are performed in these cases.

Table 2-9. Test Cases 4 - 5 CSNF, HLW, and DOE SNF Acceptance Rates

Year	CSNF Acceptance Rate (MTHM)	HLW Receipt Rate (MT)	DOE SNF Receipt Rate (Can)
2010	400	0	20
2011	600	0	40
2012	1200	0	40
2013	2000	0	40
2014	3000	0	40
2015	3000	27.5	40
2016	3000	37.5	40
2017	3000	75	40

Table 2-10. Test Cases 4 - 5 Input Assumptions

Parameter	Test Case 4	Test Case 5
General Options		
Calendar or Fiscal Year	Fiscal Year	Fiscal Year
180(c) Model	RTDA Model	RTDA Model
RSC/WAST Calculation	No	No
Reactor Options		
Shifts/Day	2	2
Days/Week	5	5
Hours/Shift	6	6
Holidays	10	10
ISF Options		
No ISF		
MGR Options		
Calculate Number of Cells	No	No
Bare Cells	3	3
Canistered Cells	2	2
Shifts/Day	3	3
Days/Week	5	5
Hours/Shift	6	6
Holidays	11	11
Latitude	36.859	36.859
Longitude	116.474	116.474
Co-Dispose	Yes	Yes
Limit Rounding	Yes	Yes
Fuel Blending	No	No
PWR Basket Size	N/A	N/A
BWR Basket Size	N/A	N/A
Waste Package (WP) Upper Heat Limit (Watts)	N/A	N/A
PWR WP Lower Heat Limit (Watts)	N/A	N/A
Cask Unloads Before Blending	N/A	N/A
PWR Cold Assemblies Set Aside	N/A	N/A
Transportation Options		
From Reactor		
Dedicated Train	General Rail	General Rail
Unit Train Size	1	1
Return Train Size	1	1

Table 2-10. Test Case 4 - 5 Assumptions (Continued)

Parameter	Test Case 4	Test Case 5
Fleet Purchase Size	1	1
From ISF		
Dedicated Train	N/A	N/A
Unit Train Size	N/A	N/A
Return Train Size	N/A	N/A
HLW/DOE SNF		
Dedicated Train	General Rail	General Rail
Unit Train Size	1	1
Return Train Size	1	1
MGR Heavy Haul (HH) Days	2	2
MGR Rail Spur	Yes	Yes
Year Avail	2010	2010
Regions	5	5
Rail Algorithm	98 Update	98 Update
Negotiation Factor (%)	60	60
Buffer Car Unit Cost ($M)	0.05	0.05
Personnel Car Unit Cost ($M)	0.25	0.25
Cask Contingency Factor (%)	25	25
Operations Contingency Factor (%)	15	15
Utility Options		
Pool Selection	OFF[a] only	OFF[a] only
Years Early/Max. Reactor Life	5	20
Unload Shutdown	Yes	Yes
Unload Shutdown Years	5	5
Earliest Unload Year	1998	1998
Min. Years (Unload - final pickup)	0	0
Fuel Options		
Fuel Selection	YFF10[b]	YFF10[b]
Strict YFF	N/A	N/A
Age to Switch to dry	5	5
Defer Dry-By Failed Cask	No	No
Number of failed casks	N/A	N/A
Minimum Fuel Age	5	5
Ignore Cask Limits	No	No
Utility Operating Costs ($M)		

Table 2-10. Test Cases 4 - 5 Assumptions (Continued)

Parameter	Test Case 4	Test Case 5
ISFSI[c] Construction Cost	10.16	10.16
ISFSI[c] Operating Cost	0.762	0.762
ISFSI[c] Operating Cost (shutdown)	4.064	4.064
Pool Operating Cost (shutdown)	8.128	8.128
Cost Per MTU	0.1016	0.1016
Transportation Cost ($)		
Satellite Transmissions	5.62E-02	5.62E-02
Barge Cost/Day	4871.592	4871.592
HH Crane Cost/Day	2165.151	2165.151
HH Labor Cost/Day	2165.151	2165.151
HH Tractor Cost/Day	1082.576	1082.576
Truck Loading Cost	8313.491	8313.491
CSNF Rail Loading Cost	31067.31	31067.31
HLW/DOE Rail Loading Cost	14908.1	14908.1
Min 2nd Driver Charge	169.2716	169.2716
2nd Driver Charge/Mile	0.3526491	0.3526491
Truck Security/Mile	5.219207	5.219207
Truck C180/State	1000	1000
Rail Security/Mile	0.2164924	0.2164924
Rail Security/Day	290.0999	290.0999
Rail Security Escorts	6	6
Rail C180/State	2000	2000
Waste Acceptance		
CSNF Acceptance - Begin	Apr-10	Apr-10
HLW Acceptance - Begin	Jan-10	Jan-10

[a] OFF = Oldest Fuel First
[b] YFF10 = Youngest Fuel First (YFF) Less Than 10 Years Old
[c] ISFSI = Independent Spent Fuel Storage Installation

The early reactor shutdown test case (4) was modeled by setting the "Early Reactor Shutdown Years" parameter in the "Utility Options" screen to 5. This has the effect of cutting off the last 5 years of fuel discharges from all three reactors. The maximum reactor shutdown test case (5) was modeled by setting the "Maximum Rx Life" parameter to 20 (years). This has the effect of cutting off all discharges from the three reactors that take place more than 20 years after the first discharge. The annual fuel shipments predicted by CALVIN V3.0 were then compared to hand calculations.

2.1.3 CSNF Acceptance Rate Adjustments

Test Case 6 was designed to test the adjustment of CSNF acceptance rates for mid-year acceptance start and fiscal year calculations. Test Case 4 (see Section 2.1.2) was used as a basis for this case; the acceptance start month and calendar/fiscal year option were varied to produce the output for comparison to the test case. As in Test Cases 1 through 3, a "Debug.print" statement was temporarily added to the code to print out the input acceptance rates and adjusted acceptance rates for each year in the "Immediate Window" on the screen. These results were then compared to hand calculations. Table 2-11 shows the Test Case 6 validation input values. Note that this test case was not included in the Validation Test Plan (CRWMS M&O 1999a).

Table 2-11. Test Case 6 Validation Input Values

Calendar or Fiscal Year	Start Month
Calendar	April
Calendar	October
Fiscal	April
Fiscal	October

2.1.4 Fuel Selection, Cask Loading, and Shipping

Four test cases have been selected to test the fuel selection, cask loading, and shipping functions in CALVIN V3.0. Three of these cases (7 through 9) vary the fuel selection method at the reactor pools, while Test Case 10 adds shipping to an ISF in addition to the MGR. Test Case 10 also tests the use of the transportation cask burnup-enrichment (B-E) curve option; the "Cask_VTP2" data table is used for this case, which differs from the "Cask_VTP" data table only in that the "B-E Curve" for the "P-R-21-SP" cask is set to "7" (a made-up curve for this case). Note that in the Validation Test Plan (CRWMS M&O 1999a), this B-E curve is identified as curve "6," which is one of the standard curves already in the data table. A new curve had to be made up for Test Case 10 in order to match the fuel input data. Table 2-12 shows the key assumptions for these cases, including the values for the B-E Curve in Test Case 10, and Table 2-13 shows the fuel acceptance rates for Test Case 10.

Table 2-12. Test Cases 7 - 10 Assumptions

Parameter	Test Case 7	Test Case 8	Test Case 9	Test Case 10
Pool Allocation Method[a]	OFF	OFF	OFF	OFF
Fuel Selection Method[b]	OFF	YFF10	Strict YFF10	YFF10
Shipping Destination	MGR	MGR	MGR	ISF and MGR
Transportation Cask B-E Curve (#7)				
35,000 MWD/MT	N/A	N/A	N/A	3 %
40,000 MWD/MT	N/A	N/A	N/A	3.2 %

Table 2-12. Test Cases 7 - 10 Assumptions (Continued)

Parameter	Test Case 7	Test Case 8	Test Case 9	Test Case 10
45,000 MWD/MT	N/A	N/A	N/A	3.5 %
55,000 MWD/MT	N/A	N/A	N/A	4 %
60,000 MWD/MT	N/A	N/A	N/A	4.5 %
65,000 MWD/MT	N/A	N/A	N/A	5 %

[a] OFF = oldest fuel first
[b] YFF10 = youngest fuel first >= 10 years old; Strict YFF10 = YFF >= 10 years old in strict age order

Table 2-13. Test Case 10 CSNF Acceptance Rates

Year	Acceptance Rate (MTHM/year)	To ISF (MTHM/year)	To MGR (MTHM/year)
2010	200	90	110
2011	600	0	600
2012	1200	0	1200
2013	2000	0	2000
2014	3000	0	3000
2015	3000	0	3000
2016	3000	0	3000
2017	3000	0	3000

The remaining input assumptions and data tables used in these test cases (including HLW and DOE SNF acceptance rates) are identical to those used in Test Cases 4 and 5.

2.1.5 Reactor Pool Allocation Options

Four test cases have been developed to validate the reactor pool allocation functions in CALVIN V3.0. These cases test the use of the overflow priority and shutdown priority options in the "Fuel Selection/Waste Acceptance Options" menu. Test Case 11 turns on the overflow priority feature by checking the "Overflow" box in the "Global Fuel Selection" section. Test Case 12 turns on the shutdown priority feature by checking the "Shutdown" box. Test Case 13 turns on both features, selecting the overflow priority as "1" and the shutdown priority as "2." Test Case 14 selects the shutdown priority as "1" and the overflow priority as "2." In addition, Test Case 14 turns off the "Unload Fuel Post Shutdown" option. For these cases, an additional priority acceptance rate of 20 MTU/year is assumed. Table 2-14 summarizes these test case assumptions.

Note that these test cases are somewhat different than those postulated in the Validation Test Plan (CRWMS M&O 1999a). Test Case 10 in the Validation Test Plan was deleted, since the global pool selection option in that test case was the same as in Test Cases 7 through 10 above. In addition, a new test case (14) was included in this report to test the "Shutdown + Overflow" option. The CSNF acceptance rates were also modified to allow the remaining global pool selection options to be clearly demonstrated.

Table 2-14. Test Cases 11 - 14 Assumptions

	Test Case 11	**Test Case 12**	**Test Case 13**	**Test Case 14**
Fuel Selection	YFF10	YFF10	YFF10	YFF10
Minimum Fuel Age	5	5	5	5
Global Pool Selection	Overflow	Shutdown	Overflow (1) + Shutdown (2)	Shutdown (1) + Overflow (2)
Years of Shutdown To Empty Pool	N/A	5	5	5
Unload Fuel Post Shutdown	Yes	Yes	Yes	No
Years After Shutdown to Unload	5	5	5	N/A
Acceptance Begins	1/2010	1/2010	1/2010	1/2010
Calendar/Fiscal Years	Calendar Years	Calendar Years	Calendar Years	Calendar Years
CSNF Acceptance Rate (MTU)				
2010	20	20	20	20
2011	40	40	40	20
2012	100	100	100	20
2013	100	100	100	100
2014	100	100	100	100
2015	100	100	100	100
2016	100	100	100	100
2017	200	200	200	200
2018	N/A	N/A	N/A	200
CSNF Priority Acceptance Rate (MTU)				
2010	20	20	20	50
2011	20	20	20	50
2012	20	20	20	90
2013	20	20	20	90
2014	20	20	20	90
2015	20	20	20	90
2016	20	20	20	90
2017	20	20	20	90
2018	N/A	N/A	N/A	90

The input data tables and remaining input assumptions for the test cases are the same as Test Case 8, with the following exceptions:

- Test Cases 12 and 13 utilize a modified fuel data table ("Fuel VTP3"), in order to force one reactor (Beaver Valley - Reactor ID 4) to shut down prior to the others. This modified database is shown in Table 2-15.

- Test Case 14 utilizes a modified fuel data table ("Fuel VTP4") that extends the operating life of Turkey Point by 1 year. This database is shown in Table 2-16. In addition, this case uses a modified pool data table ("POOL_INFO_VTP2") that reduces the pool capacity of Turkey Point from 435 to 276 assemblies and sets the full core reserve to zero. These changes permit both the Shutdown and Overflow priority acceptances to operate in the same year.

Table 2-15. Test Cases 12 - 13 Fuel Data

Batch ID	CALVIN Rx ID	MTU	No. Assm.	Burnup (MWD/MT)	Enrichment (%)	Discharge Date	Pool ID	Dry Year
1	27	30.147	65	28745	2.83	9/28/86	1701	1997
2	4	24.373	53	27891	2.61	12/26/86	1601	1997
3	118	27.931	61	37000	3.40	3/15/87	1803	0
4	4	33.707	73	32000	3.25	12/11/87	1601	1997
5	27	33.836	73	39000	3.50	3/14/90	1701	0
6	118	23.972	52	46000	3.40	4/4/94	1803	0
7	27	33.382	72	45000	3.94	2/29/96	1701	0
8	118	24.894	54	53000	4.00	9/15/98	1803	0
9	4	29.691	64	47000	3.73	3/7/02	1601	0
10	118	20.745	45	52520	4.00	4/15/03	1803	0
11	27	30.136	65	46000	4.20	3/1/04	1701	0
12	118	21.206	46	54111	4.00	10/21/07	1803	0
13	4	72.848	157	48611	3.73	2/4/08	1601	0
14	27	82.062	177	47911	3.94	3/2/10	1701	0
15	118	19.394	42	52231	4.24	10/15/10	1803	0
16	118	72.377	157	49380	4.00	7/19/12	1803	0

Table 2-16. Test Case 14 Fuel Data

Batch ID	CALVIN Rx ID	MTU	No. Assm.	Burnup (MWD/MT)	Enrichment (%)	Discharge Date	Pool ID	Dry Year
1	27	30.147	65	28745	2.83	9/28/86	1701	1997
2	4	24.373	53	27891	2.61	12/26/86	1601	1997
3	118	27.931	61	37000	3.40	3/15/87	1803	0
4	4	33.707	73	32000	3.25	12/11/87	1601	1997
5	27	33.836	73	39000	3.50	3/14/90	1701	0
6	118	23.972	52	46000	3.40	4/4/94	1803	0
7	27	33.382	72	45000	3.94	2/29/96	1701	0
8	118	24.894	54	53000	4.00	9/15/98	1803	0
9	4	29.691	64	47000	3.73	3/7/02	1601	0
10	118	20.745	45	52520	4.00	4/15/03	1803	0
11	27	30.136	65	46000	4.20	3/1/04	1701	0
12	118	21.206	46	54111	4.00	10/21/07	1803	0
13	4	72.848	157	48611	3.73	2/4/08	1601	0
14	27	82.062	177	47911	3.94	3/2/10	1701	0
15	118	19.394	42	52231	4.24	10/15/10	1803	0
16	118	35.497	77	54111	4.24	7/19/12	1803	0
17	118	72.377	157	49380	4	12/30/13	1803	0

2.1.6 MGR Disposal Options

Four test cases were developed to test disposal options at the MGR. Test Cases 15 and 16 test the effect of the "Limit Repository Rounding" option; in addition, Test Case 16 tests the "Co-dispose DOE SNF/HLW" option. Test Case 17 tests waste package heat calculations with the blending option, and Test Case 18 tests waste package heat calculations without blending. Table 2-17 summarizes the key assumptions for Test Cases 15 through 18. For Test Case 16, the MGR dry/emplace modals for HLW and DOE SNF were changed to include the co-disposal waste packages; Table 2-18 shows these changes. For Test Case 17, the CSNF acceptance only runs from 2010 to 2016, since this was considered sufficient to test the blending methodology. The remainder of the data input and assumptions for these cases are the same as for Test Case 8.

Table 2-17. Test Cases 15 - 18 Assumptions

Parameter	Test Case 15	Test Case 16	Test Case 17	Test Case 18
ISF	Yes	Yes	No	No
Limit Repository Rounding	No	Yes	Yes	Yes
Co-Dispose DOE SNF/HLW	No	Yes	No	Yes
WP Blending	No	No	Yes	No

Table 2-17. Test Cases 15 - 18 Assumptions (Continued)

Parameter	Test Case 15	Test Case 16	Test Case 17	Test Case 18
Basket size	N/A	N/A	4	N/A
Waste Package Max Heat (W)	N/A	N/A	25000	N/A
PWR WP Min. Heat (W)	N/A	N/A	10000	N/A
Trans Cask Unloads	N/A	N/A	10	N/A
PWR Max. Holdover (assm)	N/A	N/A	200	N/A
MGR CSNF Acceptance Rate (MT/yr)				
2010	20	20	40	40
2011	40	40	80	80
2012	80	80	100	100
2013	100	100	100	100
2014	100	100	100	100
2015	100	100	100	100
2016	100	100	100	100
2017	250	250	0	350
ISF CSNF Acceptance Rate (MT/yr)				
2010	20	20	0	0
2011	40	40	0	0
2012	20	20	0	0
2013	0	0	0	0
2014	0	0	0	0
2015	0	0	0	0
2016	0	0	0	0
2017	0	0	0	0

Table 2-18. Test Case 16 MGR Dry/Emplace Modal Changes

Pool No.	Pool Name	Modal	Modal No.	Years	Priority 0 Cask	Years	Priority 1 Cask
7056	MGR1-HLW	H-MGR	46	1968-2014	H-E-5-SP	N/A	N/A
			46	2015-2099	H-E-5-CO	2015-2099	H-E-5-SP
7057	MGR1-DOE	D-MGR	47	1968-2014	D-E-4-SP-Grp1	N/A	N/A
			47	2015-2099	D-E-1-CO	2015-2099	D-E-4-SP-Grp1

Note that these test cases are different from those postulated in the Validation Test Plan (CRWMS M&O 1999a) in several ways. The "Limit Repository Rounding" test was changed so that only Test Case 16 has the "Yes" option set. This is because the "No" option is the standard assumption; therefore, only one case with the "Yes" option is required. In addition, WP blending without holdover of cold assemblies was not tested, since it is a subset of the general blending calculation model tested in Test Case 17. Because there is no holdover of cold assemblies in the blending calculation for BWR fuel, this calculation was also not tested.

2.2 COST TEST CASES

Two types of cost test cases were developed: cases to validate the detailed transportation costs, and cases to validate the costs associated with the M&O and RSCs. This was done because the M&O and RSC cost calculations in CALVIN use the detailed transportation costs as input.

2.2.1 Detailed Transportation Costs

Test Cases 19 through 23 test detailed transportation cost calculations, utility dry storage cost calculations, and ISF/MGR cask cost calculations. It is assumed that the transportation logistics calculations, as validated previously in the report, are accurate. These test cases utilize the limited reactor sites, pools and fuel data tables, cask data, and modal assumptions used in Test Case 8.

Table 2-19 shows the scenario options chosen for Test Cases 19 through 23. The principal differences between the five cases are in the selection of rail cost model and rail cask shipment option, with the exception that Test Case 23 also turns off the "Regions" option.

- Test Case 19: Reference Transportation Data and Assumptions (RTDA) rail cost model with general rail option
- Test Case 20: RTDA rail cost model with one-way dedicated rail option
- Test Case 21: 1998 updated rail cost model with general rail option
- Test Case 22: 1998 updated rail cost model with one-way dedicated rail option
- Test Case 23: Average rail cost model with two-way dedicated rail option; no regions.

Note that these test case assumptions differ from those in the Validation Test Plan (CRWMS M&O 1999a) in that the RSC/WAST cost calculations are not performed for these cases.

Table 2-19. Test Cases 19 - 23 Scenario Options

Parameter	Test Case 19	Test Case 20	Test Case 21	Test Case 22	Test Case 23
General Options					
Calendar or Fiscal Year	Fiscal Year	Fiscal Year	Fiscal Year	Fiscal Year	Fiscal Year
180C Model	RTDA Model	RTDA Model	RTDA Model	RTDA Model	RTDA Model
RSC/WAST Calculation	No	No	No	No	No
Reactor Options					
Shifts/Day	2	2	2	2	2
Days/Week	5	5	5	5	5

Table 2-19. Test Cases 19 - 23 Scenario Options (Continued)

Parameter	Test Case 19	Test Case 20	Test Case 21	Test Case 22	Test Case 23
Hours/Shift	6	6	6	6	6
Holidays	10	10	10	10	10
ISF Options					
No ISF					
MGR Options					
Calculate Number of Cells	No	No	No	No	No
Bare Cells	3	3	3	3	3
Canistered Cells	2	2	2	2	2
Shifts/Day	3	3	3	3	3
Days/Week	5	5	5	5	5
Hours/Shift	6	6	6	6	6
Holidays	11	11	11	11	11
Latitude	36.859	36.859	36.859	36.859	36.859
Longitude	116.474	116.474	116.474	116.474	116.474
Co-Dispose	Yes	Yes	Yes	Yes	Yes
Limit Rounding	Yes	Yes	Yes	Yes	Yes
Fuel Blending	No	No	No	No	No
PWR Basket Size	N/A	N/A	N/A	N/A	N/A
BWR Basket Size	N/A	N/A	N/A	N/A	N/A
WP Upper Heat Limit (Watts)	N/A	N/A	N/A	N/A	N/A
PWR WP Lower Heat Limit (Watts)	N/A	N/A	N/A	N/A	N/A
Cask Unloads Before Blending	N/A	N/A	N/A	N/A	N/A
PWR Cold Assemblies Set Aside	N/A	N/A	N/A	N/A	N/A
MTU Over Emplacement Limit (%)	N/A	N/A	N/A	N/A	N/A
Transportation Options					
From Reactor					
Dedicated Train	General Rail	1 Way Dedicated	General Rail	1 Way Dedicated	2 Way Dedicated
Unit Train Size	1	3	1	3	3
Return Train Size	1	1	1	1	3
Fleet Purchase Size	1	1	1	1	1
From ISF					
Dedicated Train	Dedicated	Dedicated	Dedicated	Dedicated	Dedicated

Table 2-19. Test Cases 19 – 23 Scenario Options (Continued)

Parameter	Test Case 19	Test Case 20	Test Case 21	Test Case 22	Test Case 23
Unit Train Size	5	5	5	5	5
Return Train Size	5	5	5	5	5
HLW/DOE SNF					
Dedicated Train	General Rail	1 Way Dedicated	General Rail	1 Way Dedicated	2 Way Dedicated
Unit Train Size	1	5	1	5	5
Return Train Size	1	1	1	1	5
MGR Rail Spur	Yes	Yes	Yes	Yes	Yes
Year Avail	2010	2010	2010	2010	2010
Regions	4	4	4	4	1
Rail Algorithm	RTDA	RTDA	98 Update	98 Update	Average
Negotiation Factor (%)	N/A	N/A	60	60	N/A
Buffer Car Unit Cost ($M)	0.05	0.05	0.05	0.05	0.05
Personnel Car Unit Cost ($M)	0.25	0.25	0.25	0.25	0.25
Cask Contingency Factor (%)	25	25	25	25	25
Operations Cont. Factor (%)	15	15	15	15	15
Utility Options					
Pool Selection	OFF only	OFF only	OFF only	OFF only	OFF only
Years Early/Max. Reactor Life	N/A	N/A	N/A	N/A	N/A
Unload Shutdown	Yes	Yes	Yes	Yes	Yes
Unload Shutdown Years	5	5	5	5	5
Earliest Unload Year	1998	1998	1998	1998	1998
Min. Yrs. (Unload – final pickup)	0	0	0	0	0
Fuel Options					
Fuel Selection	YFF10	YFF10	YFF10	YFF10	YFF10
Age to Switch to dry	5	5	5	5	5
Defer Dry-By Failed Cask	No	No	No	No	No
Number of failed casks	N/A	N/A	N/A	N/A	N/A
Minimum Fuel Age	5	5	5	5	5
Ignore Cask Limits	No	No	No	No	No
Utility Operating Costs ($M)					
ISFSI Construction Cost	10.16	10.16	10.16	10.16	10.16
ISFSI Operating Cost	0.762	0.762	0.762	0.762	0.762
ISFSI Operating Cost (shutdown)	4.064	4.064	4.064	4.064	4.064
Pool Operating Cost (shutdown)	8.128	8.128	8.128	8.128	8.128

Table 2-19. Test Cases 19 - 23 Scenario Options (Continued)

Parameter	Test Case 19	Test Case 20	Test Case 21	Test Case 22	Test Case 23
Cost Per MTU	0.1016	0.1016	0.1016	0.1016	0.1016
Transportation Cost ($)					
Satellite Transmissions	5.62E-02	5.62E-02	5.62E-02	5.62E-02	5.62E-02
Barge Cost/Day	4871.592	4871.592	4871.592	4871.592	4871.592
HH Crane Cost/Day	2165.151	2165.151	2165.151	2165.151	2165.151
HH Labor Cost/Day	2165.151	2165.151	2165.151	2165.151	2165.151
HH Tractor Cost/Day	1082.576	1082.576	1082.576	1082.576	1082.576
Truck Loading Cost	8313.491	8313.491	8313.491	8313.491	8313.491
CSNF Rail Loading Cost	31067.31	31067.31	31067.31	31067.31	31067.31
HLW/DOE Rail Loading Cost	14908.1	14908.1	14908.1	14908.1	14908.1
Min. 2nd Driver Charge	169.2716	169.2716	169.2716	169.2716	169.2716
2nd Driver Charge/Mile	0.3526491	0.3526491	0.3526491	0.3526491	0.3526491
Truck Security/Mile	5.219207	5.219207	5.219207	5.219207	5.219207
Truck C180/State	1000	1000	1000	1000	1000
Rail Security/Mile	0.2164924	0.2164924	0.2164924	0.2164924	0.2164924
Rail Security/Day	290.0999	290.0999	290.0999	290.0999	290.0999
Rail Security Escorts	6	6	6	6	6
Rail C180/State	2000	2000	2000	2000	2000
Acceptance Rates					
Begin Acceptance – CSNF	4/2010	4/2010	4/2010	4/2010	4/2010
Begin Acceptance – HLW	1/2010	1/2010	1/2010	1/2010	1/2010

2.2.2 M&O and RSC Costs

Two test cases have been developed to validate the calculation of costs associated with the activities of the CRWMS M&O and the RSCs. Test Case 24 uses the same assumptions and data as was used in the 1999 Total System Life Cycle Cost (TSLCC) Update (CRWMS M&O 1999b) except for assumptions related to RSC costs, which have been altered because of potential Source Selection sensitivity of RSC data. These RSC assumptions also differ from those in the Validation Test Plan (CRWMS M&O 1999a). Test Case 25 was adapted from Test Case 24, and differs in the following ways:

- Co-located ISF with receipt of CSNF at the ISF beginning in 2007; receipt of CSNF, HLW, and DOE SNF begins at the MGR in 2010
- Unit train size of 3 for CSNF and 5 for HLW and DOE SNF
- Cask costs are allocated in the year that the cask is needed
- Test Case 25 uses Calendar Year calculations.

Table 2-20 summarizes the assumptions for Test Cases 24 and 25. Tables 2-21, 2-22, and 2-23 show the acceptance rates for CSNF, HLW, and DOE SNF. Table 2-24 lists the Waste Acceptance, Storage, and Transportation (WAST) M&O costs for Test Case 25, and Table 2-25 lists the DOE 180(c) model parameters for Test Case 25 (the corresponding values for Test Case 24 are in Reference CRMWS 1999b).

Table 2-20. Test Cases 24 - 25 Assumptions

Parameter	Test Case 24	Test Case 25
General Options		
Calendar or Fiscal Year	Fiscal Year	Calendar Year
180C Model	Revised DOE Model	Revised DOE Model
RSC/WAST Calculation	Yes	Yes
Reactor Options		
Shifts/Day	2	2
Days/Week	5	5
Hours/Shift	6	6
Holidays	10	10
ISF Options		
Calculate Number of Cells	N/A	Yes
Bare Cells	N/A	2
Canistered Cells	N/A	1
Shifts/Day	N/A	3
Days/Week	N/A	5
Hours/Shift	N/A	6
Holidays	N/A	11
Co-located	N/A	Yes
Latitude	N/A	36.8
Longitude	N/A	116.4
MGR Options		
Calculate Number of Cells	No	No
Bare Cells	3	3
Canistered Cells	2	2
Shifts/Day	3	3
Days/Week	5	5

Table 2-20. Test Cases 24 - 25 Assumptions (Continued)

Parameter	Test Case 24	Test Case 25
Hours/Shift	6	6
Holidays	11	11
Latitude	36.859	36.859
Longitude	116.474	116.474
Co-Dispose	Yes	Yes
Limit Rounding	Yes	Yes
Fuel Blending	No	No
Transportation Options		
From Reactor		
Dedicated Train	General Rail	General Rail
Unit Train Size	1	1
Return Train Size	1	1
Fleet Purchase Size	1	1
From ISF		
Dedicated Train	N/A	Dedicated Trail
Unit Train Size	N/A	5
Return Train Size	N/A	5
HLW/DOE SNF		
Dedicated Train	General Rail	General Rail
Unit Train Size	1	1
Return Train Size	1	1
MGR HH Days	2	2
MGR Rail Spur	Yes	Yes
Year Avail	2010	2010
Regions	5	5
Rail Algorithm	98 Update	98 Update
Negotiation Factor (%)	60	60
Buffer Car Unit Cost ($M)	0.05	0.05
Personnel Car Unit Cost ($M)	0.25	0.25
Cask Contingency Factor (%)	25	25
Operations Contingency Factor (%)	15	15
RSC Options		
Phase A Start-Mo/Year	May-03	Oct-01
Phase A End-Mo/Year	May-05	Oct-03
Phase B Start (CSNF)	Nov-05	Apr-04

Table 2-20. Test Cases 24 - 25 Assumptions (Continued)

Parameter	Test Case 24	Test Case 25
Phase C Start (CSNF)	Apr-10	Apr-07
Phase C Duration (Years)	10	10
Phase B Start (HLW)	Nov-05	Apr-06
Phase C Start (HLW)	Apr-10	Jan-10
RSC Perform. Award (%)	3	3
RSC Fee (%)	20	20
RSC Interest Rate (%)	8.0	8.0
Phase B Repay Period (yrs)	10	10
Phase B Labor Contingency Factor (%)	15	15
RSC Phase A Cost ($M)	18	18
RSC Phase B Labor Rate ($M/FTE)	0.15	0.15
RSC Phase B Staff (All RSCs) (FTE)	350	350
RSC Phase C Labor Rate ($M/FTE)	0.1	0.1
RSC Phase C Staff (All RSCs) (FTE)	300	300
RSC Phase B Travel Cost ($M/yr/RSC)	0.12	0.12
RSC Phase B/C QPMR Cost ($M/qtr/RSC)	0.025/0.025	0.025/0.025
RSC Phase C C&O Cost ($M/yr/RSC)	1.1125	1.1125
Site Welding Equipment Cost ($M/site)	0.54	0.54
Site Welding Equipment Last Use Year	2009	2009
Utility Site Support Equipment Cost ($M/site)	0.3	0.3
Utility Site Training Cost ($M/site)	0.05	0.05
Fed Facility Support Equip. Cost ($M/facil)	1	1
Fed Facility Training Cost ($M/facil)	0.5	0.5
FFSE Shipping Cost ($M/facil)	0.3	0.3
Utility Options		
Pool Selection	OFF only	OFF only
Years Early/Max. Reactor Life	N/A	N/A
Unload Shutdown	Yes	Yes
Unload Shutdown Years	5	5
Earliest Unload Year	1998	1998
Min. Yrs (Unload – final pickup)	0	0
Fuel Options		
Fuel Selection	YFF10	YFF10
Strict YFF	N/A	N/A
Age to Switch to dry	5	5

Table 2-20. Test Cases 24 - 25 Assumptions (Continued)

Parameter	Test Case 24	Test Case 25
Defer Dry-By Failed Cask	No	No
Number of failed casks	N/A	N/A
Minimum Fuel Age	5	5
Ignore Cask Limits	No	No
Utility Operating Costs ($M)		
ISFSI Construction Cost	10.16	10.16
ISFSI Operating Cost	0.762	0.762
ISFSI Operating Cost (shutdown)	4.064	4.064
Pool Operating Cost (shutdown)	8.128	8.128
Cost Per MTU	0.1016	0.1016
Transportation Cost ($)		
Satellite Transmissions	5.62E-02	5.62E-02
Barge Cost/Day	4871.592	4871.592
HH Crane Cost/Day	2165.151	2165.151
HH Labor Cost/Day	2165.151	2165.151
HH Tractor Cost/Day	1082.576	1082.576
Truck Loading Cost	8313.491	8313.491
CSNF Rail Loading Cost	31067.31	31067.31
HLW/DOE Rail Loading Cost	14908.1	14908.1
Min 2nd Driver Charge	169.2716	169.2716
2nd Driver Charge/Mile	0.3526491	0.3526491
Truck Security/Mile	5.219207	5.219207
Truck C180/State	Revised DOE Model	Revised DOE Model
Rail Security/Mile	0.2164924	0.2164924
Rail Security/Day	290.0999	290.0999
Rail Security Escorts	6	6
Rail C180/State	Revised DOE Model	Revised DOE Model
Acceptance Rates		
Begin Acceptance – CSNF	Apr-10	Apr-07
Begin Acceptance – HLW	Jan-10	Jan-10

Table 2-21. CSNF Acceptance Rates for Test Cases 24 - 25

	Test Case 24			Test Case 25		
Year	Acceptance Rate (MTU)	To ISF	To MGR	Acceptance Rate (MTU)	To ISF	To MGR
2007	0	0	0	1200	1200	0
2008	0	0	0	1200	1200	0
2009	0	0	0	2000	2000	0
2010	400	0	400	2000	1600	400
2011	600	0	600	2700	2100	600
2012	1200	0	1200	3000	1800	1200
2013	2000	0	2000	3000	1000	2000
2014 - 2041	3000	0	3000	3000	0	3000
2042	0	0	0	0	0	0

Table 2-22. HLW Acceptance Rates for Test Cases 24 - 25

	Test Case 24			Test Case 25		
Year	Acceptance Rate (MT)	To ISF	To MGR	Acceptance Rate (MT)	To ISF	To MGR
2007	0	0	0	0	0	0
2008	0	0	0	0	0	0
2009	0	0	0	0	0	0
2010	73.122	0	73.122	73.122	0	73.122
2011	73.122	0	73.122	73.122	0	73.122
2012	73.122	0	73.122	73.122	0	73.122
2013	73.122	0	73.122	73.122	0	73.122
2014	73.122	0	73.122	73.122	0	73.122
2015	448.4481	0	448.4481	448.4481	0	448.4481
2016	414.9829	0	414.9829	414.9829	0	414.9829
2017	212.809	0	212.809	212.809	0	212.809
2018	212.809	0	212.809	212.809	0	212.809
2019	207.9655	0	207.9655	207.9655	0	207.9655
2020	197.5	0	197.5	197.5	0	197.5
2021	197.5	0	197.5	197.5	0	197.5
2022	197.5	0	197.5	197.5	0	197.5

Table 2-22. HLW Acceptance Rates for Test Cases 24 - 25 (Continued)

	Test Case 24			Test Case 25		
Year	Acceptance Rate (MT)	To ISF	To MGR	Acceptance Rate (MT)	To ISF	To MGR
2023	197.5	0	197.5	197.5	0	197.5
2024	197.5	0	197.5	197.5	0	197.5
2025	197.5	0	197.5	197.5	0	197.5
2026	187.5	0	187.5	187.5	0	187.5
2027	187.5	0	187.5	187.5	0	187.5
2028	187.5	0	187.5	187.5	0	187.5
2029	227.5	0	227.5	227.5	0	227.5
2030	227.5	0	227.5	227.5	0	227.5
2031	227.5	0	227.5	227.5	0	227.5
2032	225.5	0	225.5	225.5	0	225.5
2033	126	0	126	126	0	126
2034	737.5	0	737.5	737.5	0	737.5
2035	737.5	0	737.5	737.5	0	737.5
2036	735.5	0	735.5	735.5	0	735.5
2037	725	0	725	725	0	725
2038	725	0	725	725	0	725
2039	725	0	725	725	0	725
2040	725	0	725	725	0	725
2041	728.5	0	728.5	728.5	0	728.5
2042	0	0	0	0	0	0

Table 2-23. DOE SNF Acceptance Rates for Test Cases 24 - 25

	Test Case 24			Test Case 25		
Year	Acceptance Rate (Canisters)	To ISF	To MGR	Acceptance Rate (Canisters)	To ISF	To MGR
2007	0	0	0	1	1	0
2008	0	0	0	1	1	0
2009	0	0	0	3	3	0
2010	1	0	1	6	6	0
2011	1	0	1	8	8	0
2012	3	0	3	9	9	0
2013	6	0	6	10	10	0
2014	8	0	8	11	11	0

Table 2-23. DOE SNF Acceptance Rates for Test Cases 24 - 25 (Continued)

	Test Case 24			Test Case 25		
Year	Acceptance Rate (Canisters)	To ISF	To MGR	Acceptance Rate (Canisters)	To ISF	To MGR
2015	112	0	112	12	12	0
2016	144	0	144	14	14	0
2017	118	0	118	118	0	118
2018	207	0	207	149	0	149
2019	173	0	173	122	0	122
2020	202	0	202	210	0	210
2021	202	0	202	174	0	174
2022	142	0	142	202	0	202
2023	142	0	142	202	0	202
2024	162	0	162	142	0	142
2025	232	0	232	142	0	142
2026	234	0	234	162	0	162
2027	234	0	234	232	0	232
2028	234	0	234	234	0	234
2029	250	0	250	234	0	234
2030	253	0	253	234	0	234
2031	250	0	250	250	0	250
2032	250	0	250	238	0	238
2033	138	0	138	235	0	235
2034	99	0	99	235	0	235
2035	60	0	60	123	0	123
2036	0	0	0	84	0	84
2037	0	0	0	60	0	60
2038-2042	0	0	0	0	0	0

Table 2-24. WAST M&O Costs for Test Case 25

Year	Cost (Millions of 1998 Dollars)						CF[d]
	WA[a]	PM&I[b]	MPC[c]	Storage	Transportation	Institutional	
1999	23.77	9.06	36.99	203.21	206.94	1.03	0
2000	1.237	0.571	0	0	3.52	0.381	0
2001	1.47	1.85	0	0	1.2	0.6	0
2002	1.42	1.85	0	0	1.3	0.8	0
2003	1.47	1.85	0	0	1.3	0.8	0
2004	1.92	1.85	0	0	1.3	0.8	0.1
2005	1.52	1.85	0	0	1.3	1	0.1
2006	1.92	1.85	0	0	1.3	1	0.1
2007	1.97	1.85	0	0	1.3	1	0.1
2008	1.57	0	0	0	0	1	0.1
2009	1.97	0	0	0	0	1	0.1
2010	1.57	0	0	0	0	1	0.1
2011	1.97	0	0	0	0	1	0.1
2012	1.57	0	0	0	0	1	0.1
2013	1.97	0	0	0	0	1	0.1
2014	1.57	0	0	0	0	1	0.1
2015	1.97	0	0	0	0	1	0.1
2016	1.57	0	0	0	0	1	0.1
2017	1.97	0	0	0	0	1	0.1
2018	1.57	0	0	0	0	1	0.1
2019	1.97	0	0	0	0	1	0.1
2020	1.57	0	0	0	0	1	0.1
2021	1.97	0	0	0	0	1	0.1
2022	1.57	0	0	0	0	1	0.1
2023	1.97	0	0	0	0	1	0.1
2024	1.57	0	0	0	0	1	0.1
2025	1.97	0	0	0	0	1	0.1
2026	1.57	0	0	0	0	1	0.1
2027	1.97	0	0	0	0	1	0.1
2028	1.57	0	0	0	0	1	0.1
2029	1.97	0	0	0	0	1	0.1
2030	1.57	0	0	0	0	1	0.1
2031	1.97	0	0	0	0	1	0.1
2032	1.57	0	0	0	0	1	0.1
2033	1.97	0	0	0	0	1	0.1
2034	1.57	0	0	0	0	1	0.1
2035	1.97	0	0	0	0	1	0.1
2036	1.57	0	0	0	0	1	0.1
2037-2041	0.8	0	0	0	0	1	0.1
2042	0	0	0	0	0	1	0

[a] WA = Waste Acceptance
[b] PM&I = Project Management and Integration
[c] MPC = Multi-Purpose Canister
[d] CF = Contingency Factor

Table 2-25. DOE 180(c) Model Parameters for Test Case 25

Year	180(C) Cost ($M98)	Com Supp C&O Frac[a]	Def Supp C&O Frac[b]
1999	0	0	0
2000	0	0	0
2001	0	0	0
2002	0	0	0
2003	8	0	0
2004	4	0	0
2005	10	0	0
2006	10	0	0
2007	10	1	0
2008	10	1	0
2009	10	1	0
2010	10	1	1
2011	10	1	1
2012	10	0.5	1
2013	10	0.375	1
2014	10	0.25	1
2015	10	0.125	0.5
2016	10	0	0.375
2017	10	0	0.25
2018	10	0	0.125
2019 - 2041	10	0	0
2042	0	0	0

[a] Commercial Supplemental Community and Outreach Support Fraction
[b] Defense Supplemental Community and Outreach Support Fraction

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3. VALIDATION TEST CASE RESULTS

This Section describes the results of the validation test cases, and the comparisons to values calculated by CALVIN V3.0.

3.1 LOGISTICS TEST CASES

3.1.1 SNF Heat and Reactivity

Tables 3-1, 3-2, and 3-3 show the validation test results for the CSNF heat, burnup-enrichment (B-E), and WP criticality calculations (Test Cases 1 through 3). The Microsoft EXCEL 97 files containing the detailed validation calculations are included in Appendix B. The results of the hand calculations for these test cases are essentially identical with those produced by CALVIN. Note that two of the burnup values entered in Table 3-2 were beyond the range of the particular B-E curve in CALVIN; as expected, no B-E interpolation was performed by CALVIN.

Table 3-1. Test Case 1 Validation Results

				Assembly Heat (Watts)		
Fuel Type	Burnup (GWD/MT)	Enrichment (%)	Age (years)	Hand Calculation	CALVIN	Deviation (%)
BWR	11	3.4	10	349.0250	349.0250	0.000%
BWR	35	4.2	8	1239.3089	1239.3089	0.000%
BWR	0.1	1.2	4	8.7213	8.7213	0.000%
PWR	42	4.7	12	1430.0596	1430.0596	0.000%
PWR	70	5.3	29	1823.7648	1823.7650	0.000%
PWR	1.3	2.9	125	4.4732	4.4732	0.000%
BWR-SS	32	3.1	17	967.8587	967.8587	0.000%
PWR-SS	18	3.7	33	377.9736	377.9736	0.000%
PWR-MOX	57	4.8	15	1914.7422	1914.74216	0.000%
PWR-MOX	46	4.3	23	1241.8200	1241.81997	0.000%

Table 3-2. Test Case 2 Validation Results

		Burnup (MWD/MT)		
Curve Number	Enrichment (%)	Hand Calculation	CALVIN	Deviation (%)
1	2.9	5500	5500.002	0.000%
1	3.33	12940	12940	0.000%
1	4.3	24200	24200	0.000%
1	4.85	30000	30000	0.000%

Table 3-2. Test Case 2 Validation Results (Continued)

		Burnup (MWD/MT)		
Curve Number	**Enrichment (%)**	**Hand Calculation**	**CALVIN**	**Deviation (%)**
2	1.5	No Calculation	No Calculation	N/A
2	3.45	3500	3500	0.000%
2	3.8	7000	7000	0.000%
2	4.3	13800	13800	0.000%
2	4.95	19500	19500	0.000%
5	2.45	9750	9750.002	0.000%
5	3.35	25300	25300	0.000%
5	3.8	31666.67	31666.67	0.000%
5	4.62	46400	46400	0.000%
5	6.0	No Calculation	No Calculation	N/A

Table 3-3. Test Case 3 Validation Results

						Criticality Coefficient		
Fuel Type	**Curve Number**	**Criticality Coeff**	**Burnup (GWD/MT)**	**Enrichment (%)**	**Age (Years)**	**Hand Calc.**	**CALVIN**	**Deviation (%)**
BWR	1001	k_∞	45	4.1	25	1.025406	1.025406	0.000%
PWR	1002	k_∞	30	3.5	10	1.080096	1.080096	0.000%
BWR	1003	k_{eff}	38	3.8	15	0.887953	0.887953	0.000%
PWR	1004	k_{eff}	46	4.5	7	0.898862	0.898862	0.000%
BWR	1001	k_∞	4	3.5	10	1.458078	1.458078	0.000%
PWR	1002	k_∞	40	4.0	50	1.02943	1.02943	0.000%

3.1.2 Options for Altering Reactor Life

Table 3-4 shows the results of the validation calculation for the Test Case 4 early reactor shutdown calculation. This table was created from the "RX_DET" (Detailed Reactor Activity) reports for Test Case 4 (5-year early shutdown) and the same case run without the early shutdown option. Test Case 4 is CALVIN Scenario 431 in the "Work_99VTP" validation database. The CALVIN reports were first sorted by "mode." The lines showing assemblies shipped per year were then selected, the columns showing the transportation cask types were erased, and the remainder was copied into the table. This table demonstrates that the shipments from the reactor pools end in 2012 when the 5-year early reactor shutdown option is chosen, versus 2017 with no early shutdown; this behavior validates the early reactor shutdown calculation. Details of the validation calculations are shown in the Excel 97 worksheet for Test Case 4, included in Appendix B.

Table 3-4. Test Case 4 Validation Results

Test Case 4 (5 Year Early Shutdown)				Base Case - No Early Shutdown			
Year	**Activity**	**Facility**	**Mode**	**Year**	**Activity**	**Facility**	**Mode**
2010	Ship	BEAVER VALLEY	A	2010	Ship	BEAVER VALLEY	A
2010	Ship	CRYSTAL RVR	A	2010	Ship	CRYSTAL RVR	A
2010	Ship	HANFORD-DOE	A	2010	Ship	HANFORD-DOE	A
2010	Ship	TURKEY PT	A	2010	Ship	TURKEY PT	A
2011	Ship	BEAVER VALLEY	A	2011	Ship	BEAVER VALLEY	A
2011	Ship	CRYSTAL RVR	A	2011	Ship	CRYSTAL RVR	A
2011	Ship	HANFORD-DOE	A	2011	Ship	TURKEY PT	A
2011	Ship	TURKEY PT	A	2011	Ship	HANFORD-DOE	A
2012	Ship	BEAVER VALLEY	A	2012	Ship	TURKEY PT	A
2012	Ship	CRYSTAL RVR	A	2012	Ship	HANFORD-DOE	A
2012	Ship	HANFORD-DOE	A	2013	Ship	BEAVER VALLEY	A
2012	Ship	TURKEY PT	A	2013	Ship	HANFORD-DOE	A
2013	Ship	HANFORD-DOE	A	2014	Ship	HANFORD-DOE	A
2014	Ship	HANFORD-DOE	A	2015	Ship	CRYSTAL RVR	A
2015	Ship	HANFORD-DOE	A	2015	Ship	TURKEY PT	A
2015	Ship	SAV RIVER-HLW	A	2015	Ship	SAV RIVER-HLW	A
2016	Ship	HANFORD-DOE	A	2015	Ship	HANFORD-DOE	A
2016	Ship	SAV RIVER-HLW	A	2016	Ship	BEAVER VALLEY	A
2017	Ship	HANFORD-DOE	A	2016	Ship	SAV RIVER-HLW	A
2017	Ship	SAV RIVER-HLW	A	2016	Ship	HANFORD-DOE	A
				2017	Ship	BEAVER VALLEY	A
				2017	Ship	CRYSTAL RVR	A
				2017	Ship	TURKEY PT	A
				2017	Ship	HANFORD-DOE	A
				2017	Ship	SAV RIVER-HLW	A

For Test Case 5, the maximum reactor life option case, the "Maximum Rx Life" parameter was set to 20 years, and the shipments from the reactor pools compared to the same case without the option set. Test Case 5 is CALVIN Scenario 432 in the "Work_99VTP" validation database. For this case, limiting the reactor life to 20 years results in the shutdown of Beaver Valley and Crystal River in 2006 and Turkey Point in 2007 (since these dates are 20 years from the first discharges). The fuel file used in this case (Table 2-6) is reproduced in Table 3-5 below, with the discharges that would be ignored by CALVIN shown in bold type. The reduced discharges total 122 assemblies for Beaver Valley (Reactor 4), 88 assemblies for Turkey Point (118), and 61 assemblies for Crystal River (27).

Table 3-5. Test Case 5 Fuel File

Batch ID	CALVIN Rx ID	MTU	No. Assm.	Burnup (MWD/MT)	Enrichment (%)	Discharge Date	Pool ID	Dry Year
1	27	30.147	65	28745	2.834	9/28/86	1701	1997
2	4	24.373	53	27891	2.605	12/26/86	1601	1997
3	118	27.931	61	37000	3.404	3/15/87	1803	0
4	4	33.707	73	32000	3.248	12/11/87	1601	1997
5	27	33.836	73	39000	3.495	3/14/90	1701	0
6	118	23.972	52	46000	3.4	4/4/94	1803	0
7	27	33.382	72	45000	3.94	2/29/96	1701	0
8	118	24.894	54	53000	4	9/15/98	1803	0
9	4	29.691	64	47000	3.73	3/7/02	1601	0
10	118	20.745	45	52520	4	4/15/03	1803	0
11	27	30.136	65	46000	4.2	3/1/04	1701	0
12	**118**	**21.206**	**46**	**54111**	**4**	**10/21/07**	**1803**	**0**
13	**4**	**28.299**	**61**	**48000**	**3.73**	**2/4/08**	**1601**	**0**
14	**27**	**28.282**	**61**	**47000**	**4.2**	**3/2/10**	**1701**	**0**
15	**118**	**19.394**	**42**	**52231**	**4.24**	**10/15/10**	**1803**	**0**
16	**4**	**28.299**	**61**	**49000**	**3.73**	**1/19/11**	**1601**	**0**
17	4	72.848	157	48611	3.73	1/29/12	1601	0
18	118	72.377	157	49380	4	7/19/12	1803	0
19	27	82.062	177	47911	3.94	12/3/12	1701	0

Table 3-6 shows the results of the Test Case 5 validation calculation. These results were calculated from the "RX_DET" reports from CALVIN Test Case 5 and a base case (Test Case 5 without the maximum reactor life option). As shown, the differences in assemblies shipped match the predictions resulting from examination of the fuel file. Details of the validation calculations are shown in the Excel 97 worksheet for Test Case 5, included in Appendix B.

Table 3-6. Test Case 5 Validation Results

Facility	Assemblies Shipped		
	Test Case 5	Base Case	Difference
BEAVER VALLEY	347	469	-122
CRYSTAL RVR	452	513	-61
TURKEY PT	369	457	-88

3.1.3 CSNF Acceptance Rate Adjustment

For Test Case 6, the adjusted CSNF acceptance rates calculated in CALVIN V3.0 and displayed using the "Debug.Print" statement were compared to acceptance rates calculated using a Microsoft Excel 97 worksheet. The comparison shows that the results from the two methods are identical. Details of the validation calculations are shown in the Excel 97 worksheet for Test Case 6, included in Appendix B.

3.1.4 Fuel Selection, Cask Loading, and Shipping

Results equivalent to those in the CALVIN "RX_DET" report were calculated for Test Cases 7 through 10 using Microsoft Excel 97 worksheets. The final output shows annual shipment data for CNSF, HLW, and DOE SNF by site and transportation cask type. Results are shown in units of casks, assemblies (canisters in the case of HLW and DOE SNF), and MTHM. For Test Cases 7 through 9, these results were compared to the "RX_DET" reports from CALVIN Scenarios 433 through 435 in the validation database "Work_99VTP." For Test Case 10, a comparison to both the "ISF1" (ISF Activity) and "RX_DET" reports for CALVIN Scenario 436 was made. The "ISF1" report shows annual shipments from each site arriving at the ISF, being placed into storage, and being removed from storage. The comparisons show identical results for casks and assemblies/canisters, and occasional very small deviations (less than 1 percent) for the MTHM values. Details of the validation calculations are shown in the Excel 97 worksheets for Test Cases 7 through 10, included in Appendix B. A summary of the validation results for these cases is shown in Table 3-7.

Table 3-7. Test Cases 7 - 10 Validation Results Summary

Test Case	Maximum Deviation, Test Case vs CALVIN		
	Assemblies/Canisters	Casks	MTHM (%)
7	0	0	0.129
8	0	0	0.180
9	0	0	0.0153
10	0	0	0.498

3.1.5 Reactor Pool Allocation Options

For Test Cases 11 through 14, results equivalent to the CALVIN "RX_DET" report were calculated using Microsoft Excel 97 worksheets. These were compared to the results from CALVIN Scenarios 438 through 441. The results were identical for numbers of assemblies and transportation casks, and showed only small deviations (less than 1 percent) for MTHM values. Details of the validation calculations are shown in the Excel 97 worksheets for Test Cases 11 through 14, included in Appendix B. Table 3-8 shows a summary of the validation results for these test cases.

Table 3-8. Test Cases 11 - 14 Validation Results Summary

Test Case	Maximum Deviation, Test Case vs CALVIN		
	Assemblies/Canisters	Casks	MTHM (%)
11	0	0	.008
12	0	0	.093
13	0	0	.056
14	0	0	0.681

3.1.6 MGR Disposal Options

For Test Cases 15 and 16, results equivalent to the CALVIN "ISF1," "MGR1" (MGR Activity), and "RX_DET" reports were calculated using Microsoft Excel 97 worksheets. These were compared to the results from CALVIN Scenarios 442 and 443. The comparisons show identical results for numbers of assemblies, transportation casks, and WPs. Occasional small deviations (less than 1 percent) occur in MTHM values. Details of the validation calculations are shown in the Excel 97 worksheets for Test Cases 15 and 16, included in Appendix B. Table 3-9 shows a summary of the validation results for these cases.

Table 3-9. Test Cases 15 - 16 Validation Results Summary

Test Case	Maximum Deviation, Test Case vs CALVIN		
	Assemblies/Canisters	Casks	MTHM (%)
15	0	0	0.174
16	0	0	0.093

For Test Cases 17 and 18, results equivalent to the CALVIN "Detailed WP Heat" report were calculated using Microsoft Excel 97 worksheets. In addition, for Test Case 17, results equivalent to the CALVIN "Lag Storage Requirements for Blending" report were calculated. For Test Case 18, results equivalent to the CALVIN "Annual WP Heat Summary" report were calculated. These were compared to the results from CALVIN Scenarios 444 and 445. The comparisons for Test Cases 17 and 18 show identical results for numbers of WPs and occasional small deviations (less than 1 percent) in calculated WP heats. The lag storage results for Test Case 17 are identical. The WP heat summary results for Test Case 18 are identical for WPs, and show deviations less that 1 percent for average WP heat. Details of the validation calculations are shown in the Excel 97 worksheets for Test Cases 17 and 18, included in Appendix B. Tables 3-10 and 3-11 show summaries of the validation results for Test Cases 17 and 18.

Table 3-10. Test Case 17 Validation Results Summary

Parameter	Maximum Deviation
WP Heat (%)	0.4317 %
Lag Storage Assemblies	0
Lag Storage MTHM (%)	0.043 %

Table 3-11. Test Case 18 Validation Results Summary

Parameter	Maximum Deviation
Waste Package Heat	0.025 %
Waste Package Annual Heat Bins	0
Waste Package Annual Average Heat	0.0042 %

3.2 COST TEST CASES

3.2.1 Detailed Transportation Costs

Table 3-12 shows the summary results of the validation calculations for Test Cases 19 through 23. The detailed cost breakdown (in the format of the CALVIN detailed transportation cost report) is shown in the Microsoft Excel 97 validation calculation, which is included in Appendix B. The summary results in Table 3-12 are within the 1 percent deviation criterion for cost calculations. In addition, the results for each cost category in the detailed transportation cost report are also within the 1 percent deviation criterion, except for the rail satellite communications costs. For Test Cases 20, 22, and 23, these costs deviated by 2.8 – 5.4 percent, due to round-off errors in comparisons of very small costs (CALVIN only calculates costs to 4 decimal places).

Table 3-12. Test Cases 19 - 23 Validation Summary Results

Transportation Costs ($M)	Test Case 19	Test Case 20	Test Case 21	Test Case 22	Test Case 23
Excel Calculation	107.985	106.292	121.0576	117.6581	128.262
CALVIN	107.968	106.295	121.0490	117.6717	128.275
Deviation (%)	0.02%	-0.003%	0.01%	-0.010%	-0.01%

3.2.2 M&O and RSC Costs

Table 3-13 shows the summary results of the validation calculations for Test Cases 24 and 25. The detailed cost breakdown (in the format of the CALVIN detailed transportation cost report) is shown in the Microsoft Excel 97 validation calculation, which is included in Appendix B. Note that in the Excel 97 calculation, costs are calculated in 1998 dollars (which is the dollar year that CALVIN uses for RSC and WAST M&O cost data inputs), and then are converted to 1999 dollars using an escalation factor taken from reference CRWMS M&O 1999c. The summary results in Table 3-13 are within the 1 percent deviation criterion for cost calculations.

Table 3-13. Test Cases 24 - 25 Validation Summary Results

Total RSC & M&O Costs ($M)	**Test Case 24**	**Test Case 25**
All Wastes		
Excel Calculation	3133.60	3201.36
CALVIN	3133.42	3200.96
Deviation (%)	0.006%	0.012%
Commercial Wastes		
Excel Calculation	2530.98	2595.01
CALVIN	2530.86	2594.92
Deviation (%)	0.005%	0.003%
HLW and DOE SNF		
Excel Calculation	604.04	606.35
CALVIN	602.36	606.03
Deviation (%)	0.28%	0.052%

4. CONCLUSIONS

Twenty-four test cases were established in the CALVIN V3.0 Validation Test Plan (CRWMS M&O 1999a) to test the principal calculation models and options in CALVIN V3.0. Results for the test cases were calculated using Microsoft Excel 97 worksheets. The test case results were compared with CALVIN V3.0 scenarios using the same assumptions and data input. All of the test case results compare with the CALVIN results within the bounds of the acceptance criteria established in the Validation Test Plan (CRWMS M&O 1999a). Therefore, it is concluded that the CALVIN V3.0 calculation model and options included in this report are validated.

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5. REFERENCES

5.1 DOCUMENTS CITED

Civilian Radioactive Waste Management System Management and Operating Contractor (CRWMS M&O) 1999a. *Validation Test Plan for CALVIN 3.0 Revision 01.* 10074-VTP-3.0-01. Washington, D.C.: CRWMS M&O. ACC: MOV.20000214.0021.

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5.2 CODES, STANDARDS, REGULATIONS, AND PROCEDURES

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APPENDIX A

TEMPORARY CALVIN V3.0 CODING CHANGES FOR VALIDATION CALCULATONS

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TEMPORARY CALVIN V3.0 CODING CHANGES FOR VALIDATION CALCULATONS

A.1 Function GETHEAT# in Module Get_Heat (Test Case 1, 7 – 18)

A "Debug.Print" statement was added to print out heat values for each assembly (added line shown in bold type).

```
Public Function GetHeat#(assemblytype As Integer, burn As Double, enrich As Single,
Age As Double, SS_Flag As String)
.
.
.

Debug.Print Current_Year; burn; enrich; Age; GetHeat#
End Function
```

A.2 Function Test_B_E in Module Fuel_Bas (Test Case 2 and 10)

A "Debug.Print" statement was added to print out interpolated burnup and enrichment values for the selected Burnup Enrichment Curve.

```
Function test_B_E(Curve As Integer, burn2 As Double, enrich2 As Single)

Dim slope As Single, burn As Single
Dim x1 As Single, x2 As Single, y1 As Single, y2 As Single
Dim I As Integer, j As Integer

test_B_E = 0
j = UBound(Burn_Enrich(Curve).enrich)
If enrich2 <= Burn_Enrich(Curve).enrich(0) Then     'below this enrich ALL assem pass
    test_B_E = 1                                    'Passes
ElseIf enrich2 > Burn_Enrich(Curve).enrich(j) Then  'off top end of curve
    Exit Function                                   'fails
'    y2 = Burn_Enrich(Curve).Burnup(J - 1)
'    If burn2 * 0.95 < y2 Then Exit Function
'    y1 = Burn_Enrich(Curve).Burnup(J - 2)
'    x1 = Burn_Enrich(Curve).Enrich(J - 2)
'    x2 = Burn_Enrich(Curve).Enrich(J - 1)
'    slope = (y2 - y1) / (x2 - x1)
'    burn = slope * enrich2 + (y1 - slope * x1)
'    If burn2 * 0.95 > burn Then test_B_E = 1        'Passes
Else
    For I = 0 To j
        If Burn_Enrich(Curve).enrich(I) >= enrich2 Then Exit For
    Next I
    If Burn_Enrich(Curve).enrich(I) = enrich2 Then 'Exact match
        burn = Burn_Enrich(Curve).Burnup(I)
    Else                                           'Interpolate (all straight lines)
        x1 = Burn_Enrich(Curve).enrich(I - 1)
        x2 = Burn_Enrich(Curve).enrich(I)
        y1 = Burn_Enrich(Curve).Burnup(I - 1)
        y2 = Burn_Enrich(Curve).Burnup(I)
        slope = (y2 - y1) / (x2 - x1)
        burn = slope * enrich2 + (y1 - slope * x1)
     Debug.Print Curve; enrich2; burn
```

```
    End If
    If burn2 * 0.95 > burn Then test_B_E = 1        'Passes
End If
End Function
```

A.3 Function test_k_infinity in Module Fuel_Bas (Test Case 3 and 17)

A "Debug.Print" statement was added to print out "k" values for each assembly tested (added line shown in bold type).

```
Function test_k_infinity(batch_id As Long, Curve As Integer) As Single
Dim Burnup As Single
Dim assay As Single
Dim Age As Single

    Burnup = Fuel(batch_id).Burnup / 1000#
    assay = Fuel(batch_id).enrich
    Age = Current_Year - Fuel(batch_id).d_year

    If Fuel(batch_id).fuel_type > 1 Then    'DSNF or HLW
        test_k_infinity = 0#
        Exit Function
    End If

    If k(Curve).Max_Age > 0 Then
        If (Age > k(Curve).Max_Age) Then Age = k(Curve).Max_Age
    End If
    If (Burnup < k(Curve).Min_Burn) Then Burnup = k(Curve).Min_Burn

    test_k_infinity = k(Curve).C0 + k(Curve).C1 * Burnup + k(Curve).C2 * Age +
k(Curve).C3 * assay + k(Curve).C4 * Burnup ^ 2 + k(Curve).C5 * assay ^ 2 + _
        k(Curve).C6 * Age ^ 2 + k(Curve).C7 * assay * Burnup + k(Curve).C8 * Burnup *
Age + k(Curve).C9 * Age * assay + k(Curve).C10 * Age * Burnup * assay + _
        k(Curve).C11 * Burnup ^ 3 + k(Curve).C12 * assay ^ 3

  Debug.Print Current_Year; Burnup; assay; Age; Curve; test_k_infinity

.
.
.
End Function
```

A.4 Subroutine Adust_Rates in Form Logistics

A "Debug.Print" statement was added to print out input and adjusted acceptance rates for CSNF (added line shown in bold type).

```
Public Sub Adjust_Rates()
ReDim temp(Accept_Init_Year - 2 To Accept_End_Year + 2) As ACCEPT_INFO
Dim CY_Adjust As Integer, Endyr As Integer, ny As Integer
Dim frac As Single
.
.
.

' CSNF
ReDim Preserve Accept(Accept_Init_Year To Accept_End_Year) As ACCEPT_INFO
```

```
For I = Accept_Init_Year To Accept_End_Year
    temp(I) = Accept(I)
Next I
ReDim Accept(Accept_Init_Year To Accept_End_Year + 1) As ACCEPT_INFO
frac = (13 - CY_Adjust - Begin_Month(AcceptCC_Flag).Accept(0)) / 12
For I = Accept_Init_Year To Accept_End_Year
    If CY_Adjust = 3 And Begin_Month(AcceptCC_Flag).Accept(0) > 9 Then
        Accept(I).Acceptance_Rate = (1 + frac) * temp(I - 1).Acceptance_Rate - frac *
temp(I - 2).Acceptance_Rate
    Else
        Accept(I).Acceptance_Rate = (1 - frac) * temp(I - 1).Acceptance_Rate + frac *
temp(I).Acceptance_Rate
    End If
Next I
frac = (13 - CY_Adjust - Begin_Month(AcceptCC_Flag).Empl(0)) / 12
For I = Accept_Init_Year To Accept_End_Year
    If CY_Adjust = 3 And Begin_Month(AcceptCC_Flag).Empl(0) > 9 Then
        Accept(I).MGR_rate(1) = (1 + frac) * temp(I - 1).MGR_rate(1) - frac * temp(I -
2).MGR_rate(1)
    Else
        Accept(I).MGR_rate(1) = (1 - frac) * temp(I - 1).MGR_rate(1) + frac *
temp(I).MGR_rate(1)
    End If
    Accept(I).isf_rate(1) = Accept(I).Acceptance_Rate - Accept(I).MGR_rate(1)

 Debug.Print I, temp(I).Acceptance_Rate, Begin_Month(AcceptCC_Flag).Accept(0),
CY_Adjust, Accept(I).Acceptance_Rate

Next I
```

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APPENDIX B

ATTACHED ELECTRONIC FILES

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ATTACHED ELECTRONIC FILES

B.1 Test Case Worksheets

The test case calculations are contained in 24 Microsoft Excel 97 files. The files are listed in the following table. The files are attached to this report on a Compact Disk (CD) in electronic format.

Table B-1. Microsoft Excel 97 files for CALVIN V3.0 Test Cases

Test Case Number	File Name	Size (kB)	Date
1	CALVIN VTR Case 1 Rev 00.XLS	2,010	7/20/00
2	CALVIN VTR Case 2 Rev 00.XLS	17	1/3/00
3	CALVIN VTR Case 3 Rev 00.XLS	19	1/3/00
4	CALVIN VTR Case 4 Rev 00.XLS	88	7/24/00
5	CALVIN VTR Case 5 Rev 00.XLS	26	7/11/00
6	CALVIN VTR Case 6 Rev 00.XLS	23	7/11/00
7	CALVIN VTR Case 7 Rev 00.XLS	264	7/20/00
8	CALVIN VTR Case 8 Rev 00.XLS	261	7/20/00
9	CALVIN VTR Case 9 Rev 00.XLS	301	7/20/00
10	CALVIN VTR Case 10 Rev 00.XLS	345	7/20/00
11	CALVIN VTR Case 11 Rev 00.XLS	365	7/14/00
12	CALVIN VTR Case 12 Rev 00.XLS	351	7/20/00
13	CALVIN VTR Case 13 Rev 00.XLS	352	7/14/00
14	CALVIN VTR Case 14 Rev 00.XLS	421	7/14/00
15	CALVIN VTR Case 15 Rev 00.XLS	618	7/25/00
16	CALVIN VTR Case 16 Rev 00.XLS	634	7/20/00
17	CALVIN VTR Case 17 Rev 00.XLS	1,070	7/20/00
18	CALVIN VTR Case 18 Rev 00.XLS	256	7/20/00
19	CALVIN VTR Case 19,21 Rev 00.XLS	226	7/10/00
20	CALVIN VTR Case 20,22 Rev 00.XLS	236	7/10/00
21	CALVIN VTR Case 19,21 Rev 00.XLS	226	7/10/00
22	CALVIN VTR Case 20,22 Rev 00.XLS	236	7/10/00
23	CALVIN VTR Case 23 Rev 00.XLS	226	7/10/00
24	CALVIN VTR Case 24 Rev 00.XLS	1,527	7/10/00
25	CALVIN VTR Case 25 Rev 00.XLS	1,652	7/11/00

B.2 CALVIN V3.0 Validation Database

The Microsoft Access 97 CALVIN V3.0 database used to produce the reports for comparison to the test cases is attached in electronic format. The file details are shown in the table below.

Table B-2. CALVIN V3.0 Validation Database Description

File Name	Size (kB)	Date
Work_99VTP_Rev_00.mdb	3,300	6/30/00