POLESTAR
NON-PROPRIETARY

PSAT 04202U.03

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Revision: 2

DOSE CALCULATION DATA BASE FOR

APPLICATION OF THE REVISED DBA SOURCE TERM

TO THE CEI PERRY NUCLEAR POWER PLANT

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	PROJECT MGR		REVIEWER		CEI TECH CONT	
	Print/Sign	Date	Print/Sign	Date	Print/Sign	Date
REV: 0	James Metcalf /s	3/27/96	Dave Leaver /s	3/27/96	John Spano /s	4/6/96

Reason for Revision: Initial Issue

REV: 1	James Metcalf /s	4/11/96	Jun Li /s	4/11/96	John Spano /s	4/11/96

Reasons for Revision: (1) Provide references for Items 3.8, 3.9, 3.10, 3.15, 3.20, and 3.21; (2) provide final data and references for Items 4.3 and 4.4; (3) provide value and reference for Item 4.5; (4) provide final data and references for Items 4.6 and 4.7; (5) add Item 4.8; (6) add note to Item 6.6; (7) provide references for Items 7.4, 7.5, and 7.6; (8) provide references for Items 8.1, 8.2, and 8.5; and (9) add Item 9.5

REV: 2	James Metcalf /s	6/14/96	Dave Leaver /s	6/14/96	John Spano /s	6/14/96

Reasons for Revision: (1) Remove "Generic Note" on cover page; (2) provide a thyroid DCF for Cs-137; (3) increase Items 3.11 and 3.12 by 50%; (4) make Items 3.13/3.14 consistent with Items 3.11/3.12; (5) increase Item 3.17 by 50%; (6) provide Item 4.5; (7) revise Items 4.6 and 4.7 to be consistent with Rev 1 of 04202H.08; (8) provide reference for Item 6.5; (9) provide value and reference for Item 6.7; (10) change reference for Item 7.5

1. Radionuclide Data (References - Mass and Ci Inventories: DRF A41-00054; Decay Constants and DCFs: Library Files from LOCADOSE as Documented in Controlled Copy 00126D-1 of LOCADOSE NE319 Provided to Polestar by Bechtel at Request of CEI)

1.1 Core Power - Radiological Calculations - 3758 Mw(t) (Reference CEI Calc 3.2.6.4, Rev 0, Pg 3A of 33)

1.2 Nuclide	Core Inventory @ t=0 10^7Ci	(per sec) DKlambda	(10^{-2} Rem-m^3/Ci-sec) WB DCF	Skin DCF	(10^4 Rem/Ci) Thyroid DCF
Kr-83m	1.214	1.05E-04	0.00149	0.0136	0.0
Kr-85m	2.519	4.30E-05	2.6	8.31	0.0
Kr-85	0.160	2.05E-09	0.0355	5.01	0.0
Kr-87	4.788	1.51E-04	14.2	52.3	0.0
Kr-88	6.509	6.73E-05	35.8	54.9	0.0
Kr-89	8.159	3.63E-03	32.3	77.1	0.0
Xe-131m	0.115	6.82E-07	0.136	1.78	0.0
Xe-133m	0.648	3.66E-06	0.472	3.84	0.0
Xe-133	19.84	1.53E-06	0.558	1.84	0.0
Xe-135m	4.107	7.38E-04	6.82	11.3	0.0
Xe-135	7.170	2.11E-05	3.96	11.5	0.0
Xe-137	18.01	3.02E-03	3.03	50.1	0.0
Xe-138	16.82	8.15E-04	19.9	40.9	0.0
I-131	10.23	9.98E-07	6.06	11.2	100.0
I-132	14.74	8.43E-05	37.7	61.8	0.59
I-133	20.65	9.21E-06	9.73	22.1	18.0
I-134	22.63	2.20E-04	43.8	73.2	0.1
I-135	19.35	2.91E-05	26.4	43.4	3.0
Cs-134	3.029	1.07E-08	25.4	37.1	4.0
Cs-137	1.745	7.28E-10	0.0	2.8	2.9
Ba-137m	Cs-137 daughter	4.53E-03	9.70	14.6	0.0
Te-132	14.49	2.46E-06	3.46	5.04	21.0

1.3 Core Inventory by Mass

Element	g/Mw(t)	grams*
Cs	1.33E+02	4.74E+05
I	1.05E+01	3.76E+04
Te	2.13E+01	7.62E+04
Ba	6.58E+01	2.35E+05
Sr	4.15E+01	1.49E+05
Ce	1.22E+02	4.36E+05

*Based on Item 1.1 power ÷ 105% since low power estimate (and low estimate of mass) is conservative for transport

La	5.56E+01	1.99E+05
Ru	1.06E+02	3.78E+05
Sn	3.93E+00	1.41E+04
Ag	3.13E+00	1.12E+04
As	8.87E-03	3.18E+01
Be	6.80E-06	2.43E-02
Br	9.79E-01	3.50E+03
C	1.20E-06	4.28E-03
Cd	4.90E+00	1.75E+04
Dy	6.00E-02	2.15E+02
Er	2.31E-03	8.28E+00
Eu	7.92E+00	2.84E+04
Ga	1.29E-06	4.61E-03
Gd	3.71E+00	1.33E+04
Ge	2.96E-02	1.06E+02
H	2.46E-03	8.81E+00
Ho	6.17E-03	2.21E+01
In	8.03E-02	2.88E+02
Kr	1.71E+01	6.11E+04
Li	9.30E-06	3.33E-02
Mo	1.48E+02	5.30E+05
Nb	1.14E+00	4.09E+03
Nd	1.72E+02	6.17E+05
Pd	5.63E+01	2.01E+05
Pm	5.09E+00	1.82E+04
Pr	4.99E+01	1.79E+05
Rb	1.59E+01	5.68E+04
Rh	1.71E+01	6.13E+04
Sb	1.31E+00	4.68E+03
Se	2.58E+00	9.23E+03
Sm	3.43E+01	1.23E+05
Tb	1.10E-01	3.95E+02
Tc	3.48E+01	1.25E+05
Tm	2.25E-06	8.06E-03
Xe	2.31E+02	8.26E+05
Y	2.17E+01	7.78E+04
Yb	4.70E-07	1.68E-03
Zn	2.70E-04	9.65E-01
Zr	1.63E+02	5.82E+05

2. Source Terms (Reference Calc PSAT 04212H.01, Rev 0)

2.1 Fraction of core inventory, 0 - 30 seconds: no releases

2.2 Fraction of core inventory, 30 - 1830 seconds: Gases - Xe, Kr - 2.8E-5 /sec (0.05 total)
Elemental I - 1.3E-6 /sec (2.4E-3 total)
Organic I - 4.2E-8 /sec (7.5E-5 total)

Aerosols - Iodine - 2.6E-5 /sec (0.0475 total)
Cesium - 2.8E-5 /sec (0.05 total)

2.3 Fraction of core inventory, 1830 - 7230 seconds: Gases - Xe, Kr - 1.8E-4 /sec (0.95 total)
Elemental I - 2.2E-6 /sec (1.2E-2 total)
Organic I - 6.9E-8 /sec (3.8E-4 total)

Aerosols - Iodine - 4.4E-5 /sec (0.2375 total)
Cesium - 3.7E-5 /sec (0.2 total)
Tellurium - 9.3E-6 /sec (0.05 total)

3. Volumes and Volumetric Flowrates

3.1 Volume of Drywell - 276500 ft^3 (Reference CEI Calc 3.2.6.4, Rev 0, Pg 3A of 33)

3.2 Volume of Wetwell/Lower Containment (Unsprayed) - 684226 ft^3 (Reference CEI Calc 3.2.6.4, Rev 0, Pg 3A of 33)

3.3 Volume of Upper Containment (Sprayed) - 481174 ft^3 (Reference CEI Calc 3.2.6.4, Rev 0, Pg 3A of 33)

3.4 Volume of Suppression Pool - 114379 ft^3 (Reference Sht 1, Design Change Control for CL-ECA-036, Rev 0)

3.5 Volume of Upper Pool Dump - 32573 ft^3 (Reference Table 4-1, NEDC-31940, March 1991)

3.6 Volume of Annulus - 1.96E5 ft^3 (Reference CEI Calc 3.2.6.4, Rev 0, Pg 3A of 33, including 50% decrease to account for incomplete mixing)

3.7 Volume of Control Room (CR) - 3.44E5 ft^3 (Reference CEI Calc CL-M26-01, Rev 1, Pg 3a)

3.8 Volume of One Main Steamline between MSIVs - 146 ft^3 (Reference Calc PSAT 04202H.08, Rev 0)

3.9 Volumetric Flowrate, Drywell to Wetwell/Lower Cont: (Reference Calc PSAT 04212H.02,

Rev 0 with conversion from cfs to cfm)

From t=0 to t=1830 seconds - 0
From t=1830 to t=7230 seconds - 6180 cfm
From t=7230 to t=7333 seconds - 0
From t=7333 to t=7344 seconds - 5.4E4 cfm
From t=7344 to t=7356 seconds - 1.3E5 cfm
From t=7356 to t=7369 seconds - 1.8E5 cfm
From t=7369 to t=7383 seconds - 2.1E5 cfm
From t=7383 to t=7397 seconds - 2.3E5 cfm
From t=7397 to t=7411 seconds - 2.5E5 cfm
From t=7411 to t=7425 seconds - 2.6E5 cfm
From t=7425 to t=7439 seconds - 2.1E5 cfm
From t=7439 to t=7451 seconds - 1.6E5 cfm
From t=7451 to t=7463 seconds - 1.0E5 cfm
From t=7463 to t=7474 seconds - 5.5E4 cfm
From t=7474 to t=7484 seconds - 1.2E4 cfm
From t=7484 seconds to end of problem - 500 cfm

3.10 Volumetric Flowrate, Wetwell/Lower Cont to Drywell: (Reference Calc PSAT 04212H.02, Rev 0 with conversion from cfs to cfm)

From t=0 to t=7484 seconds - 0
From t=7484 seconds to end of problem - 500 cfm

3.11 Volumetric Flowrate, Upper Cont to Environment

- 0.67 cfm (Initial)
- 0.0675 cfm (After 40 seconds)

(Reference Perry Technical Specifications Section 3.6.1.2, 0.2%/day x Item 3.3/24 hours/day for first 40 seconds, then from CEI Calc 3.2.6.4, Rev 0, as modified by memo Ortalan to Bordley dated 5/20/96, 10.08% of initial value bypasses annulus after 40 seconds)

3.12 Volumetric Flowrate, Lower Cont* to Environment
(*includes Drywell volume)

- 1.34 cfm (Initial)
- 0.135 cfm (After 40 seconds)

(Reference Perry Technical Specifications, Section 3.6.1.2, 0.2%/day x Item 3.2/24 hours/day for first 40 seconds, then from CEI Calc 3.2.6.4, Rev 0, as modified by memo Ortalan to Bordley dated 5/20/96, 10.08% of

initial value bypasses annulus after 40 seconds)

3.13 Volumetric Flowrate, Upper Cont to Annulus - 0 (Initial)

0.603 cfm (After 40 seconds)

(Same basis as Item 3.11)

3.14 Volumetric Flowrate, Lower Cont* to Annulus - 0 (Initial)
(*includes Drywell volume)

1.205 cfm (After 40 seconds)

(Same basis as Item 3.12)

3.15 Volumetric Mixing Flowrate between Upper and Lower Cont - 71400 cfm
(Reference Calc PSAT 04212H.06, Rev 0)

3.16 Volumetric Flowrate, Annulus to Environment (Filtered) - 2000 cfm
(Reference CEI Calc 3.2.6.4, Rev 0, Pg 10 of 33)

3.17 Volumetric Flowrate, ESF Leakage:

From t=0.175 to t=720 hours - 15 gph (Reference 10 gph from CEI Calc 3.2.6.4, Rev 0, Pg 9 of 33, except starting at time of spray initiation, see Item 9.1. Per Scope of Work attached to PSAT 04202U.01, this value has been increased - see CEI memo Ortalan to Bordley dated 5/20/96 for 15 gph)

From t=24 to t=24.5 hours - 3000 gph additional
(Reference SRP Section 15.6.5, Rev 2, as 50 gpm)

3.18 Volumetric Flowrate, Environment to CR (Unfiltered) - 1375 cfm
(Reference CEI Calc 3.2.6.5, Rev 0, Pg 20 of 20, maximum flow of 1375 cfm for immediate isolation case)

3.19 Volumetric Flowrate, CR Recirculation (Filtered) - 2.7E4 cfm
(Reference Perry Technical Specifications Section 3/4.7.2)

3.20 Volumetric Flowrate, Drywell to All Main Steamlines (Total Leakage):
- 298 cfh from t=0 to t=7484 seconds
- 247 cfh from t=7484 seconds to end (Reference Calc PSAT 04202H.04, Rev 0)

3.21 Volumetric Flowrate (Maximum), One Main Steamline to Environment - 191 cfh (Reference Calc PSAT 04202H.08, Rev 0)

3.22 Combined MSIV Tested Leakrates - 250 scfh (To be established by Perry Revised Accident Source Term Project - no reference required)

3.23 Per Line MSIV Tested Leakrate - 100 scfh (Same as 3.22)

3.24 Core Spray - One Pump Flowrate at Low RCS Pressure - 7800 gpm (Reference Fax Spano to Metcalf dated 1/9/96)

3.25 RHR Cont Spray Mode - One Pump - 5250 gpm (Reference Fax Spano to Metcalf dated 1/9/96)

3.26 H_2 Mixing Fans, One Fan - 500 cfm or 3E4 cfh (Reference CEI Calc 3.2.6.4, Rev 0, Pg 9 of 33)

4. Filter Efficiencies, Removal Lambdas, and Decontamination Factors

4.1 Filter Efficiency - Annulus Exhaust Gas Treatment System (AEGTS): (Reference CEI Calc 3.2.6.4, Rev 0, Pg 10 of 33, assuming other particulates behave like particulate iodine)

- For Particulate Iodine, Cesium (including Ba-137m), and Tellurium - 99%
- For Elemental and Organic Iodine and Noble Gasses - 0%

4.2 Filter Efficiency - CR Recirculation: (Reference Gilbert & Associates, Inc. Bill of Material for HVAC, Perry Nuclear Power Plant Units 1 and 2, Sht 170, Issue 2, 4/6/77 and RG 1.52, Rev 2, assuming other particulates behave like particulate iodine. Per Scope of Work attached to PSAT 04202U.01, CR recirculation delayed - assumed to start at start of fuel release.)

From t=0 to t=1830 seconds:

- For Iodine, Cesium (including Ba-137m), and Tellurium - 0%
- For Noble Gasses - 0%

From t=1830 to t=end of problem:

- For Iodine, Cesium (including Ba-137m), and Tellurium - 95%
- For Noble Gasses - 0%

4.3 Removal (Sedimentation) Lambdas in Drywell: (Reference Calc PSAT 04202H.04, Rev 0 - values are medians over cited intervals)

For Particulate and Elemental Iodine, Cesium (including Ba-137m), and Tellurium:

- From t=0 to t=30 seconds - 0/hour
- From t=30 to t=66 seconds - 0.084/hour
- From t=66 to t=1867 seconds - 0.184/hour
- From t=1867 to t=3203 seconds - 0.25/hour
- From t=3203 to t=4384 seconds - 0.35/hour
- From t=4384 to t=5862 seconds - 0.45/hour
- From t=5862 to t=7333 seconds - 0.54/hour
- From t=7333 to t=7484 seconds - 0.58/hour
- From t=7484 to t=9254 seconds - 0.54/hour
- From t=9254 to t=15881 seconds - 0.45/hour
- From t=15881 to t=30669 seconds - 0.35/hour
- From t=30669 to t=51639 seconds - 0.25/hour
- From t=51639 to t=100000 seconds - 0.16/hour
- From t=100000 seconds to end - 0/hour

For Organic Iodine and Noble Gasses

- From t=0 to end - 0/hour

4.4 Removal (Spray) Lambdas in Upper Containment:

(Reference Calc PSAT 04202H.05, Rev 0 - values are end points for cited intervals - conservative since values are generally decreasing - see Item 9.1 for explanation of initial time shift, 630 to 690 seconds and Item 9.5 for spray duration)

For Particulate and Elemental Iodine, Cesium (including Ba-137m), and Tellurium:

- From t=0 to t=690 seconds - 0/hour
- From t=690 to t=728 seconds - 8.13/hour
- From t=728 to t=924 seconds - 4.32/hour
- From t=924 to t=1317 seconds - 3.02/hour
- From t=1317 to t=1710 seconds - 2.52/hour
- From t=1710 to t=1897 seconds - 14.3/hour
- From t=1897 to t=2070 seconds - 8.76/hour
- From t=2070 to t=2529 seconds - 5.07/hour
- From t=2529 to t=3141 seconds - 3.84/hour
- From t=3141 to t=4030 seconds - 3.25/hour
- From t=4030 to t=5339 seconds - 3.22/hour
- From t=5339 to t=6702 seconds - 3.30/hour
- From t=6702 to t=7377 seconds - 6.55/hour
- From t=7377 to t=7760 seconds - 3.30/hour
- From t=7760 to t=11724 seconds - 1.19/hour
- From t=11724 to t=17469 seconds - 0.50/hour
- From t=17469 to t=30823 seconds - 0.27/hour
- From t=30823 to t=40039 seconds - 0.23/hour
- From t=40039 to t=69513 seconds - 0.20/hour

- From t=69513 to t=87090 seconds - 0.19/hour
- From t=87090 seconds to end - 0/hour

For Organic Iodine and Noble Gasses

- From t=0 to end - 0/hour

4.5 Minimum DF for Elemental Iodine in Containment - 70000 (Reference Calc PSAT 04212H.03, Rev 0)

4.6 Filter Efficiency for Flowpath From Drywell through Main Steamlines, One Inboard MSIV Failed

(Reference Calcs PSAT 04202H.08, Rev 1 and .09, Rev 0)

- For Particulate Iodine, Cesium (including Ba-137m), and Tellurium
  - 76.7% from t = 0 to t = 1200 seconds
  - 94.5% from t = 1200 to t = 1800 seconds
  - 96.9% from t = 1800 to t = 5400 seconds
  - 97.4% from t = 5400 to t = 10800 seconds
  - 97.8% from t = 10800 to t = 18000 seconds
  - 98.0% from t = 18000 to t = 25200 seconds
  - 97.6% from t = 25200 to t = 32400 seconds
  - 97.1% from t = 32400 to t = 39600 seconds
  - 94.4% from t = 39600 seconds to end
- For Elemental Iodine - 50%
- For Organic Iodine and Noble Gasses - 0%

4.7 Filter Efficiency for Flowpath From Drywell through Main Steamlines, All Third Isolation Valves Failed

(Reference Calcs PSAT 04202H.08, Rev 1 and .09, Rev 0)

- For Particulate Iodine, Cesium (including Ba-137m), and Tellurium
  - 84.2% from t = 0 to t = 1800 seconds
  - 91.2% from t = 1800 to t = 5400 seconds
  - 93.0% from t = 5400 to t = 10800 seconds
  - 93.7% from t = 10800 to t = 18000 seconds
  - 92.5% from t = 18000 to t = 25200 seconds
  - 90.4% from t = 25200 to t = 32400 seconds
  - 88.0% from t = 32400 to t = 39600 seconds
  - 68.0% from t = 39600 seconds to end
- For Elemental Iodine - 50%
- For Organic Iodine and Noble Gasses - 0%

4.8 Release Fraction of Radioiodine in ESF Leakage - 0.1 (Reference SRP 15.6.5, Rev 2)

5. X/Q Values, Breathing Rates, and Occupancy Factors

5.1 X/Q (sec/m^3):

	EAB	LPZ	CR
From t=0 to 2 hours	4.3E-4	4.8E-5	7E-5
From t=2 to t=8 hours		4.8E-5	7E-5
From t=8 to t=24 hours		3.3E-5	5.6E-5
From t=24 to t=96 hours		1.4E-5	4.3E-5
From t=96 to t=720 hours		4.1E-6	1.5E-5

(Reference CEI Calc 3.2.6.4, Rev 0, Pg 10 of 33 for EAB and LPZ, and Perry Design Input Record 3.2.6.5, Rev 1, Attachment 1 for CR)

5.2 Breathing rates: (Reference CEI Calc 3.2.6.4, Rev 0, Pg 10 of 33)

0 - 8 hours - 3.47E-4 m^3/sec (used in CR for 0 - 720 hours)
8 - 24 hours - 1.75E-4 m^3/sec
24 - 720 hours - 2.32E-4 m^3/sec

5.3 CR Occupancy Factors: (Reference SRP Section 6.4, Rev 2)

From t=0 to t=1 day - 1.0
From t=1 to t=4 days - 0.6
From t=4 to t=30 days - 0.4

6. Chemistry Data

6.1 Initial Pool pH - 6.0 (Average Based on Reference RPI-1103, Rev 1 Data)

6.2 Mass of Chloride-Bearing Cable Insulation in Containment (Reference Memo "E" SO-16662, Maloney to Spano dated 10/27/95)

- Hypalon - 2.9E4 lbm
- PVC - negligible

6.3 Thickness of Hypalon Jacket - 45 mils (Reference Memo "E" SO-16662, Maloney to Spano dated 10/27/95 and Rockbestos Letter, Konnik to Zarca dated 10/10/95)

6.4 Mass of Sodium Pentaborate Available for Injection - 5236 lbm (Reference Perry Tech Specs Section 4.1.5)

6.5 Formula of Sodium Pentaborate - Na_2O-$5B_2O_3$-$10H_2O$* (Reference CEI telecon memo, J. Spano, J. Ratchen, D. Leaver, dated 4/19/96)

*Natural boron

6.6 Water Volume in Containment (including RCS) - 1.7E5 ft^3*

*Note that this does not include all possible in-containment water which is conservative for iodine

concentration effect; pH not greatly sensitive
(Reference Fax Spano to Metcalf dated 3/22,28/96)

6.7 Mass of Item 6.2 Hypalon in Drywell - 3750 lbm (Reference CEI telecon memo, J. Spano, J. Maloney, dated 3/12/96)

6.8 Reference Cable OD (Approx Average for Chloride-Bearing) - 2.26 cm
(Reference J. Wing, "Post-Accident Gas Generation from Radiolysis of Organic Materials", NUREG-1081, September 1984)

7. Fission Product Transport Data

7.1 Approximate Containment Dimensions: (Reference Containment Definition, 762E576, Rev 5)

- Radius of Drywell Cylinder - 36.5 feet
- Height of Drywell Cylinder (Above Support Mat) - 76.5 feet
- Height of Drywell Head (Above Drywell Concrete) - 16.5 feet
- Radius of Drywell Head - 16 feet
- Height of Containment Above Suppression Pool Surface - 154 feet
- Radius of Containment Cylinder - 60 feet
- Thickness of Drywell Wall - 5 feet
- Height of Containment Cylinder Above Suppression Pool Surface - 124 feet
- Height of Containment Cylinder Above Operating Floor - 37.5 feet

7.2 Sedimentation Area in Drywell - 8712 ft^2

(Reference Fax Spano to Leaver dated 11/1/95 giving data that totals to 4527 ft^2*. This can be added to simple cross-section of drywell = $\pi(36.5\ ft)^2 = 4185\ ft^2$ to obtain the given value.)
*Note that addition error in fax would give value 0.8% higher, but error is small and conservative.

7.3 Sedimentation Area in Wetwell/Lower Containment - 5899 ft^2

(Simple cross-section of containment outside drywell wall = $\pi[(60\ ft)^2 - (36.5 + 5\ ft)^2] = 5899\ ft^2$)

7.4 Vessel ID - 238" (Reference Fax Spano to Metcalf dated 1/29/96)

7.5 Steamline ID - 23.36" (Reference Gilbert Calc IN11G38A, Rev 6, Page 18.1)

7.6 Length of Steamline, Inboard MSIV to Outboard MSIV - 49' (Reference Calc 04202H.08, Rev 0)

7.7 Length of Steamline, Outboard MSIV to 3rd Isolation Valve - 29' (Reference Calc 04202H.08,

Rev 0)

7.8 Spray System Parameters: (Reference Fax Ortalan to Leaver dated 6/21/95)

- Mean Spray Fall Height - 53.2'
- r_g for drop size distribution - 0.025 cm
- σ for drop size distribution - 2.9

8. Thermal-Hydraulic Data

8.1 Containment Conditions after Blowdown, but Prior to End of Debris Quench (Up to 7484 seconds) (Reference Calc PSAT 04212H.02, Rev 0)

Maximum Containment Conditions:

Drywell Pressure: Approx 0 to 630 seconds (sprays on at 630 sec) - 32 psia

630 to 1830 sec (end of gap) - uniform decrease from 32 to 20 psia

1830 to 7333 sec (start of steam from reflood) - 20 psia

7333 to 7484 sec (end of steam from reflood) - 32 psia

Drywell Temperature: 330 F

Containment Pressure: Approx 0 to 630 seconds (sprays on at 630 sec) - uniform increase from 20 to 24 psia

630 to 1830 sec (end of gap) - uniform decrease from 24 to 20 psia

1830 to 7333 sec (start of steam from reflood) - 20 psia

7333 to 7484 sec (end of steam from reflood) - 24 psia

Containment Temp: Approx 0 to 630 seconds (sprays on) - uniform increase from 145 F to 160 F

630 to 1830 sec (end of gap) - uniform decrease from 160 F to 140 F

1830 to 7333 sec (start of steam from reflood) - 140 F

7333 sec to 7484 sec (end of steam from reflood) - 185 F

Minimum Containment Conditions:

Drywell and Containment Pressure: 1 psig (15.7 psia)

Drywell Temperature: 215 F

Containment Temp: 100 F

8.2 Containment Conditions after Debris Quench (Reference Calc PSAT 04212H.02, Rev 0)

Maximum Containment Conditions:

Drywell Pressure: 7484 to 86400 sec - 30 psia

1 to 12 days - uniform decrease from 30 to 20 psia

12 to 30 days - uniform decrease from 20 psia to 18 psia

Drywell Temperature: 7484 to 10800 sec - 330 F

10800 to 21600 sec - 320 F

21600 to 86400 sec - 250 F

1 to 12 days - uniform decrease from 250 to 150 F

12 to 30 days - uniform decrease from 150 to 130 F

Containment Pressure: 7484 to 6E5 sec - 24 psia

6E5 sec to 30 days - uniform decrease from 24 to 19 psia

Containment Temp: 7484 to 86400 sec - 185 F

1 to 30 days - uniform decrease to 115 F

Minimum Containment Conditions:

Drywell and Containment Pressure: 1 psig (15.7 psia)

Drywell and Containment Temperature: 100 F

8.3 Core Power - Thermal-Hydraulic Calculations - 3729 Mw(t) (Reference Table 4-1, NEDC-31940, March 1991)

8.4 Reference Pressure for Determination of Initial Steamline Temperature* - 1060 psia

(*saturation temperature at the pressure specified)

(Reference Table 4-1, NEDC-31940, March 1991)

8.5 Maximum Suppression Pool Temperature - 212 F (Reference Calc PSAT 04212H.02, Rev 0)

8.6 Minimum ECCS Injection Temperature Post-Blowdown - 100 F
(Reference Figure 5-6, NEDC-31940, March 1991 which shows approx 10 F pool temperature increase during first 10 seconds of blowdown and Figure 5-9, same reference, which shows pool temperature in excess of 105 F at same 10 seconds after blowdown and increasing thereafter. ECCS assumed to start at t=7230 seconds.)

8.7 Area of Equipment Transfer Opening in Refueling Floor - 340 ft^2
(Reference 20'7" x 16'6" Opening on Dwg D511-025, Rev D)

9. System-Related Data (Other than Volumetric Flows)

9.1 Spray Initiation Time - 10 minutes after low vessel level if 9 psig reached in containment*
(Reference Loop Diagram 808-309, Sht 5, Rev D)
*Preliminary data of 10 minutes/9 psig used in thermal-hydraulic and removal lambda calculations - no change required since outputs of thermal-hydraulic calculation (for dose calculatons of record) would be unchanged and outputs of removal lambda calculation are conservative for dose calculatons as long as 11 minutes (+ 30 seconds for reactor blowdown/loss of level) is used in the dose calculations - see Item 4.4

9.2 Third Steamline Isolation Valve Closure Time - Manual action at t=20 min
(Reference as Acceptable Assumption - Fax Spano to Metcalf dated 3/22,28/96)

9.3 RHR HX Kvalue - 440 BTU/sec-F (Reference Tabel 4-1, NEDC-31940, March 1991)

9.4 Service Water Temp - 85 F (Reference Tabel 4-1, NEDC-31940, March 1991)

9.5 Spray Duration - 6 hours or 24 hours after spray start (Reference CEI Calc 3.2.6.4, Rev 0, Pg 11 of 33 for 6 hour duration. 24 hour duration being treated parametrically)

PSAT 04212H.01

POLESTAR
NON-PROPRIETARY

CALCULATION TITLE PAGE

CALCULATION NUMBER: PSAT 04212H.01

CALCULATION TITLE:

"Source Term for Use on Perry Application of NUREG-1465"

	ORIGINATOR Print/Sign	Date	CHECKER Print/Sign	Date	IND REVIEWER Print/Sign	Date
REVISION: 0	James Metcalf [signature]	3/4/96	David Leaver [signature]	3/5/96	David Leaver [signature]	3/5/96
1						
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REASON FOR REVISION:

	Nonconformance Rpt
0 - Initial Issue	N/A
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Purpose

The purpose of this calculation is to relate the source terms of Reference 1 to their application to the CEI Perry Nuclear Power Plant.

Methodology

The application of the revised source terms of Reference 1 to any plant requires the identification of the plant type (PWR or BWR) and a decision as to the time of the start of the gap release. For application to Perry the plant type is BWR, and for BWRs (according to Reference 1) the time to the onset of activity release (i.e., the start of the gap release phase) would be conservatively established if PWR timing were used. This is what has been done.

Assumptions

Assumption 1: The 10CFR100 Design Basis Accident (DBA), for purposes of applying the revised DBA source terms of Reference 1, is a large main steamline loss-of-coolant-accident (MSL LOCA).

Justification: This accident is the current limiting DBA for the containment design, and will also lead to a slower core damage progression and a greater time-integrated airborne

activity in the drywell (the source of the MSIV leakage and a region not benefitted by the mitigating effects of containment spray) than would a recirculation line LOCA.

Assumption 2: For application to Perry the PWR timing for the start of release is applied. This timing is approximated by the use of a 30 second delay from the time of reactor shutdown to that of the start of the gap activity release. Once begun, the gap activity release is assumed to be at a uniform rate over the 30 minute duration of the gap release phase.

Justification: By the commentary of Reference 1, this is conservative for Perry. Reference 1 states that for accidents where long-term cooling of fuel is maintained (e.g.,for a fuel handling accident), the release of the gap activity in failed pins (during the transient overheating of the fuel or immediately after mechanical damage) must be assumed to be instantaneous. This is a reasonable position. It also states that for accidents where long-term cooling is not maintained (e.g., for the 10CFR100 DBA which is the subject of this calculation), the release of the gap activity in the failed pins would be instantaneous, followed by an additional release (equal to 2/3 of the instantaneous release) over the full duration of the "gap release" (that release which occurs prior to the onset of fuel melting). This may be a reasonable position for an individual pin that has been operating at a high power level, but the timing of pin failures and the subsequent temperature rise in individual pins varies across core. This variation needs to be considered, as well as the fact that the magnitude of the gap inventory will not be uniform; i.e., higher burnup pins will, to a degree, exhibit higher gap activity.

According to Reference 1, the failures of the first pin is predicted to occur for PWRs at about 30 seconds after the loss of coolant; other pin failures will follow. A review of some of the analyses supporting Reference 1 (e.g., those listed on Tables 3.1 and 3.2 of Reference 1) indicate that the average core temperature can lag the peak core temperature by many minutes; and while this effect accounts for both radial and axial temperature distributions (and only the radial distribution is significant for the issue of relative timing of pin failures), it still suggests that the assumption of all pins failing in unison at approximately 30 seconds after the loss of coolant accident is excessively conservative.

A more reasonable assumption is one of a uniform release (over the duration of the gap release) totaling 1.67 times the assumed maximum gap inventory available for release at the start of the accident. This takes into account both the progressive nature of the pin failures and the additional release which will occur as pins increase in temperature after failure (but prior to fuel melting). In other words, if

one assumes that 3% of the core inventory of a radionuclide of interest is in the gap at the time of the coolant loss, then 5% would be assumed to be released uniformly over the 30 minute duration of the gap release. This would correspond to a rate of 0.17 % of the core inventory/minute for that radionuclide.

Assumption 3: HI may be neglected in terms of containment behavior and all iodine other than particulate CsI and organic iodine may be considered I_2.

Justification: Reference 2 states that I and HI will coexist and that I will be favored if hydrogen pressures are low and/or if temperatures are relatively high in the location where equilibrium is attained. Specifically, is seven accident sequences studied in Reference 2, the only sequence in which the overall I + HI release exceeded 0.1% of the total iodine was a large break PWR LOCA. For this case, the relatively high temperature gradients within the RCS and the relatively low production of hydrogen (both due to the low steam generation rates characteristic of large break LOCAs) contributed to a relatively high percentage of non-CsI iodine (about 3.2%) but also to a relatively low ratio of HI to I (only 0.4% out of the 3.2%). It should be noted that a large break <u>BWR</u> LOCA was also studied (as one of the other six sequences for which almost no HI or I was found). Given these findings, it is evident that for relatively large release fractions of non-CsI iodine (characteristic of a PWR large break LOCA), little HI will be found, and that for BWRs, even for large break LOCAs, little HI will be found. I_2, on the other hand, has non-RCS sources as well as RCS sources and must be considered even for BWRs. Reference 1 also <u>requires</u> its consideration.

Once in containment, both I_2 and HI are reactive. The solubility of HI, however, is considerably greater than I_2 (nearly 3000 times greater on a molar basis); therefore, one would expect the persistence of HI as an airborne component to be less than I_2 in a steam and water environment. For this reason, as well as for its small release relative to I under the conditions where non-CsI iodine releases occur, it is considered reasonable to treat all non-particulate, non-organic iodine in containment as I_2.

References

Reference 1: Soffer, L., et al., "Accident Source Terms for Light-Water Nuclear Power Plants", NUREG-1465, February 1995

Reference 2: Beahm, E. C., et al., "Iodine Chemical Forms in LWR Severe Accidents", NUREG/CR-5732, April 1992

Reference 3: Taylor, J., "Proposed Issuance of Final NUREG-1465, 'Accident Source Terms for Light-Water Nuclear Power Plants'", SECY-94-300, December 15, 1994

Calculation

Specification of Release Phases

Reference 1 describes four release phases: gap, early in-vessel, ex-vessel, and late in-vessel. Reference 3 establishes a precedent for advanced reactors (judged to be applicable to operating plants, as well) that only the first two phases need to be considered for DBA applications. Therefore, two release phases will be referred to: the gap release phase and the fuel release phase, with the fuel release phase making use of only the early in-vessel contribution from Reference 1.

Beginning, Duration, and Release Magnitudes of the Gap Release Phase

By Assumption 2 the gap release starts at 30 seconds and is uniform over time. By Reference 1 the duration of the gap release is 30 minutes. Release magnitudes are as follows (from Reference 1) given as fractions of core inventory and fractions of core inventory per second:

Noble Gas - 0.05 or 2.8E-5 /sec
Iodine* ---- particulate (CsI) - 0.0475 or 2.6E-5 /sec
---- elemental - 2.4E-3 or 1.3E-6 /sec
---- organic - 7.5E-5 or 4.2E-8 /sec
Cesium - 0.05 or 2.8E-5 /sec

*Based on 95% particulate, 4.85% elemental (see Assumption 3), and 0.15% organic

Beginning, Duration, and Release Magnitudes of the Fuel Release Phase

This phase begins at 1830 seconds (i.e., at the end of the gap release phase). The duration (from Reference 1) is 1.5 hours for BWRs; therefore, this release phase ends 7230 seconds after the beginning of the accident. Release magnitudes are as follows (from Reference 1) given as fractions of core inventory and fractions of core inventory per second:

Noble Gas - 0.95 or 1.8E-4 /sec
Iodine* ---- particulate (CsI) - 0.2375 or 4.4E-5 /sec
---- elemental - 1.2E-2 or 2.2E-6 /sec
---- organic - 3.8E-4 or 6.9E-8 /sec

Cesium - 0.2 or 3.7E-5 /sec
Tellurium - 0.05 or 9.3E-6 /sec

*Based on 95% particulate, 4.85%

elemental (see Assumption 3), and
0.15% organic

Results

Fraction of core inventory, 0 - 30 seconds: no releases

Fraction of core inventory, 30 - 1830 seconds:	Gases -	Noble Gas - 2.8E-5 /sec (0.05 total) Elemental I - 1.3E-6 /sec (2.4E-3 tot) Organic I - 4.2E-8 /sec (7.5E-5 total)
	Aerosols -	Iodine - 2.6E-5 /sec (0.0475 total) Cesium - 2.8E-5 /sec (0.05 total)
Fraction of core inventory, 1830 - 7230 seconds:	Gases -	Noble Gas - 1.8E-4 /sec (0.95 total) Elemental I - 2.2E-6 /sec (1.2E-2 tot) Organic I - 6.9E-8 /sec (3.8E-4 total)
	Aerosols -	Iodine - 4.4E-5 /sec (0.2375 total) Cesium - 3.7E-5 /sec (0.2 total) Tellurium - 9.3E-6 /sec (0.05 total)

Conclusions

The source term specification based on Reference 1 has the following characteristics:

1. Two release phases: a Gap Release Phase beginning at t=30 seconds, lasting 1800 seconds, and a Fuel Release Phase beginning at t=1830 seconds, lasting 5400 seconds.

2. Iodine is in either particulate (dominant, as CsI aerosol) or in gaseous form (as I_2 or organic).

POLESTAR
NON-PROPRIETARY

PSAT 04212H.02

CALCULATION TITLE PAGE

CALCULATION NUMBER: PSAT 04212H.02

CALCULATION TITLE:

"Drywell Sweep-Out Rate and Related Thermal-Hydraulic Conditions inside Containment"

	ORIGINATOR		CHECKER		IND REVIEWER	
	Print/Sign	Date	Print/Sign	Date	Print/Sign	Date
REVISION: 0	James Metcalf [signature]	3/27/96	John Trotter [signature]	4/9/96	David Leaver [signature]	4/9/96
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REASON FOR REVISION:	Nonconformance Rpt
0 - Initial Issue	N/A
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Purpose

The purpose of this calculation is to specify the volumetric exchange rates between the Perry drywell and containment during two periods of the problem: during the fission product release (gap release phase from 30 seconds to 1830 seconds and early in-vessel or "fuel" release phase from 1830 seconds to 7230 seconds - see Table 3.6 of Reference 1) and after the fission product release phase (7230 seconds until 30 days which is the end of the dose calculation interval from Reference 2). During (and immediately after) the fission product release phase the flow is only from the drywell to the containment and may be referred to as the "sweep-out" rate.

Methodology

In order to specify the volumetric sweep-out rate, it is necessary to know the quantity of water remaining in the vessel after the DBA blowdown, the thermodynamic state in the drywell, and the rate at which steam is produced from the core debris in-vessel up to and including the point in time where the core debris quench is complete (assuming that to be shortly after 7230 seconds, the end of the in-vessel release phase). Beyond 7230 seconds + the reflood/quench time, the drywell and wetwell/lower containment are assumed to be well-mixed, but a mixing rate must be

specified to reflect that assumption. (Note that the mixing rate between the upper containment which is sprayed and the wetwell/lower containment which is not sprayed is the subject of a separate calculation).

A manual calculation is shown below which:

- Quantifies the minimum water mass remaining in the vessel after DBA blowdown,
- Determines a minimum steaming rate (as a function of time) for that remaining water, and
- Calculates the volumetric flowrate rate (drywell to wetwell/lower containment) that corresponds to that steaming rate and to the final quench of the core debris.

Assumptions

Assumption 1: Reactor vessel reflood occurs at 7230 seconds, terminating the release and quenching the core debris.

Justification: This assumption reflects the position that Reference 3 takes with respect to the release phases of Reference 1. Reference 3 refers to an NRC position taken on the advanced light water reactors in Reference 4, which is:

> "In a forthcoming paper, the NRC staff will indicate that for evaluation of design basis accidents (DBA) for evolutionary and passive light-water reactor designs, only the releases associated with the gap and early in-vessel release phases will be used. The inclusion of the ex-vessel and late in-vessel releases are considered to be unduly conservative for DBA purposes. Such releases would only result from core damage accidents with vessel failure and core-concrete interactions."

This NRC position, as extended to operating reactors by Reference 3, means that vessel failure is not to be included in the DBA. This position also implies, then, that debris coolability must be re-established at about the time of the end of the in-vessel release phase; otherwise, reactor vessel failure would likely follow.

Assumption 2: Suppression pool scrubbing is neglected.

Justification: It is conservative to neglect pool scrubbing. However, it is also technically true that should design levels of pool bypass exist ($A/\sqrt{K} = 1.7\ ft^2$ from Section 4 of Reference 5), then most of the flow from the drywell to the wetwell would bypass the pool in any case.

Assumption 3: Drywell and wetwell/lower containment are mixed by the H_2 mixing fans following the core debris quench at t = 7230 seconds + time to reflood and quench.

Justification: Once the core debris is quenched in-vessel, the production of hydrogen will cease. However, the degree of core damage implied by Reference 1 is such that the hydrogen concentration in the containment necessitating operation of the mixing fans will certainly be exceeded during the core degradation prior to quench. Therefore, it is reasonable to consider the drywell and wetwell/lower containment (i.e., the entire unsprayed containment) to be mixed post-quench by at least one of the mixing fans and to continue that mixing for the 30-day dose calculation period.

Assumption 4: Containment spray mode of RHR is actuated 10 minutes after start of fission product release (i.e., at 630 seconds).

Justification: Since ECCS is not being credited for reflood for the first 7230 seconds and since reflood can be accomplished by core spray operation alone (high- or low-pressure), one loop of RHR containment spray is assumed to be actuated as designed after a delay of 10 minutes following low coolant level being reached in-vessel. This actuation time would be no more than 10 minutes after the start of the assumed fission product release as long as the containment pressure permissive is satisfied.

Nine psig (23.7 psia) in the containment is needed to satisfy the pressure permissive for spray actuation (Reference 6, Item 9.1). It is assumed that pool scrubbing is neglected on the basis of design levels of suppression pool bypass being present (as previously discussed) and since the containment will reach a pressure of at least 19 psia and 1.04 times the initial temperature due solely to airspace compression by air purged from the drywell (see Short-Term Containment Response in the Calculation section, below), it is judged likely that steam bypassed from the drywell will raise the containment pressure the additional 4.7 psi needed for spray actuation. Referring to Exhibit 1 from Reference 7, a steam partial pressure of 4.7 psi requires (1) a saturation temperature of about 160 F (66 F higher than the 94 F given on Page 25 as the expected post-blowdown containment temperature) and (2) an amount of water vapor equal to approximately 15000 lbm (containment free volume of 1.17×10^6 ft^3 from Reference 6, Items 3.2 and 3.3 divided by 79 ft^3/lbm for saturated steam at 160 F and 4.7 psia - see Exhibit 1). If the energy to raise the containment atmosphere temperature also comes from leaking steam, the amount of steam required would be roughly the constant volume heat capacity of the containment atmosphere (approximately 110000 lbm of air x 0.17 BTU/lbm-F) times the temperature change (66 F) divided by 1000 BTU/lbm for condensing steam or slightly more

Exhibit 1

TABLE 2. SATURATION: PRESSURES

Abs Press. Lb/Sq In. p	Temp F t	Specific Volume Sat. Liquid v_f	Specific Volume Sat. Vapor v_g	Enthalpy Sat. Liquid h_f	Enthalpy Evap h_{fg}	Enthalpy Sat. Vapor h_g	Entropy Sat. Liquid s_f	Entropy Evap s_{fg}	Entropy Sat. Vapor s_g	Internal Energy Sat. Liquid u_f	Internal Energy Evap u_{fg}	Internal Energy Sat. Vapor u_g	Abs Press. Lb/Sq In. p
1.0	101.74	0.01614	333.6	69.70	1036.3	1106.0	0.1326	1.8456	1.9782	69.70	974.6	1044.3	1.0
2.0	126.08	0.01623	173.73	93.99	1022.2	1116.2	0.1749	1.7451	1.9200	93.98	957.9	1051.9	2.0
3.0	141.48	0.01630	118.71	109.37	1013.2	1122.6	0.2008	1.6855	1.8863	109.36	947.3	1056.7	3.0
4.0	152.97	0.01636	90.63	120.86	1006.4	1127.3	0.2198	1.6427	1.8625	120.85	939.3	1060.2	4.0
5.0	162.24	0.01640	73.52	130.13	1001.0	1131.1	0.2347	1.6094	1.8441	130.12	933.0	1063.1	5.0
6.0	170.06	0.01645	61.98	137.96	996.2	1134.2	0.2472	1.5820	1.8292	137.94	927.5	1065.4	6.0
7.0	176.85	0.01649	53.64	144.76	992.1	1136.9	0.2581	1.5586	1.8167	144.74	922.7	1067.4	7.0
8.0	182.86	0.01653	47.34	150.79	988.5	1139.3	0.2674	1.5383	1.8057	150.77	918.4	1069.2	8.0
9.0	188.28	0.01656	42.40	156.22	985.2	1141.4	0.2759	1.5203	1.7962	156.19	914.6	1070.8	9.0
10	193.21	0.01659	38.42	161.17	982.1	1143.3	0.2835	1.5041	1.7876	161.14	911.1	1072.2	10
14.696	212.00	0.01672	26.80	180.07	970.3	1150.4	0.3120	1.4446	1.7566	180.02	897.5	1077.5	14.696
15	213.03	0.01672	26.29	181.11	969.7	1150.8	0.3135	1.4415	1.7549	181.06	896.7	1077.8	15
20	227.96	0.01683	20.089	196.16	960.1	1156.3	0.3356	1.3962	1.7319	196.10	885.8	1081.9	20
30	250.33	0.01701	13.746	218.82	945.3	1164.1	0.3680	1.3313	1.6993	218.73	869.1	1087.8	30
40	267.25	0.01715	10.498	236.03	933.7	1169.7	0.3919	1.2844	1.6763	235.90	856.1	1092.0	40
50	281.01	0.01727	8.515	250.09	924.0	1174.1	0.4110	1.2474	1.6585	249.93	845.4	1095.3	50
60	292.71	0.01738	7.175	262.09	915.5	1177.6	0.4270	1.2168	1.6438	261.90	836.0	1097.9	60
70	302.92	0.01748	6.206	272.61	907.9	1180.6	0.4409	1.1906	1.6315	272.38	827.8	1100.2	70
80	312.03	0.01757	5.472	282.02	901.1	1183.1	0.4531	1.1676	1.6207	281.76	820.3	1102.1	80
90	320.27	0.01766	4.896	290.56	894.7	1185.3	0.4641	1.1471	1.6112	290.27	813.4	1103.7	90
100	327.81	0.01774	4.432	298.40	888.8	1187.2	0.4740	1.1286	1.6026	298.08	807.1	1105.2	100
120	341.25	0.01789	3.728	312.44	877.9	1190.4	0.4916	1.0962	1.5878	312.05	795.6	1107.6	120
140	353.02	0.01802	3.220	324.82	868.2	1193.0	0.5069	1.0682	1.5751	324.35	785.2	1109.6	140
160	363.53	0.01815	2.834	335.93	859.2	1195.1	0.5204	1.0436	1.5640	335.39	775.8	1111.2	160
180	373.06	0.01827	2.532	346.03	850.8	1196.9	0.5325	1.0217	1.5542	345.42	767.1	1112.5	180
200	381.79	0.01839	2.288	355.36	843.0	1198.4	0.5435	1.0018	1.5453	354.68	759.0	1113.7	200
250	400.95	0.01865	1.8438	376.00	825.1	1201.1	0.5675	0.9588	1.5263	375.14	740.7	1115.8	250
300	417.33	0.01890	1.5433	393.84	809.0	1202.8	0.5879	0.9225	1.5104	392.79	724.3	1117.1	300
350	431.72	0.01913	1.3260	409.69	794.2	1203.9	0.6056	0.8910	1.4966	408.45	709.6	1118.0	350
400	444.59	0.0193	1.1613	424.0	780.5	1204.5	0.6214	0.8630	1.4844	422.6	695.9	1118.5	400
450	456.28	0.0195	1.0320	437.2	767.4	1204.6	0.6356	0.8378	1.4734	435.5	683.2	1118.7	450
500	467.01	0.0197	0.9278	449.4	755.0	1204.4	0.6487	0.8147	1.4634	447.6	671.0	1118.6	500
550	476.93	0.0199	0.8422	460.8	743.1	1203.9	0.6608	0.7934	1.4542	458.8	659.4	1118.2	550
600	486.21	0.0201	0.7698	471.6	731.6	1203.2	0.6720	0.7734	1.4454	469.4	648.3	1117.7	600
700	503.10	0.0205	0.6554	491.5	709.7	1201.2	0.6925	0.7371	1.4296	488.8	627.5	1116.3	700
800	518.23	0.0209	0.5687	509.7	688.9	1198.6	0.7108	0.7045	1.4153	506.6	607.8	1114.4	800
900	531.98	0.0212	0.5006	526.6	668.8	1195.4	0.7275	0.6744	1.4020	523.1	589.0	1112.1	900
1000	544.61	0.0216	0.4456	542.4	649.4	1191.8	0.7430	0.6467	1.3897	538.4	571.0	1109.4	1000
1100	556.31	0.0220	0.4001	557.4	630.4	1187.8	0.7575	0.6205	1.3780	552.9	553.5	1106.4	1100
1200	567.22	0.0223	0.3619	571.7	611.7	1183.4	0.7711	0.5956	1.3667	566.7	536.3	1103.0	1200
1300	577.46	0.0227	0.3293	585.4	593.2	1178.6	0.7840	0.5719	1.3559	580.0	519.4	1099.4	1300
1400	587.10	0.0231	0.3012	598.7	574.7	1173.4	0.7963	0.5491	1.3454	592.7	502.7	1095.4	1400
1500	596.23	0.0235	0.2765	611.6	556.3	1167.9	0.8082	0.5269	1.3351	605.1	486.1	1091.2	1500
2000	635.82	0.0257	0.1878	671.7	463.4	1135.1	0.8619	0.4230	1.2849	662.2	403.4	1065.6	2000
2500	668.13	0.0287	0.1307	730.6	360.5	1091.1	0.9126	0.3197	1.2322	717.3	313.3	1030.6	2500
3000	695.36	0.0346	0.0858	802.5	217.8	1020.3	0.9731	0.1885	1.1615	783.4	189.3	972.7	3000
3206.2	705.40	0.0503	0.0503	902.7	0	902.7	1.0580	0	1.0580	872.9	0	872.9	3206

than 1000 lbm of additional steam. Therefore, raising the containment atmosphere temperature to 160 F and saturating that atmosphere with steam would require about 16000 lbm of steam.

From the section below on Short-Term Containment Response, the design bypass flowrate is approximately 100-150 lbm/sec during blowdown and will be sustained even after blowdown as the drywell and the containment equalize. Even if the bypass were only one-half this value, sufficient steam would bypass the pool over the approximately 360 seconds of blowdown to reach the necessary 4.7 psi steam partial pressure in the containment for the spray permissive. It should also be noted that in Reference 5, Section 4 it is stated that the containment design pressure of about 30 psia would be exceeded during blowdown for a large LOCA if a bypass area three times design (i.e., $A/\sqrt{K}$ greater than 5 ft^2) were present. This 30 psia represents an increase over the "design" post-blowdown pressure (i.e., without bypass) of about 10 psi. One would therefore expect that for the design bypass case an increase in the containment pressure (over the design case without bypass) of at least 3-4 psi would be expected during blowdown, bringing the pressure to nearly that for the spray permissive. Given that some hydrogen production, drywell heat-up, and drywell equalization will be occurring post-blowdown for a large steamline LOCA without ECCS, it is certain that the spray permissive pressure would be reached within 10 minutes of start of fission product release for a DBA with design pool bypass.

Assumption 5: Following the DBA (main steamline large LOCA inside containment) the water mass remaining in the vessel is that corresponding to the initial inventory from Reference 5 (Section 3.2.1) less the integrated blowdown from Reference 5 (Table 3.3.1.1).

Justification: The use of a main steamline large LOCA as the DBA is discussed in Reference 8. Since the mass and energy releases from Reference 5 are maximized to maximize the containment design conditions, this assumption yields a conservatively small value for the water mass remaining in the bottom of the vessel after blowdown.

Assumption 6: In order to calculate the steaming rate from the core debris, it is assumed that the fraction of the core participating in the boil-off of the water mass remaining in the bottom of the vessel post-blowdown increases uniformly from zero at 1830 seconds (end of the gap release phase) to 50% at 7230 seconds (end of the in-vessel release phase).

Justification: This assumption is based in part on Assumption 1. At the end of the in-vessel release all of the core debris will be quenched, both that which has relocated to the lower part of the vessel and that remaining in the original core region. For

conservatism, the debris remaining in the core region is neglected in the calculation of the steaming rate during core degradation; only the assumed 50% of the core debris which relocates to the lower part of the vessel and its interaction with the residual water (Assumption 5) is included in the quantification of the steam production during the in-vessel release phase.

Assumption 7: The exchange rate between the drywell and the wetwell/lower containment is assumed to be constant during the release phase (up to 7230 seconds).

Justification: This assumption is slightly non-conservative because it overestimates the removal rate from the drywell early in the release phase. However, it does simplify the analysis; and for relatively low removal rates (of the order of one per hour) the underestimate of the late removal compensates nearly completely for the overestimate of the early removal. A further demonstration of the adequacy of this assumption is presented in Appendix A.

Assumption 8: The final core debris quench requires the time it takes minimum ECCS (one core spray pump) to refill the core region, and it involves only the energy stored in the one-half of the core debris assumed not to relocate to the lower part of the vessel. A bottom-up quench is assumed; i.e., the core spray is assumed not to interact with fuel debris on the way down, but rather collects in the vessel head and refloods from below. This minimizes steam production which is conservative.

Justification: Leaving one-half the core uncovered for a period of 7230 seconds (less the blowdown/core uncovery time) results in core debris left in the core region with significant stored energy. The restoration of minimum ECCS will remove this stored energy at a rate determined by the coolant injection rate (drawn from the suppression pool) and the rising water level (reflood rate). To determine the reflood rate, the ECCS injection rate must be reduced by the rate of steam production. The rate of steam production in this analysis corresponds to a low estimate of stored energy in only one-half of the core debris.

If a top-down quench were modeled, steam production would begin immediately as individual spray droplets (at an injection rate of more than 1000 lbm/sec) come in contact with the debris. These droplets have the potential to remove heat at the rate of more than 1000 Mw (i.e., $>10^6$ BTU/sec), producing steam at a rate approaching one-tenth that of the initial blowdown or about one drywell volume per minute or 60 volumes per hour. This steam would vent from the core debris counter to the spray flow, and some of the steam would be condensed by the counterflowing spray, but since the subcooling of the injection water would be less than 200 BTU/lbm even at an elevated vessel/drywell pressure, only a small

fraction (e.g., 20 percent or less) would condense. Therefore, a bottom-up quench, with its delayed and reduced steam production, is conservative.

Reference 9 indicates that the sweep-out rate corresponding to the final core debris quench would be expected to be of the order of 10 drywell volumes per hour.

Assumption 9: Core debris remaining in the core region during reflood may be characterized as naked fuel pellets and similar sized debris. It is further assumed that the height of the debris bed is approximately one-half the original core height or six feet.

Justification: Much of the core debris observed at TMI-2 and in various core-damage experiments using LWR or LWR-like fuel which has not melted or relocated has exhibited these characteristics.

Assumption 10: Sprays operate for six hours (minimum) after the initiation.

Justification: It is likely that the RHR system operating mode would be changed to pool or shutdown cooling at some point, but six hours of spray operation after initiation reflects a conservative minimum estimate of spray duration.

References

Reference 1: Soffer, L., et al., "Accident Source Terms for Light-Water Nuclear Power Plants", NUREG-1465, February 1995

Reference 2: DiNunno, J. J., et al., "Calculation of Distance Factors for Power and Test Reactor Sites", TID-14844, March 1962

Reference 3: Leaver, D. E. and Metcalf, J. E., "Generic Framework for Application of Revised Source Term to Operating Plants", EPRI TR-105909, EPRI Research Project 4080-2, November 1995

Reference 4: SECY-94-300, "Proposed Issuance of Final NUREG-1465, 'Accident Source Terms for Light-Water Nuclear Power Plants' ", December 15, 1994

Reference 5: "Containment and NSSS Interface", General Electric Data Book 22A3759AL, Rev 2, March 29, 1991

Reference 6: PSAT 04202U.03, "Dose Calculation Data Base for Application of the Revised DBA Source Term to the CEI Perry Nuclear Power Plant", Revision 0

Reference 7: Babcock and Wilcox, Steam, Its Generation and Use, New York, 1963

Reference 8: PSAT 04212H.01, "Source Term for Use on Perry Application of NUREG-1465", Revision 0

Reference 9: Leaver, D. E., et al., "Licensing Design Basis Source Term Update for the Evolutionary Advanced Light Water Reactor", DOE/ID-10298, September, 1990

Reference 10: AIF/IDCOR Report 23.1GG

Reference 11: McAdams, Heat Transmission, McGraw-Hill, New York, 1942

Reference 12: Handbook of Chemistry and Physics, 51st Edition, 1970-71

Reference 13: NRC Generic Letter 88-20

Reference 14: "Perry Technical Specifications Improvement - Containment Response Analysis", General Electric Report NEDC-31940, March 1991

Reference 15: Handbook of Chemistry and Physics, 73rd Edition, 1992-93

Reference 16: Keenan and Keyes, The Properties of Steam, John Wiley and Sons, London, 1936

Calculation

Minimum mass of water remaining in vessel post-DBA blowdown

Reference 5 provides the following:

- Total Reactor Fluid Inventory - 5.64×10^5 lbm
- Reference 5, Table 3.3.1.1 blowdown rates reproduced as Exhibit 2

Integrating the Exhibit 2 blowdown rates over the first 30 seconds without ECCS (referring to Table 3.3.2.3 of Reference 5, the first 30 seconds is the pre-ECCS blowdown phase), the total blowdown is 5.40×10^5 lbm. This leaves a minimum of 24000 lbm of water in the vessel without ECCS after blowdown. This mass of water is conservative compared to the Mark III reference analysis performed by AIF/IDCOR which indicated that for a large-break LOCA without injection (Reference 10, Figure B-16 for AE sequence) more than 13' of water would remain in the vessel after blowdown. This would mean the entire lower head of the vessel (approximately 2400 ft^3 or 1.4E5 lbm of water for the IDCOR reference Mark III plant) was predicted to remain filled.

Exhibit 2

TABLE 3.3.1.1 (MAIN STEAM LINE BREAK) REACTOR PRIMARY SYSTEM BLOWDOWN FLOW RATES AND FLUID ENTHALPY

TIME (SEC)	LIQUID FLOW (LBS/SEC)	LIQUID ENTHALPY (BTU/LB)	STEAM FLOW (LBS/SEC)	STEAM ENTHALPY (BTU/LB)
0.	0	551.6	9850.	1190.7
0.05	0	551.0	11440	1190.8
0.22	0	549.7	8259.	1191.1
0.999	0	545.4	8025.	1192.3
1.000	27000.	545.3	1094.	1192.3
2.01	26670.	545.2	1200	1192.3
4.01	25890.	544.2	1419.	1192.5
6.00	19730.	543.6	1273.	1192.7
8.03	19130.	542.7	1425.	1192.9
10.03	18430.	540.2	1560.	1193.5
15.03	16340.	528.0	1805.	1196.1
20.03	14040.	507.8	1880.	1199.7
25.03	11810.	492.7	1794.	1201.7
30.03	9877.	492.3	1634..	1201.8
50.06	5769.	356.5	652.6	1198.5
70.06	5132.	295.7	230.6	1186.5
90.15	5083.	274.7	125.7	1181.1
100.9	4984.	265.0	91.0	1178.4
119.9	4980.	257.8	62.9	1176.4
140.4	5022.	254.9	47.7	1175.5
200.4	5213.	255.0	29.1	1175.5
300.3	4450.	236.5	10.2	1170.9
350.9	1207.	220.7	1.6	1164.7
359.9	112.3	219.3	0.14	1164.3

Exhibit 3

POLESTAR
PROPRIETARY

Beyond the blowdown (which ends at 360 seconds after the break), there are three factors which could make this case different from the containment DBA case for steamline break presented in Reference 5. These are as follows:

1. Design basis levels of suppression pool bypass,

2. Spray actuation at 10 minutes after low level in the reactor vessel, and

3. Zircaloy oxidation yielding hydrogen and energy.

These are discussed in order below.

Design Levels of Suppression Pool Bypass:

For $A/\sqrt{K}$ values up to and including the design basis value of 1.7 ft^2 (see Assumptions 2 and 4), the containment pressure would increase more rapidly than the containment DBA steamline break analyzed in Reference 5. It is this increase in containment pressure (for large values of $A/\sqrt{K}$) that would bring about the early actuation of containment sprays. However, even if bypass were not sufficient to pass 16000 lbm of steam during blowdown (in 360 seconds, see Assumption 4), the sprays could be manually actuated within the first half-hour, i.e., before the start of the fuel

release at 1830 seconds. Therefore, the assumption of spray start at 10 minutes (after low level in the vessel) is not critical. If there were a bypass of only, say, $A/\sqrt{K} = 0.8\ ft^2$ and the spray did not start, pool scrubbing during the debris quench would be appreciable, and the sprays would have been delayed only an additional 20 minutes. Consider the following:

$$Mdot = A/\sqrt{K}(\sqrt{2g_c \rho \Delta P}) = \text{mass flow rate through the bypass path}$$

Figure 3.3.1.14 of Reference 5 shows that the drywell-to-containment differential pressure will be greater than about 7 psid during blowdown, and the density (after the liquid phase dropped out) would be approximately that of steam at 20 psia or 0.05 lbm/ft^3. For these values (and $A/\sqrt{K}$ = the design basis value 1.7 ft^2):

Mdot = 97 llbm/sec

Earlier in the blowdown when the differential pressure would be twice that and the drywell would be carrying airborne liquid (see Figure 3.3.1.11 of Reference 5) with a density four times as great, the bypass would be:

Mdot = 274 lbm/sec

of which perhaps one-half would be steam. Under these conditions the containment would pressurize rapidly and the estimated 16000 lbm of steam necessary to reach the threshold pressure for containment sprays (see Assumption 4) could be passed in as little as two minutes. Even if the full 360 seconds (six minutes) of blowdown were needed, the corresponding average bypass flowrate (to pass 16000 lbm of steam) would be 44 lbm/sec representing an $A/\sqrt{K}$ value of about 0.8 ft^2. For bypass values less than 0.08 ft^2 the sprays might be delayed, but the pool scrubbing during the debris quench would be substantial. Referring back to the table of debris quench steam flowrates on Page 20, it can be seen that during the debris quench an $A/\sqrt{K}$ corresponding to a bypass flow of 44 lbm/sec would pass only 6300 lbm of steam while the total flow would be about 28000 lbm. Therefore, during the more than one full purge of the drywell associated with this steam flow, the pool bypass would be only slightly greater than 20 %. This would more than compensate for the 20-minute delay in spray actuation during the gap release phase. Therefore, the assumption of design levels of pool bypass is the conservative one, even though that assumption allows crediting of containment sprays somewhat earlier.

Given that the bypass can bring the containment temperature and pressure to 160 F and approximately 24 psia at the time of spray actuation at 630 seconds (and the corresponding drywell pressure perhaps as much as 8 psid higher based on the differential pressure at 30 seconds from Reference 5, Figure 3.3.1.14), the next question is what is the impact of spray operation. (Note that 30 seconds is the point in the present analysis where the ECCS "fails" guaranteeing that subsequent drywell-to-wetwell differential pressures will be less, at least up until the time of spray actuation).

Spray Actuation at 10 Minutes after Low Level in the Reactor Vessel:

The containment spray flowrate is 5250 gpm (726 lbm/sec) with one pump operating (Reference 6, Item 3.25). The RHR HX has a K-factor of 440 BTU/sec-F (Reference 6, Item 9.3) and employs a cooling water temperature of 85 F (Reference 6, Item 9.4). Therefore, given that:

Heat Transfer Rate = 440 BTU/sec-F(T_{pool} - 85 F) (based on heat exchanger)

= 726 lbm/sec x 1 BTU/lbm-F x (T_{pool} - T_{spray}) (based on spray flow)

the spray temperature, in terms of suppression pool temperature, is:

$$T_{spray} = 0.39(T_{pool}) + 52\ F$$

Using Figure 3.3.2.6 of Reference 5 (and remembering that the delayed ECCS case would result in a lower containment pressure and temperature at this point in time), the temperature of the suppression pool at the time of spray initiation would be a maximum of about 155 F. This would result in a maximum initial spray temperature of about 112 F. For this initial spray temperature, the initial condensation rate per pound of spray flow would be about:

$$(T_{containment} - T_{spray}) \times 1\ \text{BTU/lbm-F}/h_{fg} = (160\ F - 112\ F)/960\ \text{BTU/lbm @ 20 psia}$$

$$= 0.05\ \text{lbm/lbm}$$

For a spray flow of 726 lbm/sec, the initial condensation rate would, therefore, be about 36 lbm/sec; and if that condensation rate were sustained, the 15000 lbm of steam in the containment atmosphere (see Assumption 4) would be condensed in about seven minutes. Considering the decrease in condensation rate as the spray water temperature increases and the containment temperature decreases, it would, in actuality, take several times longer. For simplicity, it can be assumed that the containment atmosphere temperature will decrease to the average of the instantaneous spray injection temperature and the instantaneous pool temperature in about 20 minutes; i.e., at the time of the start of the fuel release at 1830 seconds. This temperature would not be greater than:

$$\frac{165\ F + (165\ F \times 0.39) + 52\ F}{2} = 140\ F$$

where 165 F is taken from Figure 3.3.2.6 of Reference 5 at 1830 seconds

Once this containment temperature is reached, the containment temperature could begin to rise as the pool heats up above 165 F. Were the pool to be subjected to the continuous heat addition of successful ECCS operation (as in the case for the transient presented in Figure 3.3.2.6 of Reference 5), the temperature of the pool could increase over the next several hours to near its design maximum value of 185 F. For this degraded core case, however, the steam generation

is very low during the core degradation (4.4 lbm/sec average) and at that low value, the pool is being completely bypassed (see discussion of suppression pool bypass, above). Therefore, the 140 F containment temperature can be assumed to remain constant up until the start of the steam production associated with debris quench (at 7333 seconds). If anything, it would decrease (i.e., for a steam load on the sprays of 4.4 lbm/sec, the heat load transferred to the pool would be about 4400 BTU/sec, and with a heat exchanger K-factor of 440 BTU/sec-F and a cooling water temperature of 85 F, the pool temperature could decrease to 95 F and still dissipate this heat load). At the time of the debris quench, the pool temperature and the containment temperature would increase dramatically, but not to a value greater than the design case. This is discussed further under Long-Term Containment Response. For simplicity, it will be assumed that the containment temperature reaches its design value of 185 F, as a maximum, at the time of the debris quench. (In reality, continued application of spray for six hours after the accident, see Assumption 10, would keep the temperature below this maximum for some time, certainly as long as the sprays continued to operate). This maximum is shown on Exhibit 4, a mark-up of Figure 3.7.1 of Reference 5.

Also shown on Exhibit 4 are the maximum pressures as functions of time. The pressure at 10 seconds (part-way through the blowdown and prior to the start of ECCS for the case <u>with</u> ECCS) is taken from Figure 3.3.2.7 of Reference 5, and the value is 20 psia. Reference 14 states that the long-term containment response analysis (which constitutes the basis for Figure 3.3.2.7 of Reference 5) does not include the assumption of equilibrium between pool and containment atmosphere which is used in the short-term analysis. Rather, the thermodynamic states are calculated separately. This explains why Reference 5, Figure 3.3.2.6 begins at 10 seconds with a containment atmosphere temperature approximately 40 F higher than that of the pool.

From Reference 5, the pool begins at an assumed temperature of 95 F, 9 F less than the assumed containment atmosphere. (Maximum conditions are 95 F and 104 F, respectively). The initial containment pressure is expected to be 14.7 psia. By 10 seconds into the event, virtually all of the 2.8E5 ft^3 of drywell air has been purged into the 1.17E6 ft^3 containment, and given this rapid purge, one would expect, as a minimum, a polytropic compression of the containment air with an "n" of approximately 1.2. Using the expression:

$$T_1/T_2 = (V_1/V_2)^{1-n} = [(1.17E6 + 2.8E5)/1.17E6]^{-0.2} = 0.96$$

$$T_2 = (104 + 460)/0.96 = 588\ R = 128\ F$$

The corresponding pressure increase is about a factor of 1.3; i.e., to about 19 psia. However, the maximum containment pressure at 10 seconds taken from the Figure 3.3.2.7 of Reference 5 is 20 psia as noted above. This is because the containment temperature at 10 seconds from Figure 3.3.2.6 (about 145 F) is greater than the polytropic compression would account for. Even with an assumed initial drywell temperature of 145 F, the compression would raise the containment temperature to only 136 F. But an increase in containment temperature to 145 F would raise the

pressure to 20 psia. Therefore, one can conclude that decreasing the temperature to 140 F (average following spray actuation) would reduce the pressure to essentially the same value.

Once the production of steam begins from the debris quench at 7333 seconds, the containment pressure will increase. Given that: (1) the beginning temperature is about the same as it was at 10 seconds, (2) the time for the pressure increase during the debris quench is less than it was during the 630 seconds between the start of the accident and the start of containment sprays, and (3) the sprays are already operating, it is not likely that the containment pressure would be greater than that at the time of spray initiation, 24 psia. This pressure exceeds the long-term containment pressure peak presented in Figure 3.3.2.7 of Reference 5, and may be regarded as an upper-bound containment pressure in the long-term as well as the short-term (see next section). As was the case for just before spray initiation, the drywell pressure will not be more than 8 psid greater (i.e., 32 psia - see Page 23) during the debris quench.

The maximum short-term values for containment pressure and temperature are shown on Exhibit 4, a mark-up of Figure 3.7.1 of Reference 5. The same information is provided for the maximum drywell short-term pressures and temperatures on Exhibit 5, a mark-up of Figure 3.7.2 of Reference 5. Note that the maximum temperature in the drywell is assumed to be identical to the design values. This is reasonable for a steamline break and conservative for a liquid line break.

These maxima reflect suppression pool bypass and spray operation. The only remaining issue (of the three mentioned in connection with deviations from the Reference 5 thermal-hydraulic analyses) is zircaloy oxidation and hydrogen.

Zircaloy Oxidation Yielding Hydrogen and Energy:

For a major pipe-break, hydrogen production tends to be limited until the core debris is being quenched. This is because the core region empties rapidly of coolant, leaving residual water in the lower vessel head without a significant heat source to produce the steam necessary for the zircaloy oxidation. For a small break, a stuck-open safety/relief valve, or a transient leading to core damage, on the other hand, the production of hydrogen tends to be much greater, with potentially a greater impact on the containment thermal-hydraulics. However, for such events most, if not all, of the activity released from the core will be flushed out of the vessel and through the safety/relief valve discharge to the pool where scrubbing will occur. Steam will be replaced by hydrogen on a mole-for-mole basis in-vessel; and therefore, the vessel sweep-out will be at least the same and, in reality, much greater because of the higher gas temperatures associated with the zircaloy oxidation. Therefore, the impact of zircaloy oxidation on activity transport within the containment will be small and possibly even beneficial in the short-term, to the extent that convection of activity to and through the suppression pool may be enhanced. The long-term impact is discussed in the next section.

Up to this point this section has concentrated on short-term <u>maximum</u> containment pressures and

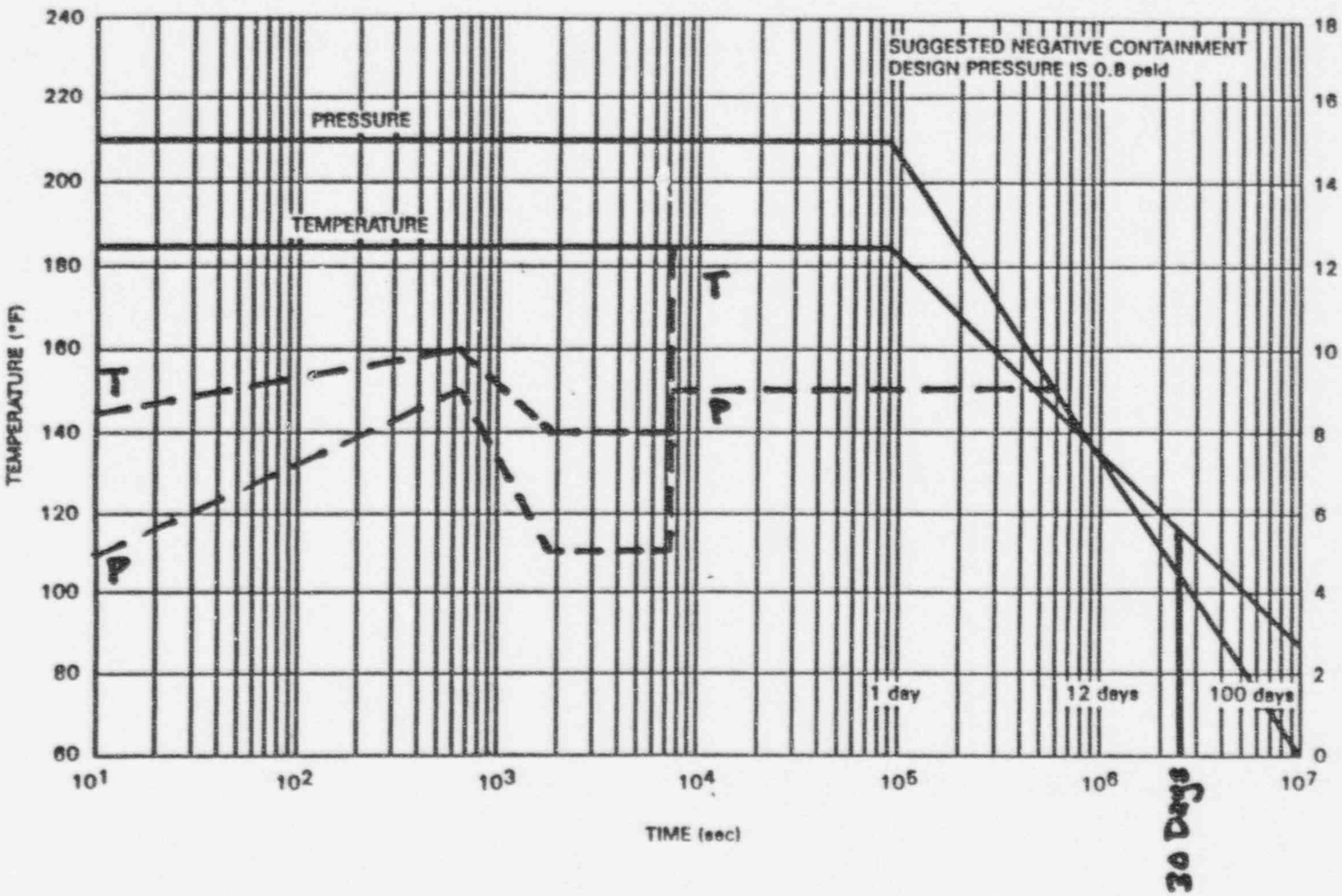


FIGURE 3.7.1 MAXIMUM CONTAINMENT ATMOSPHERE BULK TEMPERATURE AND PRESSURE ENVELOPE

Exhibit 5

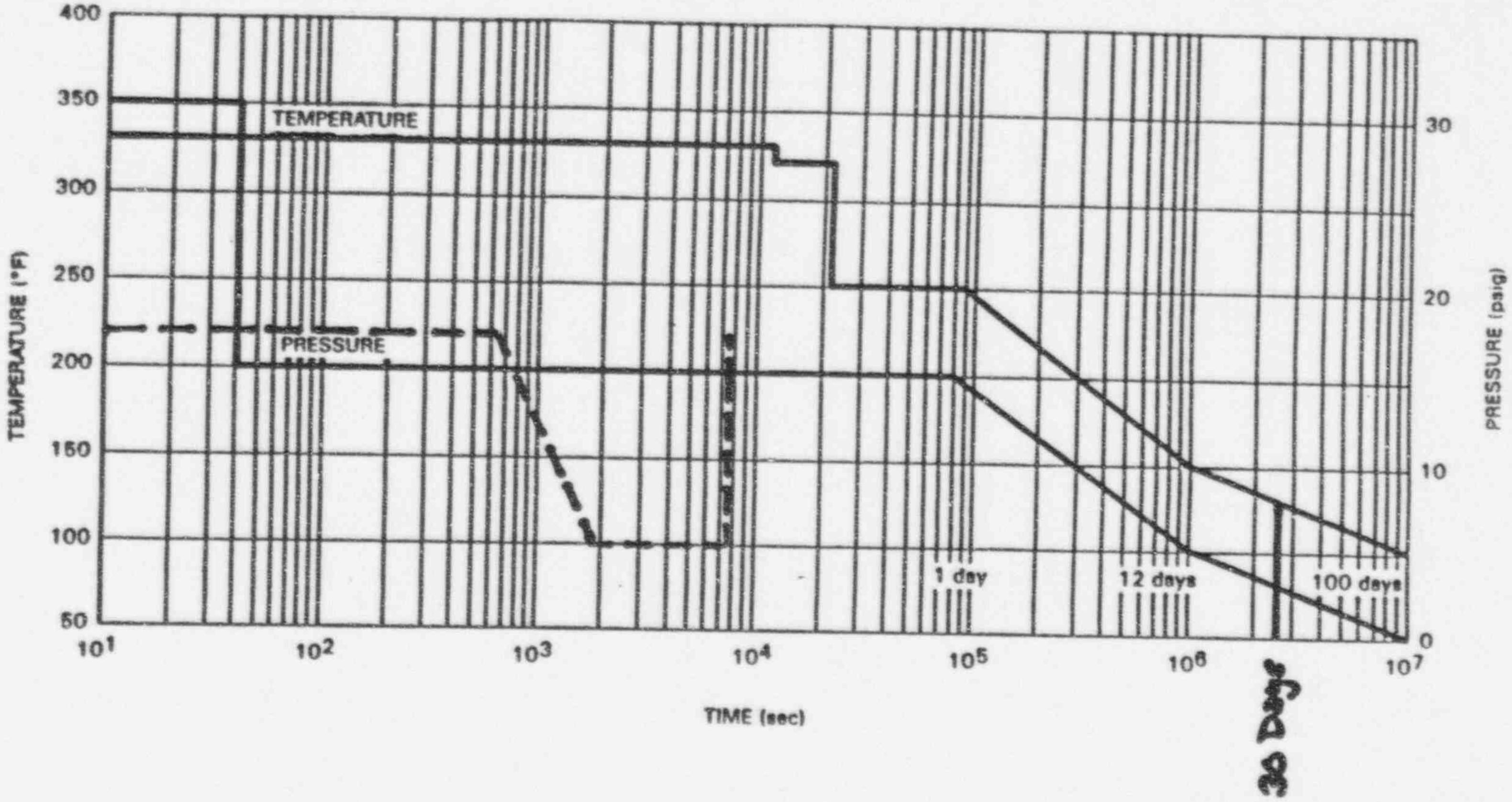


FIGURE 3.7.2 MAXIMUM DRYWELL ATMOSPHERE BULK TEMPERATURE AND PRESSURE ENVELOPE

temperatures. For short-term minimum values of drywell and containment pressure, initially and during spray operation, it will simply be assumed that the containment pressure will not be less than 15.7 psia (1 psig) and that up until the time of the end of steaming from the debris quench (7484 seconds), the drywell is steam-filled and saturated at the temperature corresponding to that pressure (i.e., 215 F from Exhibit 1). Beyond that time the drywell and the containment are assumed to be at the same minimum temperature as the containment is assumed to be at immediately after blowdown, 100 F.

Long-Term Containment Response

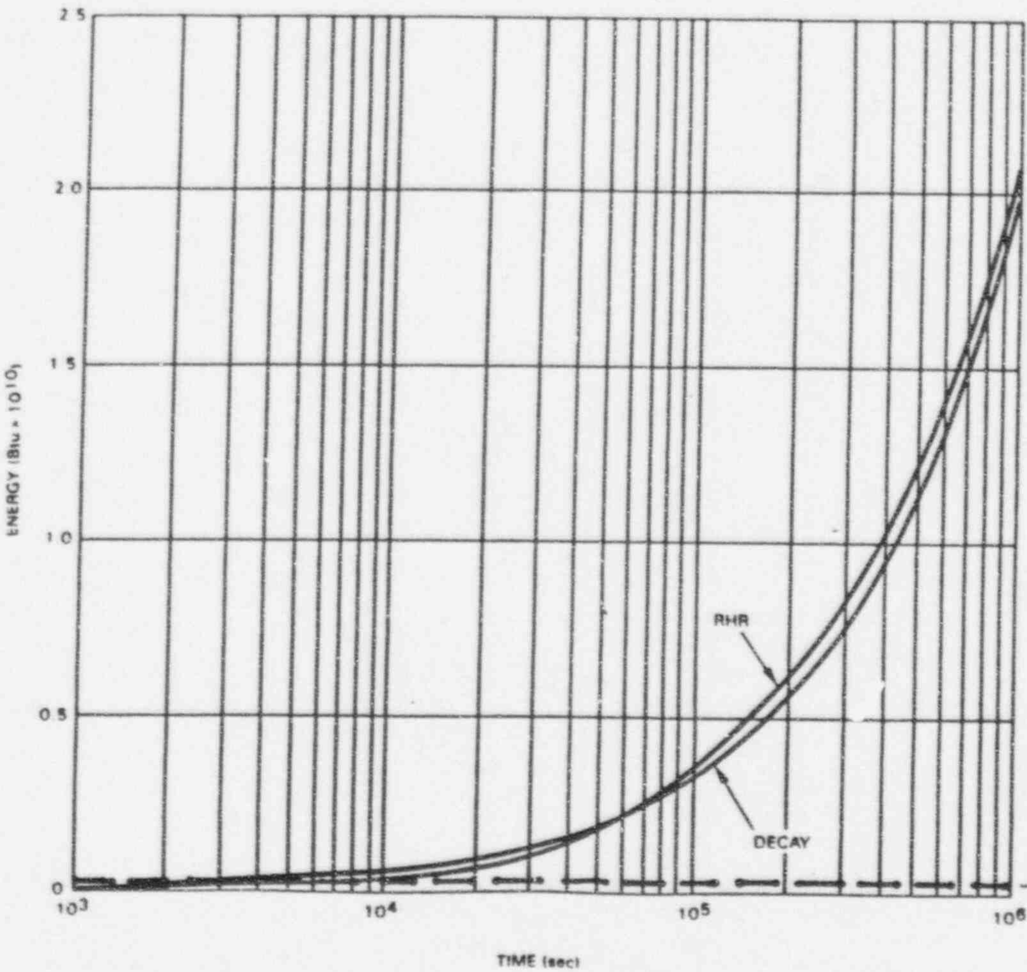
In the long-term (beyond completion of steam production from the quenching of the core debris at 7484 seconds) the existing design basis maxima presented in Exhibits 4 and 5 will be assumed to hold with one exception and one comment. The exception is that the containment design pressure (15 psig or approximately 30 psia for one day) is much too high in light of the maximum long-term drywell pressure which is only about 30 psia (15 psig). The maximum drywell pressure is assumed to decrease immediately from 32 psia to 30 psia at 7484 seconds and then to follow the pressure shown on Exhibit 5. The maximum containment pressure is assumed to increase to 24 psia and to remain constant until approximately 6E5 seconds when the pressure is then assumed to track that shown on Exhibit 4.

The comment pertains to the importance of hydrogen on long-term containment thermal-hydraulics. Exhibit 6 is Figure 3.3.2.8 of Reference 5 which compares the integrated decay power vs. integrated heat removed from the containment for a large-break LOCA. Marked on this figure is the total heat released by the oxidation of approximately 50% of the zircaloy inventory in the core. This energy has been estimated from the zircaloy mass of 8.1E4 lbm (4E5 g-moles) from Reference 5, Section 3.2.1 and from the heat released by formation of one g-mole of zirconium oxide (1106 KJ/g-mole from Reference 15 which represents, also, one g-mole of zirconium). This release yields approximately 2E8 KJ or 2E8 BTU. The impact of this energy release is mitigated in the core by the need to decompose the steam to support the reaction; this decomposition requires 286 KJ per g-mole of H_2O decomposed (from Reference 15), and since 4E5 g-moles of H_2O must be decomposed to oxidize 2E5 g-moles of zirconium, the energy needed to decompose the steam is about 1.1E8 KJ or 1.1E8 BTU. Therefore the net energy added to the core by 50% zircaloy oxidation is about 9E7 BTU or 26 Mw-hrs or about 25 full-power-seconds. This energy will eventually show up in the containment as steam or heated water released during the quenching of the core debris and will be supplemented by hydrogen recombination as the igniters operate to limit hydrogen concentrations. The total energy addition to the containment would be the 2E8 BTU.

This amount of energy is important only in the first day or so. Beyond that point it becomes increasingly overwhelmed by the decay heat (i.e., at the end of the first day it is only about seven percent of the integrated decay power). As can be seen from Exhibit 6, the rate of heat removal by the RHR system becomes equal to the rate of heat addition at about four hours (slopes are

Exhibit 6

INTEGRATED DECAY POWER AND HEAT REMOVED BY RHR vs 50% ZIRC OXIDATION



ENERGY FROM 50% ZIRC OXIDATION = 2X10⁸ BTU

equal). If more heat had been added early by zirconium oxidation (effectively, an increase in the "decay power" over the first few hours of the accident), the point of "parallel slopes" would be reached sooner, indicating an earlier (but higher) maximum pool temperature than that from Reference 5. One way of estimating the impact of this energy is to assume that the steam resulting from it (either by cooling of core debris or by igniter-induced combustion) is condensed in the suppression pool (mass = 1.2E5 ft^3 from Reference 5, Section 3.2.2 x 62 lbm/ft^3 water density = 7.4E6 lbm). This would result in a temperature increase of the pool of about 27 F. If this were added to the peak suppression pool temperature given in Reference 5 of 185 F, the result would be 212 F. At this pool temperature, the associated spray temperature would be (using the expression on Page 24):

212 F(0.39) + 52 F = 135 F

And assuming the atmosphere were at an average temperature corresponding to the average of the pool and spray temperatures, that temperature would be 174 F. For an expected initial containment temperature of 90 F the pressure increase due to the containment air heat-up would then be (460+174) R/(460+90) R or 1.15. Adding the saturated vapor pressure of steam at 174 F (approximately 6.6 psia from Exhibit 1), the corresponding containment peak pressure would be (1.15)(14.7) + 6.6 = 24 psia, and this peak would be expected within the first hour or two after quenching of the core debris. This is the same post-quench maximum containment pressure decided upon in the section on Short-Term Containment Response.

APPENDIX A

APPENDIX TITLE:

"Use of a Uniform Sweep-Out Rate During the Release Phase"

SAFETY-RELATED APPENDIX: Yes

CALCULATION NUMBER: PSAT 04212H.02

CALCULATION TITLE:

"Drywell Sweep-Out Rate and Related Thermal-Hydraulic Conditions inside Containment"

Purpose

The purpose of this appendix is to justify a uniform sweep-out rate from the drywell to the torus during the release phase from essentially t=0 to t=120 minutes.

Approach

The approach is to set up a spread-sheet wherein:

- A release of 5% radioiodine is introduced over 30 minutes with no removal, and
- An additional 25% is added over 90 minutes using (1) no removal, (2) removal at a constant rate ("lambda") of one per hour, and (3) a linearly increasing removal rate beginning at zero and increasing to two per hour at the end of the 90 minutes.

The percent airborne is plotted and the integral under each of the curves is also calculated. The area under the curve (in %-minutes) is indicative of the release that would occur from the drywell for a constant leak rate and no decay. An assumption of no decay is acceptable since I-131 is the dominant radioiodine nuclide and it has a half-life of 8.1 days compared to the two-hour duration of this calculation.

Results

The results are shown on Figure A-1. The accuracy of the spread-sheet can be checked by

observing the slope of the calculation for any percent airborne. For example, for the increasing lambda case the maximum airborne percent (about 13.1%) is reached at about 84 minutes. At 84 minutes the variable removal rate would be:

0 + 2 x (84 min -30 min)/ 90 min = 1.2 /hour

The removal in terms of %/hour would be:

1.2 x 13.1 = 15.7 %/hour = 0.261 %-min

This is almost exactly the addition rate (0.278 %-min) which explains the zero slope.

As another example, the constant removal rate case ends with an increasing slope of about 0.3 %/ 6 min or 0.05 %/min with an airborne percent of about 13.7%. The removal rate at this percent would be:

1 /hour x 13.7% x 1/60 hours/minute = 0.228 %/min

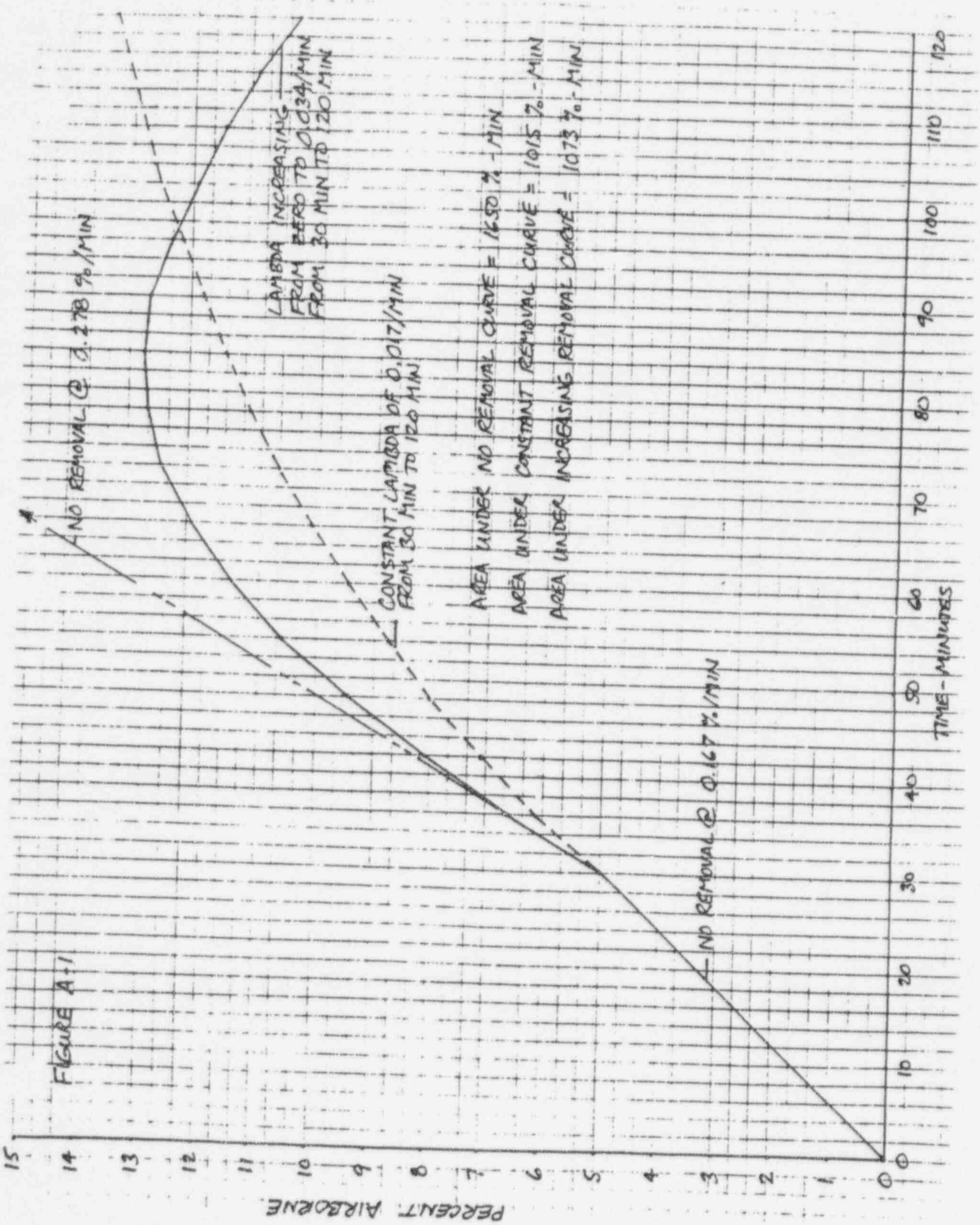
The net increase would be:

0.278 %/min (added) - 0.228 %/min (removed) = 0.05 %/min

The results in terms of areas under the curves is shown on the figure. Note that the area under the constant removal curve is only 5% less than the area under the increasing removal curve. This shows that using a constant removal rate to approximate the increasing removal rate is acceptable, at least for the case of limited removal (i.e., about one per hour). The actual removal rate for Perry is calculated in the main body of the calculation to be 3.7E5 cfh/2.8E5 ft^3 or about 1.3 per hour. A larger removal rate would increase this difference and make the constant removal rate approximation increasingly non-conservative.

It is also of interest to note that either of the removal cases are about a factor of 1.6 better than the no-removal case.

PSAT 04212H.02



APPENDIX B

APPENDIX TITLE:

"Steam Generation Rate During Reflood"

SAFETY-RELATED APPENDIX: Yes

CALCULATION NUMBER: PSAT 04212H.02

CALCULATION TITLE:

"Drywell Sweep-Out Rate and Related Thermal-Hydraulic Conditions inside Containment"

Purpose

This appendix deals with steam generation during reflood when the core debris left in the core region (assumed to be 50% of the total) is quenched by the return to operation of the ECCS. The purpose of the appendix is to calculate (1) the steam produced and (2) the time required to reflood and quench the core debris.

Approach

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CALCULATION TITLE PAGE

CALCULATION NUMBER: PSAT 04202H.12

CALCULATION TITLE:

"Calculation of Fraction of Containment Aerosol Deposited in Water"

	ORIGINATOR Print/Sign	Date	CHECKER Print/Sign	Date	IND REVIEWER Print/Sign	Date
REVISION: 0	Jun Li [signature]	4/9/96	James Metcalf [signature]	4/9/96	James Metcalf [signature]	4/9/96
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PSAT 04212H.03

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CALCULATION TITLE PAGE

CALCULATION NUMBER: PSAT 04212H.03

CALCULATION TITLE:

"Ultimate Iodine Decontamination Factor for Perry DBA"

REVISION	ORIGINATOR Print/Sign	Date	CHECKER Print/Sign	Date	IND REVIEWER Print/Sign	Date
0	James Metcalf / [signature]	3/24/96	D. E. Leaver / [signature]	4/24/96	D. E. Leaver / [signature]	4/24/96
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Purpose

The purpose of this calculation is to determine the maximum DF for iodine in containment that can be credited in the Perry drywell and containment for the purpose of applying the revised DBA source term of Reference 1 (assuming an adequate pH is maintained).

Methodology

The methodology of References 2 is used to evaluate the maximum iodine DF that can be credited (i.e., the minimum iodine DF that can be defended) assuming a pH of 7 is maintained. To confirm the suppression pool pH, a separate calculation (Reference 3) has been performed.

Assumptions

Assumption 1: The suppression pool pH will be maintained at a value of 7 or above.

Justification: The DF calculated herein is based on this minimum PH being maintained. According to Reference 4, Item 6.1, the initial suppression pool pH is not less than 6.0 at the start of the accident. The pH will rapidly increase as fission product cesium (the dominant fission product released by mass) in the form of CsOH (or other pH-basic chemical forms) is released to the containment and is deposited into

the suppression pool concurrent with the radioiodine. Acids such as HNO_3 or HCl will be formed or deposited in the water later tending to lower the pH; but with operator action to add caustic and/or buffer, the pH will remain above 7. Reference 3 addresses pool pH during the course of the accident.

Assumption 2: The water on the drywell floor and that in the suppression pool will mix sufficiently to permit a uniform iodine concentration in the liquid phase to be assumed.

Justification: One approach evaluated in Reference 3 to maintaining an adequately high suppression pool pH is the injection of the SLCS sodium pentaborate as a buffer for any accident involving substantial core damage (such as the accidents identified in Reference 1 as the basis for the DBA source term). Mixing of this sodium pentaborate solution with all available water inside containment (which is a recognized necessity) would also provide mixing and a uniform distribution of the radioiodine between water on the floor of the drywell (or in the reactor vessel) and that in the suppression pool. Even for pH-control options not involving SLCS injection, uniform iodine distribution will result from spray operation, spillage of coolant from the break (and associated purge of water volumes in the drywell), and/or core steaming carrying any re-evolved iodine from drywell water volumes to the suppression pool or to the containment sprayed region.

References

Reference 1: Soffer, L., et al., "Accident Source Terms for Light-Water Nuclear Power Plants", NUREG-1465, February 1995

Reference 2: Beahm, E. C., Lorenz, R. A., and Weber, C. F., "Iodine Evolution and pH Control", NUREG/CR-5950, November 1992

Reference 3: PSAT 04202H.11, "Suppression Pool pH for the Perry DBA", Revision 0

Reference 4: PSAT 04202U.03, "Design Data Base for Application of the Revised DBA Source Term to the CEI Perry Nuclear Power Plant", Revision 1

Reference 5: "Containment and NSSS Interface", General Electric Data Book 22A3759AL, Rev 2, March 29, 1991

Reference 6: PSAT 04212H.02, "Drywell Sweep-Out Rate and Related Thermal-Hydraulic Conditions inside Containment", Revision 0

Calculation

From Reference 4, Item 6.6, the water volume which could ultimately dissolve the iodine released from the core is about 175000 ft^3 (suppression pool volume + RCS volume) = 175000 ft^3 x 28.3 liters/ft^3 = 4.95E6 liters. This volume of water corresponds to a mass of about 1.0E7 lbm at elevated temperatures. Of this water, about 6% comes from the reactor coolant (Reference 5, Section 3.2.1 gives vessel inventory as 5.6E5 lbm) and 19% from upper pool dump (Reference 4, Item 3.5) with a temperature of 110 F (Reference 5, Section 3.2.2). Assuming the remainder to be at the initial pool temperature of 95 F (Reference 5), we have the following estimate of post-blowdown, post-upper pool dump suppression pool temperature (assuming also that the coolant is at saturation corresponding to the Reference 4, Item 8.4 pressure of 1060 psia) neglecting any other heat addition:

$$T_{pool} = (0.75)(95\ F) + (0.06)(552\ F) + (0.19)(110\ F) = 125\ F$$

Reference 5, Table 3.3.1.3 indicates that the total stored energy of the steam, vessel, internals, piping, and core is about 2E8 BTU at the start of the accident, and this energy would raise the pool temperature by about another 20 F if all of this were added prior to the peak pool temperature being reached. If hydrogen production/combustion adds another 2E8 BTU (see Reference 6) during core degradation and shortly after quench, that would raise the pool temperature by about another 20 F. It is reasonable to assume that all (or nearly all) of this energy would be added prior to the peak pool temperature being reached somewhere between two and four hours (the two hours is the approximate time of debris quench and the four hours is the time of the current peak taken from Reference 5, Figure 3.3.2.6). The difference between the decay power added and the heat removed by one RHR heat exchanger (assumed in Reference 6 to be in spray mode) up to this point in time (i.e., at two to four hours) can be estimated from Reference 5, Figure 3.3.2.8 as being about 4E8 BTU. This would raise the temperature an additional 40 F. The result would be a peak pool temperature of 205 F. In Reference 6, only the pool water mass was considered and the peak pool temperature was estimated to be somewhat higher; i.e., 212 F. This peak value will be assumed here as well, but only as a transient peak at two hours. This earlier time (over the range of two to four hours) is reasonable because the bulk of the hydrogen combustion (with igniters functioning) would be expected before this time.

It will be assumed that the pool temperature will begin to deviate from that of Reference 5, Figure 3.3.2.6 at the time of the start of ~~the start of the~~ significant fuel damage at about 1/2 hour (see Reference 6) and that the peak (of 212 F) is reached at two hours. Beyond two hours, the rate at which the temperature converges on the Reference 5, Figure 3.3.2.6 curve can be estimated by assuring that the product of the average temperature difference between the two curves times the mass of water in the pool times the heat capacity of water (i.e., the "excess" energy stored in the pool water over the convergence time) is equal to the average temperature difference between the two curves times the RHR heat exchanger removal constant times the time (i.e., the "excess" heat removal afforded by the higher temperature), or: DL 4/15/96

Time to converge = $\frac{\Delta T_{ave}(1E7\ BTU/F)}{\Delta T_{ave}(440\ BTU/sec\text{-}F)}$ = 2.3E4 seconds

In actuality, this is a characteristic time, because this "excess" energy is removed exponentially. Assuming three characteristic times to converge, we have:

Time to converge = 69000 seconds

When added to the assumed peak time of 7200 seconds, we have 76200 seconds or 0.9 days. For simplicity, it will be assumed that the convergence occurs within one day. The assumed curve is presented as Exhibit 1, a mark-up of Figure 3.3.2.6 of Reference 5. From Reference 4, Item 1.3, for the CEI high burn-up core, the core iodine mass is approximately 10.5 grams per Mw. From Reference 4, Item 1.1 the core power is 3758 Mw(t). This means the iodine mass is approximately 3.95E4 grams. The iodine core inventory (most of which is stable or near-stable iodine) would be approximately 8E-3 grams per liter if 100 percent were released. The Reference 1 source term, however, involves only a 30% release of iodine for a BWR; and therefore, the iodine concentration (taken to be I^-) is 2.4E-3 grams per liter or about 1.9E-5 gm-atoms per liter.

From Reference 2 if $H^+ = 10^{-7.0}$ (i.e., pH = 7.0 - see Assumption 1), then for I^- = 1.9E-5:

$I_2 = (H^+)^2(I^-)^2/[d + e(H^+)]$ where: d = 4.22E-14, and
e = 1.47E-9

I_2 in the liquid phase = 8.5E-11 gm-moles/liter

I in the liquid phase = 1.7E-10 gm-atoms/liter

Since I^- in the liquid phase = 1.9E-5 gram-atoms/liter, then I/I^- = 9E-6 in the liquid phase.

From Reference 2, the partition coefficient is:

$\log_{10} PC(I) = 6.29 - 0.0149T$, where T is in K

From Reference 4, Item 8.5, the maximum pool temperature is 212 F = 373 K

Then:

PC(minimum) = 5.4 (i.e., the minimum concentration of iodine, as I_2 in the liquid phase is 5.4 times that in the gas phase. A lower temperature would yield a higher PC)

Since the gas phase volume = volume of drywell + volume of containment

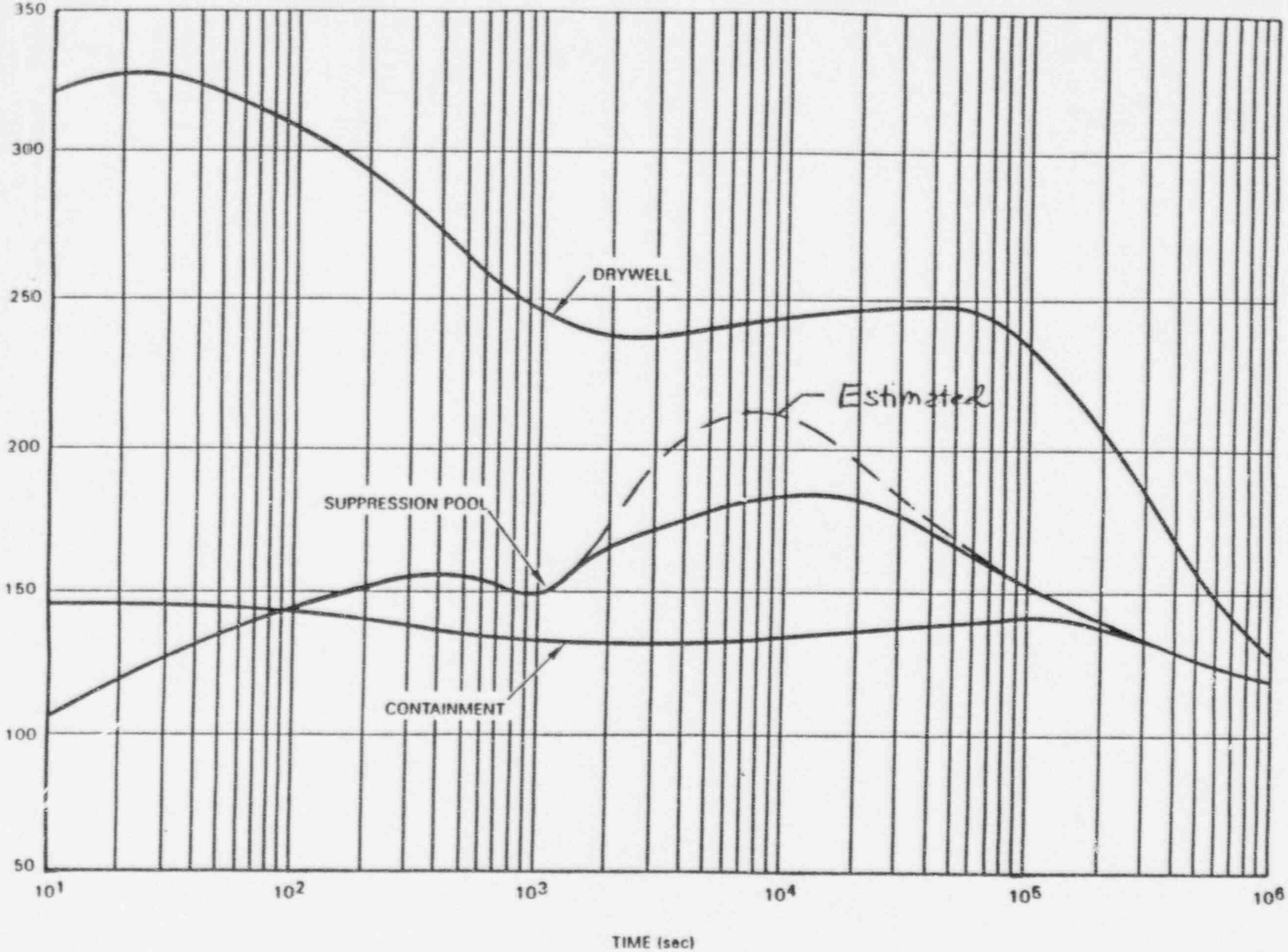

FIGURE 3.3.2.6 LONG-TERM DRYWELL, CONTAINMENT AND SUPPRESSION POOL TEMPERATURE (MINIMUM ECCS)

Exhibit 1

= (2.8E5 + 1.165E6) ft^3 (from Reference 4, Items 3.1, 3.2, and 3.3)

= 1.445E6 ft^3

And since the volume of the liquid phase is 175000 ft^3, the ratio of the gas phase volume to the liquid phase volume is 8.3:1. This means that once removed from the gas phase, the mass of iodine, as I_2, in the liquid phase would never be less than (5.4/8.3 = 0.65) that in the gas phase. Since the maximum mass ratio of I/I^- in the liquid phase is 9E-6, the maximum mass ratio of I in the gas phase to I^- in the liquid phase is 9E-6/0.65 = 1.4E-5. This means that the minimum ultimate DF of iodine (i.e., of molecular I_2 in the gas phase) for this system is approximately 1/1.4E-5 = 70000 if the iodine can be removed from the gas phase initially.

Reference 1 indicates that 0.0015 of the iodine released to containment must be considered to be organic. This fraction is 100 times greater than the fraction of the iodine released which could re-evolve as I_2 as calculated above. Moreover, the suppression pool temperature would reach 212F as a post-accident peak for only a short time and only within the first few hours of the accident as a result of the additional energy from hydrogen production (see above and Reference 6). Therefore; as a practical matter, there is no need to limit the removal of inorganic iodine in the analysis of the revised DBA source term for Perry. The organic iodine (which is not removed by deposition or pool scrubbing) will always dominate. By Assumption 2 the water in the drywell and that in the suppression pool will have the same pH and radioiodine concentration; therefore, the concentration ratio (I_2 in the gas phase to I^- in the liquid phase) will be the same. This means that the I_2 concentration in the gas phase of the containment and the drywell will be the same, and a single control volume model of the lower containment/drywell is acceptable in the long-term from the standpoint of the potential for iodine re-evolution.

Results

The minimum justifiable long-term DF for elemental iodine in both the drywell and the containment is 70000. If this degree of decontamination can be achieved by removal mechanisms, then the associated re-evolved I_2 concentration will not exceed that of the organic iodine in the Reference 1 source term specification.

Conclusions

There is no need to limit elemental iodine removal in the analyses supporting application of the revised DBA source term to Perry.

CALCULATION TITLE PAGE

CALCULATION NUMBER: PSAT 04202H.05

CALCULATION TITLE:

"Aerosol Decay Rates (Lambdas) in Containment with Spray"

	ORIGINATOR	CHECKER	IND REVIEWER
	Print/Sign Date	Print/Sign Date	Print/Sign Date
REVISION: 0	Rudolph Sher R. Sher 4/9/96	Jun Li Li Jun 4/9/96	James Metcalf James Metcalf 4/9/96
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REASON FOR REVISION:	Nonconformance Rpt
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Purpose

The purpose of this analysis is to calculate the aerosol decay (removal) rates in the containment due to sprays that remove fission and non-fission product aerosols from the containment atmosphere.

Methodology

The problem to be solved can be described as follows:

During a design base accident (DBA), fission product aerosols are released from the damaged core into the drywell, together with significant amounts of steam and non-condensable gases. The steam and gases, as well as the heat transfer to the gases in the drywell, will cause an increase in drywell pressure and result in a significant sweeping flow into the unsprayed region of the containment through the pathways that connect the drywell and the unsprayed region, which will transport aerosol particles. Leakage flows into the main steam lines through the MSIVs are also expected. In addition, there will be introduction of aerosol into the sprayed portion of the containment as a result of the significant exchange flows between the sprayed and unsprayed portions of the containment. The spray droplets will act to remove

aerosol particles by means of several collection mechanisms, including impaction, interception and diffusion.

Based on the mass conservation law, the suspended aerosol mass in the containment is governed by the following equation:

Suspended mass = Injected mass - Leaked mass - Removed mass

The injected mass of aerosols into the containment include both fission and non-fission product aerosols from the drywell. The leaked mass accounts for the aerosols that leak from the containment to the environment through normal containment leakage pathways such as penetrations. Removal processes include sedimentation, diffusiophoresis and thermophoresis, and interactions between spray droplets and aerosol particles. All of the quantities in the equation can be functions of time. As will be seen, the leakage term is set equal to zero,

The above equation is solved by the STARNAUA Rev. 1 (STARNAUA Version 1.01) code [1] in which the aerosol removal processes mentioned above are modeled, and the suspended aerosol concentration is calculated for the specified timing and rates of injected aerosols and the specified aerosol leakage rate to the environment. Removal by sprays is also explicitly modeled in STARNAUA Rev. 1 at the user's option.

Assumptions

Assumption 1: The containment is well-mixed during the entire time period of the accident.

Justification: Given the fact that steam, non-condensable gases (e.g., hydrogen) and fission product gases and aerosols are entering the containment atmosphere, while significant heat and mass transfers are going on in the containment, this assumption is reasonable.

Assumption 2: Condensation and sensible heat transfer onto the containment walls are not considered.

Justification: This assumption is conservative in the sense that it will result in a smaller aerosol decay rate.

Assumption 3: Hygroscopicity of aerosols is ignored and relative humidity in the drywell is assumed to be 98% through-out the accident.

Justification: The cesium and iodine species (mostly CsI and CsOH) released into the containment are likely to be soluble and the hygroscopic

effect on the growth of the soluble aerosols is significant, which enhances the removal of such aerosols by increasing sedimentation. The assumption to ignore the hygroscopicity will thus be conservative. The relative humidity is immaterial, since both the hygroscopic effect on aerosol growth and diffusiophoresis (which is indirectly affected by the relative humidity) are not considered. Neglecting diffusiophoresis is also conservative.

Assumption 4: The leakage aerosol from the drywell, which is the source to the containment, can be characterized as a single specie with an approximately average density and molecular weight of the various species used in the drywell calculation, and geometric mean radius and geometric standard deviation equal to 0.22 micrometers and 1.81, respectively, (i.e., those of the aerosol source in the drywell calculation).

Justification: The spray removal efficiency is not sensitive to properties of the aerosol such as density and molecular weight, and the calculation is conservative when the chosen values of geometric mean radius and standard deviation are used, as compared with the actual values for the leaked aerosol from the drywell.

Assumption 5: Diffusiophoresis of aerosol to spray droplets due to condensation onto the droplets is neglected.

Justification: It contributes little to the spray collection efficiency [2], and its neglect is conservative.

Assumption 6: The temperature of the spray is input as 60 °C.

Justification: Since condensation (or evaporation) onto the droplets is not considered (see assumption 5), the input value of the droplet temperature is immaterial.

Assumption 7: The leak rate from the containment to the environment is set equal to zero.

Justification: The leak rate is less than 0.000083 hr^{-1} [3]; the spray lambdas are 1-10 hr^{-1}. Thus the leak rate can be ignored.

Calculation

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CALCULATION TITLE PAGE

CALCULATION NUMBER: PSAT 04202H.04

CALCULATION TITLE:

"Aerosol Decay Rates (Lambda) in Drywell"

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	Print/Sign	Date	Print/Sign	Date	Print/Sign	Date
REVISION: 0	Jun Li / Li Jun	4/9/96	Rudolph Sher / R. Sher	4/9/96	Rudolph Sher / R. Sher	4/9/96
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Purpose

The purpose of this analysis is to calculate the aerosol decay (removal) rates in the drywell due to natural removal mechanisms that remove fission and non-fission product aerosols from the drywell atmosphere.

Methodology

The problem to be solved can be described as follows:

During a design base accident (DBA), fission product aerosols are released from the damaged core into the drywell, together with significant amounts of steam and non-condensable gases. The steam and gases, as well as the heat transfer to the gases in the drywell, will cause an increase in drywell pressure and result in a significant sweeping flow into the unsprayed region of the containment through the pathways that connect the drywell and the unsprayed region. Leakage flows into the main steam lines through the MSIVs is also expected. All these flows will dilute or remove the aerosols in the

drywell and, at the same time, the aerosols will experience other removal processes, such as sedimentation, diffusiophoresis, thermophoresis, etc., the rates of which are to be determined in this analysis.

Based on the mass conservation law, the suspended aerosol mass in the drywell is governed by the following equation:

Suspended mass = Injected mass - Leaked mass - Removed mass

The injected mass of aerosols include both fission and non-fission product aerosols from the primary system. The leaked mass accounts for the aerosols entrained in the leak flows through several leakage pathways, such as the pathways that connect the drywell and the unsprayed region of the containment and the MSIV leakage, and the removed mass represents the aerosols deposited on the surfaces in the drywell due to sedimentation, diffusiophoresis, thermophoresis, and other aerosol removal processes. All of the quantities in the equation can be functions of time.

The above equation is solved by the STARNAUA Rev. 1 (STARNAUA Version 1.01) code [reference 1] in which the aerosol removal processes mentioned above are modeled, and the suspended aerosol concentration is calculated for the specified timing and rates of injected aerosols and the specified aerosol leakage rates through different pathways.

Assumptions

Assumption 1: The drywell is well-mixed during the entire time period of the accident.

Justification: Given the fact that steam, non-condensable gases (e.g., hydrogen) and fission product gases and aerosols are blowing into the drywell atmosphere, while significant heat and mass transfers are going on in the drywell, this assumption is reasonable.

Assumption 2: Condensation and sensible heat transfer onto the drywell walls are not considered.

Justification: This assumption is conservative in the sense that it will result in a smaller aerosol decay rate.

Assumption 3: Hygroscopicity of aerosols is ignored and relative humidity in the drywell is assumed to be 98% throughout the accident.

Justification: The cesium and iodine species (mostly CsI and CsOH) released into the drywell are likely to be soluble and the hygroscopic effect on the growth of the soluble aerosols is significant, which enhances the removal of such aerosols by increasing sedimentation. The assumption to ignore the hygroscopicity will then be conservative. A relative humidity of 98%, on the other hand, has no impact on this analysis since both the hygroscopic effect on aerosol growth and diffusiophoresis (that is indirectly affected by the relative humidity) are not considered. Neglecting diffusiophoresis is also conservative.

Assumption 4: The release fractions of the fission products are obtained from NUREG-1465 [reference 2] (see Tables 3.8 and 3.12) and the core inventories are from reference 3, all of which are summarized in Table 1 below. The timings are also obtained from NUREG-1465. Two phases of the fission product release are assumed. First, the gap release starts at 30 seconds after the initiation of the accident and lasts 1800 seconds. It is then followed by the early in-vessel release that lasts 1.5 hours.

According to NUREG-1465, the iodine specie released to the containment is in the forms of particulate and gases (organic and elemental). 95% of the iodine released to the containment is aerosol, while 5% is gases. Of the iodine gases, 97% are elemental and 3% are organic. Organic iodine behaves like a noble gas, so it is assumed to be non-removable. Elemental iodine, on the other hand, tends to deposit on aerosols or other surfaces, and is assumed to be removed similarly to the aerosols.

Assumption 5: The amount of non-fission product aerosols released to the containment is the same as that of fission product aerosols (i.e., about 129 kg). They are released uniformly during the in-vessel release period, similar to the fission product aerosol release. The average density of the non-fission product aerosols is assumed to be 5.6 g/cm^3.

Justification: The assumption that the ratio of fission to non-fission in-vessel releases is 1:1 is obtained from reference 4. It should be pointed out that it was mentioned in NUREG-1465 that about 780 kg of in-vessel non-fission masses was calculated in NUREG-0956 for one Peach Bottom sequence. Since the Peach Bottom reactor is not too different from the Perry reactor that is analyzed here, the same

order of magnitude of non-fission product release is expected. But, the non-fission product release that we assume is only 20% of what was calculated in NUREG-0956. Our assumption should then be conservative, since a larger amount of non-fission product release will enhance overall aerosol agglomeration and, therefore, increase aerosol sedimentation. As for the density, most of the non-fission product aerosols are Zr, Fe_2O_3 and UO_2 species whose densities are 6.4, 5.24 and 10.09 g/cm^3, respectively. So, a density of 5.6 g/cm^3 for the non-fission product aerosols represents a conservative value, considering that the Zr inventory in the core is almost three times higher than that of the iron (table 4.5, reference 5).

Table 1. Fission Product Releases Into Containment

Group	Title	Elements in group	Gap release[1]	Early in-vessel release[1]	Core inventory (kg)
1	Noble Gases	Xe, Kr	0.05	0.95	887
2	Halogens	I, Br	0.05	0.25	41.1
3	Alkali Metals	Cs, Rb	0.05	0.20	531
4	Tellurium Group	Te, Sb, Se	0	0.05	91.1
5	Barium, Strontium	Ba, Sr	0	0.02	384
6	Noble Metals	Ru, Rh, Mo, Tc	0	0.0025	1090
7	Lanthanides	La, Zr, Nd, Eu, Nb, Pm, Pr, Sm, Y	0	0.0002	1830
8	Cerium Group	Ce	0	0.0005	436

[1] Fractions of core inventories.

Assumption 6: The flow exchange between the drywell and the unsprayed region of the containment is ignored after containment heat removal (or reflood) is over.

Justification: According to PSAT 04202U.03 [reference 3] (Items 3.9 and 3.10), before 7484 seconds the flow exchange between the drywell and the unsprayed region of the containment is only in one direction, i.e., from the drywell to the unsprayed region of the containment. So,

the flow can be considered as a leakage flow out of the drywell. After 7484 seconds the flow from the drywell to the unsprayed region of the containment is balanced by the flow from the unsprayed region of the containment to the drywell. To fully model the two-way flow exchange, the calculation of aerosol behavior in both the drywell and the unsprayed region of the containment needs to be conducted in parallel, which will be very difficult. This assumption, evidently, simplifies the problem. The implication of the effect on the drywell aerosol decay rate calculation needs to be discussed when the result is used. Nevertheless, it should be pointed out that the suspended aerosol concentration in the unsprayed region of the containment is very likely to be less than that in the drywell because of the combination of the spray removal of aerosols in the sprayed region of the containment and the existence of large exchange flow rates between both the sprayed and the unsprayed regions of the containment.

Assumption 7: Aerosol size distribution is lognormal, with a geometric mean radius of 0.22 micron and a geometric standard deviation of 1.81.

Justification: As discussed in Reference 6 (page 12-13), the overwhelming majority of aerosols are observed to have a lognormal size distribution. It is also a common practice to assume such a distribution for the fission product aerosols in nuclear safety studies. A lognormal distribution is defined by the geometric mean radius and the geometric standard deviation. The values for them to be used in this calculation are based on an analysis of data from several degraded fuel experiments [reference 7]. It should be pointed out that the aerosols size distribution specified here yields a mass mean diameter of about 1.3 microns. For comparison, the mass mean diameters used in NUREG/CR-5966 [reference 8] range from 1.5 to 5.5 microns and the geometric standard deviations range from 1.6 to 3.7 (see page 84). Thus, our assumption is evidently at the lower end of what were used in reference 8, and is thus conservative compared with reference 8.

Reference

Reference 1: PSAT C101.02, "STARNAUA - A Code for Evaluating Severe Accident Aerosol Behavior in Nuclear Power Plant Containment: A Validation and Verification Report, Revision 1, February 1996

Reference 2: Soffer, L., et al., "Accident Source Terms for Light-Water Nuclear Power Plants", NUREG-1465, February 1995

Reference 3: PSAT 04202U.03, "Dose Calculation Data Base For Application of the Revised DBA Source Term to the CEI Perry Nuclear Power Plant", Revision 0

Reference 4: Letter from J. C. DeVine, Jr. to Leonard Soffer, "Additional ALWR Program comments on the NRC draft source term report, NUREG 1465", July 30, 1993

Reference 5: Denning, R. S., et al., "Radionuclide Release Calculations for Selected Severe Accident Scenarios, BWR, Mark I Design", NUREG/CR-4624, BMI-2139, Vol. 1, July 1986

Reference 6: Fuchs, N. A., "The Mechanics of Aerosols", Dovers Publications, Inc., New York, 1964

Reference 7: Polestar Memo from R. Sher to D. E. Leaver, "Aerosol Source Size Parameters", July 28, 1995

Reference 8: Powers, D. A. and Burson, S. B., "A Simplified Model of Aerosol Removal by Containment Sprays", NUREG/CR-5966, SAND92-2689, June 1993

Calculation

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PSAT 04212H.06

Rev: (0) 1 2 3 4

CALCULATION TITLE PAGE

CALCULATION NUMBER: PSAT 04212H.06

CALCULATION TITLE:

"Mixing between the Sprayed and Unsprayed Portions of the Perry Containment"

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REVISION: 0	James E. Metcalf [signature]	4/9/96	David Leaver [signature]	4/9/96	David Leaver [signature]	4/9/96
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REASON FOR REVISION:

	Nonconformance Rpt
0 - Initial Issue	N/A
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Purpose

The purpose of this calculation is to determine time-dependent mixing rates between the sprayed and unsprayed portions of the Perry containment.

Methodology

Spraying of the upper containment atmosphere will cool that atmosphere relative to that of the lower containment and wetwell. The lower containment/wetwell atmosphere is exposed to the suppression pool (which is hotter than the spray temperature) and is also more likely to receive any suppression pool bypass (due to greater exposure to the drywell pressure boundary). Based on the cooling effects of the spray (even with the steam condensation effect conservatively neglected - see Assumption 1), an expression will be developed which will relate the density-driven flow between the denser atmosphere of the sprayed region and the less dense atmosphere of the unsprayed region to the temperature of the suppression pool (used to characterize the temperature of the wetwell/lower containment) and the temperature of the spray (used to characterize the temperature of the sprayed region). Suppression pool bypass is neglected (see Assumption 2).

The expression for mixing will be written in terms of a controlling "orifice" area that limits the flow between the sprayed and unsprayed regions. As applied to the Perry containment, this area is that of the equipment opening at the outer periphery of the refueling floor. As the spray

droplets transfer their momentum to the sprayed region atmosphere, this opening represents the longest, unimpeded vertical flowpath for sustained interaction between the falling spray droplets and the atmosphere, creating a natural downward flow (due to momentum exchange) to be supplemented by the density-driven component of the circulation potential. While the momentum exchange, itself, is conservatively neglected in quantifying the mixing rate (see Assumption 3), the geometry of the Perry containment will encourage downward flow through this controlling flow area with the return flow re-entering the sprayed region through multiple flowpaths in areas protected from direct spray impingement.

Assumptions

Assumption 1: Steam condensation in the sprayed region may be neglected in determining the mixing rate between the sprayed and unsprayed regions of the containment.

Justification: The effect of steam in the unsprayed region (which then mixes with the sprayed region atmosphere and is condensed there) is to increase the density difference between the two regions, tending to increase the mixing rate.

Assumption 2: Suppression pool bypass may be neglected in determining the mixing rate between the sprayed and unsprayed regions of the containment.

Justification: The effect of suppression pool bypass is to increase the heat load in the unsprayed region. A large and positive dT_u/dt (rate of temperature change in the unsprayed region) or a large and negative dT_s/dt (rate of temperature change in the sprayed region) contributes to increased mixing.

Assumption 3: Momentum exchange between the spray droplets and the containment atmosphere may be neglected in determining the mixing rate between the sprayed and unsprayed regions of the containment.

Justification: Momentum exchange can be appreciable in creating forces on the containment atmosphere that must be balanced by recirculation. Consider that the terminal velocity for a 1 mm droplet is about 20 fps (600 cm/sec at atmospheric pressure from Chapter 10, Figure 1 of Reference 2). For a spray flowrate of 5250 gpm and a minimum fall height of about 40 feet (Reference 3 Items 3.25 and 7.1), there would be about 2 seconds of spray flow or 175 gallons airborne at any time. The weight of this water is about 1450 lbf, and it is this force that would have to be reacted by air drag associated with the movement of the recirculating atmosphere.

The average pressure created by this weight of water across the operating floor

would be about 1450 lbf/11310 ft^2 (Item 7.4 of Reference 3) or roughly 0.13 psf or 0.001 psi. In certain areas where the fall height might be greater, the local pressure could be even higher.

The 0.001 psi may seem like a very small pressure, but it is equivalent to about 0.03" of water, and 0.03" of water is the velocity pressure corresponding to about seven MPH or 600 fpm (Reference 2, Chapter 19, Figure 1). With a mixing length of about 400 feet around the containment, a 600 fpm velocity would recirculate the containment atmosphere about once every 0.67 minutes or 90 volumes per hour. Although this is a simplistic assessment and does not take into account drag on the recirculating air due to obstacles in the path of the air flow or the fact that in some locations the downward pressure may act to resist flow created by an even greater downward pressure in other locations, it dose illustrate the magnitude of the effect that is being neglected.

Assumption 4: Structural heat sinks in the containment may be neglected in determining the mixing rate between the sprayed and unsprayed regions of the containment.

Justification: Most of the structural heat sinks in the containment are in the unsprayed region. Once sprays and the containment cooldown begins, these heat sinks will become heat sources low in the containment, tending to promote natural circulation.

Assumption 5: Introduction of hydrogen through the vent system, through safety/relief valve discharge, or through pool bypass may be neglected in determining the mixing rate between the sprayed and unsprayed regions of the containment.

Justification: As noted in Reference 1, 50% cladding oxidation would result in the decomposition (and eventual recombination in containment) of about 4E5 g-moles of steam. The recombination would require about 2E5 g-moles or 6.4E3 kg of O_2 in the containment. At the start of the accident (after the purge of the drywell), the unsprayed region (about 6.8E5 ft^3 + 60% of the 2.8E5 drywell volume - Reference 3 Items 3.1, 3.2, and 3.3) would contain about 64000 lbm of air or about 12800 lbm of oxygen. This quantity of oxygen represents about 90% of that needed to recombine the hydrogen even without any exchange of atmosphere with the sprayed region. With igniters functioning in the wetwell/lower containment, and the bulk of the hydrogen entering the wetwell/lower containment prior to entering the upper containment, one would expect the bulk of the hydrogen combustion to occur in the lower region. This combustion would encourage even more rapid mixing between the sprayed and unsprayed regions.

While bypassing steam could potentially inert the wetwell and lower containment (if steam generation were many times greater than the conservatively low values of Reference 1 and the bypass area were of the order of the design value) and force combustion in the upper containment, this introduction of steam into the wetwell and lower containment would encourage (and the associated transport of hydrogen would be indicative of) good containment mixing. Fission product aerosols would tend to follow the hydrogen-rich flow from the vessel/drywell to the upper containment.

Assumption 6: The temperature of the wetwell/lower containment is that of the suppression pool.

Justification: Given that there is no bypass or hydrogen combustion considered, the temperature of the lower containment can reasonably be assumed to be that of the suppression pool once the effects of the initial compression (due to air purged from the drywell at the beginning of the accident) have abated.

Assumption 7: The temperature of the upper containment is the average of the temperature of the wetwell/lower containment and the inlet temperature of the spray.

Justification: The exact temperature in the upper containment will be determined by the heat load of the air being recirculated in from the wetwell/lower containment and the inlet temperature of the spray. If the recirculation is very high, then the temperature of the upper containment will be closer to that of the wetwell/lower containment. If the recirculation is very low, then the temperature of the upper containment will be closer to that of the spray inlet. Assuming an average temperature will lead to a moderate degree of recirculation which should be self-consistent with the temperature assumed.

Assumption 8: A low containment temperature is conservative in determining the mixing rate between the sprayed and unsprayed regions of the containment.

Justification: The higher the unsprayed region temperature (corresponding to the temperature of the suppression pool) the greater the temperature difference between the spray inlet temperature and the pool temperature and, therefore, between the sprayed and unsprayed regions and the greater the mixing. Also, consider that:

T_u (temperature of the unsprayed region) = T_p (temperature of the pool)

T_s (temperature of the sprayed region) = $(T_p + T_{spray})/2$

Then recalling that $T_{spray} = T_p - C(T_p - T_{cooling\ water})$ where C and $T_{cooling\ water}$ are constants,

$$dT_u/dt = dT_p/dt \text{ and } dT_s/dt = (1-C/2)dT_p/dt$$

This means that the rate of change of the unsprayed region temperature will be greater than the rate of change of the sprayed region temperature. The two temperatures will converge during the cooldown and will be the same when $T_p = T_{cooling\ water}$ = 85 F (Reference 3, Item 9.4)

References

Reference 1: PSAT 04212H.02, "Drywell Sweep-Out Rate and Related Thermal-Hydraulic Conditions inside Containment", Revision 0

Reference 2: American Society of Heating, Refrigerating, and Air Conditioning Engineers, Handbook of Fundamentals, New York, 1972

Reference 3: PSAT 04202U.03. "Dose Calculation Data Base for Application of the Revised Source Term to the CEI Perry Nuclear Power Plant", Revision 0

Calculation

Conclusions

POLESTAR
NON-PROPRIETARY

CALCULATION TITLE PAGE

CALCULATION NUMBER: PSAT 04202H.07

CALCULATION TITLE:

" Main Steam Line Heat Transfer Analysis"

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	Print/Sign	Date	Print/Sign	Date	Print/Sign	Date
REVISION: 0	Jun Li [signature]	4/9/96	Rudolph Sher [signature]	4/9/96	Rudolph Sher [signature]	4/9/96
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REASON FOR REVISION:	Nonconformance Rpt
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Purpose

The object of this heat transfer analysis is to calculate the temperature profile along the section of the process pipe of interest to us (i.e., between the inboard and outboard MSIVs). The results of this analysis will then be used to determine the axial natural circulation velocity induced by the axial temperature variation. Since the process pipe is insulated and its temperature is uniform at the start of the isolation, the temperature variation will only be significant if there exist significant localized heat losses.

Introduction

In the section of the process pipe of interest to us, two locations at which significant heat losses are possible are identified. One is between the outboard MSIV and the shield building wall where the guard pipe is welded to the process pipe. It is shown in Figure 1 at the point marked "Welding Location". The other is where the process clamp is located. At this location six lugs that are physically connected to the process pipe and six lubrite plugs that are physically connected to the guard pipe are separated by a very narrow gap (only about 0.06" according to Reference 1), as shown in Figure 2 (only one device is shown). Because most of the guard pipe is directly exposed to the atmosphere, the guard pipe becomes a heat sink to the process pipe at those locations mentioned above. However, at the welding location, the guard pipe is insulated all the way to the inner face of the shield building wall, the heat transferred from the process pipe to the

guard pipe will be conducted through this insulated section before being "released" to the atmosphere. At the process clamp location, on the other hand, the heat transferred from the process pipe to the guard pipe has to go through the process clamp, the lug welded to the process clamp, the gap, the lubrite plug press fit into the bolt, and the bolt, as shown in Figure 2. Thermal resistance is expected at all the interfaces among them. Though, the process pipes are insulated, heat loss from the process pipe through the insulation material may not be negligible for the time frame in consideration (i.e., from 1 to 24 hours).

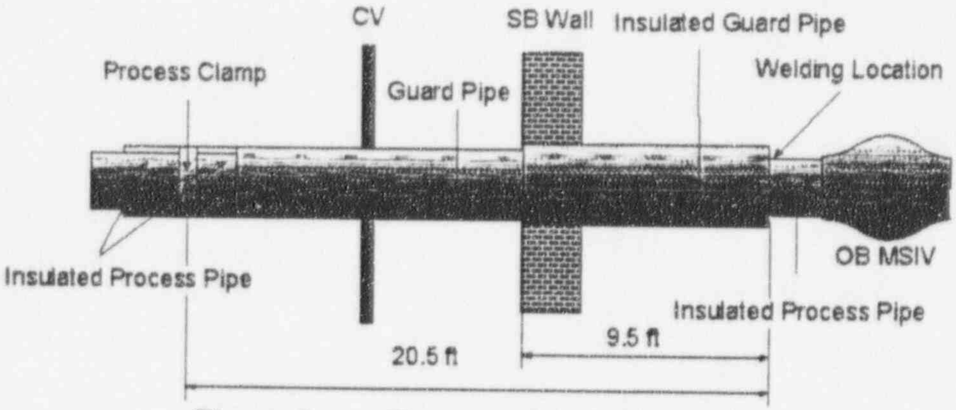


Figure 1. Process pipe Schematics

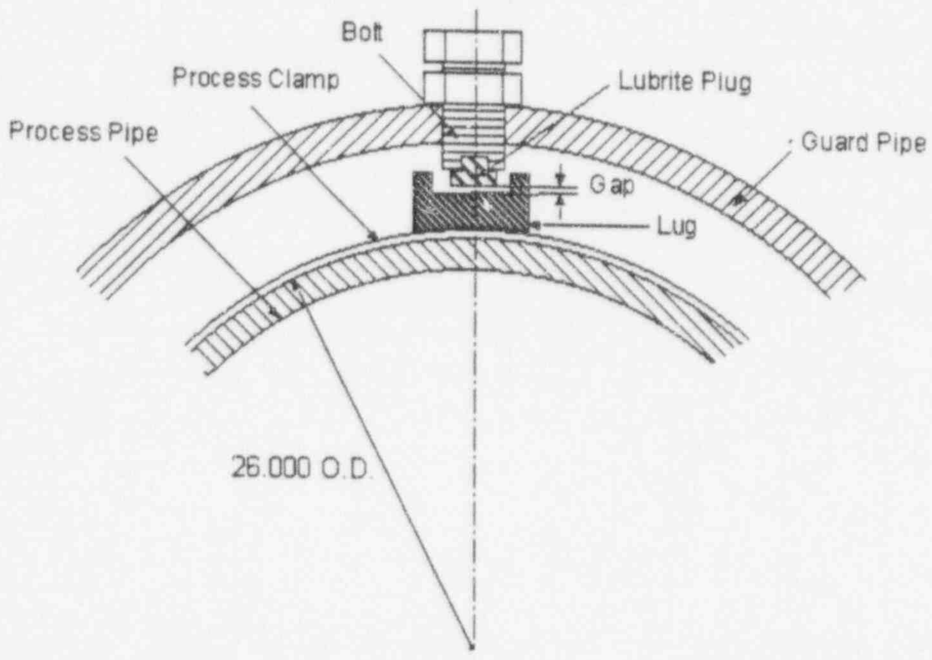


Figure 2. Schematics of Joint of process pipe and guard pipe at process clamp Location

Assumptions

To analyze the heat transfer process, the following assumptions are made.

Assumption 1: Heat loss through the insulation material from the process pipe is uniform over the entire section of the pipe under analysis. The heat transfer coefficient for the heat loss is assumed to be a constant and is obtained from Reference 2 (see below).

Justification: The uniformity assumption for the heat loss through the insulation material is based on the fact that the pipe is uniformly insulated and, in addition, any small difference resulting from a possible inhomogeneous insulation will be smoothed out by the conduction in the pipe since the conduction resistance in a metal pipe is always much smaller than the thermal resistance in the insulated material. A study on uniform cooling of the process pipe has been reported in Reference 2; as shown in Exhibit 1, the main steam line temperature decreases as a function of time. The plot is used to derive a heat transfer coefficient through the insulation material in this analysis. Doing so is appropriate since, first of all, the main steam line insulation will not be too different from one nuclear plant to another in the US. Secondly, it is the temperature difference (between the temperature at any location of the process pipe and that at the hottest spot of the pipe) that is of interest to us, which will not be significantly affected by variations in a uniform cooling calculation.

Assumption 2: The insulated portion of the guard pipe is treated as an extension of the process pipe at the welding location.

Justification: The materials for the process pipe and the guard pipe are not different as far as the heat transfer is concerned. The difference between their cross-section areas is negligible, too.

Assumption 3: Heat transfer from the outboard MSIV to the section of the process pipe at the welding location is ignored.

Justification: This is for the simplicity and is conservative in the sense that it will cause the temperature variation along the section of the process pipe of interest to us to be overestimated. That is because the outboard MSIV has huge mass and heat capacity and therefore is a heat reservoir that tends to maintain the temperature of the process

pipe at the welding location against heat loss through the guard pipe.

Assumption 4: The temperatures of the guard pipe at the end of insulation (which coincides with the inner surface of the shield building wall) and at the process clamp location are the ambient temperature of the environment.

Justification: Evidently, this is also a conservative assumption since the guard pipe should be hotter than the environment in order to transfer heat to the environment. The ambient temperature is assumed to be 102 °F (as will be shown later in the calculation), which is believed to be conservative since the ambient temperature at that location should be higher than that.

Assumption 5: On both sides of the process clamp, the temperature distributions along the process pipe in the vicinity of the process clamp are assumed to be symmetric.

Justification: The process pipe is insulated on both sides of the process clamp and is at uniform temperature initially. Each side can be modeled as a semi-infinite body starting at the process clamp location. This is why only one side of the process pipe needs to be analyzed. And it is also the reason why only three bolts out of the total six need to be considered in the heat transfer analysis.

Assumption 6: Thermal contact resistance at all interfaces from the process pipe to the guard pipe is ignored, except for the gap resistance between the lug and the plug.

Justification: This will greatly simplify the problem, and will be conservative.

Assumption 7: The initial thermal hydraulic conditions in the process pipes are assumed to be 562 °K (552 °F) in temperature and 1 atm in pressure.

Justification: The initial temperature in the process pipe is the same as that during normal operation, so it equals 562 °K (552 °F), which is the steam saturation temperature at the RCS pressure of 1060 psia (the pressure given in Reference 3 as Item 8.4). After the MSIV closes following a postulated severe accident, the pressure in the process pipe drops to about atmospheric pressure, while the wall

Reference

Reference 1: Fax from J. Spano to J. Metcalf on Jan. 9, 1996

Reference 2: J. Cline, "MSIV Leakage Iodine Transport Analysis," Prepared for the U.S. Nuclear Regulatory Commission under contract NRC-03-87-029, Task Order 75, March 26, 1991.

Reference 3: PSAT 04202U.03, "Dose Calculation Data Base For Application of the Revised DBA Source Term to the CEI Perry Nuclear Power Plant", Revision 0

Reference 4: F. Kreith, "Principles of Heat Transfer", 3rd Edition, Intext Educational Publishers, New York, 1973.

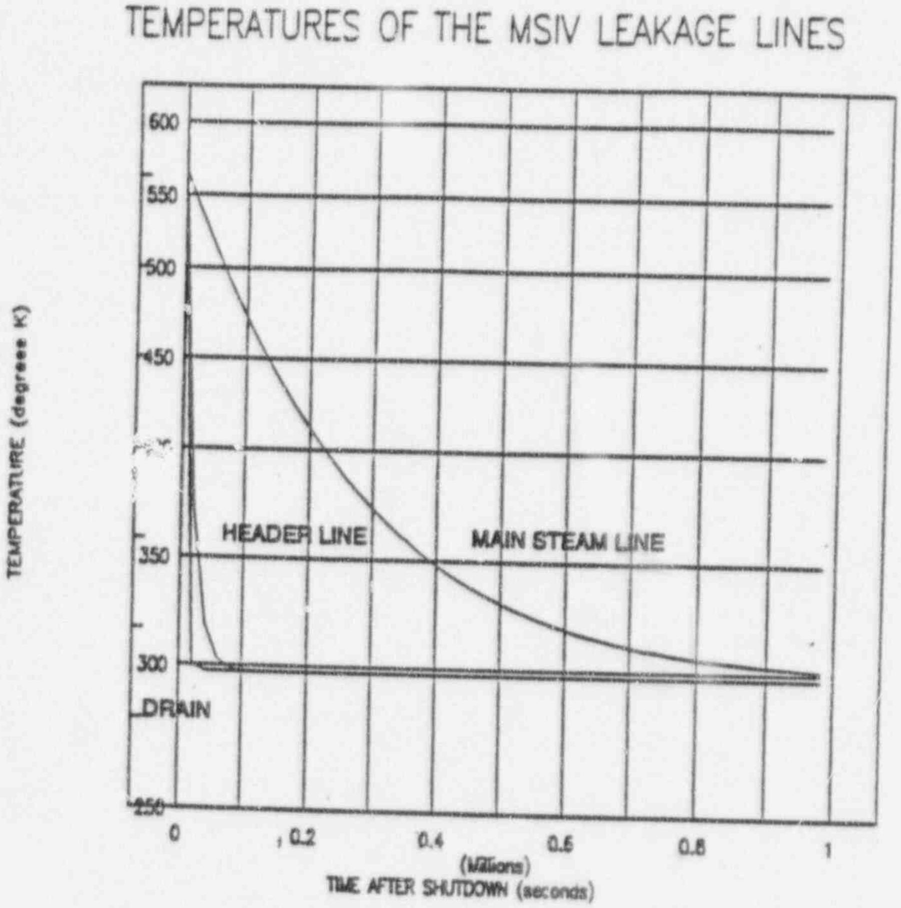
Reference 5: W.M. Kays and M.E. Crawford, "Convective Heat and Mass Transfer", 2nd Edition, McGraw Hill, NY , 1980.

Reference 6: W.C Reynolds, H. C. Perkins "Engineering Thermodynamics", McGraw Hill, NY , 1964

Calculation

Results

Exhibit 1
(Taken from Reference 2)



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CALCULATION TITLE PAGE

CALCULATION NUMBER: PSAT 04202H.08

CALCULATION TITLE:

"Steamline: Particulate Decontamination Calculation"

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REVISION: 0	Jun Li	4/8/96	James Metcalf	4/10/96	Rudolph Sher	4/11/96
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0 - Initial Issue	N/A
1 - To correct mean free path of steam and associated Cunningham slip factor (based on comparative DEPOSITION calculation required by PSAT 04202U.02), to credit retention in the intact steamlines inboard of the inboard MSIV, and to use time-dependent particle size distribution based on drywell STARNAUA computer runs.	N/A - error found in-process.
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Purpose

The purpose of this analysis is to model the behavior of the aerosols as they travel through the main steam lines and, thus, to calculate the removal efficiency of the aerosols in the main steam lines.

Introduction

There is a total of 4 main steam lines in the Perry plant; each has an inboard MSIV, an outboard MSIV and a third isolation valve. Since the Design Basis Accident considered

here is assumed to be initiated by a double guillotine pipe rupture in one of the four main steamlines (see Assumption 2 below), the fission products suspended in the drywell atmosphere are assumed to leak to the environment through the MSIVs in the broken line, as well as to be entrained in the gas flow back through the break and into the intact steam lines via the reactor vessel, and then to leak out to the environment through the MSIVs in the intact lines.

The MSIVs in main steam lines are required to close when an accident occurs. Failure to close any of these valves will affect the retention of the fission product aerosols in the steamlines (and therefore the fission product release to the environment) as will the location of the pipe rupture in the broken steam line and the distribution of the 250 scfh total steam line leakage among the four lines.

Therefore, in order to assure that the most limiting (i.e., conservative) dose is evaluated for the DBA dose calculation, it is necessary to determine the worst case single failure, break location, and MSIV leakage distribution.

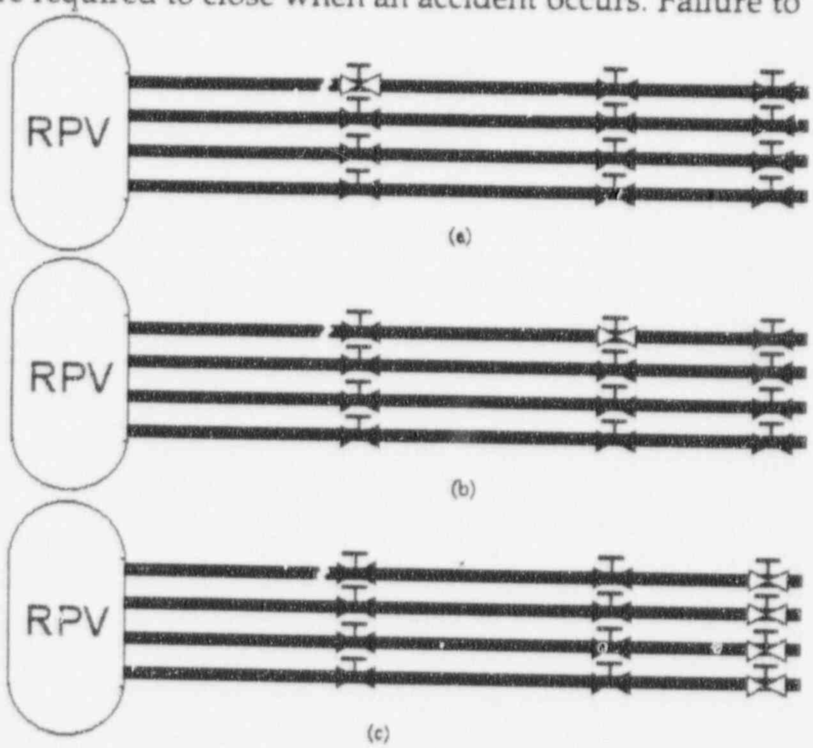

Figure 1. MSIV leak path configurations

<u>Steam Line Single Failure Possibilities</u>

There are three single failure possibilities:

(1) Failure of a single inboard MSIV to close (see Figure 1.a)

(2) Failure of a single outboard MSIV to close (see Figure 1.b)

(3) Failure of one or more third isolation valves (MOV 20 valves) to close (see Figure 1.c)

The aerosol retention is dependent on steam line length (i.e., fraction retained increases with the length of steam line available) and on the retention modeling assumptions for the steam line volume. With regard to retention, the reality is that for most steam line configurations the gas and entrained aerosol from the leakage will flow with uniform velocity (determined by the volumetric flow from the MSIV leak rate) with a delay between the time of entry into the steam line and the time of arrival at the end of the steam line. Aerosol settles in the pipe as the gas and entrained aerosol flow down the pipe so that at the end of the pipe (i.e., the end of that portion of the pipe being credited as a retention volume), the concentration of aerosol in the leaking gas mixture is reduced (in effect, a filtering process). The time delay is not taken into account in making the determination of aerosol retention efficiency.

The retention has been modeled in one of two ways. For steam line sections which are completely isolated (i.e., where there is a closed isolation valve upstream and downstream of the volume comprising the steam line section) and where significant axial temperature variation does not exist along the steam line pipe wall, uniform velocity is assumed. For steam line sections where the upstream end is open to the drywell or reactor vessel, or where there is a significant axial temperature variation along the steam line pipe wall, some mixing can occur. In this situation a well-mixed model is assumed for conservatism; that is, aerosol settling is based on the aerosol mixing immediately as it enters the pipe.

On the basis of the assumptions discussed below, the first and third of the single failure possibilities will be considered in the dose evaluation to determine the more limiting. These two configurations are as follows:

(1) One line leaking at 100 scfh, with the break assumed to occur immediately upstream of the failed open inboard MSIV in this line; credit for two retention volumes in series, one between the two MSIVs (a well-mixed volume with no uniform flow velocity due to the location of the break and the upstream MSIV having failed open) and one between the outboard MSIV and the third isolation valve (no retention prior to 20 minutes to effect closure of the third isolation valve, and uniform flow velocity after 20 minutes).

A second line (intact) leaking at 100 scfh; credit for three retention volumes in series, one upstream of the inboard MSIV (a well-mixed volume due to the presence of the reactor vessel upstream), one between the two MSIVs (uniform flow velocity since both ends of the volume are isolated), and one between the outboard MSIV and the third isolation (again, uniform flow velocity after 20 minutes).

A third line (also intact) leaking at 50 scfh; credit for three retention volumes in series, one upstream of the inboard MSIV (a well-mixed volume due to the presence of the reactor vessel upstream), one between the two MSIVs (uniform flow velocity since both ends of the volume are isolated), and one between the outboard MSIV and the third isolation (again, uniform flow velocity after 20 minutes).

(2) All four third isolation valves fail open (due to common power supply).

The broken line leaking at 100 scfh, with the break assumed to occur immediately upstream of the inboard MSIV; credit for one retention volume between the two MSIVs (uniform flow velocity since both MSIVs are closed).

A second line (intact) leaking at 100 scfh; credit for two retention volumes in series, one upstream of the inboard MSIV (a well-mixed volume due to the presence of the reactor vessel upstream), and one between the two MSIVs (uniform flow velocity since both ends of the volume are isolated).

A third line (also intact) leaking at 50 scfh; credit for two retention volumes in series, one upstream of the inboard MSIV (a well-mixed volume with no uniform flow velocity due to the presence of the reactor vessel upstream), and one between the two MSIVs (uniform flow velocity since both ends of the volume are isolated).

Reference [1] establishes that because of the presence of the process clamp in the space between the guard pipe and the steamline about mid-way between the inboard and outboard MSIVs, that portion of the steamline will cool down at a rate somewhat greater than the steamline, in general. Therefore, an internal circulation can be established over much of the steam line section between the inboard and outboard MSIVs after a certain period of time. This section will then be considered well-mixed.

Methodology

The problem to be solved can be described as follows:

During a postulated DBA accident, the drywell pressure drives a small leakage flow to travel through the isolated main steamlines out to the environment. The fission products suspended in the drywell may be entrained in this leakage flow. As the fission product aerosols are traveling through the main steam lines, they will experience removal processes, such as sedimentation, Brownian diffusion, diffusiophoresis,

thermophoresis, etc. The removal efficiency of the aerosols in a steam line depends on the condition and configuration in that steam line.

When most of the steam line is at uniform temperature, the gas flow is driven by the steam line leakage only and is then expected to be uniform, so the steam line retention of aerosols is modeled as the aerosol sedimentation during the time interval when the aerosols traverse through the section of the steamline under consideration at the uniform flow velocity corresponding to the leak rate. The aerosols that are still suspended (i.e., have not settled) when they arrive at the containment boundary (which is either the outboard MSIV or the third isolation valve) are considered to be released to the environment. The detailed modeling for this case is given below and the calculation is done in Appendix C.

When a temperature variation prevails over some portion of the steam line, natural circulation flow may dominate over the flow induced by the leakage. Consequently, the steamline aerosols are better mixed than the case discussed above. In this case, the steam line section of interest is modeled as a well-mixed volume with an aerosol source rate and leak rate specified by the leakage rate. The computer code STARNAUA 1.01 is used to calculate the aerosol sedimentation. The discussion for this case and the calculation details are provided in Appendix B.

Assumptions

Assumption 1: The single failure of outboard MSIV failure to close need not be considered further on the basis that it will have higher aerosol retention and thus is less limiting than the inboard MSIV failure to close.

Justification: The outboard MSIV failure to close is identical to the inboard MSIV failure to close except that it would provide retention from uniform flow velocity over the steam line length from the inboard MSIV to the third isolation valve. The inboard MSIV failure to close, on the other hand, provides retention from a well-mixed volume over the steam line length from the inboard MSIV to the outboard MSIV, and uniform flow velocity from the outboard MSIV to the third isolation valve. Thus the outboard MSIV failure to close will have higher aerosol retention and is less limiting than the inboard MSIV failure to close.

Assumption 2: For the remaining two single failure possibilities, the worst case break location is in a main steam line, immediately upstream of the inboard MSIV.

Justification: A main steam line break is more limiting than a recirculation line break since the drywell pressure for a main steam line break is somewhat higher than for a recirculation line break. This higher drywell pressure is conservative since it reduces the volumetric flow (and thus the fission product removal effect of drywell sweepout) from steam generation during and after core damage (with a fixed mass flow rate from steam generation as calculated in Reference [2], a higher drywell pressure reduces volumetric flow from the drywell). A stuck open SRV is also not limiting since the SRV line will blow down into the suppression pool which would reduce airborne fission products significantly relative to what results from a main steam or recirculation line break.

A break immediately upstream of the inboard MSIV is limiting since with this break location, there is no credit for retention in any portion of the broken line upstream of the inboard MSIV.

Assumption 3: The worst case distribution of the 250 scfh total steam line leakage is to concentrate the leakage into three lines with the broken line and one other line at the 100 scfh per line maximum, and a third line at 50 scfh.

Justification: The broken line will have less retention length, and thus less retention, than the intact lines as noted in Assumption 2 above. Thus, assuming 100 scfh through the broken line is conservative.

For the remaining 150 scfh, assuming one line at 100 scfh is conservative since increased leak rate decreases residence time in the steam line volume and thus decreases retention efficiency.

Assumption 4: For the calculation of the actual MSIV leak flow rate, thermal hydraulic conditions in the main steamlines are assumed to be 562 °K in temperature and 1 atm in pressure over the time period in the accident of interest, i.e., from 0 to about 28 hours to be consistent with other aerosol removal calculations (e.g., drywell aerosol calculation in Reference [3])

Justification: The initial temperature in the main steamlines is the same as that during normal operation, namely 562 °K, the steam saturation temperature at the RCS pressure of 1060 psia (the pressure is given

in Reference [4] as Item 8.4). After the MSIV closes following a postulated core damage DBA, the pressure in the main steamlines drops to a reduced pressure (assumed conservatively to be atmospheric), while the wall temperature remains unchanged at least for a while. The temperature is expected to drop as time goes on, but ignoring the temperature drop leads to a higher MSIV leakage flow that, in turn, leads to a smaller decontamination factor, and is thus conservative.

Assumption 5: The MSIV leakage flow becomes a uniform flow velocity after the entrance into the main steam lines when the main steam line temperature is uniform.

Justification: If the leakage flow is jet-like, jet-induced vortices will occur in the immediate vicinity of the leak pathway. It is expected that these vortices will efficiently mix the incoming leakage flow with the bulk gas. If there are multiple leak paths, the leakage flow mixes with the bulk gas even more efficiently. Thus, the MSIV leakage is considered to result in uniform flow velocity in the main steamline starting from the immediate vicinity of the MSIV.

Assumption 6: In evaluating the average residence time that the aerosols spend in traversing the section of the main steamline of interest, only the part of this section where the gas flow is expected to be uniform is taken into account. The time that the aerosols spend in the part of the main steamline where a natural circulation may exist due to the temperature variation is ignored.

Justification: This assumption implies that the aerosols traverse the part of the main steamline where a natural circulation may exist from one side to the other instantaneously. This is evidently a very conservative assumption in the sense that the residence time will be underestimated so that the decontamination factor of the aerosols will underestimated. A detailed discussion on the actual aerosol behavior in the natural circulation to be encountered in this analysis is given in Appendix C below.

Assumption 7: Aerosol sedimentation is considered to be the only removal mechanism for aerosols in the main steamlines. Only the horizontal sections of the main steamlines are credited for aerosol removal.

Justification: The assumption is necessary for simplifying the problem. As a result of this assumption, main steamline decontamination factors will be underestimated and, therefore, the assumption is conservative.

Assumption 8: In the calculation of aerosol removal, the aerosol source is assumed to be log normal, with a geometric mean radius, a geometric standard deviation and average aerosol density determined by the standard statistical analysis of the aerosol source.

Justification: As discussed in Reference [5] (page 12-13), the overwhelming majority of aerosols are observed to have a lognormal size distribution. It is also a common practice to assume such a distribution for the fission product aerosols in nuclear safety studies. A lognormal distribution is defined by the geometric mean radius and the geometric standard deviation. Since the aerosols in the main steamlines are from the drywell, the aerosol size distribution for the suspended drywell aerosols is used (see Reference [3]).

The average density calculated in Reference [3] is about 3.77 g/cm^3 for the first 1800 seconds (i.e., from 30 to 1830 seconds in accident time) and the total leaked mass into steamlines is 7.36 grams for this time interval (sweeping flow is assumed to be zero during this time). The average density becomes about 4.7 g/cm^3 after 1800 seconds and the total leaked mass into the steamlines is calculated to be 201.49 grams using the suspended aerosol mass concentration data given in Reference [3] and the MSIV leakage rates. Thus, the weighted average density for the aerosols that enter the steamlines is given by the following expression:

$$\bar{\rho}_p = \frac{3.77\,g/cm^3 \times 7.36g + 4.7\,g/cm^3 \times 201.49g}{7.36g + 201.49g} = 4.667\,g/cm^3$$

The aerosol source rate into the main steam line is dependent on the flow rate in that steam line (100 scfh or 50 scfh) and is derived from the suspended aerosol concentration in the drywell as a function of time. To have a better suspended aerosol concentration profile in the drywell over the time of interest, the drywell aerosol calculation from Reference [3] has been repeated using more frequent edits. The results are shown in Appendix A of this

calculation. A comparison has been made in Appendix A to show that the new calculation is identical to the original, except that the results are printed out at better distributed time points in the new calculation.

References

Reference 1: PSAT 04202H.07, " Main Steam Line Heat Transfer Analysis ", Revision 0

Reference 2: PSAT 04212H.02, "Drywell Sweep-out and Related Thermal-Hydraulic Conditions Inside Containment", Revision 0

Reference 3: PSAT 04202H.04, "Aerosol Decay Rates (Lambda) in Drywell", Revision 0

Reference 4: PSAT 04202U.03, "Dose Calculation Data Base For Application of the Revised DBA Source Term to the CEI Perry Nuclear Power Plant", Revision 0

Reference 5: Fuchs, N. A., "The Mechanics of Aerosols", Dovers Publications, Inc., New York, 1964

Reference 6: S.K. Friedlander, "Smoke, Dust and Haze - Fundamentals of Aerosol Behavior", John Wiley & Sons, New York, 1977

Reference 7: PSAT C101.02, "STARNAUA - A Code for Evaluating Severe Accident Aerosol Behavior in Nuclear Power Plant Containment: A Validation and Verification Report", Revision 1, February 1996

Reference 8: Fax from Spano (CEI) to Leaver (Polestar) dated 8/17/95 - Attachment 1 to this calculation.

Mathematical Modeling

Results

PSAT 04202H.08

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Rev 1

MEMORANDUM

G-26 REV. 11-64

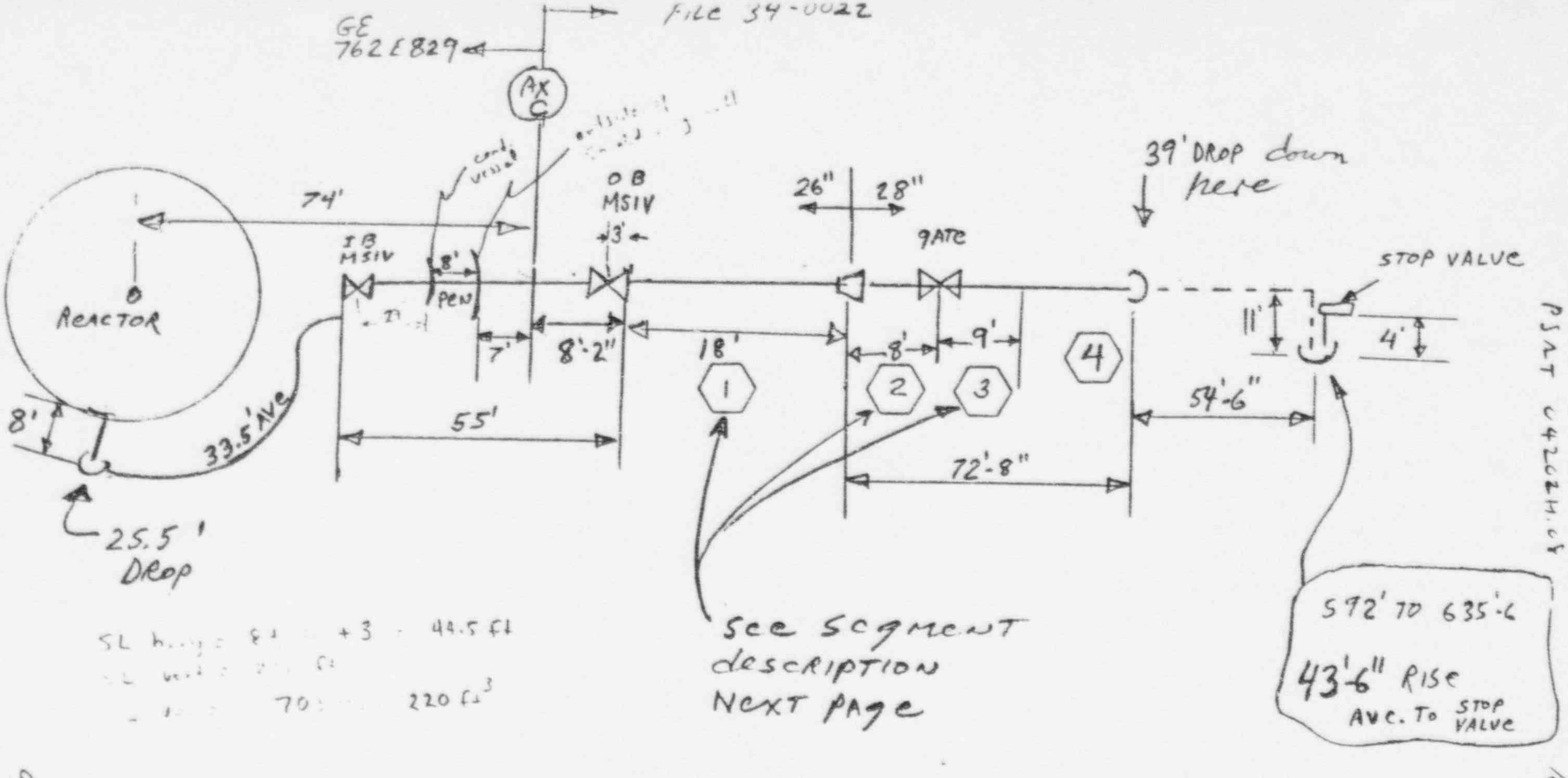
Attachment 1

TO	ROOM NO.	FROM	DATE	
D. Leaver [Polestar]		John Spano	8-17-95	
		SUBJECT	PHONE NO.	ROOM NO.
		Source Term ReEval for Perry Plant	x 5650	

This is some initial info I gathered related to the subject analysis. I will be sending more, per your 7-19-95 letter sect. 4. John

Attachment 1

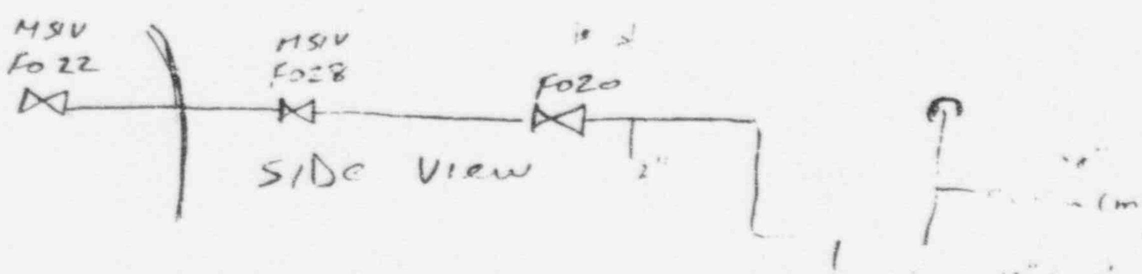
PSAT C4202H.08



MAIN STEAM LINE RUN TYPICAL OF (4) LINES

NOTE
≈48' of 28"Φ equalizer pipe Neglected

RUNS TO BYPASS VALVES Neglected



PSAT 04202H.08

Attachment 1

Page 3 of 3
Rev 1

OUTBOARD MSIV TO TURBINE STOP VALVE 242' RUN

SEGMENT	SIZE	RUN	ID	OD		LB/FT
1	26"	18'	23.36	26.00	1.32" min (ID ASSUMED)	349.1
2	28"	8'	24.53	28.00	1.74" min	
3	28"	9'	19	28.00	RUN includes ½ VALVE	657.7
4	28"	207'	24.53	28.00		487

PSAT 04202H.09

POLESTAR NON-PROPRIETARY

Rev: (0) 1 2 3 4

CALCULATION TITLE PAGE

CALCULATION NUMBER: PSAT 04202H.09

CALCULATION TITLE:

"Steam Line: Elemental Iodine Decontamination Calculation"

	ORIGINATOR	CHECKER	IND REVIEWER
	Print/Sign Date	Print/Sign Date	Print/Sign Date
REVISION: 0	David Leaver [signature] 3/28/96	James Metcalf [signature] 4/11/96	James Metcalf [signature] 4/11/96
1			
2			
3			
4			

REASON FOR REVISION:

	Nonconformance Rpt
0 - Initial Issue	N/A
1	
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3	
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Table of Contents

Purpose

The purpose of this calculation is to determine the elemental iodine released into the main steam lines and the ultimate decontamination factor (DF) of the iodine which deposits in the steam line. A fraction of the I_2 in the steam lines is assumed to resuspend as organic iodide and is then released to the environment. This calculation will estimate the fraction of I_2 which resuspends as organic and convert this resuspension fraction to an effective filter efficiency for I_2 entering the steam lines. The calculation will also consider the ultimate decontamination of iodine aerosol which deposits in the steam line.

Methodology

To determine the I_2 released into the steam lines, it will be assumed that the I_2 released from the damaged core, as specified in NUREG 1465 [1], is assumed to plate out on the aerosol suspended in the drywell atmosphere and is transported with the aerosol. Thus the I_2 leaks with the aerosol through the MSIVs and deposits on the steam line pipewall (with the aerosol).

In order to determine the effective filter efficiency of the I_2 entering the steam lines, a manual calculation will be performed which compares the resuspension rate of I_2 with the fixation rate in order to determine the fraction of deposited I_2 which resuspends over time. This resuspended fraction is then converted to a filter efficiency.

Assumptions

Assumption 1: The I_2 will tend to plate out on surfaces in the drywell.

Justification: Elemental iodine is a gas at containment temperatures and is reactive with many materials [2]. It is well documented that it will tend to deposit on surfaces by chemical adsorption [3]. Since the I_2 is released to the drywell where there are large surface areas of various types, a significant amount of the I_2 will plate out in the drywell.

Assumption 2: The resuspended I_2 in the steam line is converted to organic iodide.

Justification: According to Reference [3], resuspended I_2 can change its chemical form (conversion) to organic. For simplicity and conservatism, this conversion is assumed to be 100%.

References

1. L. Soffer et al, "Accident Source Terms for light-Water Reactor Nuclear Power Plants," NUREG 1465, February, 1995.

2. "Handbook of Chemistry and Physics," 73rd Edition, 1992-1993.

3. J. Cline, "MSIV Leakage Iodine Transport Analysis," Prepared for the U.S. Nuclear Regulatory Commission under contract NRC-03-87-029, Task Order 75, March 26, 1991.

4. N. A. Fuchs, "The Mechanics of Aerosols," Dover Publishing, 1964.

5. "Aerosol Decay Rate (Lambda) in Drywell," Polestar QA Record PSAT 04202H.04.

6. "Dose Calculation Data Base for Application of the Revised DBA Source Term to the CEI Perry Nuclear Power Plant, " Polestar QA Record PSAT 04202U.03.

7. "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," U.S. NRC, NUREG 0800, Section 6.5.2, Revision 0.

8. "Steam Line: Particulate Decontamination Calculation," Polestar QA Record PSAT 04202H.08.

Calculation

<u>Calculation of Plateout Area of Aerosol vs. Plateout Area of Drywell Shell, Equipment, and Structural Surfaces</u>

Per the Assumption 1., the I_2 will tend to plate out on surfaces. This calculation is to determine the relative magnitude areas of potential plate out surfaces in the drywell.

The aerosol particle surface area is estimated as follows. From Reference [4], the mass fraction for aerosols of radius r is expressed by

$$f(r)dr = \frac{1}{\ln\sigma \cdot \sqrt{2\pi}} \exp\left\{ -\frac{\left[\ln r - (\ln r_g + 3\ln^2\sigma)\right]^2}{2\ln^2\sigma} \right\} d\ln r$$

$$= \theta(r) d\ln r$$

The subtotal of the mass for aerosols of radius r to r + dr is

$$\Delta m = Mf(r)dr = \frac{M}{\ln\sigma\sqrt{2\pi}} \exp\left\{ -\frac{\left[\ln r - (\ln r_g + 3\ln^2\sigma)\right]^2}{2\ln^2\sigma} \right\} d\ln r$$

$$= M\theta(r) d\ln r$$

where the total mass of aerosols is M.

The subtotal of the volume is

$$\Delta v = \frac{\Delta m}{\rho}$$

where the volume per particle is

$$v = \frac{4}{3}\pi r^3$$

Thus the number of particles in r to r + dr is

$$N(r) = \frac{\Delta v}{v}$$

where the surface area per particle is

$$A = 4\pi r^2$$

The subtotal of surface area for aerosols in r to r + dr is

$$S = N(r).A \; = \; \frac{\Delta v}{v} 4\pi r^2 \; = \; \frac{\Delta v}{\frac{4}{3}\pi r^3} 4\pi r^2 \; = \; \frac{3\Delta v}{r}$$

$$= \frac{3\Delta m}{\rho r} = \frac{3M}{\rho r}\theta(r) d\ln r = \frac{3M\theta(r)}{\rho r^2} dr$$

Using a total aerosol mass of 27.1 kg and a particle density ρ of 3770 kg/m^3, the total surface area of the aerosol is

$$\int_o^\infty \frac{3M\theta(r)}{\rho r^2} dr = 4.01\text{E}4 \text{ m}^2 \text{ for } r_g = 0.22 \text{ µm and } \sigma = 1.81.$$

These values of aerosol mass, density, and size distribution are taken from Reference [5] for the conditions existing at the start of the fuel release. This is very conservative (i.e., lower than actually would be expected) with regard to aerosol mass and surface area since the peak aerosol suspended mass will be much larger after fuel release begins.

The drywell shell, equipment, and structural surface area is estimated by summing the following: (1) calculating the horizontal surface area of the drywell shell (A_h), (2) using a multiplicative factor based on a calculation by CEI to account for additional horizontal surface area (m), (3) calculating the vertical surface area of the drywell shell (A_v), (4) applying the same multiplicative factor to the vertical surface area, and (5) calculating the downward facing surface area of the drywell shell (A_d).

Using dimensional information from Reference [6], Item 7.1, A_h can be calculated as follows:

$$A_h = (\pi)(36.5)^2 = 4186 \text{ ft}^2$$

The total horizontal surface area for sedimentation from Reference [6], Item 7.1, is 8712 ft^2. Thus the multiplicative factor is

$$m = 8712/4186 = 2.08$$

A_v can be calculated as follows:

$$A_v = A_1 + A_2$$

where A_1 is the sidewall area of the cylinder (based on a height of 76.5 feet per Reference [6]), and A_2 is the sidewall area of the upper drywell head (based on a height of 16.5 feet and a radius of 16 feet per Reference [6]). From Reference [6],

$$A_1 = (73\pi)(76.5) = 17544\,ft^2$$

and

$$A_2 = (32\pi)(16.5) = 1659\,ft^2$$

Thus,

$$A_v = A_1 + A_2 \approx 19200\ ft^2$$

The downward facing area A_d can be calculated from Reference [6] as

$$A_d = \pi(16)^2 = 804\,ft^2$$

Thus, the total plateout area of drywell surfaces including equipment and structures is

$$A_{tot} = (A_h + A_v)(m) + A_d$$

$$= (4186 + 19200) \times 2.08 + 804$$

Thus,

$$A_{tot} = 49447\ ft^2 \times 0.0929\ m^2/ft^2 = 4594\ m^2$$

The minimum aerosol surface area during fuel release is 40100/4594 = ~9 times that of the drywell surfaces. This would tend to make the I_2 plate out on the aerosol.

A second consideration with regard to I_2 plateout on aerosol is the fact that the aerosol gradually is removed from the drywell and thus its effective plate out area decreases with time. However, the I_2 plateout rate constant from Reference [7] (= 5m/hr x Area/Volume where the Area/Volume is ~0.6) is significantly larger than the sedimentation rate constant of the aerosol (0.6 hr^{-1} maximum from Reference [5]). While the aerosol sweepout rate constant is somewhat larger, sweepout will remove both aerosol and I_2. Thus the I_2 will tend to plateout much faster than the aerosol is removed from the drywell even if plateout were only on structures. In

fact, using the Reference [7] expression for plateout of elemental iodine gas on surfaces,

$$\text{lambda} = (5\ \text{m/hr}) \times \text{Area/Volume},$$

for a BWR drywell, the lambda could be 1-2 per hour or even higher depending upon the fraction of surface area that is wetted.

As calculated above, the total surface area of the aerosol particles is an order of magnitude larger than the total surface area of structures and equipment in the drywell. Therefore, one would expect aerosol plateout to dominate. Further, it is conservative to assume that the I_2 plates out on the aerosol rather than the drywell surfaces since the aerosol leaks to the steam line and the I_2 can subsequently be released to the environment. I_2 plated out on drywell surfaces will tend to remain in the drywell. Thus it will be assumed that the I_2 plates out on the aerosol and subsequently leaks with the aerosol to the steam lines on the basis that the aerosol particle area dominates and the fact that this assumption is conservative from the standpoint I_2 release to the environment.

Fraction of I_2 Resuspended from Steam Lines

Based on Reference [8], essentially all of the aerosol which leaks through the MSIVs and into the steam lines will deposit on the pipewalls. Thus the I_2 attached to this aerosol will also be deposited, and some fraction of this I_2 will resuspend. This fraction is estimated by comparing the rate constant for fixation with the rate constant for resuspension.

From Reference [3], the resuspension rate of I_2 (assumed to be resuspended as 100% organic per Assumption 2) as well as the fixation rate of I_2 varies with temperature of the steam line wall. Also from Reference [3], main steam line temperature varies from about 565 K to 400 K over the first few days after shutdown (see Exhibit 1). From Exhibit 1, it may also be seen that the average fixation rate over the first 3 days (260,000 seconds) is about 1E-5 sec^{-1}, and the average resuspension rate is about 8E-6 sec^{-1}. Thus the fraction which resuspends is something less than half of the total deposited. For conservatism, it is assumed that half of the I_2 resuspends. This resuspension will occur over a period of several days (i.e., about 90% of the resuspension occurs in the first 72 hours).

Results

Transporting the elemental iodine with the aerosol leaking into the steam line is consistent with the relative plateout areas in the drywell and is conservative from the standpoint of eventual I_2 release.

Treating the resuspension of the I_2 form the deposited aerosol in the steam line as a filtering process is conservative since the actual resuspension occurs over a several day period, whereas the filtering process assumes that the release is instantaneous at the time of deposition on the steam lines. The effective filter efficiency on the I_2 entering the steam lines is conservatively taken as 0.5. The unfiltered I_2 is then assumed to be released as organic iodide per Assumption 2.

Conclusions

It is concluded that treating the elemental iodine as aerosol up to the point that it is deposited in the steam lines is reasonable (and conservative since plating the I_2 out in the drywell will release less I_2 to the environment), and that the elemental iodine entering the steam lines may be conservatively modeled with an effective filter efficiency of 50%. Essentially none of the deposited aerosol is released from the stream lines.

Exhibit 1
(Taken from Reference [3])

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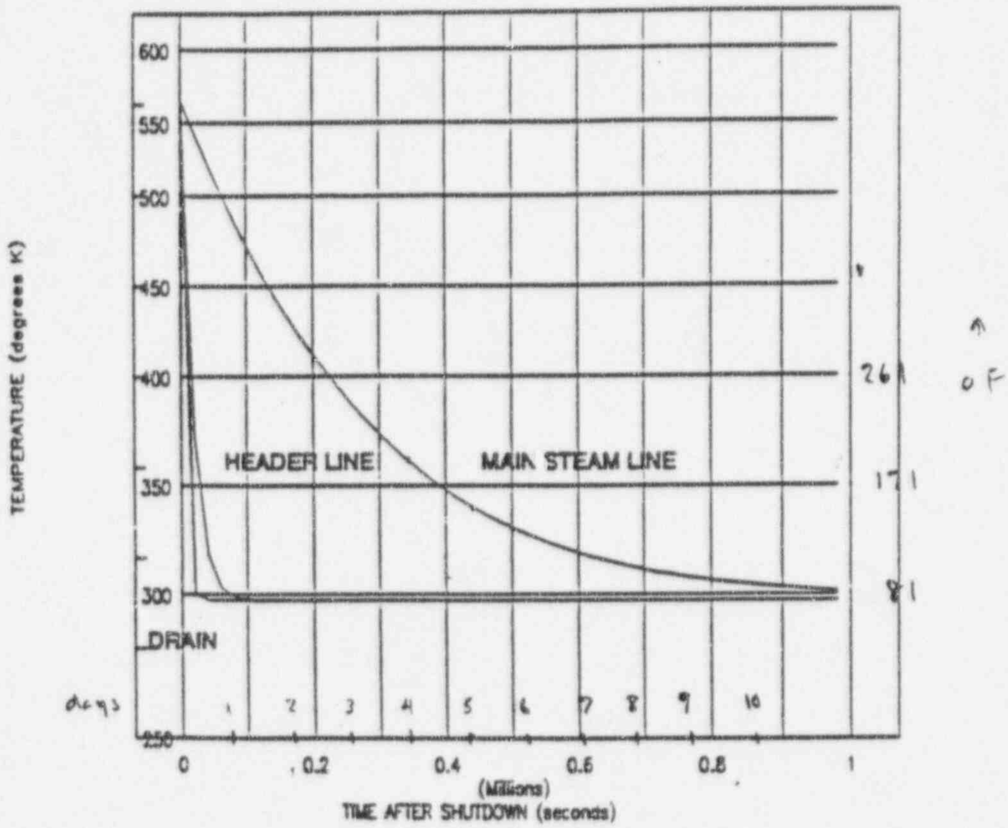
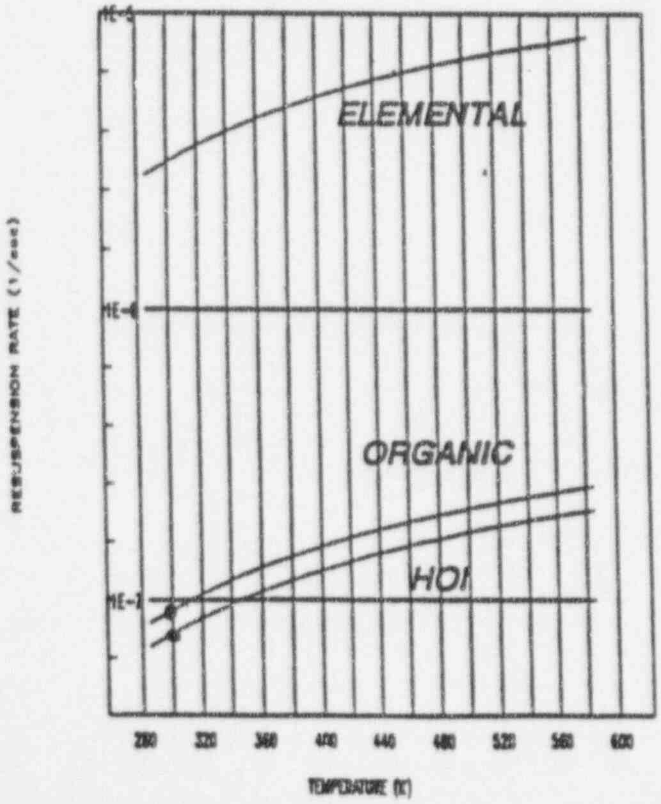
Rev 0

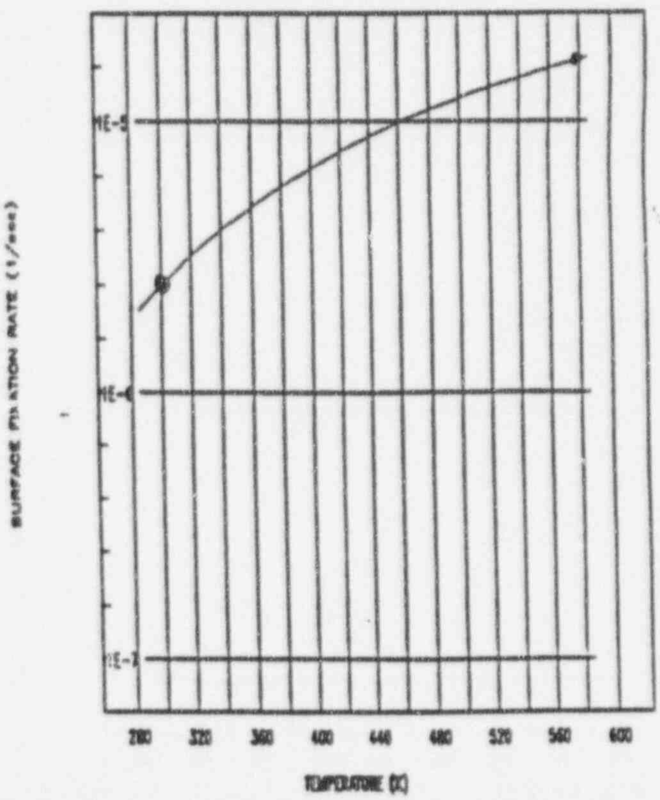
TEMPERATURES OF THE MSIV LEAKAGE LINES



RESUSPENSION RATE



SURFACE FIXATION RATE



DL 4/24/96

CALCULATION TITLE PAGE

CALCULATION NUMBER: PSAT 04202H.11

CALCULATION TITLE:

"Perry Containment Water Pool pH"

	ORIGINATOR Print/Sign Date	CHECKER Print/Sign Date	IND REVIEWER Print/Sign Date
REVISION: 0	Richard Hobbins RR Hobbins 04/19/96	D.E. Leaver 4/24/96 DE Leaver	D. E. Leaver 4/24/96 DE Leaver
1			
2			
3			
4			

REASON FOR REVISION:	Nonconformance Rpt
0 - Initial Issue	N/A
1	
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Purpose

The purpose of this calculation is to determine the pH of the Perry containment water pool as a function of time following a severe accident out to 30 days.

Methodology

- Calculate the [OH-] or [H+] concentration in the water pool as a function of time after reactor scram using the Radiolysis of Water model of the STARpH 1.02 code [1].
- Calculate the [HCl] concentration in the water pool as a function of time using the Radiolysis of Cable model of the STARpH 1.02 code [1].
- Manually calculate the [H+] concentration added to the pool as a function of time from the results of the two previous calculations.
- Calculate the pH of the water pool considering the sodium pentaborate concentration in the pool and [H+] additions as a function of time using the Add Acid model of the STARpH 1.02 code [1].

Assumptions

1. Reactor power = 3758 MWt
2. Containment water pool volume (including RCS) = 1.7E5 ft^3
3. Volume of drywell = 276,500 ft^3
4. Volume of wetwell/lower containment = 684,226 ft^3

5. Volume of upper containment = 481,174 ft^3
6. Containment water pool initial pH = 6.0
7. Cable insulation 2.9E4 lbm Hypalon
8. Cable insulation jacket thickness = 0.045 inch
9. Cable insulation outside diameter = 2.26 cm
10. Mass of sodium pentaborate available for injection is 5236 lbm
11. Chemical formula for sodium pentaborate is $Na_2O \bullet 5B_2O_3 \bullet 10H_2O$
12. The fission product inventory is 1.05 times the inventory in Item 1.3 of Ref. 2
13. Fraction of aerosol source term in water pool is 0.87
14. Density of Hypalon insulation jacket = 1.55 g/cm^3
15. Containment water pool is in equilibrium with CO_2 in the air in containment

The first 12 assumptions are from the Dose Calculation Data Base for Application of the Revised DBA Source Term to the CEI Perry Nuclear Power Plant [2]. Assumption No. 13 is from Ref. 3 and No. 14 is from the Ref. 4.

References

1. PSAT C107.02, STARpH Code Description and Validation and Verification Report, Revision 2, February 27, 1996.

2. PSAT 04202U.03, Dose Calculation Data Base for Application of the Revised DBA Source Term to the CEI Perry Nuclear Power Plant.

3. PSAT 04202H.12, Fraction of Containment Aerosol Deposited in Water.

4. J. Wing, Post-Accident Gas Generation from Radiolysis of Organic Materials, NUREG-1081, September 1984.

5. E. C. Beahm, R. A. Lorenz and C. F. Weber, Iodine Evolution and pH Control, NUREG/CR-5950, ORNL/TM-12242, December 1992.

Calculation

POLESTAR
PROPRIETARY

EXHIBIT 1

Sheet1 (3)

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[1]

POLESTAR
PROPRIETARY

EXHIBIT 2

Sheet1 (4)

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EXHIBIT 3

POLESTAR PROPRIETARY

Perry Add Acid QA

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Purpose

This analysis calculates the fraction of the total aerosols eventually released into the drywell that have either not yet been released (a factor prior to the end of the release period) or that will ultimately transport into water during a postulated severe reactor accident. This fraction includes the aerosols deposited in the water sump (or on the floor that is later flooded with water) in the drywell and the aerosols swept from the drywell atmosphere into the containment where spray removal is quite rapid.

Terminology

Released aerosols: Total aerosols released into the drywell from the damaged core up to the end of the release period.

Leaked aerosols: Aerosols leaked out of the drywell through the MSIV leakage path.

Swept aerosols: Aerosols swept from the drywell atmosphere into the containment due to the sweeping flow from the drywell to the wetwell.

Settled aerosols: Aerosols settled on all projected horizontal surfaces under gravity.

Diffused aerosols: Aerosols deposited on walls in the drywell.

Floor surface: Projected horizontal surface at the bottom of the drywell that is either initially covered by water or flooded early in the accident. It is also referred to as the water sump surface.

Non-floor surfaces: Projected horizontal surfaces in the drywell that are above the water sump. They are assumed to be dry most of the time during the accident.

Methodology

Aerosol behavior in the drywell has been studied in Reference 1. The suspended aerosol concentration, the total settled aerosol mass, the diffused aerosol mass and the sum of the swept and the leaked aerosol masses as functions of time were calculated and provided in Appendices C and D. These results, together with some geometry information and assumptions, will allow us to calculate the fraction of the released aerosols that are ultimately in water due to either sedimentation or pool scrubbing.

Assumptions

Assumption 1: Drywell is well-mixed during entire time period of the accident.

Justification: Given the fact that steam, non-condensable gases (e.g., hydrogen) and fission product gases and aerosols are blowing into the drywell atmosphere, while significant heat and mass transfers are going on in the drywell, this assumption is reasonable.

Assumption 2: Aerosol sedimentation flux (e.g., grams per square centimeter per second) does not change from one deposition surface to another in the drywell.

Justification: Aerosol sedimentation flux to a surface is the product of the aerosol concentration at that surface and the terminal settling velocity of aerosol particles. In a well-mixed containment, the aerosol concentration and the terminal velocity are uniform everywhere, so the aerosol sedimentation flux is uniform, too.

Assumption 3: Floor surface of the drywell is covered by water from the beginning of the accident to the end.

Justification: Reflooding of the core has to occur in order to prevent vessel failure in the design base accident. So, the drywell floor is expected to be all covered by water most of the time during the accident.

Assumption 4: Swept aerosols are assumed to be removed to water pool in the sprayed region of the containment.

Justification: No justification is needed.

Reference

Reference 1: PSAT 04202H.04, "Aerosol Decay Rates (Lambda) in Drywell", Revision 0

Reference 2: PSAT 04202U.03, "Dose Calculation Data Base for Application of the Revised DBA Source Term to the CEI Perry Nuclear Power Plant", Revision 0

Calculation

Results

POLESTAR
NON-PROPRIETARY

CALCULATION TITLE PAGE

CALCULATION NUMBER: PSAT 04202H.13

CALCULATION TITLE:

"Offsite and Control Room Dose Calculation"

	ORIGINATOR Print/Sign Date	CHECKER Print/Sign Date	IND REVIEWER Print/Sign Date
REVISION: 0	Jun Li 4/25/96 [signature]	D.E. Leaver [signature] 4/25/96	D.E. Leaver [signature] 4/25/96
1	Jun Li 6/14/96 [signature]	D.E. Leaver [signature] 6/14/96	D.E. Leaver [signature] 6/14/96
2			
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REASON FOR REVISION:

	Nonconformance Rpt
0 - Initial Issue	N/A
1 - To incorporate revision to PSAT 04202H.08 calculation, and CEI's requests (1) to increase containment bypass and ESF leakages and (2) to decrease efficiency of charcoal filter in control room recirculation system.	N/A
2	
3	
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Purpose

The purpose of this calculation is to evaluate the doses for the Perry Nuclear Plant design basis accident (DBA) using the revised accident source term based on NUREG 1465 (Reference [1]) release parameters and on associated fission product removal phenomena.

The dose evaluations are based on results generated in the Perry Plant PSAT calculation series prepared by Polestar Applied Technology, Inc. Key results from these calculations, as well as the Perry Plant design inputs, are contained in reference [2].

Methodology

The dose evaluations were performed using the LOCADOSE code developed by Bechtel Corporation [3]. LOCADOSE was transmitted to Polestar for use on the Perry Plant revised source term application by reference [4].

LOCADOSE is a computer code for multi-region radioactive transport and dose calculation for DBA evaluations. The LOCADOSE Program structure is illustrated in Exhibit 1. The LOCADOSE transport and dose calculation consists of three computer programs.

The Activity Transport Program calculates activities, integrated activities, and releases over a time period using a multi-region model that can accommodate up to nine regions and unlimited time steps. Daughter isotope activities, spray removal, and LOCA during purge options can be performed by this program. Activities, integrated activities, and releases are saved on a file for use by other programs, including the Dose Calculation and Filter Loading Programs, and printed as output as requested.

The Dose Calculation Program uses the file generated by the Activity Transport Program, the isotope library file and a user generated data file to calculate dose rates and doses. Doses and dose rates can be obtained for all the regions used by the Activity Transport Program and for up to 20 offsite locations.

The Filter Loading Program uses the file generated by the Activity Transport Program, the isotope library file and data supplied by the user interactively to calculate mass and heat loadings on charcoal filters. This program can handle up to a maximum of 50 time steps.

In addition, the LOCADOSE CENTER program stores and manipulates data using a database file structure. This program generates input data files and the isotope library files for the above programs.

Further details on LOCADOSE are contained in reference [3] and related documentation.

Assumptions

Assumption 1: The doses to be evaluated are the 10 CFR 100 exclusion area boundary and low population zone whole body and thyroid doses, and the 10 CFR 50, Appendix A, General Design Criterion (GDC) 19 control room doses.

Justification: These are the regulatory requirements for DBA radiological consequence evaluations.

Assumption 2: The core damage which leads to the DBA source term of reference [1] is arrested by the restoration of core cooling at about two hours after the start of the accident.

Justification: This is an extension to operating plants of a position presented by NRC in reference [5] for ALWRs and is discussed fully in reference [6].

Assumption 3: The source terms of Reference [1] can be applied to Perry without regard for fuel burn-up limitations.

Justification: Since the reference [1] source term is specified in terms of fractions of core inventory and since core inventories are calculated for this application to Perry using an appropriate burn-up, the Section 3.6 statement is not related to core inventory. As noted in reference [1], the focus of the statement is the gap activity release, and because of the nature of this application to Perry, the results would not be greatly sensitive to the exact gap release timing or magnitude in any case.

Assumption 4: The MSIV leakage control system (LCS) is not credited in the revised source term evaluations and the main steam line leakage is assumed to be attenuated in the main steam line from the reactor vessel out to the outboard MSIV or to the third isolation valve, depending upon the break location and the single failure assumption.

Justification: Not crediting the MSIV LCS is consistent with the approach taken by several BWRs which have applied for, and received NRC approval of, this change as part of the BWR Owners Group methodology. Crediting main steam line leakage attenuation for the main steam line out to the third isolation valve is based on the fact that for the Perry Plant, the main steam lines are seismically qualified out to and including the third isolation valves. While the BWR Owners Group methodology involves qualifying the main steam lines out to and including the drain line and main condenser, the existence of a qualified third isolation valve downstream of the outboard MSIV, together with the characteristics of the revised source term (i.e., predominantly aerosol which is largely retained in the steam lines) creates the option of using only the main steam line itself for leakage attenuation.

Assumption 5: The results of these analyses are sufficiently conservative to constitute a basis for demonstrating compliance with the requirements of 10CFR100 and with 10CFR50, Appendix A, GDC 19.

Justification: The source terms of reference [1] are comparable in conservatism to the DBA source terms previously used on Perry as based on 10CFR100 (and reference [7]) and subsequent regulatory guidance. The noble gas and iodine release fractions (which are the main determinants of the whole body and thyroid dose evaluations specified in 10CFR100) are about the same. The reference [1] timing and chemical form, while different from the previous source terms, are nonetheless conservative compared to what is expected under actual accident conditions, (e.g., the 1979 accident at Three Mile Island) and provide a more physically correct representation of activity release to containment. Moreover, in terms of activity transport within and through the containment system and release to environment, there are many other conservatisms included in the PSAT calculation series. These are as follows:

Conservatism 1 - Early Gap Release Start Time: In general, the PWR gap release is expected to occur much more rapidly than the BWR gap release (refer to discussion in reference [1]). However, this application has used a gap release start time of 30 seconds (appropriate for a PWR) to represent the Perry BWR. See reference [8].

Conservatism 2 - Underestimated Volumetric Flow from Drywell During Core Damage and Debris Quench: Only gamma energy is considered in calculating the core power used to determine vent flow from the drywell to the containment during core degradation and the associated debris quench. Core debris sensible heat during the core degradation (and the formation of debris bed that would enhance heat transfer to the overlaying water), metal-water reactions, and beta heating are neglected. Noncondensible gas is also neglected. See reference [6].

Conservatism 3 - Neglected Pool Scrubbing: All of the leakage flow from the drywell is assumed to enter directly into the containment via the pool bypass area, totally neglecting pool scrubbing.

Conservatism 4 - Neglected Natural Aerosol Removal in Unsprayed Region: Natural aerosol removal in the unsprayed region of containment is neglected. Thus the only way aerosol is removed from the unsprayed region is by mixing with the sprayed region and subsequent removal by the sprays.

Conservatism 5 - Underestimated Containment Spray Effectiveness: The spray effectiveness has been conservatively underestimated in two ways. First, the mixing rate between the sprayed and unsprayed regions (which determines the rate at which unsprayed region aerosol is removed) has been underestimated since the only mixing mechanism considered was density difference due to temperature difference between the sprayed and unsprayed regions. Other mixing mechanisms which would be effective include momentum transfer of the spray droplets to the unsprayed region, heat transfer from equipment in the unsprayed region, and flow from the unsprayed region due to steam condensation in the sprayed region. Second, the size distribution of the aerosol entrained in flow from the drywell to containment has been underestimated. A larger size distribution would result in faster aerosol removal in the sprayed region.

Conservatism 6 - Most Conservative Break Location: A break location immediately upstream of the inboard MSIV in the main steam line is the most conservative. This is because a main steam line break results in maximum drywell pressure (and thus minimum volumetric flow from the drywell to the containment), and because a break immediately upstream of the inboard MSIV results in the steam line section between the reactor vessel and the inboard MSIV not being credited for aerosol retention.

Conservatism 7 - Most Conservative Distribution of Total Main Steam Line Leakage: The worst case distribution of the 250 scfh total steam line leakage is to concentrate the leakage into three lines with the broken line and one other line at the 100 scfh per line maximum, and a third line at 50 scfh.

Conservatism 8 - Most Conservative Main Steam Line Valve Single Failure: There are three single failure possibilities:

(1) Failure of a single inboard MSIV to close

(2) Failure of a single outboard MSIV to close

(3) Failure of one or more third isolation valves (MOV 20 valves) to close

As discussed in detail in reference [10], the last of these single failures (i.e., all four third isolation valves failing to close since all

four depend on a common power supply) is the worst case and thus is the most conservative.

Conservatism 9 - Underestimated Natural Aerosol Removal in Main Steam Lines: The steam line aerosol deposition is conservatively modeled from a number of standpoints: (1) the aerosol agglomeration which will occur as the aerosol is transported down the steam line has been neglected which will result in steam line removal being underestimated, (2) aerosol removal mechanisms other than sedimentation have been neglected, (3) for the most conservative steam line valve single failure (i.e., all four third isolation valves fail open) no aerosol removal is credited downstream of the outboard MSIV even though it is expected that removal will occur up to the point of the failed open third isolation valve, (4) no credit is taken for aerosol removal at the location of the pressure drop between the drywell and the steam lines (i.e., the MSIV leak path) even though the constricting streamlines will result in inertial impaction and probably even plugging, (5) the cold gas stratification which will exist in the main steam piping upstream of the inboard MSIV (due to the elevation drop of the piping as it exits the reactor vessel) and the resultant delay of the relatively hot fission product gas and aerosol release from the upper reactor vessel head out the MSIV has been neglected, and (6) the aerosol retention in steam line sections downstream of open isolation valves and the reactor vessel has been underestimated by assuming a well-mixed volume (vs. a plug flow which provides increased aerosol removal and is expected even in this situation).

Conservatism 10 - Underestimated Drywell Aerosol Natural Removal: The natural aerosol removal rate in the drywell is conservatively small due to use of a smaller sedimentation area than actually exists and neglecting hygroscopicity and natural aerosol removal mechanisms other than sedimentation.

Conservatism 11 - Instantaneous I_2 Release in Main Steam Lines: The conversion of deposited elemental iodine (in the steam line) to re-evolved organic iodine is assumed to be instantaneous as opposed to requiring several days. See reference [9].

References

1. L. Soffer et al, "Accident Source Terms for Light-Water Reactor Nuclear Power Plants," NUREG 1465, February, 1995.

2. PSAT 04202U.03, "Dose Calculation Data Base for Application of the Revised DBA Source Term to the Perry Nuclear Power Plant.", Rev 2.

3. LOCADOSE, NE319, "A Computer Code System for Multi-Region Radioactive Transport and Dose Calculation," User's Manual, Revision 4A, August, 1995.

4. Bechtel Letter to Polestar, dated September 25, 1995, Mercedes Dumlao to D. Leaver, forwarding LOCADOSE, Bechtel ID Number 00126D.

5. Taylor, J., "Proposed Issuance of Final NUREG-1465, "Accident Source Terms for Light-Water Nuclear Power Plants", SECY-94-300, December 15, 1994.

6. PSAT 04212H.02, "Drywell Sweep-Out Rate and Related Thermal-Hydraulic Conditions Inside Containment.", Rev 0.

7. DiNunno, L.L., et al., "Calculation of Distance Factors for Power and Test Reactor Sites", TID-14844, March 1962.

8. PSAT 04212H.01, "Source Term for Use on Perry Application of NUREG 1465.", Rev 0.

9. PSAT 04202H.09, "Steam Line: Elemental Iodine Decontamination Calculation.", Rev 0.

10. PSAT 04202H.08, "Steamline: Particulate Decontamination Calculation.", Rev 1.

11. Perry QA Record No. 3.2.6.5, "Revised Post LOCA Offsite and Control Room Doses," 1993.

Calculation

<u>Perry Plant Revised DBA Source Term Dose Model</u>

The LOCADOSE code was used in the Perry revised DBA source term dose calculations as described in the Methodology section above.

Exhibit 2 describes the dose model which was used. The main changes from the existing licensing basis dose model are:

- Elimination of the MSIV leakage control system
- MSIV leak rate increased to 250 scfh total, 100 scfh maximum per line
- Removal of airborne fission products from the drywell
- Containment spray duration increased to 24 hours
- Retention of fission product leakage in the steam line volume between the reactor vessel and the third isolation valve, or the outboard MSIV, depending upon the configuration (with no holdup credit for the main condenser)
- No credit for charcoal filtration in annulus exhaust gas treatment system
- A 30 minute delay in actuation of control room recirculation mode
- ESF leakage increased by 50%
- Control room recirculation mode charcoal filter efficiency for elemental and organic iodine decreased to 50%
- Containment bypass leakage increased by 50%
- Control of pH so as to support use of mainly particulate iodine form

Plant Configurations Considered

In order to assure that the most limiting (i.e., conservative) dose was evaluated, it was necessary to determine the worst case single failure, break location, and MSIV leakage distribution. Reference [10] discusses these worst cases in detail. Exhibits 3 and 4 describe the two configurations for which dose calculations are to be performed. Configuration (1) is for an inboard MSIV failed open. Configuration (2) is for all four third isolation valves failed open. The worst case break location is immediately upstream of the inboard MSIV. Worst case leakage distribution is to assume 100 scfh in the broken line, 100 scfh in one intact line, and 50 scfh in another intact line (with one intact line at zero scfh).

It should be noted that it would be possible to neglect further consideration of configuration (1) by inspection were it not for the fact that the third isolation valves are delayed in closing by 20 minutes. This can be seen by comparing configuration (1) with configuration (2). Configuration (1), in which the third isolation valves are closed, credits retention in the entire steam line out to the third valve. Configuration (2) on the

other hand, credits retention only out to the outboard MSIV and thus would be expected to have higher release than configuration (1), everything else being equal. However, it is necessary to perform a dose calculation to be certain that the 20 minute delay in closing the four third isolation valves does not significantly impact the release for configuration (1).

Thus, a total of two LOCADOSE calculations were performed, one for configuration (1), and one for configuration (2).

Description of the LOCADOSE Input Files

1. The first LOCADOSE input file is a library file generated by LOCADOSE CENTER (see LIBRARY on Exhibit 1 and see Appendix A) that contains information about isotopes considered in the dose calculation. In this file the list of isotopes, the corresponding dose conversion factors, and the core inventories are specified in Item 1.2 of reference [2].

To confirm that the list of isotopes specified in reference [2] accurately represents the whole body, thyroid, and beta skin dose resulting from a more complete list of fission products including those in the eight major groups of reference [1], an additional calculation was performed using configuration (2) with the isotopes from reference [2] plus the isotopes in Table 1.

Table 1. Addition Isotopes Considered in Confirmation Dose Calculation

Group title	Elements in Group	Release fraction*	
		Gap	In-vessel
Alkali Metals	RB-87, RB-88, RB-89, CS-135, CS-138	0.05	0.20
Barium, strontium	BA-140, SR-89	0.0	0.02
Noble Metals	MO-99, RU-103, RU-105, RU-106, TC-99M, TC-99, RH103M, RH-105, RH-106	0.0	0.0025
Lanthanides	LA-140 NB-95 ZR-95 NB-95M	0.0	0.0002
Cerium group	NP-239 PU-239	0.0	0.0005

*Fraction of initial core inventory

The confirmation calculation results show that the difference between the two cases with and without the additional isotopes is 1 to 2% maximum. The complete input and output files for the confirmation calculation are stored on a diskette as part of Appendix D.

The core inventories for all isotopes in this library file are specified as coefficients in the units of curies per mega-watt thermal power. The total core inventories for the various isotopes in the library file are obtained by multiplying these coefficients by the total thermal power (i.e., 3758 mega-watt as specified in Item 1.1 of reference [2]). However, the values for the coefficients provided by the LIBRARY do not yield the same total core inventories as that specified in reference [2]. Thus, the LIBRARY coefficients were replaced by calculated values which are based on the following expression:

Coefficient = total core inventory in Item 1.2 of reference [2]/ 3758 Mwt

2. There are a total of two input files prepared to provide necessary information to calculate fission product transport for the two configurations discussed above. These files are listed in Appendix B and are the input to the LOCATRAN program. As an example, the following is a detailed description of the Perry plant-specific portions of one such input file for Configuration (2).

```
PERRY DOSE CALC. W/ REVISED SOURCE TERM, CFG 2, 24 HR SPRAY        Problem title
JUN LI                                                                Originator
PERRY DOSE CALC.                                                    Project name
PSAT 04202H                                                            Project #
04202H.13  0                                                         Calc #, Rev
1                                                          First page # of output
```

The above specifies the header of the output file.

```
8 12 32 1 0 0                   # Nodes, # Time steps, # Iso, ICR, CALCDA, LSPRAY
```

The drywell, unsprayed region of the containment, sprayed region, annulus and suppression pool comprise 5 nodes in this calculation model. Three additional volumes

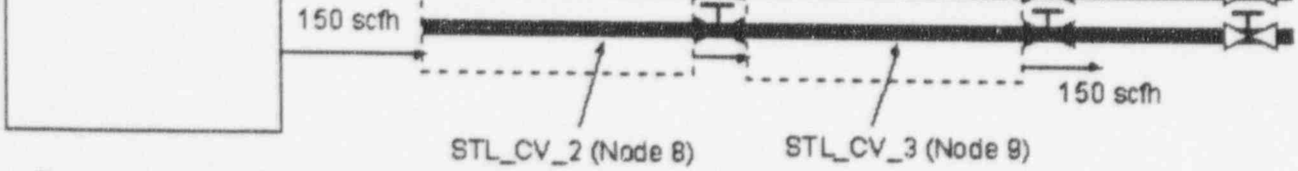


Figure 1. Model of Steam Lines in LOCADOSE Calculation for Configuration (2)

are considered for steamlines, which are labeled as STL_CV_1, STL_CV_2 and STL_CV_3. Figure 1 shows these three steamline volumes for configuration (2). The volumes are the same for configuration (1) between 0 to 20 minutes. After 20 minutes,

however, Nodes 7 and 9 are expanded to include the 29 foot section (≈ 86 ft^3) between the outboard MSIV and the third isolation valve, so the new volume for Node 9 = 292 ft^3 + 2 × 86 ft^3 = 464 ft^3, and that for Node 7 = 146 + 86 = 232 ft^3 This volume change has been considered in the Configuration (1) calculation. The control room is also included when ICR is set equal to 1. It should be noted that LOCADOSE limits the user specified number of nodes to eight when the control room is considered, which is why we have to combine the 2 intact steam lines into 1 for both Configurations (1) and (2). Number of time steps is only a dummy, and is not used in the calculation. Number of isotopes is 32 since each iodine isotope is considered as 3 for elemental, organic and particulate forms.

```
1 0 3758 0 2 0 0    ITID, IPURGE, Power, SD time, NPF, # Spr nodes, # Delay calcs
CFM  CUFT CURIES                          Flow unit, Volume unit, Activity unit
1 1 1 1 1 1 1 1 1 1 1 1                          Release frac for iso group 1-12
```

The release fractions (above) for all isotope groups are set to unity so that the actual release fractions to the drywell (see below) are based on the initial core inventories.

```
0.0485 0.0015 0.95                                 Elem, org, part iodine frac
DRYWELL  UNSPRAYED SPRAYED  ANNULUS SUP POOL STL_CV_1 STL_CV_2 STL_CV_3 Node name
8.333E-3 0.011111  1 0 0 1      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
```

The calculation block starts at 30 seconds and covers the 10 second time interval out to 40 seconds.

```
0 1 1                                                        LACTIN, LPTIN, LVOL
0.100000 0 0 0 0.6 0 0 0             Initial I-131 elem act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0             Initial I-131 orgn act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0             Initial I-131 part act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0             Initial I-132 elem act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0             Initial I-132 orgn act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0             Initial I-132 part act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0             Initial I-133 elem act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0             Initial I-133 orgn act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0             Initial I-133 part act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0             Initial I-134 elem act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0             Initial I-134 orgn act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0             Initial I-134 part act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0             Initial I-135 elem act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0             Initial I-135 orgn act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0             Initial I-135 part act frac in nodes 2-9
0.100000 0 0 0     0 0 0             Initial Kr-83m act frac in nodes 2-9
0.100000 0 0 0     0 0 0             Initial Kr-85  act frac in nodes 2-9
0.100000 0 0 0     0 0 0             Initial Kr-85m act frac in nodes 2-9
0.100000 0 0 0     0 0 0             Initial Kr-87  act frac in nodes 2-9
0.100000 0 0 0     0 0 0             Initial Kr-88  act frac in nodes 2-9
0.100000 0 0 0     0 0 0             Initial Kr-89  act frac in nodes 2-9
0.100000 0 0 0     0 0 0             Initial Xe-131m act frac in nodes 2-9
0.100000 0 0 0     0 0 0             Initial Xe-133m act frac in nodes 2-9
0.100000 0 0 0     0 0 0             Initial Xe-133  act frac in nodes 2-9
0.100000 0 0 0     0 0 0             Initial Xe-135m act frac in nodes 2-9
0.100000 0 0 0     0 0 0             Initial Xe-135 act frac in nodes 2-9
0.100000 0 0 0     0 0 0             Initial Xe-137 act frac in nodes 2-9
0.100000 0 0 0     0 0 0             Initial Xe-138 act frac in nodes 2-9
0.100000 0 0 0     0 0 0             Initial CS-134 act frac in nodes 2-9
0.100000 0 0 0     0 0 0             Initial CS-137 act frac in nodes 2-9
0 0 0 0 0          0 0 0             Initial TE-132 act frac in nodes 2-9
0 0 0 0 0          0 0 0             Initial BA137M act frac in nodes 2-9
```

The gap release to the drywell (Node 2) is specified above at 10% core inventory per hour. To model ESF leakage, iodine is assumed to be released into the suppression pool (Node 6) at 60% core inventory per hour. (For conservatism and simplicity, this release to the suppression pool was assumed to occur in this first time interval even though the fuel release does not begin until 30 minutes). Since these two release rates will be changed or terminated after 30 minutes, the release to the drywell will be 5% of the core inventory and that to the suppression pool will be 30% of the core inventory.

```
276500. 684226. 481174. 1.96E+5 146952. 146. 440. 292. Volumes for nodes 2-9
```

The volume of the suppression pool (Node 6) includes the volume of the upper pool dump (i.e., the sum of Items 3.4 and 3.5 of reference [2]), so it equals 146952 ft3. The volume of the STL_CV_1 (Node 7) is the volume in the broken line between the inboard and outboard MSIVs, which is about 146 ft^3 [10]. The volume of STL_CV_2 (Node 8) is for the combined spaces in both intact steamlines between the reactor vessel and the inboard MSIV (including the vertical portions of these lines), which is 440 ft^3 total (220 ft^3 each) [10]. The volume of STL_CV_3 (Node 9) is for the combined spaces in both intact steamlines between the inboard and outboard MSIVs, which is then twice the volume of STL_CV_1, i.e., 292 ft^3 [10].

```
2 7 0 1.987
0 0 0 0 0 0 0 0 0 0 0 0              From node, To node, Filt flow, Unfilt flow
2 8 0 2.98                                              Filt eff for iso groups 1-12
0 0 0 0 0 0 0 0 0 0 0 0              From node, To node, Filt flow,.Unfilt flow
8 9 4.775 0                                             Filt eff for iso groups 1-12
                                     From node, To node, Filt flow, Unfilt flow
50 0 74.6 0 74.6 74.6 74.6 74.6 74.6 74.6 74.6 74.6 Filt eff 4 iso grps 1-12
7 1 3.183 0
                                     From node, To node, Filt flow, Unfilt flow
50 0 71.0 0 71.0 71.0 71.0 71.0 71.0 71.0 71.0 71.0 Filt eff 4 iso grps 1-12
9 1 4.775 0
                                     From node, To node, Filt flow, Unfilt flow
50 0 74.0 0 74.0 74.0 74.0 74.0 74.0 74.0 74.0 74.0 Filt eff 4 iso grps 1-12
3 1 0 2.01
0 0 0 0 0 0 0 0 0 0 0 0              From node, To node, Filt flow, Unfilt flow
3 4 0 71400.                                            Filt eff for iso groups 1-12
0 0 0 0 0 0 0 0 0 0 0 0              From node, To node, Filt flow, Unfilt flow
3 5 0 1.0E-5                                            Filt eff for iso groups 1-12
0 0 0 0 0 0 0 0 0 0 0 0              From node, To node, Filt flow, Unfilt flow
4 1 0 1.005                                             Filt eff for iso groups 1-12
0 0 0 0 0 0 0 0 0 0 0 0              From node, To node, Filt flow, Unfilt flow
4 3 0 71400.                                            Filt eff for iso groups 1-12
0 0 0 0 0 0 0 0 0 0 0 0              From node, To node, Filt flow, Unfilt flow
4 5 0 1.0E-5                                            Filt eff for iso groups 1-12
0 0 0 0 0 0 0 0 0 0 0 0              From node, To node, Filt flow, Unfilt flow
5 1 2000. 0                                             Filt eff for iso groups 1-12
0 0 99 0 99 99 99 99 99 99 99 99     From node, To node, Filt flow, Unfilt flow
6 1 1.0E-05 0                        (Item 4.1)         Filt eff for iso groups 1-12
99 99 99 99 99 99 99 99 99 99 99 99  From node, To node, Filt flow, Unfilt flow
-1,0,0,0                                                Filt eff for iso groups 1-12
                                                                    End flow input
```

The flow rates between the nodes and from nodes to the environment (i.e., Node 1 by default) are specified. It should be noted that 1.0E-5 was used for zero flow rate to avoid a singularity in the calculation. Flow from Node 2 to Node 8, from Node 8 to Node 9 and from Node 9 to Node 1 represent the main steam line leakage from the drywell through two intact lines out to the environment (i.e., Node 1). The Node 2 to

Node 9 flow is just the 150 scfh converted for steam line temperature (i.e., 150 scfh × 1.91 = 286.5 cfh = 4.775 cfm) similar to the calculation in Appendix C of Reference [10]. Since the two intact steamlines are modeled one line, the combined aerosol removal efficiencies ($\overline{\eta}$) for Nodes 8 and 9 are determined by the following expression:

$$\overline{\eta} = \frac{\sum_i \text{Leakrate in steamline i} \times \eta_i}{\sum_i \text{Leakrate in steamline i}}$$

where η_i is the aerosol removal efficiency for the corresponding space in steamline i (which can be obtained from Tables 2.a and 2.b on pages 17 and 18 of Reference [10]) and the leakrate is either 100 scfh or 50 scfh. To demonstrate the calculation, the removal efficiency in Node 8 (which is modeled as the filtration efficiency between Nodes 8 and 9) is calculated as follows:

Since the input is for Configuration (2), the links between the steamline spaces and the removal efficiencies (labeled by Case numbers) are given in Tables 3.c and 3.d in Reference [10]. These two tables indicate that the aerosol removal efficiencies in the two volumes comprising Node 8 are given in Cases 2 and 4. From Table 2.b in Reference [10], we get:

Removal efficiency in 100 scfh steamline (Case 2) = 0.711
Removal efficiency in 50 scfh steamline (Case 4) = 0.815

Thus, the combined removal efficiency for Node 8 = (100 × 0.711+50 × 0.815)/150
= 0.746

Similarly, the combined removal efficiency for Node 9 (which is modeled as the filtration efficiency between Node 9 and the environment) is calculated to be 0.74. This is the way the aerosol removal efficiencies for the flow from Node 8 to Node 9 and that from Node 9 to Node 1 are calculated throughout the two dose calculations for Configurations (1) and (2).

```
1 2 0.084                                   Iso group, Node, Lambda
3 2 0.084                                   Iso group, Node, Lambda
5 2 0.084                                   Iso group, Node, Lambda
6 2 0.084                                   Iso group, Node, Lambda
7 2 0.084                                   Iso group, Node, Lambda
8 2 0.084                                   Iso group, Node, Lambda
9 2 0.084                                   Iso group, Node, Lambda
10 2 0.084                                  Iso group, Node, Lambda
11 2 0.084                                  Iso group, Node, Lambda
12 2 0.084                                  Iso group, Node, Lambda
-1,0,0,0                                             End lambda input
```

Removal lambdas are specified for each isotope group in the drywell (Node 2).

```
1 7.0E-5                                        LCHG, Control room X/Q
3.44E5 0 1375 2.7E4 1375      CR vol,Filt intake,Unfilt intake,Recirc,Outleak
```

```
0 0 0 0 0 0 0 0 0 0 0 0 0                  Intake filt eff for iso groups 1-12
0 0 0 0 0 0 0 0 0 0 0 0 0      (Item 4.2)  Recirc filt eff for iso groups 1-12
```

Control room parameters are specified.

```
0.011111 0.018333 1 0 0 1   From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                               LACTIN, LPTIN, LVOL
```

Input for the next time interval (40 seconds to 66 seconds) begins.

The input is repeated for each time interval until the end of the problem. In each interval, only those parameters that change from their previous values need be input.

3. The final input file is the input to LOCADOSE, which specifies the dose-related parameters. This file is listed as Appendix C.

Results

The results of the two dose calculations are given in Table 2. The detailed output of the calculations is given in Appendix D.

As is evident from Table 2, configuration (2) is limiting. This is not unexpected since the 20 minute delay in closing the third isolation valves for configuration (1) does not add significantly to the fission product release since only the gap source term exists in containment during this interval. The additional retention due to the 29 foot main steam line section downstream of the outboard MSIV, which is credited in configuration (1), more than compensates for the effect of the 20 minute delay.

It should be noted that LOCADOSE calculates the control room immersion dose, and the control room personnel dose due to external exposure of the control room (from direct gamma dose) has not been recalculated for the NUREG-1465 source term. The

Table 2 Dose Results (Rem)

Configuration	Nodes	Thyroid	Whole Body	Skin
Configuration (1)	CR	12.5	0.10*	4.68
Single Failure -	EAB	75.5	1.29	
Inboard MSIV	LPZ	93.9	1.60	
Configuration (2)	CR	16.2	0.11*	4.81
Single Failure -	EAB	157.9	1.88	
Four 3rd Isolation Valves	LPZ	130.3	1.73	

*Immersion dose only

It should be noted that LOCADOSE calculates the control room immersion dose, and the control room personnel dose due to external exposure of the control room (from direct gamma dose) has not been recalculated for the NUREG-1465 source term. The combined containment direct gamma and cloud direct gamma doses are reported in CEI Calculation No. 3.2.6.5 as 0.13 rem and 0.002 rem, respectively, over 30 days. It is possible that the direct dose could increase slightly using NUREG-1465 source term (due to the increased radiocesium in liquid in the long term), but it is expected there would be a substantial corresponding decrease in the secondary containment airborne dose contribution. Moreover, with application of the revised DBA source term the whole body dose contribution from sources within the control room has remained low (~0.12 rem) and therefore, there is no possibility that the 10CFR50, Appendix A, GDC-19 whole body dose acceptance value of 5 rem would be exceeded even in the unlikely event there were a small net increase in the contribution from external sources.

Conclusions

The main conclusions from the dose calculation are as follows:

- The failure of the four third isolation valves to close is the limiting single failure for the revised source term application to the Perry Plant.

- All doses for the limiting single failure meet regulatory limits with considerable margin (roughly a factor of 2 margin).

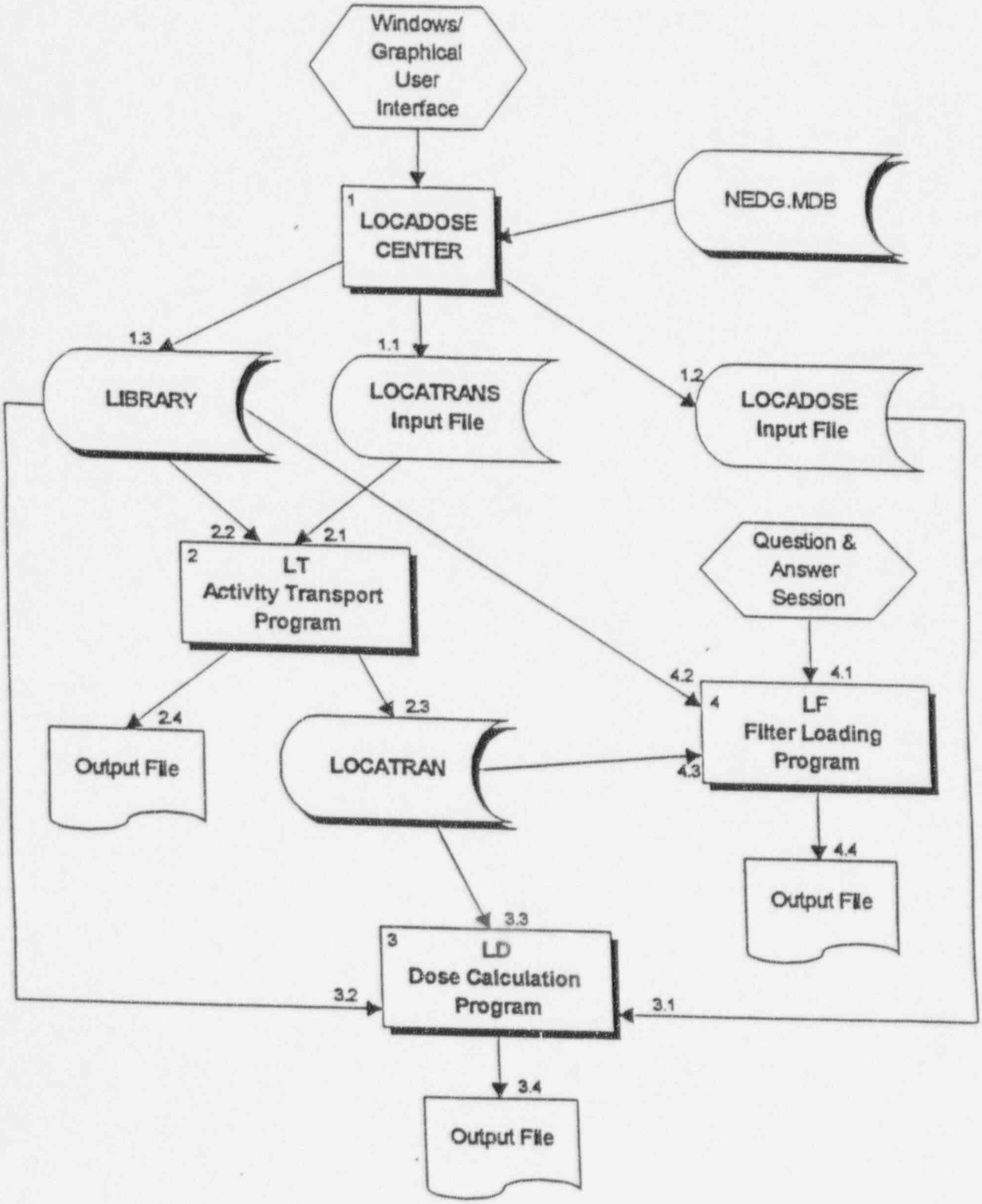
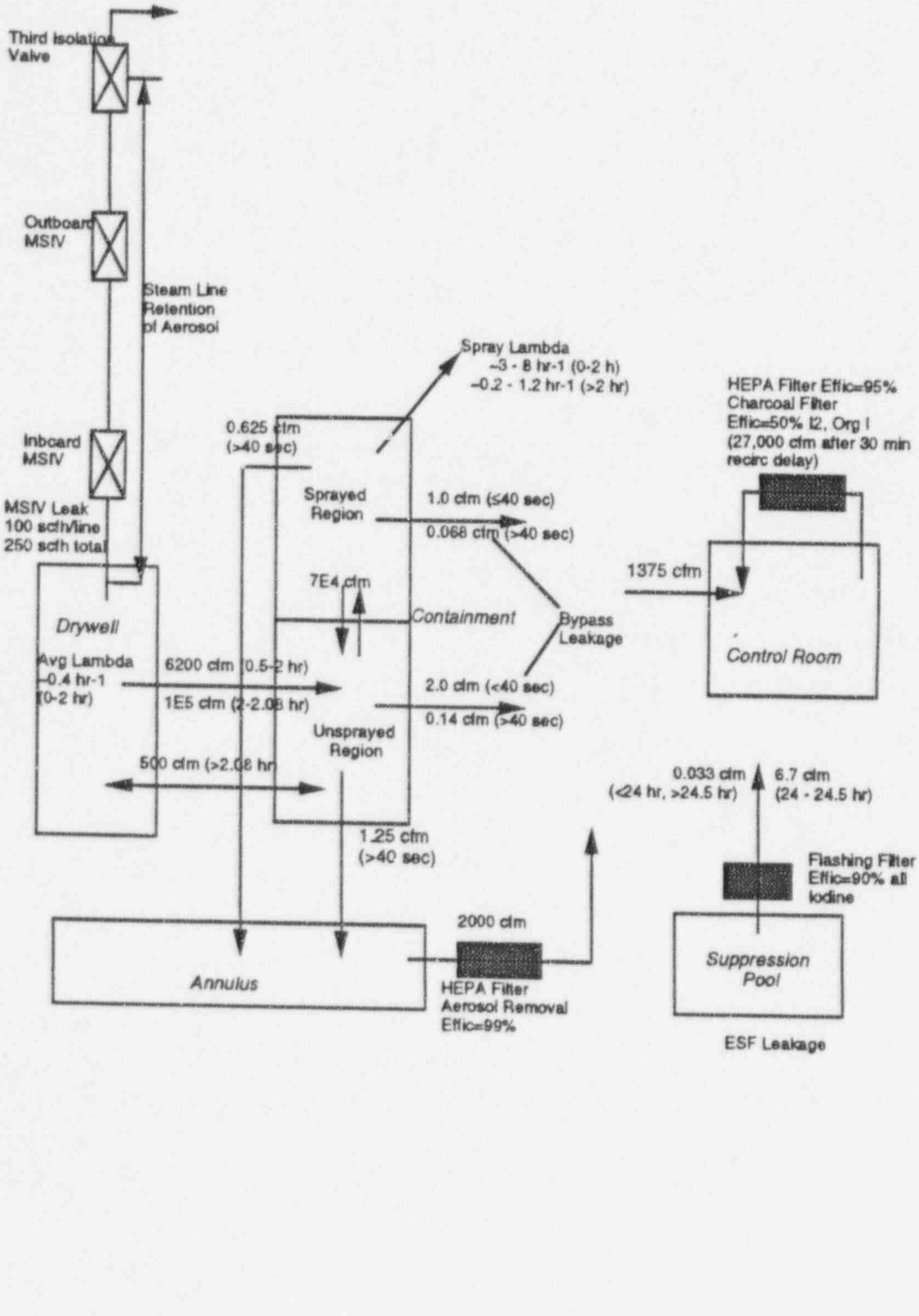


Exhibit 1

LOCADOSE Program Structure
(taken from Reference [3])

EXHIBIT 2
PERRY REVISED DBA SOURCE TERM DOSE MODEL



Main Steam Line Isolation Valve Configuration (1)

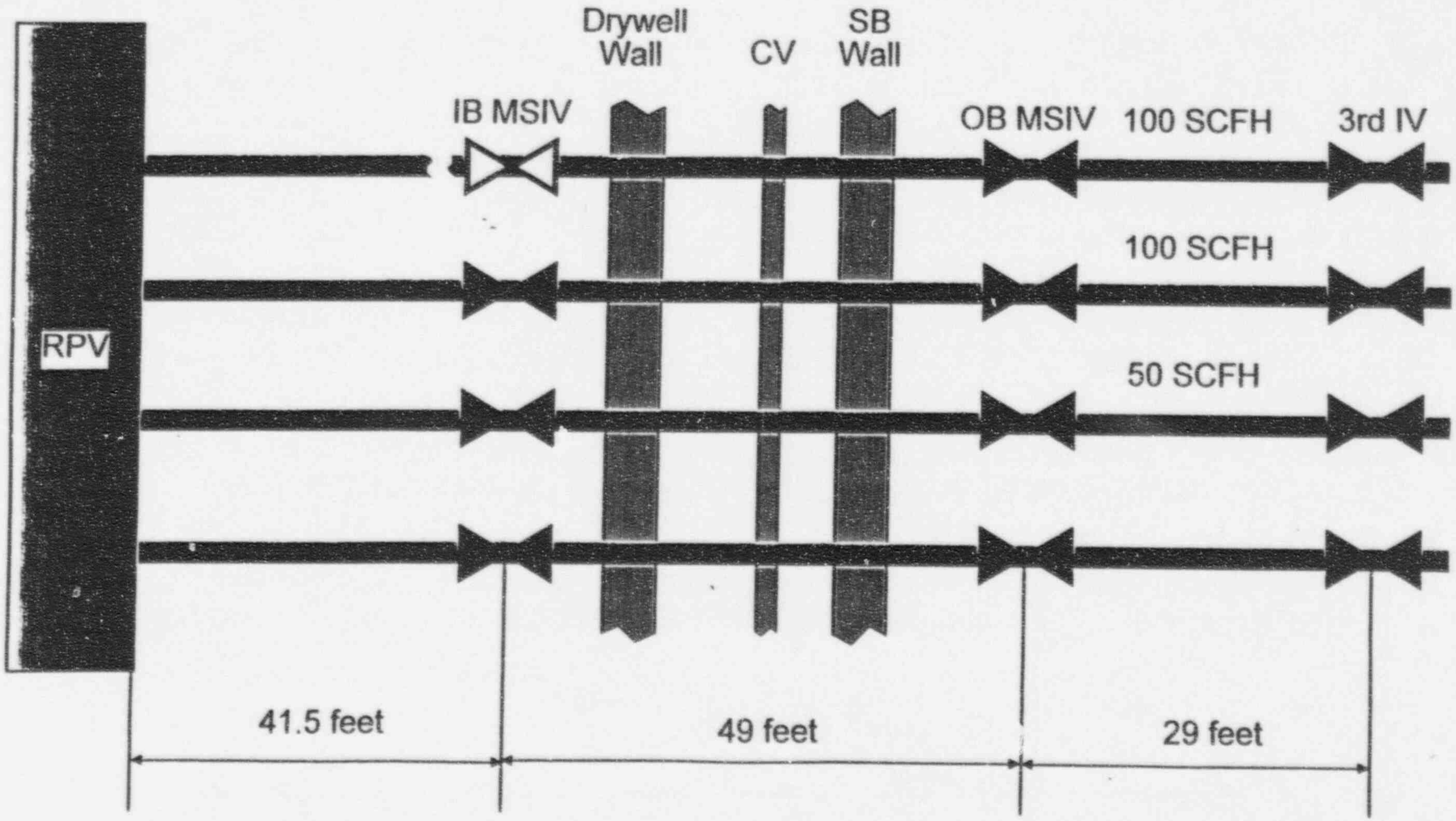


EXHIBIT 3

Main Steam Line Isolation Valve Configuration (2)

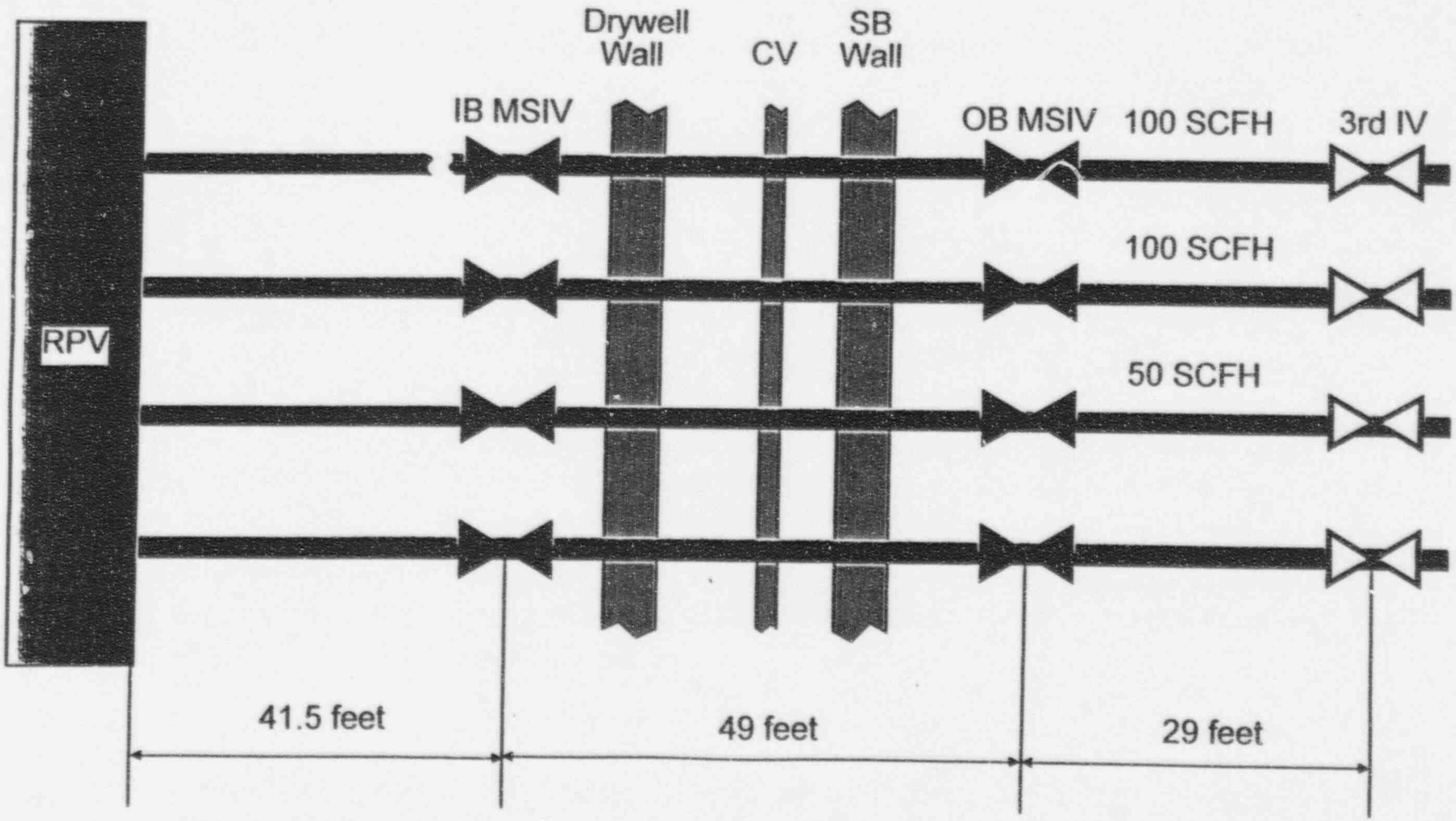


EXHIBIT 4

Appendix A: "LIBRARY file"

```
Version 2.0 CEDE       Thryoid   Red MarrowBeta Skin Whole Body
I--131 2.722E+04 9.976E-07 3.000E+04 1.000E+06 2.200E+02 1.120E-01 6.060E-02 01
1 22 00 00 00 00 00
1.100E-02 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 01 1.817E-01 3.789E-01
I--131 2.722E+04 9.976E-07 3.000E+04 1.000E+06 2.200E+02 1.120E-01 6.060E-02 02
1 22 00 00 00 00 00
1.100E-02 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 02 1.817E-01 3.789E-01
I--131 2.722E+04 9.976E-07 3.000E+04 1.000E+06 2.200E+02 1.120E-01 6.060E-02 03
1 22 00 00 00 00 00
1.100E-02 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 03 1.817E-01 3.789E-01
I--132 3.922E+04 8.425E-05 3.600E+02 5.900E+03 4.800E+01 6.180E-01 3.770E-01 01
 00 00 00 00 00 00
0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 29 4.824E-01 3.559E+00
I--132 3.922E+04 8.425E-05 3.600E+02 5.900E+03 4.800E+01 6.180E-01 3.770E-01 02
 00 00 00 00 00 00
0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 30 4.824E-01 3.559E+00
I--132 3.922E+04 8.425E-05 3.600E+02 5.900E+03 4.800E+01 6.180E-01 3.770E-01 03
 00 00 00 00 00 00
0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 31 4.824E-01 3.559E+00
I--133 5.495E+04 9.211E-06 5.800E+03 1.800E+05 9.600E+01 2.210E-01 9.730E-02 01
2 24 23 00 00 00 00
9.710E-01 2.900E-02 0.000E+00 0.000E+00 0.000E+00 0.000E+00 04 4.067E-01 6.047E-01
I--133 5.495E+04 9.211E-06 5.800E+03 1.800E+05 9.600E+01 2.210E-01 9.730E-02 02
2 24 23 00 00 00 00
9.710E-01 2.900E-02 0.000E+00 0.000E+00 0.000E+00 0.000E+00 05 4.067E-01 6.047E-01
I--133 5.495E+04 9.211E-06 5.800E+03 1.800E+05 9.600E+01 2.210E-01 9.730E-02 03
2 24 23 00 00 00 00
9.710E-01 2.900E-02 0.000E+00 0.000E+00 0.000E+00 0.000E+00 06 4.067E-01 6.047E-01
I--134 6.022E+04 2.200E-04 1.300E+02 1.000E+03 2.200E+01 7.320E-01 4.380E-01 01
 00 00 00 00 00 00
0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 07 6.052E-01 2.620E+00
I--134 6.022E+04 2.200E-04 1.300E+02 1.000E+03 2.200E+01 7.320E-01 4.380E-01 02
 00 00 00 00 00 00
0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 08 6.052E-01 2.620E+00
I--134 6.022E+04 2.200E-04 1.300E+02 1.000E+03 2.200E+01 7.320E-01 4.380E-01 03
 00 00 00 00 00 00
0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 09 6.052E-01 2.620E+00
I--135 5.149E+04 2.912E-05 1.200E+03 3.000E+04 7.800E+01 4.340E-01 2.640E-01 01
2 26 25 00 00 00 00
8.450E-01 1.550E-01 0.000E+00 0.000E+00 0.000E+00 0.000E+00 10 3.691E-01 1.617E+00
I--135 5.149E+04 2.912E-05 1.200E+03 3.000E+04 7.800E+01 4.340E-01 2.640E-01 02
2 26 25 00 00 00 00
8.450E-01 1.550E-01 0.000E+00 0.000E+00 0.000E+00 0.000E+00 11 3.691E-01 1.617E+00
I--135 5.149E+04 2.912E-05 1.200E+03 3.000E+04 7.800E+01 4.340E-01 2.640E-01 03
2 26 25 00 00 00 00
8.450E-01 1.550E-01 0.000E+00 0.000E+00 0.000E+00 0.000E+00 12 3.691E-01 1.617E+00
KR-83M 3.230E+03 1.052E-04 0.000E+00 0.000E+00 0.000E+00 1.360E-04 1.490E-05 04
 00 00 00 00 00 00
0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 13 0.000E+00 4.610E-04
KR--85 4.258E+02 2.054E-09 0.000E+00 0.000E+00 0.000E+00 5.010E-02 3.550E-04 04
 00 00 00 00 00 00
0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 32 2.505E-01 2.236E-03
KR-85M 6.703E+03 4.297E-05 0.000E+00 0.000E+00 0.000E+00 8.310E-02 2.590E-02 04
1 17 00 00 00 00 00
2.100E-01 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 14 2.902E-01 1.610E-01
KR--87 1.274E+04 1.514E-04 0.000E+00 0.000E+00 0.000E+00 5.230E-01 1.420E-01 04
1 00 00 00 00 00 00
1.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 15 1.324E+00 8.032E-01
KR--88 1.732E+04 6.731E-05 0.000E+00 0.000E+00 0.000E+00 5.490E-01 3.580E-01 04
1 00 00 00 00 00 00
1.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 16 3.587E-01 1.981E+00
KR--89 2.171E+04 3.632E-03 0.000E+00 0.000E+00 0.000E+00 7.710E-01 3.230E-01 04
1 00 00 00 00 00 00
1.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 17 1.363E+00 1.867E+00
```

```
XE131M 3.060E+02 6.815E-07 0.000E+00 0.000E+00 0.000E+00 1.780E-02 1.360E-03 04
 00 00 00 00 00 00
0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 18 0.000E+00 3.116E-03
XE133M 1.724E+03 3.663E-06 0.000E+00 0.000E+00 0.000E+00 3.840E-02 4.720E-03 04
1 24 00 00 00 00 00
1.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 19 0.000E+00 2.332E-02
XE-133 5.279E+04 1.528E-06 0.000E+00 0.000E+00 0.000E+00 1.840E-02 5.580E-03 04
 00 00 00 00 00 00
0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 20 1.004E-01 2.997E-02
XE135M 1.093E+04 7.380E-04 0.000E+00 0.000E+00 0.000E+00 1.130E-01 6.820E-02 04
1 26 00 00 00 00 00
1.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 21 3.000E-01 4.266E-01
XE-135 1.908E+04 2.115E-05 0.000E+00 0.000E+00 0.000E+00 1.150E-01 3.960E-02 04
1 00 00 00 00 00 00
1.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 22 3.028E-01 2.466E-01
XE-137 4.792E+04 3.024E-03 0.000E+00 0.000E+00 0.000E+00 5.010E-01 3.030E-02 04
1 30 00 00 00 00 00
1.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 23 1.774E+00 1.895E-01
XE-138 4.476E+04 8.151E-04 0.000E+00 0.000E+00 0.000E+00 4.090E-01 1.990E-01 04
1 00 00 00 00 00 00
1.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 24 6.140E-01 1.241E+00
CS-134 8.060E+03 1.066E-08 4.300E+04 4.000E+04 4.400E+04 3.710E-01 2.540E-01 05
 00 00 00 00 00 00
0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 25 1.568E-01 1.561E+00
CS-137 4.643E+03 7.284E-10 3.000E+04 2.900E+04 3.100E+04 2.770E-02 0.000E+00 05
1 32 00 00 00 00 00
9.460E-01 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 26 1.708E-01 0.000E+00
TE-132 3.856E+04 2.462E-06 8.600E+03 2.100E+05 1.300E+03 5.040E-02 3.460E-02 06
3 04 05 06 00 00 00
1.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 27 5.940E-02 2.123E-01
BA137M 3.328E+03 4.529E-03 0.000E+00 0.000E+00 0.000E+00 1.460E-01 9.700E-02 07
 00 00 00 00 00 00
0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 28 0.000E+00 5.948E-01
```

Appendix B: "LOCATRAN Input Files"

For configuration 1

```
PERRY DOSE CALC. W/ REVISED SOURCE TERM, CFG 1, 24 HR SPRAY           Problem title
JUN LI                                                                     Originator
PERRY DOSE CALC.                                                         Project name
PSAT 04202H                                                                 Project #
04202H.13  0                                                              Calc #, Rev
1                                                              First page # of output
8 12 32 1 0 0               # Nodes, # Time steps, # Iso, ICR, CALCDA, LSPRAY
1 0 3758 0 2 0 0   ITID, IPURGE, Power, SD time, NPF, # Spr nodes, # Delay calcs
CFM  CUFT CURIES                          Flow unit, Volume unit, Activity unit
1 1 1 1 1 1 1 1 1 1 1 1                        Release frac for iso group 1-12
0.0485 0.0015 0.95                                Elem, org, part iodine frac
DRYWELL  UNSPRAYED SPRAYED  ANNULUS SUP POOL STL_CV_1 STL_CV_2 STL_CV_3 Node name
8.333E-3 0.011111  1 0 0 1      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 1 1                                                     LACTIN, LPTIN, LVOL
0.100000 0 0 0 0.6 0 0 0              Initial I-131 elem act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0              Initial I-131 orgn act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0              Initial I-131 part act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0              Initial I-132 elem act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0              Initial I-132 orgn act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0              Initial I-132 part act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0              Initial I-133 elem act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0              Initial I-133 orgn act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0              Initial I-133 part act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0              Initial I-134 elem act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0              Initial I-134 orgn act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0              Initial I-134 part act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0              Initial I-135 elem act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0              Initial I-135 orgn act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0              Initial I-135 part act frac in nodes 2-9
0.100000 0 0 0 0   0 0 0              Initial Kr-83m act frac in nodes 2-9
0.100000 0 0 0 0   0 0 0              Initial Kr-85  act frac in nodes 2-9
0.100000 0 0 0 0   0 0 0              Initial Kr-85m act frac in nodes 2-9
0.100000 0 0 0 0   0 0 0              Initial Kr-87  act frac in nodes 2-9
0.100000 0 0 0 0   0 0 0              Initial Kr-88  act frac in nodes 2-9
0.100000 0 0 0 0   0 0 0              Initial Kr-89  act frac in nodes 2-9
0.100000 0 0 0 0   0 0 0              Initial Xe-131m act frac in nodes 2-9
0.100000 0 0 0 0   0 0 0              Initial Xe-133m act frac in nodes 2-9
0.100000 0 0 0 0   0 0 0              Initial Xe-133  act frac in nodes 2-9
0.100000 0 0 0 0   0 0 0              Initial Xe-135m act frac in nodes 2-9
0.100000 0 0 0 0   0 0 0              Initial Xe-135 act frac in nodes 2-9
0.100000 0 0 0 0   0 0 0              Initial Xe-137 act frac in nodes 2-9
0.100000 0 0 0 0   0 0 0              Initial Xe-138 act frac in nodes 2-9
0.100000 0 0 0 0   0 0 0              Initial CS-134 act frac in nodes 2-9
0.100000 0 0 0 0   0 0 0              Initial CS-137 act frac in nodes 2-9
0 0 0 0 0          0 0 0              Initial TE-132 act frac in nodes 2-9
0 0 0 0 0          0 0 0              Initial BA137M act frac in nodes 2-9
276500. 684226. 481174. 1.96E+5 146952. 146. 440. 292. Volumes for nodes 2-9
2 7 0 1.987                        From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0 0                      Filt eff for iso groups 1-12
2 8 0 2.98                         From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0 0                      Filt eff for iso groups 1-12
8 9 4.775 0                        From node, To node, Filt flow, Unfilt flow
50 0 74.6 0 74.6 74.6 74.6 74.6 74.6 74.6 74.6 74.6 Filt eff 4 iso grps 1-12
7 1 3.183 0                        From node, To node, Filt flow, Unfilt flow
50 0 58.2 0 58.2 58.2 58.2 58.2 58.2 58.2 58.2 58.2 Filt eff 4 iso grps 1-12
9 1 4.775 0                        From node, To node, Filt flow, Unfilt flow
50 0 62.4 0 62.4 62.4 62.4 62.4 62.4 62.4 62.4 62.4 Filt eff 4 iso grps 1-12
3 1 0 2.01                         From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0 0                      Filt eff for iso groups 1-12
3 4 0 71400.                       From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0 0                      Filt eff for iso groups 1-12
```

```
3 5 0 1.0E-5                         From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0 0                       Filt eff for iso groups 1-12
4 1 0 1.005                          From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0 0                       Filt eff for iso groups 1-12
4 3 0 71400.                         From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0 0                       Filt eff for iso groups 1-12
4 5 0 1.0E-5                         From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0 0                       Filt eff for iso groups 1-12
5 1 2000. 0                          From node, To node, Filt flow, Unfilt flow
0 0 99 0 99 99 99 99 99 99 99 99  (Item 4.1)    Filt eff for iso groups 1-12
6 1 1.0E-05 0                        From node, To node, Filt flow, Unfilt flow
99 99 99 99 99 99 99 99 99 99 99 99 99          Filt eff for iso groups 1-12
-1,0,0,0                                                      End flow input
1 2 0.084                                             Iso group, Node, Lambda
3 2 0.084                                             Iso group, Node, Lambda
5 2 0.084                                             Iso group, Node, Lambda
6 2 0.084                                             Iso group, Node, Lambda
7 2 0.084                                             Iso group, Node, Lambda
8 2 0.084                                             Iso group, Node, Lambda
9 2 0.084                                             Iso group, Node, Lambda
10 2 0.084                                            Iso group, Node, Lambda
11 2 0.084                                            Iso group, Node, Lambda
12 2 0.084                                            Iso group, Node, Lambda
-1,0,0,0                                                    End lambda input
1 7.0E-5                                              LCHG, Control room X/Q
3.44E5 0 1375 2.7E4 1375   CR vol,Filt intake,Unfilt intake,Recirc,Outleak
0 0 0 0 0 0 0 0 0 0 0 0 0               Intake filt eff for iso groups 1-12
0 0 0 0 0 0 0 0 0 0 0 0 0  (Item 4.2)   Recirc filt eff for iso groups 1-12
0.011111 0.018333 1 0 0 1  From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                 LACTIN, LPTIN, LVOL
3 1 0 0.135                          From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0 0                       Filt eff for iso groups 1-12
3 5 0 1.205                          From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0 0                       Filt eff for iso groups 1-12
4 1 0 0.0675                         From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0 0                       Filt eff for iso groups 1-12
4 5 0 0.603                          From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0 0                       Filt eff for iso groups 1-12
-1,0,0,0                                                      End flow input
-1,0,0,0                                                    End lambda input
0 7.0E-5                                              LCHG, Control room X/Q
0.018333 0.175 1 0 0 1     From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                 LACTIN, LPTIN, LVOL
-1,0,0,0                                                      End flow input
1 2  0.184                                            Iso group, Node, Lambda
3 2  0.184                                            Iso group, Node, Lambda
5 2  0.184                                            Iso group, Node, Lambda
6 2  0.184                                            Iso group, Node, Lambda
7 2  0.184                                            Iso group, Node, Lambda
8 2  0.184                                            Iso group, Node, Lambda
9 2  0.184                                            Iso group, Node, Lambda
10 2 0.184                                            Iso group, Node, Lambda
11 2 0.184                                            Iso group, Node, Lambda
12 2 0.184                                            Iso group, Node, Lambda
-1,0,0,0                                              Iso group, Node, Lambda
0 7.0E-5                                                    End lambda input
0.175 0.19167 1 0 0 1                                 LCHG, Control room X/Q
0 0 0                      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
6 1 0.03342 0                                         LACTIN, LPTIN, LVOL
90 90 90 90 90 90 90 90 90 90 90 90  From node, To node, Filt flow, Unfilt flow
-1,0,0,0                                        Filt eff for iso groups 1-12
-1,0,0,0                                                      End flow input
0 7.0E-5                                                    End lambda input
0.19167 0.20222 1 0 0 1                               LCHG, Control room X/Q
0 0 0                      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
-1,0,0,0                                              LACTIN, LPTIN, LVOL
1 4  8.13                                                     End flow input
3 4  8.13                                             Iso group, Node, Lambda
                                                      Iso group, Node, Lambda
```

```
5 4  8.13                                                        Iso group, Node, Lambda
6 4  8.13                                                        Iso group, Node, Lambda
7 4  8.13                                                        Iso group, Node, Lambda
8 4  8.13                                                        Iso group, Node, Lambda
9 4  8.13                                                        Iso group, Node, Lambda
10 4 8.13                                                        Iso group, Node, Lambda
11 4 8.13                                                        Iso group, Node, Lambda
12 4 8.13                                                        Iso group, Node, Lambda
-1,0,0,0                                                         Iso group, Node, Lambda
0 7.0E-5                                                               End lambda input
0.20222 0.25667 1 0 0 1                                          LCHG, Control room X/Q
0 0 0                            From time, To time, IPRTAC, IAACT, IPACT, IPRINT
-1,0,0,0                                                           LACTIN, LPTIN, LVOL
1 4  4.32                                                               End flow input
3 4  4.32                                                        Iso group, Node, Lambda
5 4  4.32                                                        Iso group, Node, Lambda
6 4  4.32                                                        Iso group, Node, Lambda
7 4  4.32                                                        Iso group, Node, Lambda
8 4  4.32                                                        Iso group, Node, Lambda
9 4  4.32                                                        Iso group, Node, Lambda
10 4 4.32                                                        Iso group, Node, Lambda
11 4 4.32                                                        Iso group, Node, Lambda
12 4 4.32                                                        Iso group, Node, Lambda
-1,0,0,0                                                         Iso group, Node, Lambda
0 7.0E-5                                                               End lambda input
0.25667 0.33333 1 0 0 1                                          LCHG, Control room X/Q
0 0 0                            From time, To time, IPRTAC, IAACT, IPACT, IPRINT
-1,0,0,0                                                           LACTIN, LPTIN, LVOL
1 4  3.02                                                               End flow input
3 4  3.02                                                        Iso group, Node, Lambda
5 4  3.02                                                        Iso group, Node, Lambda
6 4  3.02                                                        Iso group, Node, Lambda
7 4  3.02                                                        Iso group, Node, Lambda
8 4  3.02                                                        Iso group, Node, Lambda
9 4  3.02                                                        Iso group, Node, Lambda
10 4 3.02                                                        Iso group, Node, Lambda
11 4 3.02                                                        Iso group, Node, Lambda
12 4 3.02                                                        Iso group, Node, Lambda
-1,0,0,0                                                         Iso group, Node, Lambda
0 7.0E-5                                                               End lambda input
0.33333 0.36583 1 0 0 1                                          LCHG, Control room X/Q
0 0 1                            From time, To time, IPRTAC, IAACT, IPACT, IPRINT
276500. 684226. 481174. 1.96E+5 146952. 232. 440. 464.            LACTIN, LPTIN, LVOL
7 1 3.183 0                                                         Volumes for nodes 2-9
50 0 92.9 0 92.9 92.9 92.9 92.9 92.9 92.9 92.9 92.9     From node, To node, Filt flow, Unfilt flow
9 1 4.775 0                                                  Filt eff 4 iso grps 1-12
50 0 83.9 0 83.9 83.9 83.9 83.9 83.9 83.9 83.9 83.9     From node, To node, Filt flow, Unfilt flow
-1,0,0,0                                                     Filt eff 4 iso grps 1-12
-1,0,0,0                                                                End flow input
0 7.0E-5                                                               End lambda input
0.36583 0.475   1 0 0 1                                          LCHG, Control room X/Q
0 0 0                            From time, To time, IPRTAC, IAACT, IPACT, IPRINT
-1,0,0,0                                                           LACTIN, LPTIN, LVOL
1 4  2.52                                                               End flow input
3 4  2.52                                                        Iso group, Node, Lambda
5 4  2.52                                                        Iso group, Node, Lambda
6 4  2.52                                                        Iso group, Node, Lambda
7 4  2.52                                                        Iso group, Node, Lambda
8 4  2.52                                                        Iso group, Node, Lambda
9 4  2.52                                                        Iso group, Node, Lambda
10 4 2.52                                                        Iso group, Node, Lambda
11 4 2.52                                                        Iso group, Node, Lambda
12 4 2.52                                                        Iso group, Node, Lambda
-1,0,0,0                                                         Iso group, Node, Lambda
0 7.0E-5                                                               End lambda input
0.475 0.500000  1 0 0 1                                          LCHG, Control room X/Q
0 0 0                            From time, To time, IPRTAC, IAACT, IPACT, IPRINT
-1,0,0,0                                                           LACTIN, LPTIN, LVOL
                                                                        End flow input
```

```
1 4  14.3                                                        Iso group, Node, Lambda
3 4  14.3                                                        Iso group, Node, Lambda
5 4  14.3                                                        Iso group, Node, Lambda
6 4  14.3                                                        Iso group, Node, Lambda
7 4  14.3                                                        Iso group, Node, Lambda
8 4  14.3                                                        Iso group, Node, Lambda
9 4  14.3                                                        Iso group, Node, Lambda
10 4 14.3                                                        Iso group, Node, Lambda
11 4 14.3                                                        Iso group, Node, Lambda
12 4 14.3                                                        Iso group, Node, Lambda
-1,0,0,0                                                         Iso group, Node, Lambda
0 7.0E-5                                                                End lambda input
0.500 0.508333  1 0 0 1                                         LCHG, Control room X/Q
0 0 0                      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
7 1 3.183 0                                                     LACTIN, LPTIN, LVOL
50 0 95.9 0 95.9 95.9 95.9 95.9 95.9 95.9 95.9 95.9 From node, To node, Filt flow, Unfilt flow
9 1 4.775 0                                              Filt eff 4 iso grps 1-12
50 0 91.4 0 91.4 91.4 91.4 91.4 91.4 91.4 91.4 91.4 From node, To node, Filt flow, Unfilt flow
-1,0,0,0                                                 Filt eff 4 iso grps 1-12
-1,0,0,0                                                                  End flow input
0 7.0E-5                                                                End lambda input
0.50833 0.51861 1 0 0 1                                         LCHG, Control room X/Q
0 1 0                      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0.1666667 0 0 0 0 0 0 0                                          LACTIN, LPTIN, LVOL
0.1666667 0 0 0 0 0 0 0             Initial I-131 elem act frac in nodes 2-9
0.1666667 0 0 0 0 0 0 0             Initial I-131 orgn act frac in nodes 2-9
0.1666667 0 0 0 0 0 0 0             Initial I-131 part act frac in nodes 2-9
0.1666667 0 0 0 0 0 0 0             Initial I-132 elem act frac in nodes 2-9
0.1666667 0 0 0 0 0 0 0             Initial I-132 orgn act frac in nodes 2-9
0.1666667 0 0 0 0 0 0 0             Initial I-132 part act frac in nodes 2-9
0.1666667 0 0 0 0 0 0 0             Initial I-133 elem act frac in nodes 2-9
0.1666667 0 0 0 0 0 0 0             Initial I-133 orgn act frac in nodes 2-9
0.1666667 0 0 0 0 0 0 0             Initial I-133 part act frac in nodes 2-9
0.1666667 0 0 0 0 0 0 0             Initial I-134 elem act frac in nodes 2-9
0.1666667 0 0 0 0 0 0 0             Initial I-134 orgn act frac in nodes 2-9
0.1666667 0 0 0 0 0 0 0             Initial I-134 part act frac in nodes 2-9
0.1666667 0 0 0 0 0 0 0             Initial I-135 elem act frac in nodes 2-9
0.1666667 0 0 0 0 0 0 0             Initial I-135 orgn act frac in nodes 2-9
0.6333333 0 0 0 0 0 0 0             Initial I-135 part act frac in nodes 2-9
0.6333333 0 0 0 0 0 0 0                Initial Kr-83m act frac in nodes 2-9
0.6333333 0 0 0 0 0 0 0                 Initial Kr-85 act frac in nodes 2-9
0.6333333 0 0 0 0 0 0 0                Initial Kr-85m act frac in nodes 2-9
0.6333333 0 0 0 0 0 0 0                 Initial Kr-87 act frac in nodes 2-9
0.6333333 0 0 0 0 0 0 0                 Initial Kr-88 act frac in nodes 2-9
0.6333333 0 0 0 0 0 0 0                 Initial Kr-89 act frac in nodes 2-9
0.6333333 0 0 0 0 0 0 0              Initial Xe-131m act frac in nodes 2-9
0.6333333 0 0 0 0 0 0 0              Initial Xe-133m act frac in nodes 2-9
0.6333333 0 0 0 0 0 0 0               Initial Xe-133 act frac in nodes 2-9
0.6333333 0 0 0 0 0 0 0              Initial Xe-135m act frac in nodes 2-9
0.6333333 0 0 0 0 0 0 0               Initial Xe-135 act frac in nodes 2-9
0.6333333 0 0 0 0 0 0 0               Initial Xe-137 act frac in nodes 2-9
0.1333333 0 0 0 0 0 0 0               Initial Xe-138 act frac in nodes 2-9
0.1333333 0 0 0 0 0 0 0               Initial CS-134 act frac in nodes 2-9
0.0333333 0 0 0 0 0 0 0               Initial CS-137 act frac in nodes 2-9
0.0133333 0 0 0 0 0 0 0               Initial TE-132 act frac in nodes 2-9
2 3 0 6180.0                          Initial BA137M act frac in nodes 2-9
0 0 0 0 0 0 0 0 0 0 0 0 0 0   From node, To node, Filt flow, Unfilt flow
-1,0,0,0                                            Filt eff for iso groups 1-12
-1,0,0,0                                                          End flow input
1 7.0E-5                                                        End lambda input
3.44E5 0 1375 2.7E4 1375                                  LCHG, Control room X/Q
0 0 0 0 0 0 0 0 0 0 0 0 0 0   CR vol,Filt intake,Unfilt intake,Recirc,Outleak
50 50 95 0 95 95 95 95 95 95 95 95 (4.2) Intake filt eff for iso groups 1-12
0.51861 0.52694 1 0 0 1       Recirc filt eff for iso groups 1-12
0 0 0                      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
-1,0,0,0                                                  LACTIN, LPTIN, LVOL
1 2  0.25                                                         End flow input
3 2  0.25                                                Iso group, Node, Lambda
                                                         Iso group, Node, Lambda
```

```
5 2  0.25                                          Iso group, Node, Lambda
6 2  0.25                                          Iso group, Node, Lambda
7 2  0.25                                          Iso group, Node, Lambda
8 2  0.25                                          Iso group, Node, Lambda
9 2  0.25                                          Iso group, Node, Lambda
10 2 0.25                                          Iso group, Node, Lambda
11 2 0.25                                          Iso group, Node, Lambda
12 2 0.25                                          Iso group, Node, Lambda
-1,0,0,0                                           End lambda input
0 7.0E-5                                           LCHG, Control room X/Q
0.52694 0.575    1 0 0 1    From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                              LACTIN, LPTIN, LVOL
-1,0,0,0                                           End flow input
1 4  8.76                                          Iso group, Node, Lambda
3 4  8.76                                          Iso group, Node, Lambda
5 4  8.76                                          Iso group, Node, Lambda
6 4  8.76                                          Iso group, Node, Lambda
7 4  8.76                                          Iso group, Node, Lambda
8 4  8.76                                          Iso group, Node, Lambda
9 4  8.76                                          Iso group, Node, Lambda
10 4 8.76                                          Iso group, Node, Lambda
11 4 8.76                                          Iso group, Node, Lambda
12 4 8.76                                          Iso group, Node, Lambda
-1,0,0,0                                           End lambda input
0 7.0E-5                                           LCHG, Control room X/Q
0.575   0.7025  1 0 0 1     From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                              LACTIN, LPTIN, LVOL
-1,0,0,0                                           End flow input
1 4  5.07                                          Iso group, Node, Lambda
3 4  5.07                                          Iso group, Node, Lambda
5 4  5.07                                          Iso group, Node, Lambda
6 4  5.07                                          Iso group, Node, Lambda
7 4  5.07                                          Iso group, Node, Lambda
8 4  5.07                                          Iso group, Node, Lambda
9 4  5.07                                          Iso group, Node, Lambda
10 4 5.07                                          Iso group, Node, Lambda
11 4 5.07                                          Iso group, Node, Lambda
12 4 5.07                                          Iso group, Node, Lambda
-1,0,0,0                                           End lambda input
0 7.0E-5                                           LCHG, Control room X/Q
0.7025  0.8725  1 0 0 1     From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                              LACTIN, LPTIN, LVOL
-1,0,0,0                                           End flow input
1 4  3.84                                          Iso group, Node, Lambda
3 4  3.84                                          Iso group, Node, Lambda
5 4  3.84                                          Iso group, Node, Lambda
6 4  3.84                                          Iso group, Node, Lambda
7 4  3.84                                          Iso group, Node, Lambda
8 4  3.84                                          Iso group, Node, Lambda
9 4  3.84                                          Iso group, Node, Lambda
10 4 3.84                                          Iso group, Node, Lambda
11 4 3.84                                          Iso group, Node, Lambda
12 4 3.84                                          Iso group, Node, Lambda
-1,0,0,0                                           End lambda input
0 7.0E-5                                           LCHG, Control room X/Q
0.8725  0.88972 1 0 0 1     From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                              LACTIN, LPTIN, LVOL
-1,0,0,0                                           End flow input
1 4  3.25                                          Iso group, Node, Lambda
3 4  3.25                                          Iso group, Node, Lambda
5 4  3.25                                          Iso group, Node, Lambda
6 4  3.25                                          Iso group, Node, Lambda
7 4  3.25                                          Iso group, Node, Lambda
8 4  3.25                                          Iso group, Node, Lambda
9 4  3.25                                          Iso group, Node, Lambda
10 4 3.25                                          Iso group, Node, Lambda
11 4 3.25                                          Iso group, Node, Lambda
12 4 3.25                                          Iso group, Node, Lambda
```

```
-1,0,0,0                                                         End lambda input
0 7.0E-5                                                   LCHG, Control room X/Q
0.88972 1.11944 1 0 0 1      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                       LACTIN, LPTIN, LVOL
-1,0,0,0                                                          End flow input
1 2  0.35                                               Iso group, Node, Lambda
3 2  0.35                                               Iso group, Node, Lambda
5 2  0.35                                               Iso group, Node, Lambda
6 2  0.35                                               Iso group, Node, Lambda
7 2  0.35                                               Iso group, Node, Lambda
8 2  0.35                                               Iso group, Node, Lambda
9 2  0.35                                               Iso group, Node, Lambda
10 2 0.35                                               Iso group, Node, Lambda
11 2 0.35                                               Iso group, Node, Lambda
12 2 0.35                                               Iso group, Node, Lambda
-1,0,0,0                                                         End lambda input
0 7.0E-5                                                   LCHG, Control room X/Q
1.11944 1.21778 1 0 0 1      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                       LACTIN, LPTIN, LVOL
-1,0,0,0                                                          End flow input
1 4  3.22                                               Iso group, Node, Lambda
3 4  3.22                                               Iso group, Node, Lambda
5 4  3.22                                               Iso group, Node, Lambda
6 4  3.22                                               Iso group, Node, Lambda
7 4  3.22                                               Iso group, Node, Lambda
8 4  3.22                                               Iso group, Node, Lambda
9 4  3.22                                               Iso group, Node, Lambda
10 4 3.22                                               Iso group, Node, Lambda
11 4 3.22                                               Iso group, Node, Lambda
12 4 3.22                                               Iso group, Node, Lambda
-1,0,0,0                                                Iso group, Node, Lambda
0 7.0E-5                                                         End lambda input
1.21778 1.48306 1 0 0 1                                    LCHG, Control room X/Q
0 0 0                        From time, To time, IPRTAC, IAACT, IPACT, IPRINT
-1,0,0,0                                                    LACTIN, LPTIN, LVOL
1 2  0.45                                                         End flow input
3 2  0.45                                               Iso group, Node, Lambda
5 2  0.45                                               Iso group, Node, Lambda
6 2  0.45                                               Iso group, Node, Lambda
7 2  0.45                                               Iso group, Node, Lambda
8 2  0.45                                               Iso group, Node, Lambda
9 2  0.45                                               Iso group, Node, Lambda
10 2 0.45                                               Iso group, Node, Lambda
11 2 0.45                                               Iso group, Node, Lambda
12 2 0.45                                               Iso group, Node, Lambda
-1,0,0,0                                                Iso group, Node, Lambda
0 7.0E-5                                                         End lambda input
1.48306 1.50000 1 0 0 1                                    LCHG, Control room X/Q
0 0 0                        From time, To time, IPRTAC, IAACT, IPACT, IPRINT
-1,0,0,0                                                    LACTIN, LPTIN, LVOL
1 4  3.30                                                         End flow input
3 4  3.30                                               Iso group, Node, Lambda
5 4  3.30                                               Iso group, Node, Lambda
6 4  3.30                                               Iso group, Node, Lambda
7 4  3.30                                               Iso group, Node, Lambda
8 4  3.30                                               Iso group, Node, Lambda
9 4  3.30                                               Iso group, Node, Lambda
10 4 3.30                                               Iso group, Node, Lambda
11 4 3.30                                               Iso group, Node, Lambda
12 4 3.30                                               Iso group, Node, Lambda
-1,0,0,0                                                Iso group, Node, Lambda
0 7.0E-5                                                         End lambda input
1.50000 1.62833 1 0 0 1                                    LCHG, Control room X/Q
0 0 0                        From time, To time, IPRTAC, IAACT, IPACT, IPRINT
7 1 3.183 0                                                 LACTIN, LPTIN, LVOL
50 0 96.6 0 96.6 96.6 96.6 96.6 96.6 96.6 96.6 96.6 Filt eff 4 iso grps 1-12
9 1 4.775 0                           From node, To node, Filt flow, Unfilt flow
50 0 92.8 0 92.8 92.8 92.8 92.8 92.8 92.8 92.8 92.8 Filt eff 4 iso grps 1-12
```

```
-1,0,0,0
-1,0,0,0                                                End flow input
0 7.0E-5                                                End lambda input
1.62833 1.86167 1 0 0 1                           LCHG, Control room X/Q
0 0 0                   From time, To time, IPRTAC, IAACT, IPACT, IPRINT
-1,0,0,0                                          LACTIN, LPTIN, LVOL
1 2  0.54                                               End flow input
3 2  0.54                                   Iso group, Node, Lambda
5 2  0.54                                   Iso group, Node, Lambda
6 2  0.54                                   Iso group, Node, Lambda
7 2  0.54                                   Iso group, Node, Lambda
8 2  0.54                                   Iso group, Node, Lambda
9 2  0.54                                   Iso group, Node, Lambda
10 2 0.54                                   Iso group, Node, Lambda
11 2 0.54                                   Iso group, Node, Lambda
12 2 0.54                                   Iso group, Node, Lambda
-1,0,0,0                                    Iso group, Node, Lambda
0 7.0E-5                                                End lambda input
1.86167 2.00000 1 0 0 1                           LCHG, Control room X/Q
0 0 0                   From time, To time, IPRTAC, IAACT, IPACT, IPRINT
-1,0,0,0                                          LACTIN, LPTIN, LVOL
1 4  6.55                                               End flow input
3 4  6.55                                   Iso group, Node, Lambda
5 4  6.55                                   Iso group, Node, Lambda
6 4  6.55                                   Iso group, Node, Lambda
7 4  6.55                                   Iso group, Node, Lambda
8 4  6.55                                   Iso group, Node, Lambda
9 4  6.55                                   Iso group, Node, Lambda
10 4 6.55                                   Iso group, Node, Lambda
11 4 6.55                                   Iso group, Node, Lambda
12 4 6.55                                   Iso group, Node, Lambda
-1,0,0,0                                    Iso group, Node, Lambda
0 7.0E-5                                                End lambda input
2.00000 2.00833 1 0 0 1                           LCHG, Control room X/Q
0 0 0                   From time, To time, IPRTAC, IAACT, IPACT, IPRINT
-1,0,0,0                                          LACTIN, LPTIN, LVOL
-1,0,0,0                                                End flow input
0 7.0E-5                                                End lambda input
2.00833 2.03694 1 0 0 1                           LCHG, Control room X/Q
0 1 0                   From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0 0 0 0 0 0                                   LACTIN, LPTIN, LVOL
0 0 0 0 0 0 0 0          Initial I-131 elem act frac in nodes 2-9
0 0 0 0 0 0 0 0          Initial I-131 orgn act frac in nodes 2-9
0 0 0 0 0 0 0 0          Initial I-131 part act frac in nodes 2-9
0 0 0 0 0 0 0 0          Initial I-132 elem act frac in nodes 2-9
0 0 0 0 0 0 0 0          Initial I-132 orgn act frac in nodes 2-9
0 0 0 0 0 0 0 0          Initial I-132 part act frac in nodes 2-9
0 0 0 0 0 0 0 0          Initial I-133 elem act frac in nodes 2-9
0 0 0 0 0 0 0 0          Initial I-133 orgn act frac in nodes 2-9
0 0 0 0 0 0 0 0          Initial I-133 part act frac in nodes 2-9
0 0 0 0 0 0 0 0          Initial I-134 elem act frac in nodes 2-9
0 0 0 0 0 0 0 0          Initial I-134 orgn act frac in nodes 2-9
0 0 0 0 0 0 0 0          Initial I-134 part act frac in nodes 2-9
0 0 0 0 0 0 0 0          Initial I-135 elem act frac in nodes 2-9
0 0 0 0 0 0 0 0          Initial I-135 orgn act frac in nodes 2-9
0 0 0 0 0 0 0 0          Initial I-135 part act frac in nodes 2-9
0 0 0 0 0 0 0 0            Initial Kr-83m act frac in nodes 2-9
0 0 0 0 0 0 0 0            Initial Kr-85 act frac in nodes 2-9
0 0 0 0 0 0 0 0            Initial Kr-85m act frac in nodes 2-9
0 0 0 0 0 0 0 0            Initial Kr-87 act frac in nodes 2-9
0 0 0 0 0 0 0 0            Initial Kr-88 act frac in nodes 2-9
0 0 0 0 0 0 0 0            Initial Kr-89 act frac in nodes 2-9
0 0 0 0 0 0 0 0            Initial Xe-131m act frac in nodes 2-9
0 0 0 0 0 0 0 0            Initial Xe-133m act frac in nodes 2-9
0 0 0 0 0 0 0 0            Initial Xe-133 act frac in nodes 2-9
0 0 0 0 0 0 0 0            Initial Xe-135m act frac in nodes 2-9
0 0 0 0 0 0 0 0            Initial Xe-135 act frac in nodes 2-9
0 0 0 0 0 0 0 0            Initial Xe-137 act frac in nodes 2-9
                           Initial Xe-138 act frac in nodes 2-9
```

```
0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0                                   Initial CS-134 act frac in nodes 2-9
0 0 0 0 0 0 0 0 0                                   Initial CS-137 act frac in nodes 2-9
0 0 0 0 0 0 0 0 0                                   Initial TE-132 act frac in nodes 2-9
2 3 0 0                                             Initial BA137M act frac in nodes 2-9
0 0 0 0 0 0 0 0 0 0 0 0 0              From node, To node, Filt flow, Unfilt flow
-1,0,0,0                                           Filt eff for iso groups 1-12
-1,0,0,0                                                         End flow input
0 7.0E-5                                                       End lambda input
2.03694 2.04000 1 0 0 1                                LCHG, Control room X/Q
0 0 0                          From time, To time, IPRTAC, IAACT, IPACT, IPRINT
2 3 0 5.4E+4                                              LACTIN, LPTIN, LVOL
0 0 0 0 0 0 0 0 0 0 0 0 0              From node, To node, Filt flow, Unfilt flow
-1,0,0,0                                           Filt eff for iso groups 1-12
1 2  0.58                                                        End flow input
3 2  0.58                                              Iso group, Node, Lambda
5 2  0.58                                              Iso group, Node, Lambda
6 2  0.58                                              Iso group, Node, Lambda
7 2  0.58                                              Iso group, Node, Lambda
8 2  0.58                                              Iso group, Node, Lambda
9 2  0.58                                              Iso group, Node, Lambda
10 2 0.58                                              Iso group, Node, Lambda
11 2 0.58                                              Iso group, Node, Lambda
12 2 0.58                                              Iso group, Node, Lambda
-1,0,0,0                                               Iso group, Node, Lambda
0 7.0E-5                                                       End lambda input
2.04000 2.04333 1 0 0 1                                LCHG, Control room X/Q
0 0 0                          From time, To time, IPRTAC, IAACT, IPACT, IPRINT
2 3 0 1.3E+5                                              LACTIN, LPTIN, LVOL
0 0 0 0 0 0 0 0 0 0 0 0 0              From node, To node, Filt flow, Unfilt flow
-1,0,0,0                                           Filt eff for iso groups 1-12
-1,0,0,0                                                         End flow input
0 7.0E-5                                                       End lambda input
2.04333 2.04694 1 0 0 1                                LCHG, Control room X/Q
0 0 0                          From time, To time, IPRTAC, IAACT, IPACT, IPRINT
2 3 0 1.8E+5                                              LACTIN, LPTIN, LVOL
0 0 0 0 0 0 0 0 0 0 0 0 0              From node, To node, Filt flow, Unfilt flow
-1,0,0,0                                           Filt eff for iso groups 1-12
-1,0,0,0                                                         End flow input
0 7.0E-5                                                       End lambda input
2.04694 2.04917 1 0 0 1                                LCHG, Control room X/Q
0 0 0                          From time, To time, IPRTAC, IAACT, IPACT, IPRINT
2 3 0 2.1E+5                                              LACTIN, LPTIN, LVOL
0 0 0 0 0 0 0 0 0 0 0 0 0              From node, To node, Filt flow, Unfilt flow
-1,0,0,0                                           Filt eff for iso groups 1-12
-1,0,0,0                                                         End flow input
0 7.0E-5                                                       End lambda input
2.04917 2.05083 1 0 0 1                                LCHG, Control room X/Q
0 0 0                          From time, To time, IPRTAC, IAACT, IPACT, IPRINT
-1,0,0,0                                                  LACTIN, LPTIN, LVOL
1 4  3.30                                                        End flow input
3 4  3.30                                              Iso group, Node, Lambda
5 4  3.30                                              Iso group, Node, Lambda
6 4  3.30                                              Iso group, Node, Lambda
7 4  3.30                                              Iso group, Node, Lambda
8 4  3.30                                              Iso group, Node, Lambda
9 4  3.30                                              Iso group, Node, Lambda
10 4 3.30                                              Iso group, Node, Lambda
11 4 3.30                                              Iso group, Node, Lambda
12 4 3.30                                              Iso group, Node, Lambda
-1,0,0,0                                               Iso group, Node, Lambda
0 7.0E-5                                                       End lambda input
2.05083 2.05472 1 0 0 1                                LCHG, Control room X/Q
0 0 0                          From time, To time, IPRTAC, IAACT, IPACT, IPRINT
2 3 0 2.3E+5                                              LACTIN, LPTIN, LVOL
0 0 0 0 0 0 0 0 0 0 0 0 0              From node, To node, Filt flow, Unfilt flow
-1,0,0,0                                           Filt eff for iso groups 1-12
-1,0,0,0                                                         End flow input
                                                               End lambda input
```

```
0 7.0E-5                                              LCHG, Control room X/Q
2.05472 2.05861 1 0 0 1   From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                  LACTIN, LPTIN, LVOL
2 3 0 2.5E+5                    From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0                     Filt eff for iso groups 1-12
-1,0,0,0                                                    End flow input
-1,0,0,0                                                  End lambda input
0 7.0E-5                                              LCHG, Control room X/Q
2.05861 2.06250 1 0 0 1   From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                  LACTIN, LPTIN, LVOL
2 3 0 2.6E+5                    From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0                     Filt eff for iso groups 1-12
-1,0,0,0                                                    End flow input
-1,0,0,0                                                  End lambda input
0 7.0E-5                                              LCHG, Control room X/Q
2.06250 2.06639 1 0 0 1   From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                  LACTIN, LPTIN, LVOL
2 3 0 2.1E+5                    From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0                     Filt eff for iso groups 1-12
-1,0,0,0                                                    End flow input
-1,0,0,0                                                  End lambda input
0 7.0E-5                                              LCHG, Control room X/Q
2.06639 2.06972 1 0 0 1   From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                  LACTIN, LPTIN, LVOL
2 3 0 1.6E+5                    From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0                     Filt eff for iso groups 1-12
-1,0,0,0                                                    End flow input
-1,0,0,0                                                  End lambda input
0 7.0E-5                                              LCHG, Control room X/Q
2.06972 2.07306 1 0 0 1   From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                  LACTIN, LPTIN, LVOL
2 3 0 1.0E+5                    From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0                     Filt eff for iso groups 1-12
-1,0,0,0                                                    End flow input
-1,0,0,0                                                  End lambda input
0 7.0E-5                                              LCHG, Control room X/Q
2.07306 2.07611 1 0 0 1   From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                  LACTIN, LPTIN, LVOL
2 3 0 55000.                    From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0                     Filt eff for iso groups 1-12
-1,0,0,0                                                    End flow input
-1,0,0,0                                                  End lambda input
0 7.0E-5                                              LCHG, Control room X/Q
2.07611 2.07890 1 0 0 1   From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                  LACTIN, LPTIN, LVOL
2 3 0 12000.                    From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0                     Filt eff for iso groups 1-12
-1,0,0,0                                                    End flow input
-1,0,0,0                                                  End lambda input
0 7.0E-5                                              LCHG, Control room X/Q
2.07890 2.15556 1 0 0 1   From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                  LACTIN, LPTIN, LVOL
2 7 0 1.65                      From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0                     Filt eff for iso groups 1-12
2 8 0 2.47                      From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0                     Filt eff for iso groups 1-12
2 3 0 500.                      From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0                     Filt eff for iso groups 1-12
3 2 0 500.                      From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0                     Filt eff for iso groups 1-12
-1,0,0,0                                                    End flow input
1 2  0.54                                          Iso group, Node, Lambda
3 2  0.54                                          Iso group, Node, Lambda
5 2  0.54                                          Iso group, Node, Lambda
6 2  0.54                                          Iso group, Node, Lambda
7 2  0.54                                          Iso group, Node, Lambda
8 2  0.54                                          Iso group, Node, Lambda
9 2  0.54                                          Iso group, Node, Lambda
                                                   Iso group, Node, Lambda
```

```
10 2 0.54                                     Iso group, Node, Lambda
11 2 0.54                                     Iso group, Node, Lambda
12 2 0.54                                     Iso group, Node, Lambda
-1,0,0,0                                      End lambda input
0 7.0E-5                                      LCHG, Control room X/Q
2.15556 2.57056 1 0 0 1    From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                         LACTIN, LPTIN, LVOL
-1,0,0,0                                      End flow input
1 4  1.19                                     Iso group, Node, Lambda
3 4  1.19                                     Iso group, Node, Lambda
5 4  1.19                                     Iso group, Node, Lambda
6 4  1.19                                     Iso group, Node, Lambda
7 4  1.19                                     Iso group, Node, Lambda
8 4  1.19                                     Iso group, Node, Lambda
9 4  1.19                                     Iso group, Node, Lambda
10 4 1.19                                     Iso group, Node, Lambda
11 4 1.19                                     Iso group, Node, Lambda
12 4 1.19                                     Iso group, Node, Lambda
-1,0,0,0                                      End lambda input
0 7.0E-5                                      LCHG, Control room X/Q
2.57056 3.00000 1 0 0 1    From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                         LACTIN, LPTIN, LVOL
-1,0,0,0                                      End flow input
1 2  0.45                                     Iso group, Node, Lambda
3 2  0.45                                     Iso group, Node, Lambda
5 2  0.45                                     Iso group, Node, Lambda
6 2  0.45                                     Iso group, Node, Lambda
7 2  0.45                                     Iso group, Node, Lambda
8 2  0.45                                     Iso group, Node, Lambda
9 2  0.45                                     Iso group, Node, Lambda
10 2 0.45                                     Iso group, Node, Lambda
11 2 0.45                                     Iso group, Node, Lambda
12 2 0.45                                     Iso group, Node, Lambda
-1,0,0,0                                      End lambda input
0 7.0E-5                                      LCHG, Control room X/Q
3.00000 3.25667 1 0 0 1    From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                         LACTIN, LPTIN, LVOL
7 1 3.183 0                From node, To node, Filt flow, Unfilt flow
50 0 97.2 0 97.2 97.2 97.2 97.2 97.2 97.2 97.2 97.2 Filt eff 4 iso grps 1-12
9 1 4.775 0                From node, To node, Filt flow, Unfilt flow
50 0 94.1 0 94.1 94.1 94.1 94.1 94.1 94.1 94.1 94.1 Filt eff 4 iso grps 1-12
-1,0,0,0                                      End flow input
-1,0,0,0                                      End lambda input
0 7.0E-5                                      LCHG, Control room X/Q
3.25667 4.41139 1 0 0 1    From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                         LACTIN, LPTIN, LVOL
-1,0,0,0                                      End flow input
1 4  0.50                                     Iso group, Node, Lambda
3 4  0.50                                     Iso group, Node, Lambda
5 4  0.50                                     Iso group, Node, Lambda
6 4  0.50                                     Iso group, Node, Lambda
7 4  0.50                                     Iso group, Node, Lambda
8 4  0.50                                     Iso group, Node, Lambda
9 4  0.50                                     Iso group, Node, Lambda
10 4 0.50                                     Iso group, Node, Lambda
11 4 0.50                                     Iso group, Node, Lambda
12 4 0.50                                     Iso group, Node, Lambda
-1,0,0,0                                      End lambda input
0 7.0E-5                                      LCHG, Control room X/Q
4.41139 4.85250 1 0 0 1    From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                         LACTIN, LPTIN, LVOL
-1,0,0,0                                      End flow input
1 2  0.35                                     Iso group, Node, Lambda
3 2  0.35                                     Iso group, Node, Lambda
5 2  0.35                                     Iso group, Node, Lambda
6 2  0.35                                     Iso group, Node, Lambda
7 2  0.35                                     Iso group, Node, Lambda
8 2  0.35                                     Iso group, Node, Lambda
```

```
9 2  0.35                                                   Iso group, Node, Lambda
10 2 0.35                                                   Iso group, Node, Lambda
11 2 0.35                                                   Iso group, Node, Lambda
12 2 0.35                                                   Iso group, Node, Lambda
-1,0,0,0                                                    End lambda input
0 7.0E-5                                                    LCHG, Control room X/Q
4.85250 5.00000 1 0 0 1      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                       LACTIN, LPTIN, LVOL
-1,0,0,0                                                    End flow input
1 4  0.27                                                   Iso group, Node, Lambda
3 4  0.27                                                   Iso group, Node, Lambda
5 4  0.27                                                   Iso group, Node, Lambda
6 4  0.27                                                   Iso group, Node, Lambda
7 4  0.27                                                   Iso group, Node, Lambda
8 4  0.27                                                   Iso group, Node, Lambda
9 4  0.27                                                   Iso group, Node, Lambda
10 4 0.27                                                   Iso group, Node, Lambda
11 4 0.27                                                   Iso group, Node, Lambda
12 4 0.27                                                   Iso group, Node, Lambda
-1,0,0,0                                                    End lambda input
0 7.0E-5                                                    LCHG, Control room X/Q
5.00000 6.00000 1 0 0 1      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                       LACTIN, LPTIN, LVOL
7 1 3.183 0                           From node, To node, Filt flow, Unfilt flow
50 0 97.4 0 97.4 97.4 97.4 97.4 97.4 97.4 97.4 97.4 Filt eff 4 iso grps 1-12
9 1 4.775 0                           From node, To node, Filt flow, Unfilt flow
50 0 94.1 0 94.1 94.1 94.1 94.1 94.1 94.1 94.1 94.1 Filt eff 4 iso grps 1-12
-1,0,0,0                                                    End flow input
-1,0,0,0                                                    End lambda input
0 7.0E-5                                                    LCHG, Control room X/Q
6.00000 7.00000 1 0 0 1      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                       LACTIN, LPTIN, LVOL
-1,0,0,0                                                    End flow input
-1,0,0,0                                                    End lambda input
0 7.0E-5                                                    LCHG, Control room X/Q
7.00000 8.00000 1 0 0 1      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                       LACTIN, LPTIN, LVOL
7 1 3.183 0                           From node, To node, Filt flow, Unfilt flow
50 0 97.1 0 97.1 97.1 97.1 97.1 97.1 97.1 97.1 97.1 Filt eff 4 iso grps 1-12
9 1 4.775 0                           From node, To node, Filt flow, Unfilt flow
50 0 92.9 0 92.9 92.9 92.9 92.9 92.9 92.9 92.9 92.9 Filt eff 4 iso grps 1-12
-1,0,0,0                                                    End flow input
-1,0,0,0                                                    End lambda input
0 7.0E-5                                                    LCHG, Control room X/Q
8.00000 8.51917 1 0 0 1      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                       LACTIN, LPTIN, LVOL
-1,0,0,0                                                    End flow input
-1,0,0,0                                                    End lambda input
0 5.6E-5                                                    LCHG, Control room X/Q
8.51917 8.56194 1 0 0 1      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                       LACTIN, LPTIN, LVOL
-1,0,0,0                                                    End flow input
1 2  0.25                                                   Iso group, Node, Lambda
3 2  0.25                                                   Iso group, Node, Lambda
5 2  0.25                                                   Iso group, Node, Lambda
6 2  0.25                                                   Iso group, Node, Lambda
7 2  0.25                                                   Iso group, Node, Lambda
8 2  0.25                                                   Iso group, Node, Lambda
9 2  0.25                                                   Iso group, Node, Lambda
10 2 0.25                                                   Iso group, Node, Lambda
11 2 0.25                                                   Iso group, Node, Lambda
12 2 0.25                                                   Iso group, Node, Lambda
-1,0,0,0                                                    End lambda input
0 5.6E-5                                                    LCHG, Control room X/Q
8.56194 9.00000 1 0 0 1      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                       LACTIN, LPTIN, LVOL
-1,0,0,0                                                    End flow input
1 4  0.23                                                   Iso group, Node, Lambda
```

```
3 4  0.23                                                    Iso group, Node, Lambda
5 4  0.23                                                    Iso group, Node, Lambda
6 4  0.23                                                    Iso group, Node, Lambda
7 4  0.23                                                    Iso group, Node, Lambda
8 4  0.23                                                    Iso group, Node, Lambda
9 4  0.23                                                    Iso group, Node, Lambda
10 4 0.23                                                    Iso group, Node, Lambda
11 4 0.23                                                    Iso group, Node, Lambda
12 4 0.23                                                    Iso group, Node, Lambda
-1,0,0,0                                                           End lambda input
0 5.6E-5                                                    LCHG, Control room X/Q
9.00000 11.0000 1 0 0 1     From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                          LACTIN, LPTIN, LVOL
7 1 3.183 0                          From node, To node, Filt flow, Unfilt flow
50 0 96.6 0 96.6 96.6 96.6 96.6 96.6 96.6 96.6 96.6 Filt eff 4 iso grps 1-12
9 1 4.775 0                          From node, To node, Filt flow, Unfilt flow
50 0 91.1 0 91.1 91.1 91.1 91.1 91.1 91.1 91.1 91.1 Filt eff 4 iso grps 1-12
-1,0,0,0                                                             End flow input
-1,0,0,0                                                           End lambda input
0 5.6E-5                                                    LCHG, Control room X/Q
11.0000 11.1219 1 0 0 1     From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                          LACTIN, LPTIN, LVOL
7 1 3.183 0                          From node, To node, Filt flow, Unfilt flow
50 0 95.1 0 95.1 95.1 95.1 95.1 95.1 95.1 95.1 95.1 Filt eff 4 iso grps 1-12
9 1 4.775 0                          From node, To node, Filt flow, Unfilt flow
50 0 78.3 0 78.3 78.3 78.3 78.3 78.3 78.3 78.3 78.3 Filt eff 4 iso grps 1-12
-1,0,0,0                                                             End flow input
-1,0,0,0                                                           End lambda input
0 5.6E-5                                                    LCHG, Control room X/Q
11.1219 14.3442 1 0 0 1     From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                          LACTIN, LPTIN, LVOL
-1,0,0,0                                                             End flow input
1 4  0.2                                                     Iso group, Node, Lambda
3 4  0.2                                                     Iso group, Node, Lambda
5 4  0.2                                                     Iso group, Node, Lambda
6 4  0.2                                                     Iso group, Node, Lambda
7 4  0.2                                                     Iso group, Node, Lambda
8 4  0.2                                                     Iso group, Node, Lambda
9 4  0.2                                                     Iso group, Node, Lambda
10 4 0.2                                                     Iso group, Node, Lambda
11 4 0.2                                                     Iso group, Node, Lambda
12 4 0.2                                                     Iso group, Node, Lambda
-1,0,0,0                                                           End lambda input
0 5.6E-5                                                    LCHG, Control room X/Q
14.3442 19.3092 1 0 0 1     From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                          LACTIN, LPTIN, LVOL
-1,0,0,0                                                             End flow input
1 2  0.16                                                    Iso group, Node, Lambda
3 2  0.16                                                    Iso group, Node, Lambda
5 2  0.16                                                    Iso group, Node, Lambda
6 2  0.16                                                    Iso group, Node, Lambda
7 2  0.16                                                    Iso group, Node, Lambda
8 2  0.16                                                    Iso group, Node, Lambda
9 2  0.16                                                    Iso group, Node, Lambda
10 2 0.16                                                    Iso group, Node, Lambda
11 2 0.16                                                    Iso group, Node, Lambda
12 2 0.16                                                    Iso group, Node, Lambda
-1,0,0,0                                                           End lambda input
0 5.6E-5                                                    LCHG, Control room X/Q
19.3092 21.0000 1 0 0 1     From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                          LACTIN, LPTIN, LVOL
-1,0,0,0                                                             End flow input
1 4  0.19                                                    Iso group, Node, Lambda
3 4  0.19                                                    Iso group, Node, Lambda
5 4  0.19                                                    Iso group, Node, Lambda
6 4  0.19                                                    Iso group, Node, Lambda
7 4  0.19                                                    Iso group, Node, Lambda
8 4  0.19                                                    Iso group, Node, Lambda
```

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9 4  0.19                                                Iso group, Node, Lambda
10 4 0.19                                                Iso group, Node, Lambda
11 4 0.19                                                Iso group, Node, Lambda
12 4 0.19                                                Iso group, Node, Lambda
-1,0,0,0                                                       End lambda input
0 5.6E-5                                                 LCHG, Control room X/Q
21.0000 24.0000 1 0 0 1     From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                      LACTIN, LPTIN, LVOL
7 1 3.183 0                      From node, To node, Filt flow, Unfilt flow
50 0 89.1 0 89.1 89.1 89.1 89.1 89.1 89.1 89.1 89.1 Filt eff 4 iso grps 1-12
-1,0,0,0                                                         End flow input
-1,0,0,0                                                       End lambda input
0 5.6E-5                                                 LCHG, Control room X/Q
24.0000 24.5000 1 0 0 1     From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                      LACTIN, LPTIN, LVOL
6 1 6.684 0                      From node, To node, Filt flow, Unfilt flow
90 90 90 90 90 90 90 90 90 90 90 90               Filt eff for iso groups 1-12
-1,0,0,0                                                         End flow input
1 4  0.0                                                 Iso group, Node, Lambda
3 4  0.0                                                 Iso group, Node, Lambda
5 4  0.0                                                 Iso group, Node, Lambda
6 4  0.0                                                 Iso group, Node, Lambda
7 4  0.0                                                 Iso group, Node, Lambda
8 4  0.0                                                 Iso group, Node, Lambda
9 4  0.0                                                 Iso group, Node, Lambda
10 4 0.0                                                 Iso group, Node, Lambda
11 4 0.0                                                 Iso group, Node, Lambda
12 4 0.0                                                 Iso group, Node, Lambda
-1,0,0,0                                                       End lambda input
0 4.3E-5                                                 LCHG, Control room X/Q
24.5000 27.7778 1 0 0 1     From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                      LACTIN, LPTIN, LVOL
6 1 0.03342 0                    From node, To node, Filt flow, Unfilt flow
90 90 90 90 90 90 90 90 90 90 90 90               Filt eff for iso groups 1-12
-1,0,0,0                                                         End flow input
-1,0,0,0                                                       End lambda input
0 4.3E-5                                                 LCHG, Control room X/Q
27.7778 96.0000 1 0 0 1     From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                      LACTIN, LPTIN, LVOL
-1,0,0,0                                                         End flow input
1 2  0.0                                                 Iso group, Node, Lambda
3 2  0.0                                                 Iso group, Node, Lambda
5 2  0.0                                                 Iso group, Node, Lambda
6 2  0.0                                                 Iso group, Node, Lambda
7 2  0.0                                                 Iso group, Node, Lambda
8 2  0.0                                                 Iso group, Node, Lambda
9 2  0.0                                                 Iso group, Node, Lambda
10 2 0.0                                                 Iso group, Node, Lambda
11 2 0.0                                                 Iso group, Node, Lambda
12 2 0.0                                                 Iso group, Node, Lambda
-1,0,0,0                                                       End lambda input
0 4.3E-5                                                 LCHG, Control room X/Q
96.0000 720.000 1 0 0 1     From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                      LACTIN, LPTIN, LVOL
-1,0,0,0                                                         End flow input
-1,0,0,0                                                       End lambda input
0 1.5E-5                                                 LCHG, Control room X/Q
```

For configuration 2

```
PERRY DOSE CALC. W/ REVISED SOURCE TERM, CFG 2, 24 HR SPRAY          Problem title
JUN LI                                                                  Originator
PERRY DOSE CALC.                                                      Project name
PSAT 04202H                                                              Project #
04202H.13  0                                                            Calc #, Rev
1                                                           First page # of output
8 12 32 1 0 0                    # Nodes, # Time steps, # Iso, ICR, CALCDA, LSPRAY
1 0 3758 0 2 0 0  ITID, IPURGE, Power, SD time, NPF, # Spr nodes, # Delay calcs
CFM  CUFT CURIES                          Flow unit, Volume unit, Activity unit
1 1 1 1 1 1 1 1 1 1 1 1                         Release frac for iso group 1-12
0.0485 0.0015 0.95                                 Elem, org, part iodine frac
DRYWELL  UNSPRAYED SPRAYED  ANNULUS SUP POOL STL_CV_1 STL_CV_2 STL_CV_3 Node name
8.333E-3 0.011111  1 0 0 1      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 1 1                                                     LACTIN, LPTIN, LVOL
0.100000 0 0 0 0.6 0 0 0              Initial I-131 elem act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0              Initial I-131 orgn act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0              Initial I-131 part act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0              Initial I-132 elem act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0              Initial I-132 orgn act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0              Initial I-132 part act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0              Initial I-133 elem act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0              Initial I-133 orgn act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0              Initial I-133 part act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0              Initial I-134 elem act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0              Initial I-134 orgn act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0              Initial I-134 part act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0              Initial I-135 elem act frac in nodes 2-9
0.100000 0 0 0 0.6 0 0 0              Initial I-135 orgn act frac in nodes 2-9
0.100000 0 0 0 0    0 0 0             Initial I-135 part act frac in nodes 2-9
0.100000 0 0 0 0    0 0 0             Initial Kr-83m act frac in nodes 2-9
0.100000 0 0 0 0    0 0 0             Initial Kr-85  act frac in nodes 2-9
0.100000 0 0 0 0    0 0 0             Initial Kr-85m act frac in nodes 2-9
0.100000 0 0 0 0    0 0 0             Initial Kr-87  act frac in nodes 2-9
0.100000 0 0 0 0    0 0 0             Initial Kr-88  act frac in nodes 2-9
0.100000 0 0 0 0    0 0 0             Initial Kr-89  act frac in nodes 2-9
0.100000 0 0 0 0    0 0 0             Initial Xe-131m act frac in nodes 2-9
0.100000 0 0 0 0    0 0 0             Initial Xe-133m act frac in nodes 2-9
0.100000 0 0 0 0    0 0 0             Initial Xe-133  act frac in nodes 2-9
0.100000 0 0 0 0    0 0 0             Initial Xe-135m act frac in nodes 2-9
0.100000 0 0 0 0    0 0 0             Initial Xe-135 act frac in nodes 2-9
0.100000 0 0 0 0    0 0 0             Initial Xe-137 act frac in nodes 2-9
0.100000 0 0 0 0    0 0 0             Initial Xe-138 act frac in nodes 2-9
0.100000 0 0 0 0    0 0 0             Initial CS-134 act frac in nodes 2-9
0 0 0 0 0           0 0 0             Initial CS-137 act frac in nodes 2-9
0 0 0 0 0           0 0 0             Initial TE-132 act frac in nodes 2-9
276500. 684226. 481174. 1.96E+5 146952. 146. 440. 292. Volumes for nodes 2-9
                                      Initial BA137M act frac in nodes 2-9
2 7 0 1.987
0 0 0 0 0 0 0 0 0 0 0 0 0 0    From node, To node, Filt flow, Unfilt flow
                                             Filt eff for iso groups 1-12
2 8 0 2.98
0 0 0 0 0 0 0 0 0 0 0 0 0 0    From node, To node, Filt flow, Unfilt flow
                                             Filt eff for iso groups 1-12
8 9 4.775 0
50 0 74.6 0 74.6 74.6 74.6 74.6 74.6 74.6 74.6 74.6 Filt eff 4 iso grps 1-12
                               From node, To node, Filt flow, Unfilt flow
7 1 3.183 0
50 0 71.0 0 71.0 71.0 71.0 71.0 71.0 71.0 71.0 71.0 Filt eff 4 iso grps 1-12
                               From node, To node, Filt flow, Unfilt flow
9 1 4.775 0
50 0 74.0 0 74.0 74.0 74.0 74.0 74.0 74.0 74.0 74.0 Filt eff 4 iso grps 1-12
                               From node, To node, Filt flow, Unfilt flow
3 1 0 2.01
0 0 0 0 0 0 0 0 0 0 0 0 0 0    From node, To node, Filt flow, Unfilt flow
                                             Filt eff for iso groups 1-12
3 4 0 71400.
0 0 0 0 0 0 0 0 0 0 0 0 0 0    From node, To node, Filt flow, Unfilt flow
                                             Filt eff for iso groups 1-12
3 5 0 1.0E-5
0 0 0 0 0 0 0 0 0 0 0 0 0 0    From node, To node, Filt flow, Unfilt flow
                                             Filt eff for iso groups 1-12
```

```
0 0 0 0 0 0 0 0 0 0 0 0 0                              Filt eff for iso groups 1-12
4 3 0 71400.                          From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0 0                              Filt eff for iso groups 1-12
4 5 0 1.0E-5                          From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0 0                              Filt eff for iso groups 1-12
5 1 2000. 0                           From node, To node, Filt flow, Unfilt flow
0 0 99 0 99 99 99 99 99 99 99 99  (Item 4.1)    Filt eff for iso groups 1-12
6 1 1.0E-05 0                         From node, To node, Filt flow, Unfilt flow
99 99 99 99 99 99 99 99 99 99 99 99                    Filt eff for iso groups 1-12
-1,0,0,0                                                            End flow input
1 2 0.084                                                  Iso group, Node, Lambda
3 2 0.084                                                  Iso group, Node, Lambda
5 2 0.084                                                  Iso group, Node, Lambda
6 2 0.084                                                  Iso group, Node, Lambda
7 2 0.084                                                  Iso group, Node, Lambda
8 2 0.084                                                  Iso group, Node, Lambda
9 2 0.084                                                  Iso group, Node, Lambda
10 2 0.084                                                 Iso group, Node, Lambda
11 2 0.084                                                 Iso group, Node, Lambda
12 2 0.084                                                 Iso group, Node, Lambda
-1,0,0,0                                                          End lambda input
1 7.0E-5                                               LCHG, Control room X/Q
3.44E5 0 1375 2.7E4 1375      CR vol,Filt intake,Unfilt intake,Recirc,Outleak
0 0 0 0 0 0 0 0 0 0 0 0 0                  Intake filt eff for iso groups 1-12
0 0 0 0 0 0 0 0 0 0 0 0 0        (Item 4.2)  Recirc filt eff for iso groups 1-12
0.011111 0.018333 1 0 0 1   From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                    LACTIN, LPTIN, LVOL
3 1 0 0.135                           From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0 0                              Filt eff for iso groups 1-12
3 5 0 1.205                           From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0 0                              Filt eff for iso groups 1-12
4 1 0 0.0675                          From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0 0                              Filt eff for iso groups 1-12
4 5 0 0.603                           From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0 0                              Filt eff for iso groups 1-12
-1,0,0,0                                                            End flow input
-1,0,0,0                                                          End lambda input
0 7.0E-5                                               LCHG, Control room X/Q
0.018333 0.175 1 0 0 1      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                    LACTIN, LPTIN, LVOL
-1,0,0,0                                                            End flow input
1 2  0.184                                                 Iso group, Node, Lambda
3 2  0.184                                                 Iso group, Node, Lambda
5 2  0.184                                                 Iso group, Node, Lambda
6 2  0.184                                                 Iso group, Node, Lambda
7 2  0.184                                                 Iso group, Node, Lambda
8 2  0.184                                                 Iso group, Node, Lambda
9 2  0.184                                                 Iso group, Node, Lambda
10 2 0.184                                                 Iso group, Node, Lambda
11 2 0.184                                                 Iso group, Node, Lambda
12 2 0.184                                                 Iso group, Node, Lambda
-1,0,0,0                                                          End lambda input
0 7.0E-5                                               LCHG, Control room X/Q
0.175 0.19167 1 0 0 1       From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                    LACTIN, LPTIN, LVOL
6 1 0.03342 0                         From node, To node, Filt flow, Unfilt flow
90 90 90 90 90 90 90 90 90 90 90 90                    Filt eff for iso groups 1-12
-1,0,0,0                                                            End flow input
-1,0,0,0                                                          End lambda input
0 7.0E-5                                               LCHG, Control room X/Q
0.19167 0.20222 1 0 0 1     From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                    LACTIN, LPTIN, LVOL
-1,0,0,0                                                            End flow input
1 4  8.13                                                  Iso group, Node, Lambda
3 4  8.13                                                  Iso group, Node, Lambda
5 4  8.13                                                  Iso group, Node, Lambda
6 4  8.13                                                  Iso group, Node, Lambda
```

```
6 4  8.13
7 4  8.13                                                   Iso group, Node, Lambda
8 4  8.13                                                   Iso group, Node, Lambda
9 4  8.13                                                   Iso group, Node, Lambda
10 4 8.13                                                   Iso group, Node, Lambda
11 4 8.13                                                   Iso group, Node, Lambda
12 4 8.13                                                   Iso group, Node, Lambda
-1,0,0,0                                                    Iso group, Node, Lambda
0 7.0E-5                                                           End lambda input
0.20222 0.25667 1 0 0 1                                  LCHG, Control room X/Q
0 0 0                         From time, To time, IPRTAC, IAACT, IPACT, IPRINT
-1,0,0,0                                                  LACTIN, LPTIN, LVOL
1 4  4.32                                                         End flow input
3 4  4.32                                                   Iso group, Node, Lambda
5 4  4.32                                                   Iso group, Node, Lambda
6 4  4.32                                                   Iso group, Node, Lambda
7 4  4.32                                                   Iso group, Node, Lambda
8 4  4.32                                                   Iso group, Node, Lambda
9 4  4.32                                                   Iso group, Node, Lambda
10 4 4.32                                                   Iso group, Node, Lambda
11 4 4.32                                                   Iso group, Node, Lambda
12 4 4.32                                                   Iso group, Node, Lambda
-1,0,0,0                                                    Iso group, Node, Lambda
0 7.0E-5                                                           End lambda input
0.25667 0.36583 1 0 0 1                                  LCHG, Control room X/Q
0 0 0                         From time, To time, IPRTAC, IAACT, IPACT, IPRINT
-1,0,0,0                                                  LACTIN, LPTIN, LVOL
1 4  3.02                                                         End flow input
3 4  3.02                                                   Iso group, Node, Lambda
5 4  3.02                                                   Iso group, Node, Lambda
6 4  3.02                                                   Iso group, Node, Lambda
7 4  3.02                                                   Iso group, Node, Lambda
8 4  3.02                                                   Iso group, Node, Lambda
9 4  3.02                                                   Iso group, Node, Lambda
10 4 3.02                                                   Iso group, Node, Lambda
11 4 3.02                                                   Iso group, Node, Lambda
12 4 3.02                                                   Iso group, Node, Lambda
-1,0,0,0                                                    Iso group, Node, Lambda
0 7.0E-5                                                           End lambda input
0.36583 0.475   1 0 0 1                                  LCHG, Control room X/Q
0 0 0                         From time, To time, IPRTAC, IAACT, IPACT, IPRINT
-1,0,0,0                                                  LACTIN, LPTIN, LVOL
1 4  2.52                                                         End flow input
3 4  2.52                                                   Iso group, Node, Lambda
5 4  2.52                                                   Iso group, Node, Lambda
6 4  2.52                                                   Iso group, Node, Lambda
7 4  2.52                                                   Iso group, Node, Lambda
8 4  2.52                                                   Iso group, Node, Lambda
9 4  2.52                                                   Iso group, Node, Lambda
10 4 2.52                                                   Iso group, Node, Lambda
11 4 2.52                                                   Iso group, Node, Lambda
12 4 2.52                                                   Iso group, Node, Lambda
-1,0,0,0                                                    Iso group, Node, Lambda
0 7.0E-5                                                           End lambda input
0.475 0.500000  1 0 0 1                                  LCHG, Control room X/Q
0 0 0                         From time, To time, IPRTAC, IAACT, IPACT, IPRINT
-1,0,0,0                                                  LACTIN, LPTIN, LVOL
1 4  14.3                                                         End flow input
3 4  14.3                                                   Iso group, Node, Lambda
5 4  14.3                                                   Iso group, Node, Lambda
6 4  14.3                                                   Iso group, Node, Lambda
7 4  14.3                                                   Iso group, Node, Lambda
8 4  14.3                                                   Iso group, Node, Lambda
9 4  14.3                                                   Iso group, Node, Lambda
10 4 14.3                                                   Iso group, Node, Lambda
11 4 14.3                                                   Iso group, Node, Lambda
12 4 14.3                                                   Iso group, Node, Lambda
                                                            Iso group, Node, Lambda
```

```
-1,0,0,0                                                             End lambda input
0 7.0E-5                                                       LCHG, Control room X/Q
0.500 0.508333  1 0 0 1     From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                          LACTIN, LPTIN, LVOL
7 1 3.183 0                              From node, To node, Filt flow, Unfilt flow
50 0 85.0 0 85.0 85.0 85.0 85.0 85.0 85.0 85.0 85.0 Filt eff 4 iso grps 1-12
9 1 4.775 0                              From node, To node, Filt flow, Unfilt flow
50 0 83.0 0 83.0 83.0 83.0 83.0 83.0 83.0 83.0 83.0 Filt eff 4 iso grps 1-12
-1,0,0,0                                                             End flow input
-1,0,0,0                                                           End lambda input
0 7.0E-5                                                     LCHG, Control room X/Q
0.50833 0.51861 1 0 0 1     From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 1 0                                                        LACTIN, LPTIN, LVOL
0.1666667 0 0 0 0 0 0 0          Initial I-131 elem act frac in nodes 2-9
0.1666667 0 0 0 0 0 0 0          Initial I-131 orgn act frac in nodes 2-9
0.1666667 0 0 0 0 0 0 0          Initial I-131 part act frac in nodes 2-9
0.1666667 0 0 0 0 0 0 0          Initial I-132 elem act frac in nodes 2-9
0.1666667 0 0 0 0 0 0 0          Initial I-132 orgn act frac in nodes 2-9
0.1666667 0 0 0 0 0 0 0          Initial I-132 part act frac in nodes 2-9
0.1666667 0 0 0 0 0 0 0          Initial I-133 elem act frac in nodes 2-9
0.1666667 0 0 0 0 0 0 0          Initial I-133 orgn act frac in nodes 2-9
0.1666667 0 0 0 0 0 0 0          Initial I-133 part act frac in nodes 2-9
0.1666667 0 0 0 0 0 0 0          Initial I-134 elem act frac in nodes 2-9
0.1666667 0 0 0 0 0 0 0          Initial I-134 orgn act frac in nodes 2-9
0.1666667 0 0 0 0 0 0 0          Initial I-134 part act frac in nodes 2-9
0.1666667 0 0 0 0 0 0 0          Initial I-135 elem act frac in nodes 2-9
0.1666667 0 0 0 0 0 0 0          Initial I-135 orgn act frac in nodes 2-9
0.1666667 0 0 0 0 0 0 0          Initial I-135 part act frac in nodes 2-9
0.6333333 0 0 0 0 0 0 0             Initial Kr-83m act frac in nodes 2-9
0.6333333 0 0 0 0 0 0 0              Initial Kr-85 act frac in nodes 2-9
0.6333333 0 0 0 0 0 0 0             Initial Kr-85m act frac in nodes 2-9
0.6333333 0 0 0 0 0 0 0              Initial Kr-87 act frac in nodes 2-9
0.6333333 0 0 0 0 0 0 0              Initial Kr-88 act frac in nodes 2-9
0.6333333 0 0 0 0 0 0 0              Initial Kr-89 act frac in nodes 2-9
0.6333333 0 0 0 0 0 0 0            Initial Xe-131m act frac in nodes 2-9
0.6333333 0 0 0 0 0 0 0            Initial Xe-133m act frac in nodes 2-9
0.6333333 0 0 0 0 0 0 0             Initial Xe-133 act frac in nodes 2-9
0.6333333 0 0 0 0 0 0 0            Initial Xe-135m act frac in nodes 2-9
0.6333333 0 0 0 0 0 0 0             Initial Xe-135 act frac in nodes 2-9
0.6333333 0 0 0 0 0 0 0             Initial Xe-137 act frac in nodes 2-9
0.6333333 0 0 0 0 0 0 0             Initial Xe-138 act frac in nodes 2-9
0.1333333 0 0 0 0 0 0 0             Initial CS-134 act frac in nodes 2-9
0.1333333 0 0 0 0 0 0 0             Initial CS-137 act frac in nodes 2-9
0.0333333 0 0 0 0 0 0 0             Initial TE-132 act frac in nodes 2-9
0.0133333 0 0 0 0 0 0 0             Initial BA137M act frac in nodes 2-9
2 3 0 6180.0                        From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0 0                    Filt eff for iso groups 1-12
-1,0,0,0                                                     End flow input
-1,0,0,0                                                   End lambda input
1 7.0E-5                                             LCHG, Control room X/Q
3.44E5 0 1375 2.7E4 1375   CR vol,Filt intake,Unfilt intake,Recirc,Outleak
0 0 0 0 0 0 0 0 0 0 0 0 0             Intake filt eff for iso groups 1-12
50 50 95 0 95 95 95 95 95 95 95 95 (4.2) Recirc filt eff for iso groups 1-12
0.51861 0.52694 1 0 0 1     From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                  LACTIN, LPTIN, LVOL
-1,0,0,0                                                     End flow input
1 2  0.25                                          Iso group, Node, Lambda
3 2  0.25                                          Iso group, Node, Lambda
5 2  0.25                                          Iso group, Node, Lambda
6 2  0.25                                          Iso group, Node, Lambda
7 2  0.25                                          Iso group, Node, Lambda
8 2  0.25                                          Iso group, Node, Lambda
9 2  0.25                                          Iso group, Node, Lambda
10 2 0.25                                          Iso group, Node, Lambda
11 2 0.25                                          Iso group, Node, Lambda
12 2 0.25                                          Iso group, Node, Lambda
-1,0,0,0                                                   End lambda input
```

```
0 7.0E-5                                              LCHG, Control room X/Q
0.52694 0.575   1 0 0 1   From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                 LACTIN, LPTIN, LVOL
-1,0,0,0                                              End flow input
1 4  8.76                                             Iso group, Node, Lambda
3 4  8.76                                             Iso group, Node, Lambda
5 4  8.76                                             Iso group, Node, Lambda
6 4  8.76                                             Iso group, Node, Lambda
7 4  8.76                                             Iso group, Node, Lambda
8 4  8.76                                             Iso group, Node, Lambda
9 4  8.76                                             Iso group, Node, Lambda
10 4 8.76                                             Iso group, Node, Lambda
11 4 8.76                                             Iso group, Node, Lambda
12 4 8.76                                             Iso group, Node, Lambda
-1,0,0,0                                              End lambda input
0 7.0E-5                                              LCHG, Control room X/Q
0.575   0.7025  1 0 0 1   From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                 LACTIN, LPTIN, LVOL
-1,0,0,0                                              End flow input
1 4  5.07                                             Iso group, Node, Lambda
3 4  5.07                                             Iso group, Node, Lambda
5 4  5.07                                             Iso group, Node, Lambda
6 4  5.07                                             Iso group, Node, Lambda
7 4  5.07                                             Iso group, Node, Lambda
8 4  5.07                                             Iso group, Node, Lambda
9 4  5.07                                             Iso group, Node, Lambda
10 4 5.07                                             Iso group, Node, Lambda
11 4 5.07                                             Iso group, Node, Lambda
12 4 5.07                                             Iso group, Node, Lambda
-1,0,0,0                                              End lambda input
0 7.0E-5                                              LCHG, Control room X/Q
0.7025  0.8725  1 0 0 1   From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                 LACTIN, LPTIN, LVOL
-1,0,0,0                                              End flow input
1 4  3.84                                             Iso group, Node, Lambda
3 4  3.84                                             Iso group, Node, Lambda
5 4  3.84                                             Iso group, Node, Lambda
6 4  3.84                                             Iso group, Node, Lambda
7 4  3.84                                             Iso group, Node, Lambda
8 4  3.84                                             Iso group, Node, Lambda
9 4  3.84                                             Iso group, Node, Lambda
10 4 3.84                                             Iso group, Node, Lambda
11 4 3.84                                             Iso group, Node, Lambda
12 4 3.84                                             Iso group, Node, Lambda
-1,0,0,0                                              End lambda input
0 7.0E-5                                              LCHG, Control room X/Q
0.8725  0.88972 1 0 0 1   From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                 LACTIN, LPTIN, LVOL
-1,0,0,0                                              End flow input
1 4  3.25                                             Iso group, Node, Lambda
3 4  3.25                                             Iso group, Node, Lambda
5 4  3.25                                             Iso group, Node, Lambda
6 4  3.25                                             Iso group, Node, Lambda
7 4  3.25                                             Iso group, Node, Lambda
8 4  3.25                                             Iso group, Node, Lambda
9 4  3.25                                             Iso group, Node, Lambda
10 4 3.25                                             Iso group, Node, Lambda
11 4 3.25                                             Iso group, Node, Lambda
12 4 3.25                                             Iso group, Node, Lambda
-1,0,0,0                                              End lambda input
0 7.0E-5                                              LCHG, Control room X/Q
0.88972 1.11944 1 0 0 1   From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                 LACTIN, LPTIN, LVOL
-1,0,0,0                                              End flow input
1 2  0.35                                             Iso group, Node, Lambda
3 2  0.35                                             Iso group, Node, Lambda
5 2  0.35                                             Iso group, Node, Lambda
```

```
6 2  0.35                                                      Iso group, Node, Lambda
7 2  0.35                                                      Iso group, Node, Lambda
8 2  0.35                                                      Iso group, Node, Lambda
9 2  0.35                                                      Iso group, Node, Lambda
10 2 0.35                                                      Iso group, Node, Lambda
11 2 0.35                                                      Iso group, Node, Lambda
12 2 0.35                                                      Iso group, Node, Lambda
-1,0,0,0                                                       Iso group, Node, Lambda
0 7.0E-5                                                              End lambda input
1.11944 1.21778 1 0 0 1                                        LCHG, Control room X/Q
0 0 0                          From time, To time, IPRTAC, IAACT, IPACT, IPRINT
-1,0,0,0                                                       LACTIN, LPTIN, LVOL
1 4  3.22                                                             End flow input
3 4  3.22                                                      Iso group, Node, Lambda
5 4  3.22                                                      Iso group, Node, Lambda
6 4  3.22                                                      Iso group, Node, Lambda
7 4  3.22                                                      Iso group, Node, Lambda
8 4  3.22                                                      Iso group, Node, Lambda
9 4  3.22                                                      Iso group, Node, Lambda
10 4 3.22                                                      Iso group, Node, Lambda
11 4 3.22                                                      Iso group, Node, Lambda
12 4 3.22                                                      Iso group, Node, Lambda
-1,0,0,0                                                       Iso group, Node, Lambda
0 7.0E-5                                                              End lambda input
1.21778 1.48306 1 0 0 1                                        LCHG, Control room X/Q
0 0 0                          From time, To time, IPRTAC, IAACT, IPACT, IPRINT
-1,0,0,0                                                       LACTIN, LPTIN, LVOL
1 2  0.45                                                             End flow input
3 2  0.45                                                      Iso group, Node, Lambda
5 2  0.45                                                      Iso group, Node, Lambda
6 2  0.45                                                      Iso group, Node, Lambda
7 2  0.45                                                      Iso group, Node, Lambda
8 2  0.45                                                      Iso group, Node, Lambda
9 2  0.45                                                      Iso group, Node, Lambda
10 2 0.45                                                      Iso group, Node, Lambda
11 2 0.45                                                      Iso group, Node, Lambda
12 2 0.45                                                      Iso group, Node, Lambda
-1,0,0,0                                                       Iso group, Node, Lambda
0 7.0E-5                                                              End lambda input
1.48306 1.50000 1 0 0 1                                        LCHG, Control room X/Q
0 0 0                          From time, To time, IPRTAC, IAACT, IPACT, IPRINT
-1,0,0,0                                                       LACTIN, LPTIN, LVOL
1 4  3.30                                                             End flow input
3 4  3.30                                                      Iso group, Node, Lambda
5 4  3.30                                                      Iso group, Node, Lambda
6 4  3.30                                                      Iso group, Node, Lambda
7 4  3.30                                                      Iso group, Node, Lambda
8 4  3.30                                                      Iso group, Node, Lambda
9 4  3.30                                                      Iso group, Node, Lambda
10 4 3.30                                                      Iso group, Node, Lambda
11 4 3.30                                                      Iso group, Node, Lambda
12 4 3.30                                                      Iso group, Node, Lambda
-1,0,0,0                                                       Iso group, Node, Lambda
0 7.0E-5                                                              End lambda input
1.50000 1.62833 1 0 0 1                                        LCHG, Control room X/Q
0 0 0                          From time, To time, IPRTAC, IAACT, IPACT, IPRINT
7 1 3.183 0                                                    LACTIN, LPTIN, LVOL
50 0 88.5 0 88.5 88.5 88.5 88.5 88.5 88.5 88.5 88.5 From node, To node, Filt flow, Unfilt flow
9 1 4.775 0                               Filt eff 4 iso grps 1-12
50 0 85.1 0 85.1 85.1 85.1 85.1 85.1 85.1 85.1 85.1 From node, To node, Filt flow, Unfilt flow
-1,0,0,0                                  Filt eff 4 iso grps 1-12
-1,0,0,0                                                              End flow input
0 7.0E-5                                                              End lambda input
1.62833 1.86167 1 0 0 1                                        LCHG, Control room X/Q
0 0 0                          From time, To time, IPRTAC, IAACT, IPACT, IPRINT
-1,0,0,0                                                       LACTIN, LPTIN, LVOL
1 2  0.54                                                             End flow input
                                                               Iso group, Node, Lambda
```

```
3 2  0.54                                        Iso group, Node, Lambda
5 2  0.54                                        Iso group, Node, Lambda
6 2  0.54                                        Iso group, Node, Lambda
7 2  0.54                                        Iso group, Node, Lambda
8 2  0.54                                        Iso group, Node, Lambda
9 2  0.54                                        Iso group, Node, Lambda
10 2 0.54                                        Iso group, Node, Lambda
11 2 0.54                                        Iso group, Node, Lambda
12 2 0.54                                        Iso group, Node, Lambda
-1,0,0,0                                         End lambda input
0 7.0E-5                                         LCHG, Control room X/Q
1.86167 2.00000 1 0 0 1   From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                            LACTIN, LPTIN, LVOL
-1,0,0,0                                         End flow input
1 4  6.55                                        Iso group, Node, Lambda
3 4  6.55                                        Iso group, Node, Lambda
5 4  6.55                                        Iso group, Node, Lambda
6 4  6.55                                        Iso group, Node, Lambda
7 4  6.55                                        Iso group, Node, Lambda
8 4  6.55                                        Iso group, Node, Lambda
9 4  6.55                                        Iso group, Node, Lambda
10 4 6.55                                        Iso group, Node, Lambda
11 4 6.55                                        Iso group, Node, Lambda
12 4 6.55                                        Iso group, Node, Lambda
-1,0,0,0                                         End lambda input
0 7.0E-5                                         LCHG, Control room X/Q
2.00000 2.00833 1 0 0 1   From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                            LACTIN, LPTIN, LVOL
-1,0,0,0                                         End flow input
-1,0,0,0                                         End lambda input
0 7.0E-5                                         LCHG, Control room X/Q
2.00833 2.03694 1 0 0 1   From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 1 0                                            LACTIN, LPTIN, LVOL
0 0 0 0 0 0 0 0       Initial I-131 elem act frac in nodes 2-9
0 0 0 0 0 0 0 0       Initial I-131 orgn act frac in nodes 2-9
0 0 0 0 0 0 0 0       Initial I-131 part act frac in nodes 2-9
0 0 0 0 0 0 0 0       Initial I-132 elem act frac in nodes 2-9
0 0 0 0 0 0 0 0       Initial I-132 orgn act frac in nodes 2-9
0 0 0 0 0 0 0 0       Initial I-132 part act frac in nodes 2-9
0 0 0 0 0 0 0 0       Initial I-133 elem act frac in nodes 2-9
0 0 0 0 0 0 0 0       Initial I-133 orgn act frac in nodes 2-9
0 0 0 0 0 0 0 0       Initial I-133 part act frac in nodes 2-9
0 0 0 0 0 0 0 0       Initial I-134 elem act frac in nodes 2-9
0 0 0 0 0 0 0 0       Initial I-134 orgn act frac in nodes 2-9
0 0 0 0 0 0 0 0       Initial I-134 part act frac in nodes 2-9
0 0 0 0 0 0 0 0       Initial I-135 elem act frac in nodes 2-9
0 0 0 0 0 0 0 0       Initial I-135 orgn act frac in nodes 2-9
0 0 0 0 0 0 0 0       Initial I-135 part act frac in nodes 2-9
0 0 0 0 0 0 0 0         Initial Kr-83m act frac in nodes 2-9
0 0 0 0 0 0 0 0         Initial Kr-85 act frac in nodes 2-9
0 0 0 0 0 0 0 0         Initial Kr-85m act frac in nodes 2-9
0 0 0 0 0 0 0 0         Initial Kr-87 act frac in nodes 2-9
0 0 0 0 0 0 0 0         Initial Kr-88 act frac in nodes 2-9
0 0 0 0 0 0 0 0         Initial Kr-89 act frac in nodes 2-9
0 0 0 0 0 0 0 0         Initial Xe-131m act frac in nodes 2-9
0 0 0 0 0 0 0 0         Initial Xe-133m act frac in nodes 2-9
0 0 0 0 0 0 0 0         Initial Xe-133 act frac in nodes 2-9
0 0 0 0 0 0 0 0         Initial Xe-135m act frac in nodes 2-9
0 0 0 0 0 0 0 0         Initial Xe-135 act frac in nodes 2-9
0 0 0 0 0 0 0 0         Initial Xe-137 act frac in nodes 2-9
0 0 0 0 0 0 0 0         Initial Xe-138 act frac in nodes 2-9
0 0 0 0 0 0 0 0         Initial CS-134 act frac in nodes 2-9
0 0 0 0 0 0 0 0         Initial CS-137 act frac in nodes 2-9
0 0 0 0 0 0 0 0         Initial TE-132 act frac in nodes 2-9
0 0 0 0 0 0 0 0         Initial BA137M act frac in nodes 2-9
2 3 0 0              From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0          Filt eff for iso groups 1-12
```

```
-1,0,0,0
-1,0,0,0                                                        End flow input
0 7.0E-5                                                      End lambda input
2.03694 2.04000 1 0 0 1                                 LCHG, Control room X/Q
0 0 0                           From time, To time, IPRTAC, IAACT, IPACT, IPRINT
2 3 0 5.4E+4                                                LACTIN, LPTIN, LVOL
0 0 0 0 0 0 0 0 0 0 0 0 0 0      From node, To node, Filt flow, Unfilt flow
-1,0,0,0                                          Filt eff for iso groups 1-12
1 2  0.58                                                       End flow input
3 2  0.58                                         Iso group, Node, Lambda
5 2  0.58                                         Iso group, Node, Lambda
6 2  0.58                                         Iso group, Node, Lambda
7 2  0.58                                         Iso group, Node, Lambda
8 2  0.58                                         Iso group, Node, Lambda
9 2  0.58                                         Iso group, Node, Lambda
10 2 0.58                                         Iso group, Node, Lambda
11 2 0.58                                         Iso group, Node, Lambda
12 2 0.58                                         Iso group, Node, Lambda
-1,0,0,0                                          Iso group, Node, Lambda
0 7.0E-5                                                      End lambda input
2.04000 2.04333 1 0 0 1                                 LCHG, Control room X/Q
0 0 0                           From time, To time, IPRTAC, IAACT, IPACT, IPRINT
2 3 0 1.3E+5                                                LACTIN, LPTIN, LVOL
0 0 0 0 0 0 0 0 0 0 0 0 0 0      From node, To node, Filt flow, Unfilt flow
-1,0,0,0                                          Filt eff for iso groups 1-12
-1,0,0,0                                                        End flow input
0 7.0E-5                                                      End lambda input
2.04333 2.04694 1 0 0 1                                 LCHG, Control room X/Q
0 0 0                           From time, To time, IPRTAC, IAACT, IPACT, IPRINT
2 3 0 1.8E+5                                                LACTIN, LPTIN, LVOL
0 0 0 0 0 0 0 0 0 0 0 0 0 0      From node, To node, Filt flow, Unfilt flow
-1,0,0,0                                          Filt eff for iso groups 1-12
-1,0,0,0                                                        End flow input
0 7.0E-5                                                      End lambda input
2.04694 2.04917 1 0 0 1                                 LCHG, Control room X/Q
0 0 0                           From time, To time, IPRTAC, IAACT, IPACT, IPRINT
2 3 0 2.1E+5                                                LACTIN, LPTIN, LVOL
0 0 0 0 0 0 0 0 0 0 0 0 0 0      From node, To node, Filt flow, Unfilt flow
-1,0,0,0                                          Filt eff for iso groups 1-12
-1,0,0,0                                                        End flow input
0 7.0E-5                                                      End lambda input
2.04917 2.05083 1 0 0 1                                 LCHG, Control room X/Q
0 0 0                           From time, To time, IPRTAC, IAACT, IPACT, IPRINT
-1,0,0,0                                                    LACTIN, LPTIN, LVOL
1 4  3.30                                                       End flow input
3 4  3.30                                         Iso group, Node, Lambda
5 4  3.30                                         Iso group, Node, Lambda
6 4  3.30                                         Iso group, Node, Lambda
7 4  3.30                                         Iso group, Node, Lambda
8 4  3.30                                         Iso group, Node, Lambda
9 4  3.30                                         Iso group, Node, Lambda
10 4 3.30                                         Iso group, Node, Lambda
11 4 3.30                                         Iso group, Node, Lambda
12 4 3.30                                         Iso group, Node, Lambda
-1,0,0,0                                          Iso group, Node, Lambda
0 7.0E-5                                                      End lambda input
2.05083 2.05472 1 0 0 1                                 LCHG, Control room X/Q
0 0 0                           From time, To time, IPRTAC, IAACT, IPACT, IPRINT
2 3 0 2.3E+5                                                LACTIN, LPTIN, LVOL
0 0 0 0 0 0 0 0 0 0 0 0 0 0      From node, To node, Filt flow, Unfilt flow
-1,0,0,0                                          Filt eff for iso groups 1-12
-1,0,0,0                                                        End flow input
0 7.0E-5                                                      End lambda input
2.05472 2.05861 1 0 0 1                                 LCHG, Control room X/Q
0 0 0                           From time, To time, IPRTAC, IAACT, IPACT, IPRINT
2 3 0 2.5E+5                                                LACTIN, LPTIN, LVOL
0 0 0 0 0 0 0 0 0 0 0 0 0 0      From node, To node, Filt flow, Unfilt flow
                                                  Filt eff for iso groups 1-12
```

```
-1,0,0,0                                                          End flow input
-1,0,0,0                                                        End lambda input
0 7.0E-5                                               LCHG, Control room X/Q
2.05861 2.06250 1 0 0 1   From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                   LACTIN, LPTIN, LVOL
2 3 0 2.6E+5                     From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0 0              Filt eff for iso groups 1-12
-1,0,0,0                                                          End flow input
-1,0,0,0                                                        End lambda input
0 7.0E-5                                               LCHG, Control room X/Q
2.06250 2.06639 1 0 0 1   From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                   LACTIN, LPTIN, LVOL
2 3 0 2.1E+5                     From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0 0              Filt eff for iso groups 1-12
-1,0,0,0                                                          End flow input
-1,0,0,0                                                        End lambda input
0 7.0E-5                                               LCHG, Control room X/Q
2.06639 2.06972 1 0 0 1   From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                   LACTIN, LPTIN, LVOL
2 3 0 1.6E+5                     From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0 0              Filt eff for iso groups 1-12
-1,0,0,0                                                          End flow input
-1,0,0,0                                                        End lambda input
0 7.0E-5                                               LCHG, Control room X/Q
2.06972 2.07306 1 0 0 1   From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                   LACTIN, LPTIN, LVOL
2 3 0 1.0E+5                     From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0 0              Filt eff for iso groups 1-12
-1,0,0,0                                                          End flow input
-1,0,0,0                                                        End lambda input
0 7.0E-5                                               LCHG, Control room X/Q
2.07306 2.07611 1 0 0 1   From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                   LACTIN, LPTIN, LVOL
2 3 0 55000.                     From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0 0              Filt eff for iso groups 1-12
-1,0,0,0                                                          End flow input
-1,0,0,0                                                        End lambda input
0 7.0E-5                                               LCHG, Control room X/Q
2.07611 2.07890 1 0 0 1   From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                   LACTIN, LPTIN, LVOL
2 3 0 12000.                     From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0 0              Filt eff for iso groups 1-12
-1,0,0,0                                                          End flow input
-1,0,0,0                                                        End lambda input
0 7.0E-5                                               LCHG, Control room X/Q
2.07890 2.15556 1 0 0 1   From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                   LACTIN, LPTIN, LVOL
2 7 0 1.65                       From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0 0              Filt eff for iso groups 1-12
2 8 0 2.47                       From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0 0              Filt eff for iso groups 1-12
2 3 0 500.                       From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0 0              Filt eff for iso groups 1-12
3 2 0 500.                       From node, To node, Filt flow, Unfilt flow
0 0 0 0 0 0 0 0 0 0 0 0 0              Filt eff for iso groups 1-12
-1,0,0,0                                                          End flow input
1 2  0.54                                           Iso group, Node, Lambda
3 2  0.54                                           Iso group, Node, Lambda
5 2  0.54                                           Iso group, Node, Lambda
6 2  0.54                                           Iso group, Node, Lambda
7 2  0.54                                           Iso group, Node, Lambda
8 2  0.54                                           Iso group, Node, Lambda
9 2  0.54                                           Iso group, Node, Lambda
10 2 0.54                                           Iso group, Node, Lambda
11 2 0.54                                           Iso group, Node, Lambda
12 2 0.54                                           Iso group, Node, Lambda
-1,0,0,0                                                        End lambda input
```

```
0 7.0E-5
2.15556 2.57056 1 0 0 1                                          LCHG, Control room X/Q
0 0 0                         From time, To time, IPRTAC, IAACT, IPACT, IPRINT
-1,0,0,0                                                   LACTIN, LPTIN, LVOL
1 4  1.19                                                      End flow input
3 4  1.19                                             Iso group, Node, Lambda
5 4  1.19                                             Iso group, Node, Lambda
6 4  1.19                                             Iso group, Node, Lambda
7 4  1.19                                             Iso group, Node, Lambda
8 4  1.19                                             Iso group, Node, Lambda
9 4  1.19                                             Iso group, Node, Lambda
10 4 1.19                                             Iso group, Node, Lambda
11 4 1.19                                             Iso group, Node, Lambda
12 4 1.19                                             Iso group, Node, Lambda
-1,0,0,0                                              Iso group, Node, Lambda
0 7.0E-5                                                     End lambda input
2.57056 3.00000 1 0 0 1                                LCHG, Control room X/Q
0 0 0                         From time, To time, IPRTAC, IAACT, IPACT, IPRINT
-1,0,0,0                                                   LACTIN, LPTIN, LVOL
1 2  0.45                                                      End flow input
3 2  0.45                                             Iso group, Node, Lambda
5 2  0.45                                             Iso group, Node, Lambda
6 2  0.45                                             Iso group, Node, Lambda
7 2  0.45                                             Iso group, Node, Lambda
8 2  0.45                                             Iso group, Node, Lambda
9 2  0.45                                             Iso group, Node, Lambda
10 2 0.45                                             Iso group, Node, Lambda
11 2 0.45                                             Iso group, Node, Lambda
12 2 0.45                                             Iso group, Node, Lambda
-1,0,0,0                                              Iso group, Node, Lambda
0 7.0E-5                                                     End lambda input
3.00000 3.25667 1 0 0 1                                LCHG, Control room X/Q
0 0 0                         From time, To time, IPRTAC, IAACT, IPACT, IPRINT
7 1 3.183 0                                                LACTIN, LPTIN, LVOL
50 0 90.0 0 90.0 90.0 90.0 90.0 90.0 90.0 90.0 90.0 From node, To node, Filt flow, Unfilt flow
9 1 4.775 0                                          Filt eff 4 iso grps 1-12
50 0 85.9 0 85.9 85.9 85.9 85.9 85.9 85.9 85.9 85.9 From node, To node, Filt flow, Unfilt flow
-1,0,0,0                                             Filt eff 4 iso grps 1-12
-1,0,0,0                                                       End flow input
0 7.0E-5                                                     End lambda input
3.25667 4.41139 1 0 0 1                                LCHG, Control room X/Q
0 0 0                         From time, To time, IPRTAC, IAACT, IPACT, IPRINT
-1,0,0,0                                                   LACTIN, LPTIN, LVOL
1 4  0.50                                                      End flow input
3 4  0.50                                             Iso group, Node, Lambda
5 4  0.50                                             Iso group, Node, Lambda
6 4  0.50                                             Iso group, Node, Lambda
7 4  0.50                                             Iso group, Node, Lambda
8 4  0.50                                             Iso group, Node, Lambda
9 4  0.50                                             Iso group, Node, Lambda
10 4 0.50                                             Iso group, Node, Lambda
11 4 0.50                                             Iso group, Node, Lambda
12 4 0.50                                             Iso group, Node, Lambda
-1,0,0,0                                              Iso group, Node, Lambda
0 7.0E-5                                                     End lambda input
4.41139 4.85250 1 0 0 1                                LCHG, Control room X/Q
0 0 0                         From time, To time, IPRTAC, IAACT, IPACT, IPRINT
-1,0,0,0                                                   LACTIN, LPTIN, LVOL
1 2  0.35                                                      End flow input
3 2  0.35                                             Iso group, Node, Lambda
5 2  0.35                                             Iso group, Node, Lambda
6 2  0.35                                             Iso group, Node, Lambda
7 2  0.35                                             Iso group, Node, Lambda
8 2  0.35                                             Iso group, Node, Lambda
9 2  0.35                                             Iso group, Node, Lambda
10 2 0.35                                             Iso group, Node, Lambda
11 2 0.35                                             Iso group, Node, Lambda
                                                      Iso group, Node, Lambda
```

```
12 2 0.35                                                     Iso group, Node, Lambda
-1,0,0,0                                                             End lambda input
0 7.0E-5                                                      LCHG, Control room X/Q
4.85250 5.00000 1 0 0 1      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                         LACTIN, LPTIN, LVOL
-1,0,0,0                                                             End flow input
1 4  0.27                                                     Iso group, Node, Lambda
3 4  0.27                                                     Iso group, Node, Lambda
5 4  0.27                                                     Iso group, Node, Lambda
6 4  0.27                                                     Iso group, Node, Lambda
7 4  0.27                                                     Iso group, Node, Lambda
8 4  0.27                                                     Iso group, Node, Lambda
9 4  0.27                                                     Iso group, Node, Lambda
10 4 0.27                                                     Iso group, Node, Lambda
11 4 0.27                                                     Iso group, Node, Lambda
12 4 0.27                                                     Iso group, Node, Lambda
-1,0,0,0                                                             End lambda input
0 7.0E-5                                                      LCHG, Control room X/Q
5.00000 6.00000 1 0 0 1      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                         LACTIN, LPTIN, LVOL
7 1 3.183 0                         From node, To node, Filt flow, Unfilt flow
50 0 87.4 0 87.4 87.4 87.4 87.4 87.4 87.4 87.4 87.4 Filt eff 4 iso grps 1-12
9 1 4.775 0                         From node, To node, Filt flow, Unfilt flow
50 0 84.9 0 84.9 84.9 84.9 84.9 84.9 84.9 84.9 84.9 Filt eff 4 iso grps 1-12
-1,0,0,0                                                             End flow input
-1,0,0,0                                                             End lambda input
0 7.0E-5                                                      LCHG, Control room X/Q
6.00000 7.00000 1 0 0 1      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                         LACTIN, LPTIN, LVOL
-1,0,0,0                                                             End flow input
-1,0,0,0                                                             End lambda input
0 7.0E-5                                                      LCHG, Control room X/Q
7.00000 8.00000 1 0 0 1      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                         LACTIN, LPTIN, LVOL
7 1 3.183 0                         From node, To node, Filt flow, Unfilt flow
50 0 83.5 0 83.5 83.5 83.5 83.5 83.5 83.5 83.5 83.5 Filt eff 4 iso grps 1-12
9 1 4.775 0                         From node, To node, Filt flow, Unfilt flow
50 0 81.8 0 81.8 81.8 81.8 81.8 81.8 81.8 81.8 81.8 Filt eff 4 iso grps 1-12
-1,0,0,0                                                             End flow input
-1,0,0,0                                                             End lambda input
0 7.0E-5                                                      LCHG, Control room X/Q
8.00000 8.51917 1 0 0 1      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                         LACTIN, LPTIN, LVOL
-1,0,0,0                                                             End flow input
-1,0,0,0                                                             End lambda input
0 5.6E-5                                                      LCHG, Control room X/Q
8.51917 8.56194 1 0 0 1      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                         LACTIN, LPTIN, LVOL
-1,0,0,0                                                             End flow input
1 2  0.25                                                     Iso group, Node, Lambda
3 2  0.25                                                     Iso group, Node, Lambda
5 2  0.25                                                     Iso group, Node, Lambda
6 2  0.25                                                     Iso group, Node, Lambda
7 2  0.25                                                     Iso group, Node, Lambda
8 2  0.25                                                     Iso group, Node, Lambda
9 2  0.25                                                     Iso group, Node, Lambda
10 2 0.25                                                     Iso group, Node, Lambda
11 2 0.25                                                     Iso group, Node, Lambda
12 2 0.25                                                     Iso group, Node, Lambda
-1,0,0,0                                                             End lambda input
0 5.6E-5                                                      LCHG, Control room X/Q
8.56194 9.00000 1 0 0 1      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                         LACTIN, LPTIN, LVOL
-1,0,0,0                                                             End flow input
1 4  0.23                                                     Iso group, Node, Lambda
3 4  0.23                                                     Iso group, Node, Lambda
5 4  0.23                                                     Iso group, Node, Lambda
```

```
6 4  0.23                                                   Iso group, Node, Lambda
7 4  0.23                                                   Iso group, Node, Lambda
8 4  0.23                                                   Iso group, Node, Lambda
9 4  0.23                                                   Iso group, Node, Lambda
10 4 0.23                                                   Iso group, Node, Lambda
11 4 0.23                                                   Iso group, Node, Lambda
12 4 0.23                                                   Iso group, Node, Lambda
-1,0,0,0                                                           End lambda input
0 5.6E-5                                                     LCHG, Control room X/Q
9.00000 11.0000 1 0 0 1     From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                          LACTIN, LPTIN, LVOL
7 1 3.183 0                        From node, To node, Filt flow, Unfilt flow
50 0 79.0 0 79.0 79.0 79.0 79.0 79.0 79.0 79.0 79.0 Filt eff 4 iso grps 1-12
9 1 4.775 0                        From node, To node, Filt flow, Unfilt flow
50 0 77.8 0 77.8 77.8 77.8 77.8 77.8 77.8 77.8 77.8 Filt eff 4 iso grps 1-12
-1,0,0,0                                                           End flow input
-1,0,0,0                                                         End lambda input
0 5.6E-5                                                     LCHG, Control room X/Q
11.0000 11.1219 1 0 0 1     From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                          LACTIN, LPTIN, LVOL
7 1 3.183 0                        From node, To node, Filt flow, Unfilt flow
50 0 42.3 0 42.3 42.3 42.3 42.3 42.3 42.3 42.3 42.3 Filt eff 4 iso grps 1-12
9 1 4.775 0                        From node, To node, Filt flow, Unfilt flow
50 0 43.7 0 43.7 43.7 43.7 43.7 43.7 43.7 43.7 43.7 Filt eff 4 iso grps 1-12
-1,0,0,0                                                           End flow input
-1,0,0,0                                                         End lambda input
0 5.6E-5                                                     LCHG, Control room X/Q
11.1219 14.3442 1 0 0 1     From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                          LACTIN, LPTIN, LVOL
-1,0,0,0                                                           End flow input
1 4  0.2                                                    Iso group, Node, Lambda
3 4  0.2                                                    Iso group, Node, Lambda
5 4  0.2                                                    Iso group, Node, Lambda
6 4  0.2                                                    Iso group, Node, Lambda
7 4  0.2                                                    Iso group, Node, Lambda
8 4  0.2                                                    Iso group, Node, Lambda
9 4  0.2                                                    Iso group, Node, Lambda
10 4 0.2                                                    Iso group, Node, Lambda
11 4 0.2                                                    Iso group, Node, Lambda
12 4 0.2                                                    Iso group, Node, Lambda
-1,0,0,0                                                         End lambda input
0 5.6E-5                                                     LCHG, Control room X/Q
14.3442 19.3092 1 0 0 1     From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                          LACTIN, LPTIN, LVOL
-1,0,0,0                                                           End flow input
1 2  0.16                                                   Iso group, Node, Lambda
3 2  0.16                                                   Iso group, Node, Lambda
5 2  0.16                                                   Iso group, Node, Lambda
6 2  0.16                                                   Iso group, Node, Lambda
7 2  0.16                                                   Iso group, Node, Lambda
8 2  0.16                                                   Iso group, Node, Lambda
9 2  0.16                                                   Iso group, Node, Lambda
10 2 0.16                                                   Iso group, Node, Lambda
11 2 0.16                                                   Iso group, Node, Lambda
12 2 0.16                                                   Iso group, Node, Lambda
-1,0,0,0                                                         End lambda input
0 5.6E-5                                                     LCHG, Control room X/Q
19.3092 21.0000 1 0 0 1     From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                          LACTIN, LPTIN, LVOL
-1,0,0,0                                                           End flow input
1 4  0.19                                                   Iso group, Node, Lambda
3 4  0.19                                                   Iso group, Node, Lambda
5 4  0.19                                                   Iso group, Node, Lambda
6 4  0.19                                                   Iso group, Node, Lambda
7 4  0.19                                                   Iso group, Node, Lambda
8 4  0.19                                                   Iso group, Node, Lambda
9 4  0.19                                                   Iso group, Node, Lambda
                                                            Iso group, Node, Lambda
```

```
10 4 0.19                                                                Iso group, Node, Lambda
11 4 0.19                                                                Iso group, Node, Lambda
12 4 0.19                                                                Iso group, Node, Lambda
-1,0,0,0                                                                      End lambda input
0 5.6E-5                                                                LCHG, Control room X/Q
21.0000 24.0000 1 0 0 1      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                                    LACTIN, LPTIN, LVOL
-1,0,0,0                                                                        End flow input
-1,0,0,0                                                                      End lambda input
0 5.6E-5                                                                LCHG, Control room X/Q
24.0000 24.5000 1 0 0 1      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                                    LACTIN, LPTIN, LVOL
6 1 6.684 0                          From node, To node, Filt flow, Unfilt flow
90 90 90 90 90 90 90 90 90 90 90 90               Filt eff for iso groups 1-12
-1,0,0,0                                                                        End flow input
1 4  0.0                                                                 Iso group, Node, Lambda
3 4  0.0                                                                 Iso group, Node, Lambda
5 4  0.0                                                                 Iso group, Node, Lambda
6 4  0.0                                                                 Iso group, Node, Lambda
7 4  0.0                                                                 Iso group, Node, Lambda
8 4  0.0                                                                 Iso group, Node, Lambda
9 4  0.0                                                                 Iso group, Node, Lambda
10 4 0.0                                                                 Iso group, Node, Lambda
11 4 0.0                                                                 Iso group, Node, Lambda
12 4 0.0                                                                 Iso group, Node, Lambda
-1,0,0,0                                                                      End lambda input
0 4.3E-5                                                                LCHG, Control room X/Q
24.5000 27.7778 1 0 0 1      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                                    LACTIN, LPTIN, LVOL
6 1 0.03342 0                        From node, To node, Filt flow, Unfilt flow
90 90 90 90 90 90 90 90 90 90 90 90               Filt eff for iso groups 1-12
-1,0,0,0                                                                        End flow input
-1,0,0,0                                                                      End lambda input
0 4.3E-5                                                                LCHG, Control room X/Q
27.7778 96.0000 1 0 0 1      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                                    LACTIN, LPTIN, LVOL
-1,0,0,0                                                                        End flow input
1 2  0.0                                                                 Iso group, Node, Lambda
3 2  0.0                                                                 Iso group, Node, Lambda
5 2  0.0                                                                 Iso group, Node, Lambda
6 2  0.0                                                                 Iso group, Node, Lambda
7 2  0.0                                                                 Iso group, Node, Lambda
8 2  0.0                                                                 Iso group, Node, Lambda
9 2  0.0                                                                 Iso group, Node, Lambda
10 2 0.0                                                                 Iso group, Node, Lambda
11 2 0.0                                                                 Iso group, Node, Lambda
12 2 0.0                                                                 Iso group, Node, Lambda
-1,0,0,0                                                                      End lambda input
0 4.3E-5                                                                LCHG, Control room X/Q
96.0000 720.000 1 0 0 1      From time, To time, IPRTAC, IAACT, IPACT, IPRINT
0 0 0                                                                    LACTIN, LPTIN, LVOL
-1,0,0,0                                                                        End flow input
-1,0,0,0                                                                      End lambda input
0 1.5E-5                                                                LCHG, Control room X/Q
```

Appendix C: "LOCADOSE input file"

```
PERRY CR, EAB & LPZ DOSES (BASE) W/ REVISED SOURCE TERM                Problem title
JUN LI                                                                    Originator
PERRY PHASE II                                                          Project name
PSAT 04202H                                                                Project #
PSAT 04202H.13  0                                                        Calc #, Rev
1                                                          First page # of output
     DORDOF                                                              Output flag
 2 5 3 3 1 0 0                 NXQ, NXQT, NBRT, NOCT, NRBRT, EVACDO, OUTFIL
REM REM/HR                                           Dose unit, Dose rate unit
 4.3E-4 0 0 0 0                        SB X/Q during time step 1-5 (NXQT entries)
 3.47E-4 1.75E-4 2.32E-4    SB breath rate during time step 1-3 (NBRT entries)
 4.8E-5 4.8E-5 3.3E-5 1.4E-5 4.1E-6    LPZ X/Q for time step 1-5 (NXQT entries)
 3.47E-4 1.75E-4 2.32E-4   LPZ breath rate during time step 1-3 (NBRT entries)
 2 8 24 96 720                 Time step end points for X/Q values (NXQT entries)
 8 24 720                 Time step end pts for offsite breath rate (NBRT entries)
 1 1                                       Gamma cloud correct fac for SB, LPZ
 1 1 1                                     Occup fac for node 2 (NOCT entries)
 3.47E-4                                Breath rates for node 2 (NRBRT entries)
 1 1 1                                     Occup fac for node 3 (NOCT entries)
 3.47E-4                                Breath rates for node 3 (NRBRT entries)
 1 1 1                                     Occup fac for node 4 (NOCT entries)
 3.47E-4                                Breath rates for node 4 (NRBRT entries)
 1 1 1                                     Occup fac for node 5 (NOCT entries)
 3.47E-4                                Breath rates for node 5 (NRBRT entries)
 1 1 1                                     Occup fac for node 6 (NOCT entries)
 3.47E-4                                Breath rates for node 6 (NRBRT entries)
 1 1 1                                     Occup fac for node 7 (NOCT entries)
 3.47E-4                                Breath rates for node 7 (NRBRT entries)
 1 1 1                                     Occup fac for node 8 (NOCT entries)
 3.47E-4                                Breath rates for node 8 (NRBRT entries)
 1 1 1                                     Occup fac for node 9 (NOCT entries)
 3.47E-4                                Breath rates for node 9 (NRBRT entries)
 1 .6 .4                                   Occup fac for node 0 (NOCT entries)
 3.47E-4                                Breath rates for node 0 (NRBRT entries)
 24 96 720                      Time step end pts for occup fac (NOCT entries)
 720                   Time step end pts for onsite breath rates (NRBRT entries)
 1 1 1 1 1 1 1 1 1                   Gamma cloud correct factor for nodes 2-10
```

Appendix D: "Dose calculation results for the two cases and the confirmation on additional isotopes from Table 1."

This appendix contains three 3.5" high density IBM formatted diskettes.