Diablo Canyon Power Plant Carbon-14 Sampling During 1R17

Presented at the 2012 RETS-REMP Workshop

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Diablo Canyon C-14 Sampling

- 1st round of testing in 2010 during normal operations.
  Results presented at 2010 RETS-REMP
- 2nd round of testing in 2012 during 1R17

Sampling Method

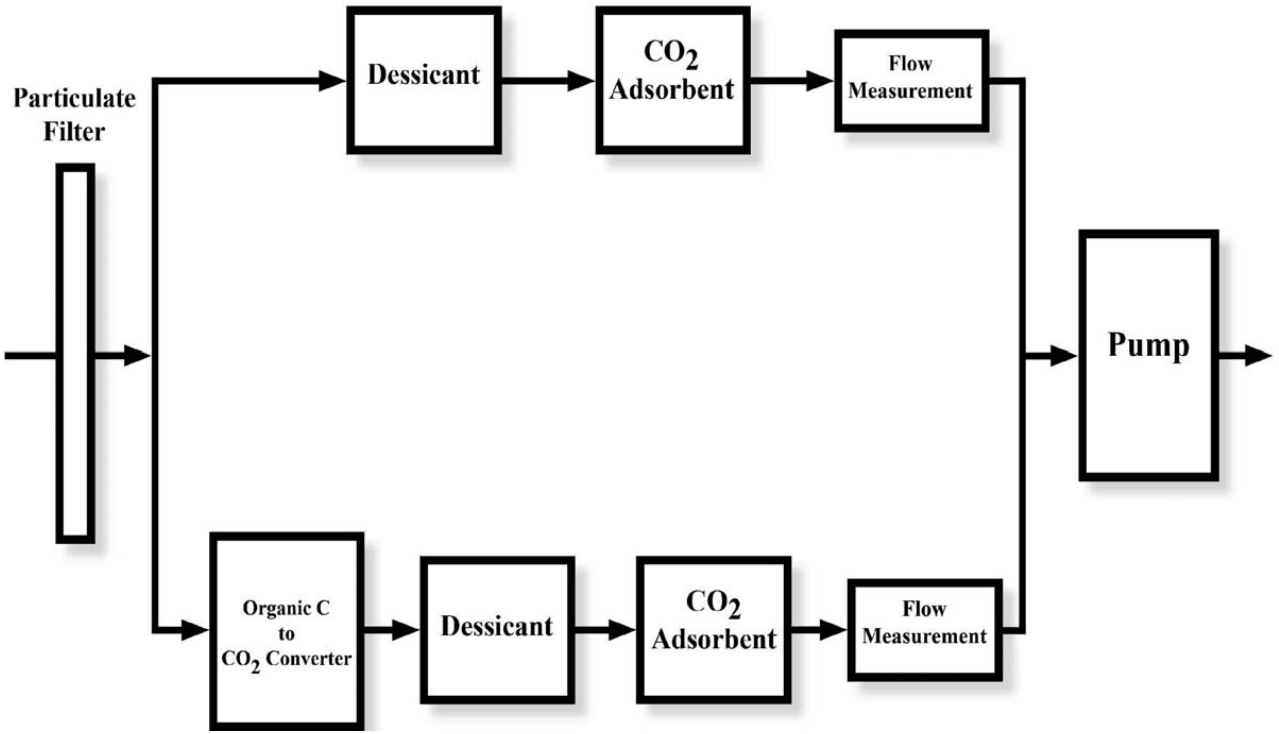
- C-14 sampling method was reviewed by Dr. James Holtzclaw (GEL) at the 2010 RETS-REMP conference:

  “Sample and Analysis Protocol for ^{14}C in Gaseous Effluents”

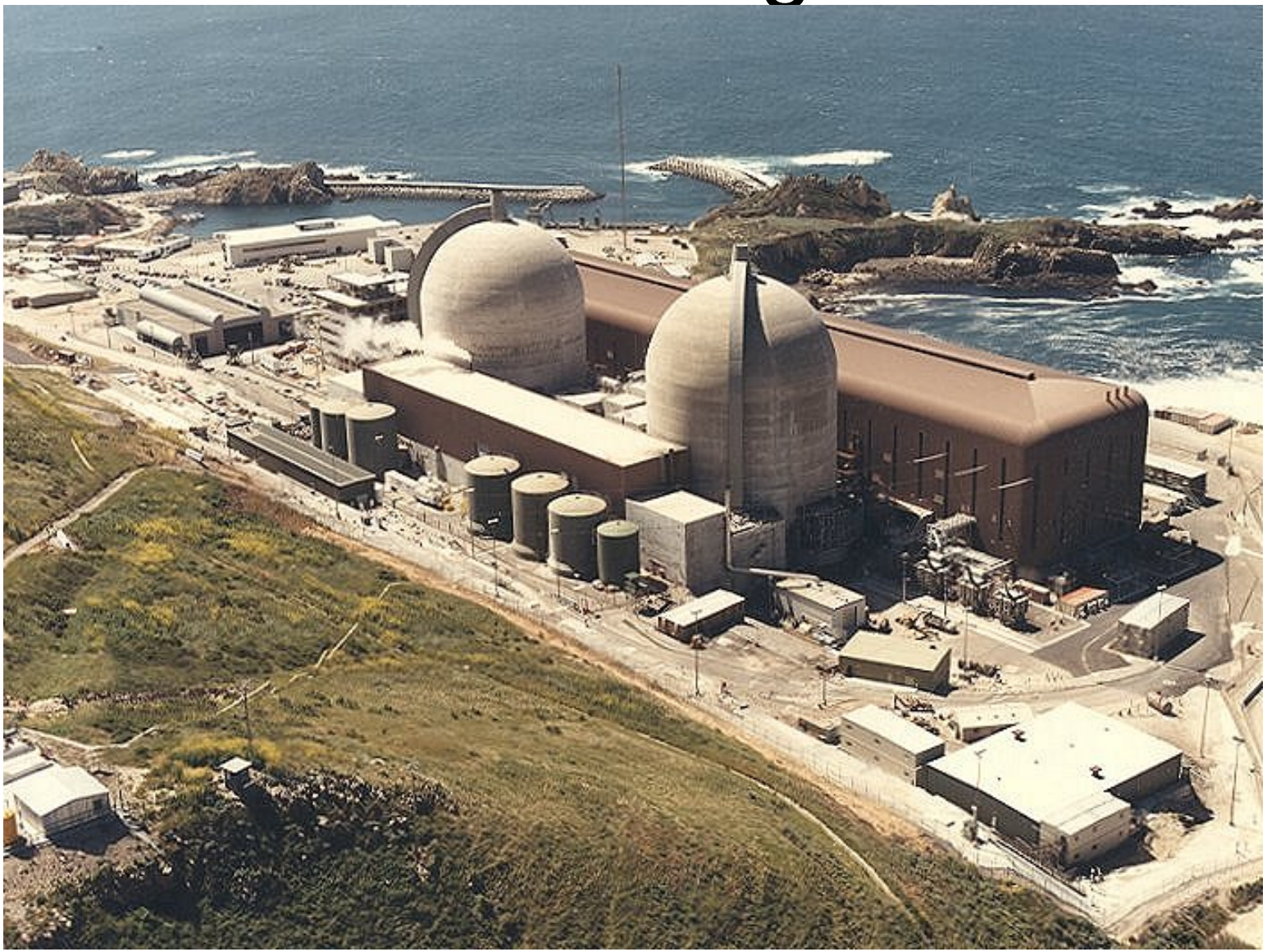
- A PDF of his discussion is available at the RETS-REMP website

Basic Review Of Sampling Apparatus

Image from "Sample and Analysis Protocol for ^{14}C in Gaseous Effluents," Holtzclaw, GEL Group, 2010 RETS-REMP Conference



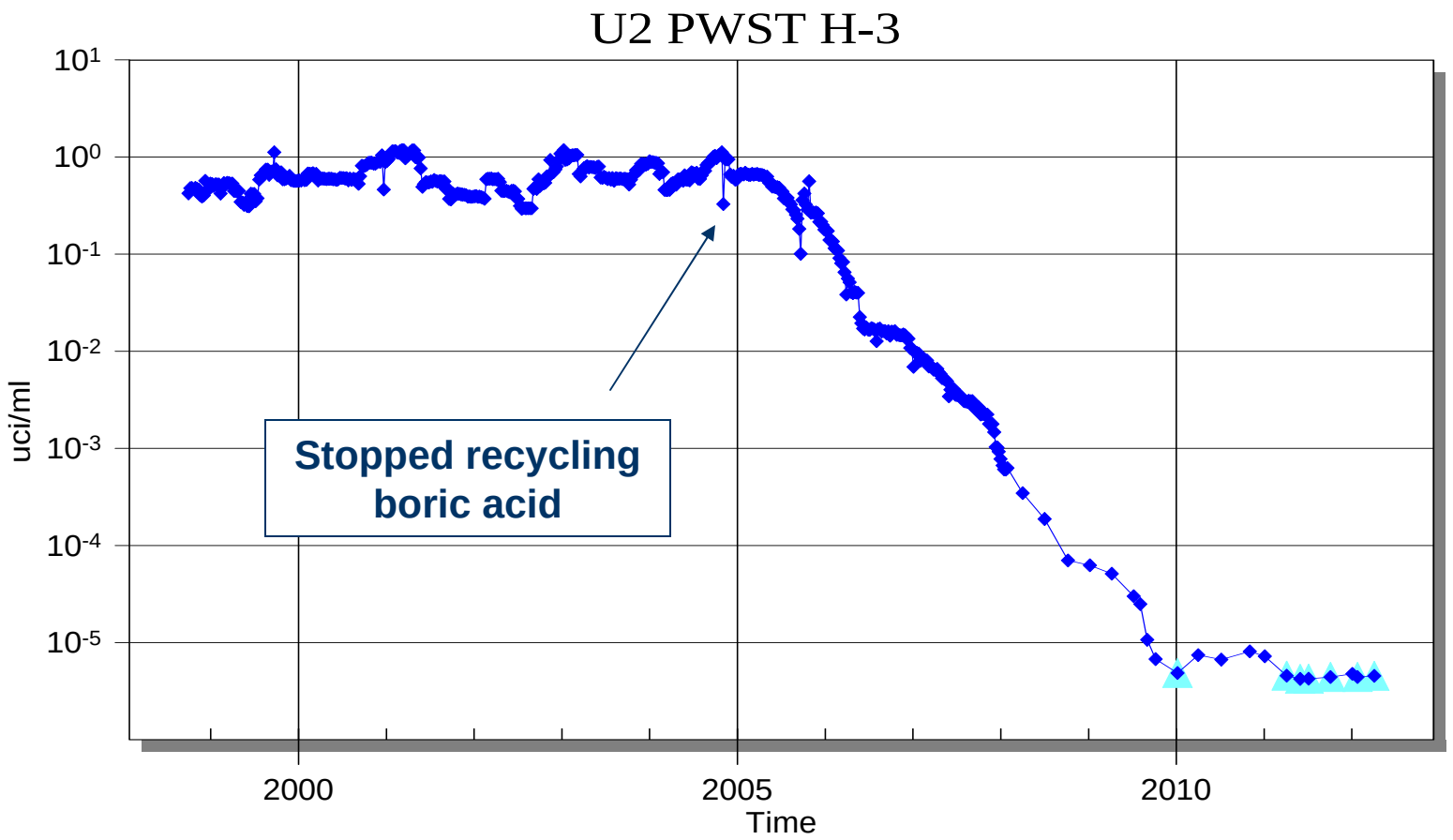
DCPP Looking West



Diablo Canyon Differences From Other Plants

- No VCT continuous purge
- No H_2 recombiner in waste gas system
  - Waste gas mostly nitrogen and hydrogen
  - Control oxygen intrusion
- Designed to recycle boric acid
  - Resulted in high ^{3}H in tanks
  - Resulted in high ^{14}C in tanks
  - Stopped recycling in 2005

Primary Storage Tank H-3 Trend



Unit 1 Systems Sampled During 1R17

- Plant Vent
- Fuel Handling Building Exhaust
- Gas Decay Tanks
  - 1-1
  - 1-2
  - 1-3
- Up-wind control

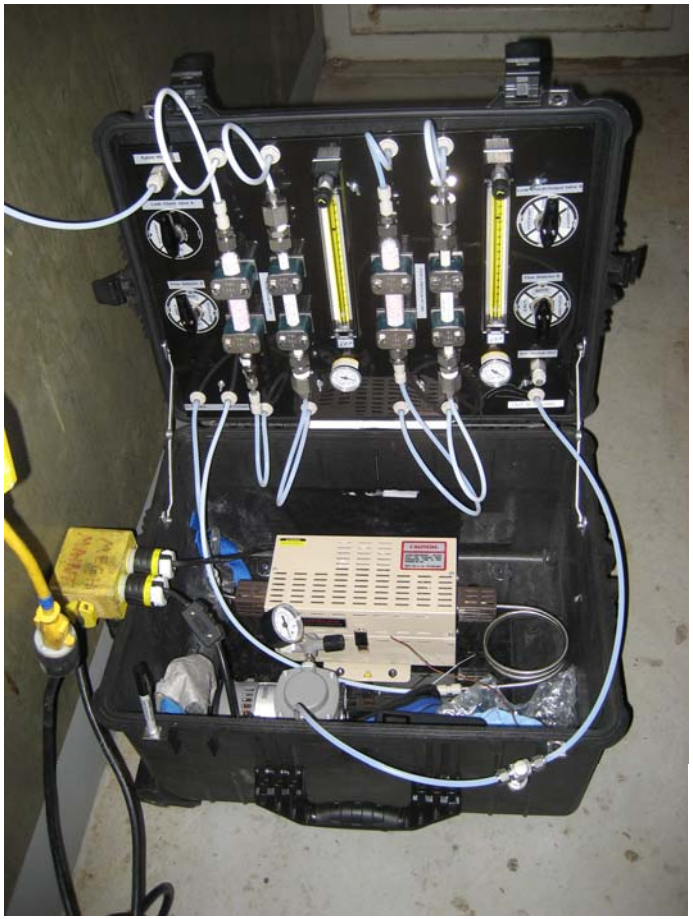
- Why not Containment Atmosphere?
  - Normal sample point (located outside containment) sometimes unavailble during outages
    (have to go into containment to sample)
  - Contamination of sampling apparatus
  - Inconsistent fan flow rates at various levels
  - A lot less convenient
  - Equipment hatch opened/closed

“Control” Sample Upwind of Plant 0.57 pCi/L (100% CO_2)

Fuel Handling Building Exhaust HEPA Filter Room

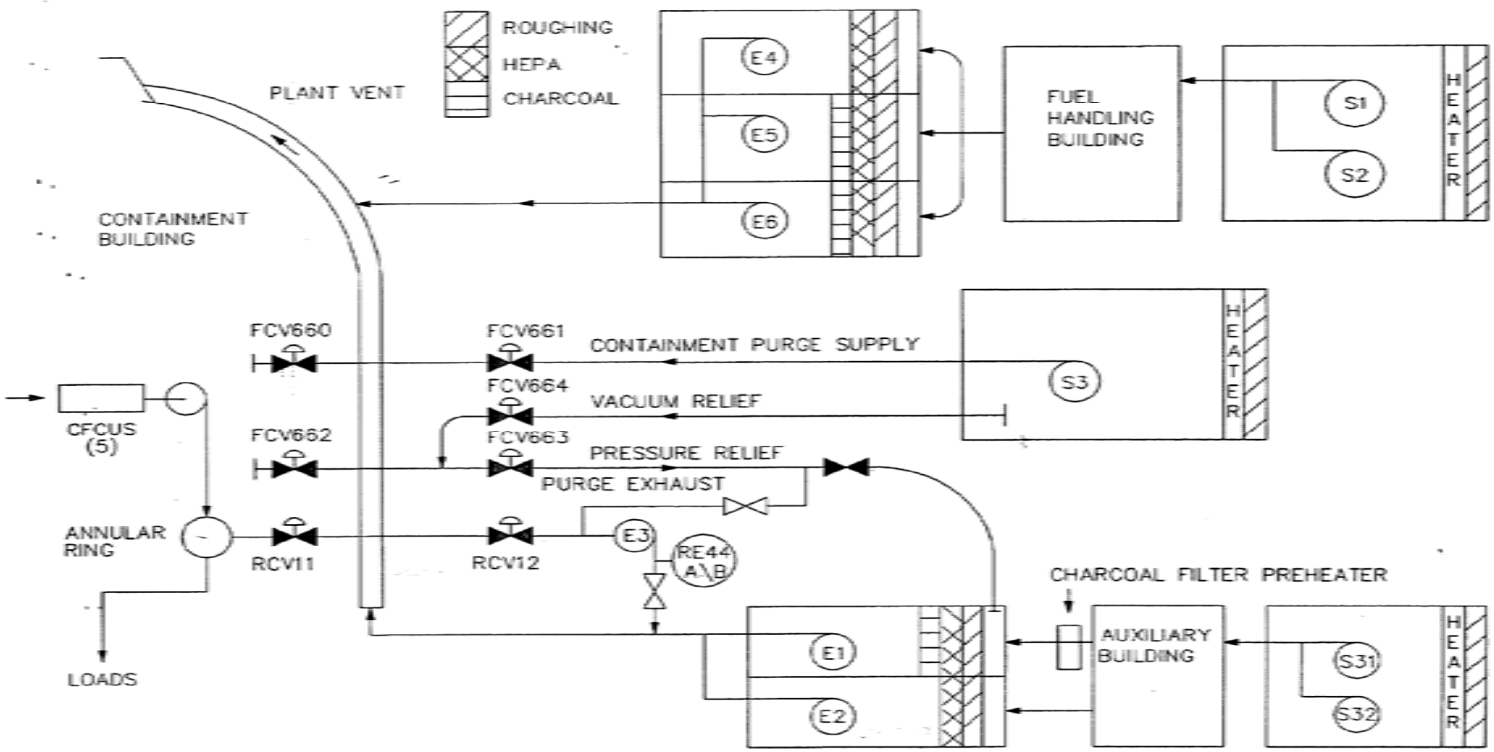
(2010 Sampling Indicated negligible particulate C-14)

Fuel Handling Building Sampler



U1 Plant Vent Sample Skid

DCPP U1 Ventilation Diagram

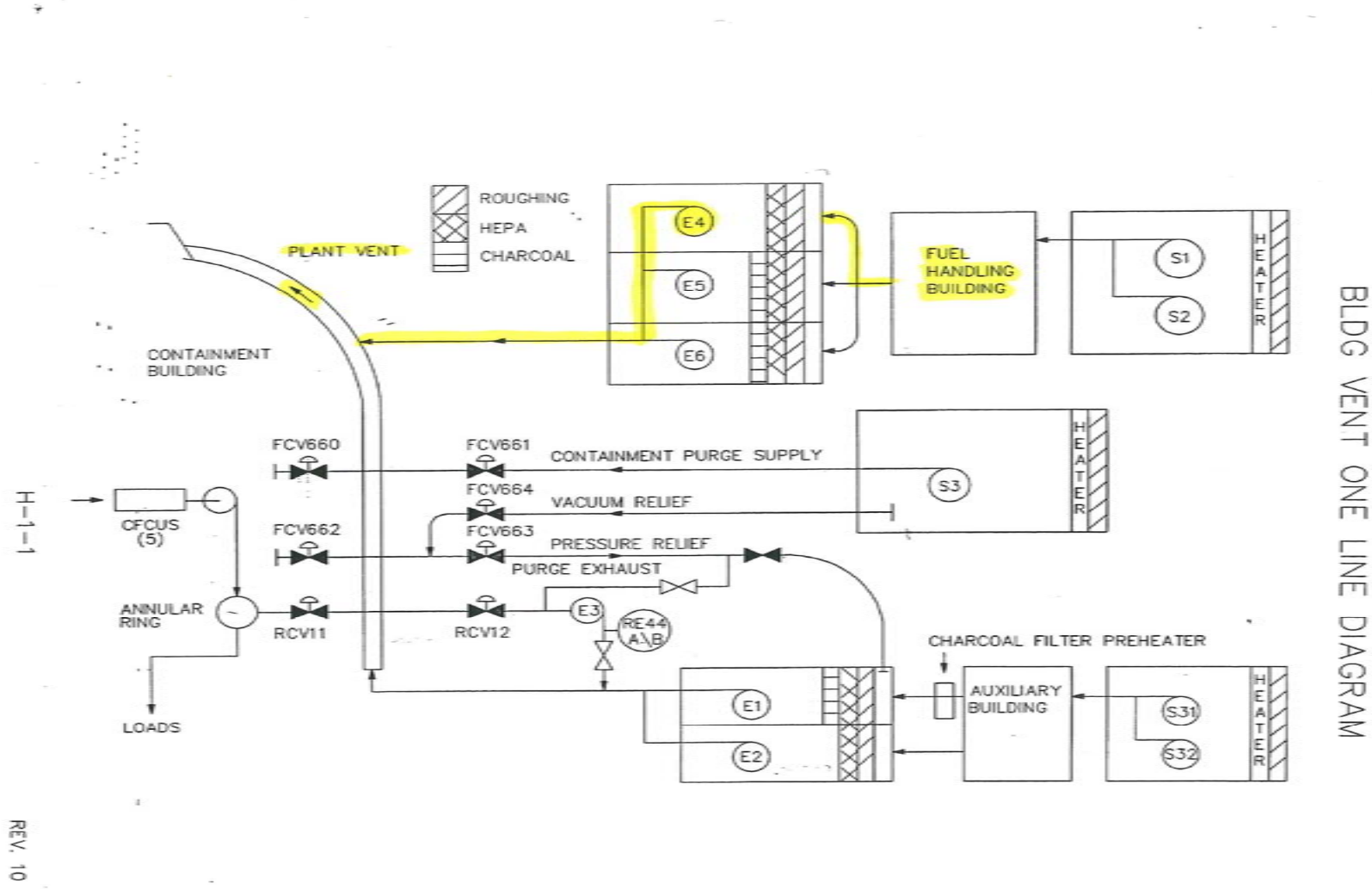


BLDG VENT ONE LINE DIAGRAM

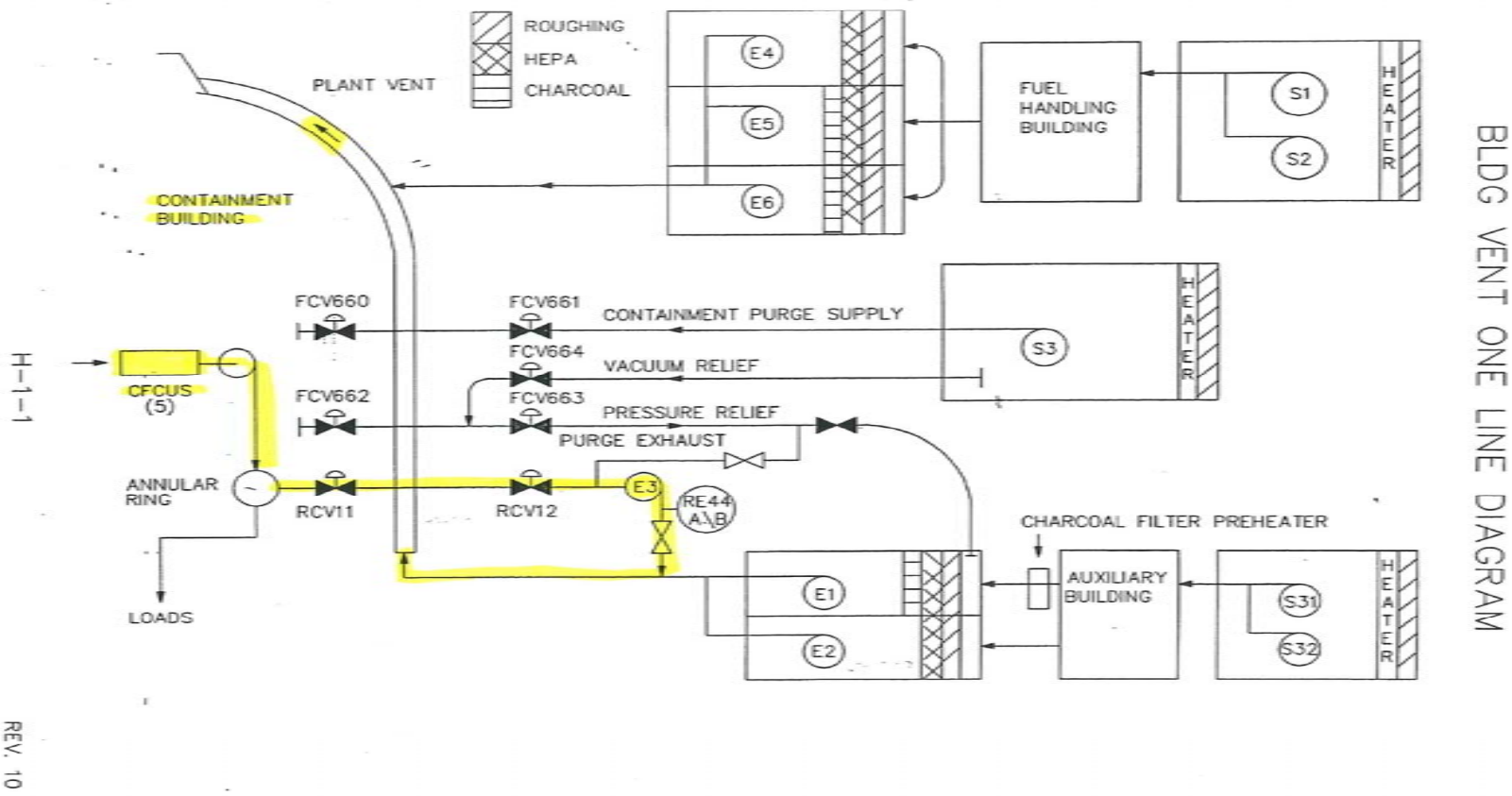
H-1-1

REV. 10

Fuel Handling Building Ventilation

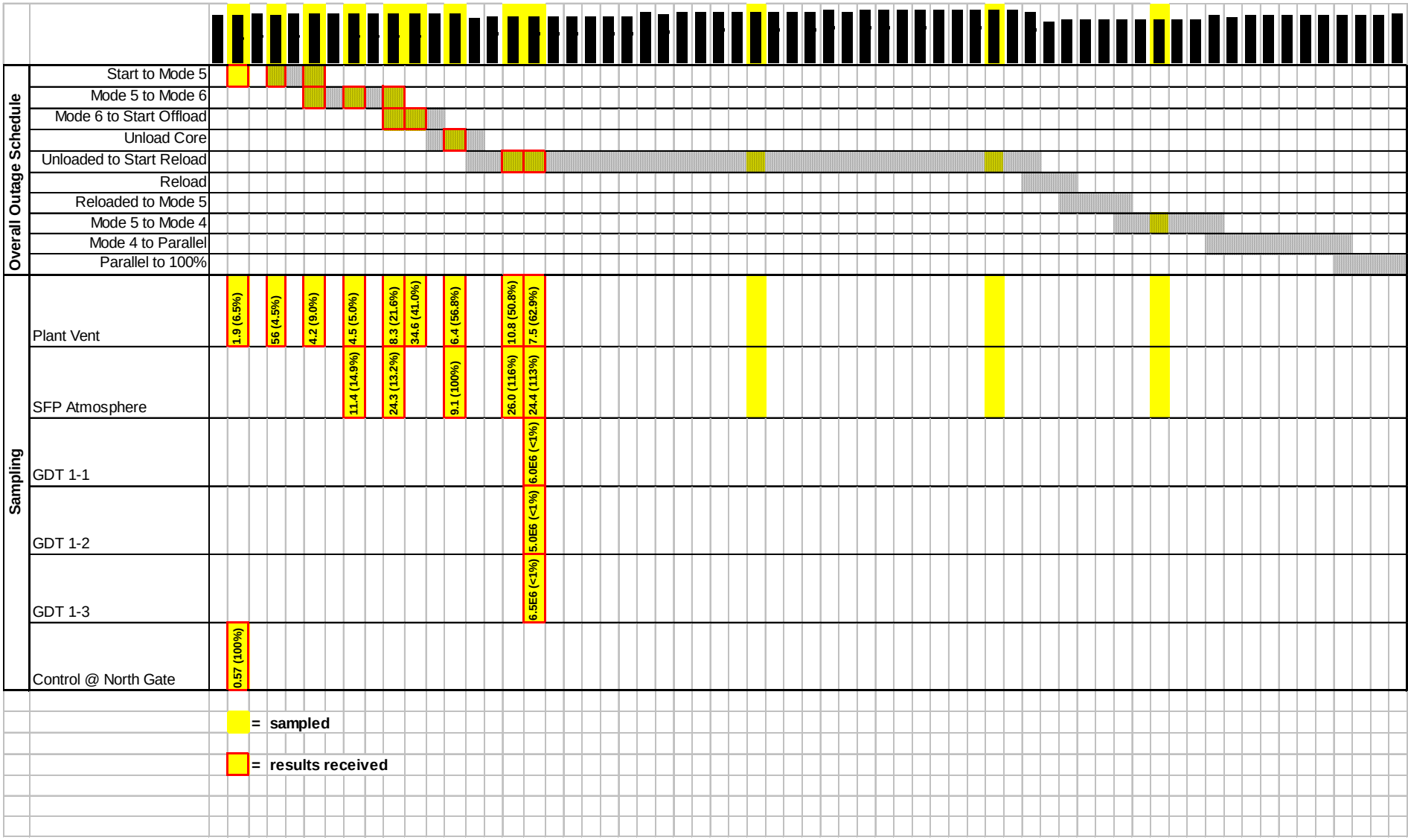


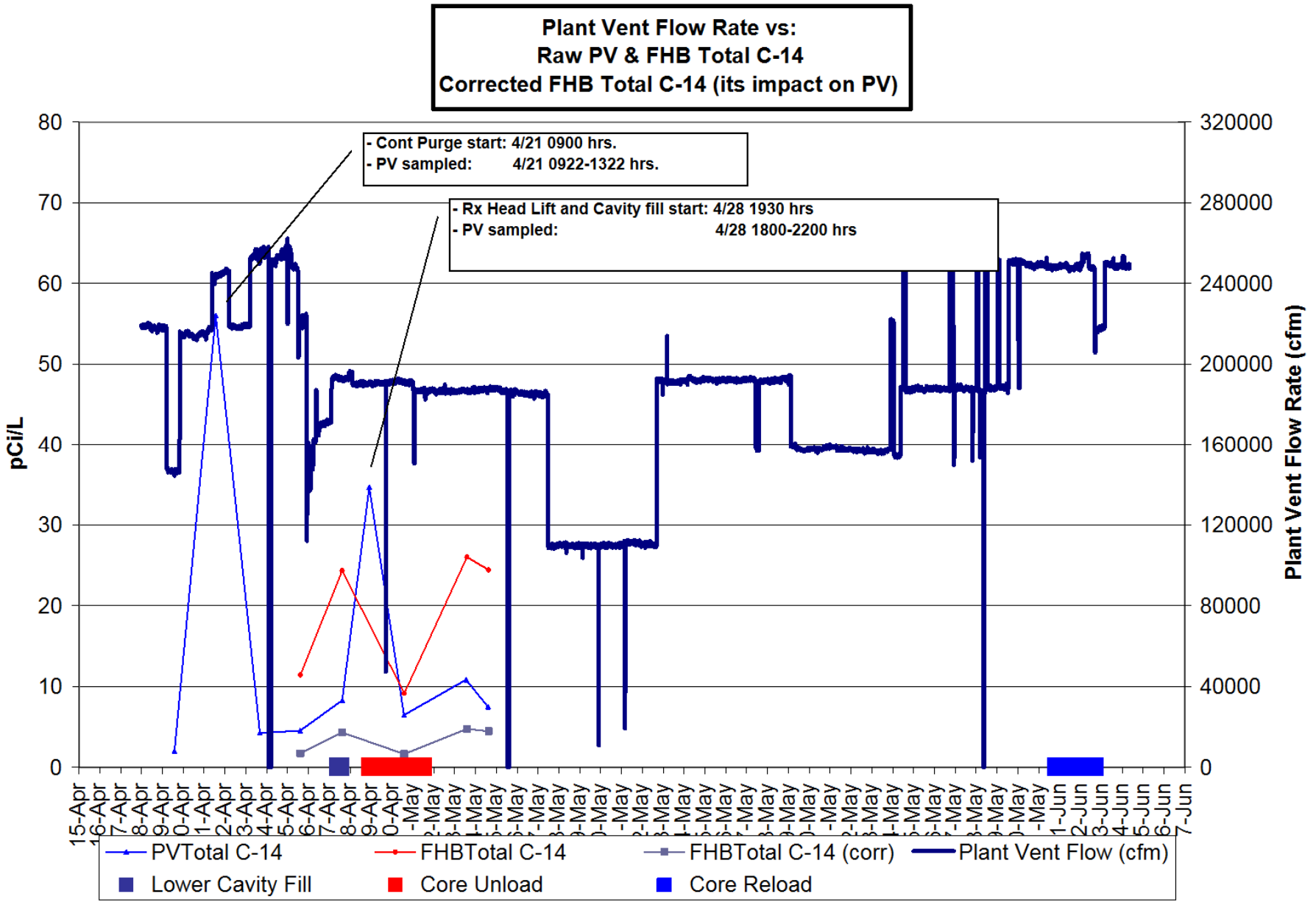
Containment Purge Ventilation



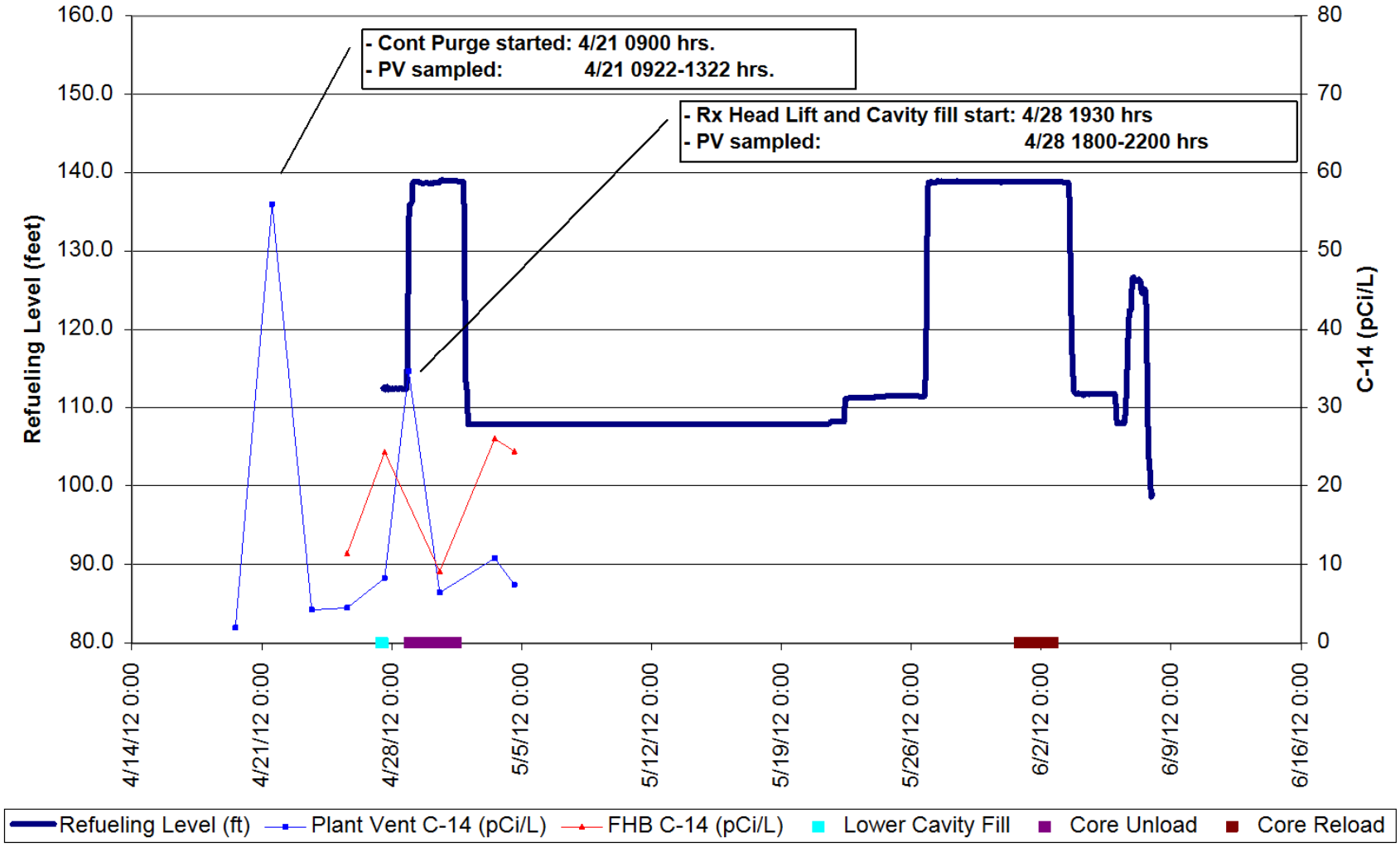
Basic Sampling Routine

- Sample Plant Vent and Fuel Handling Building at the same time.
  - Containment Atmosphere concentration could be calculated (PV – FHB) after correcting for flow rate
- Attempted to capture routine & major evolutions
  - Start of containment purge
  - Initial head lift and Refueling Cavity fill
  - Fuel movement
- Sampled 700 ml/min for 4 hours [168 L; 5.9 ft^3]
  - Balance between large sample, reasonable time period, and overwhelming furnace capability

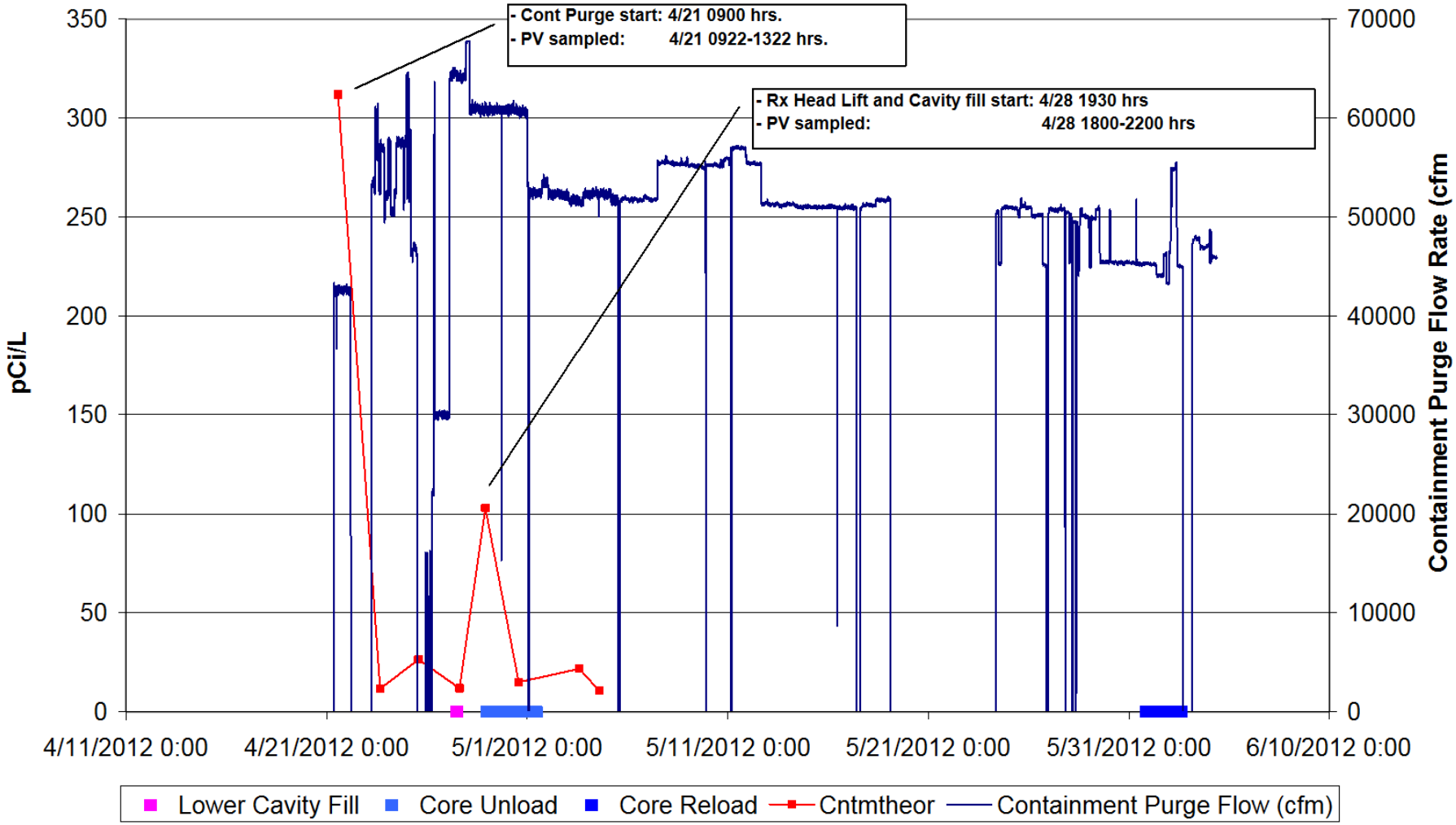

Overall Outage Schedule
Start to Mode 5
Mode 5 to Mode 6
Mode 6 to Start Offload
Unload Core
Unloaded to Start Reload
Reload
Reloaded to Mode 5
Mode 5 to Mode 4
Mode 4 to Parallel
Parallel to 100%
Sampling
Plant Vent
1.9 (6.5%)
56 (4.5%)
4.2 (9.0%)
4.5 (5.0%)
8.3 (21.6%)
34.6 (41.0%)
6.4 (56.8%)
10.8 (50.8%)
7.5 (62.9%)
SFP Atmosphere
11.4 (14.9%)
24.3 (13.2%)
9.1 (100%)
26.0 (116%)
24.4 (113%)
GDT 1-1
6.0E6 (<1%)
GDT 1-2
5.0E6 (<1%)
GDT 1-3
6.5E6 (<1%)
Control @ North Gate
0.57 (100%)
= sampled
= results received


Plant Vent Flow Rate vs:
Raw PV & FHB Total C-14
Corrected FHB Total C-14 (its impact on PV)
- Cont Purge start: 4/21 0900 hrs.
- PV sampled: 4/21 0922-1322 hrs.
- Rx Head Lift and Cavity fill start: 4/28 1930 hrs
- PV sampled: 4/28 1800-2200 hrs
pCi/L
Plant Vent Flow Rate (cfm)
0
10
20
30
40
50
60
70
80
0
40000
80000
120000
160000
200000
240000
280000
320000
15-Apr
16-Apr
17-Apr
18-Apr
19-Apr
20-Apr
21-Apr
22-Apr
23-Apr
24-Apr
25-Apr
26-Apr
27-Apr
28-Apr
29-Apr
30-Apr
1-May
2-May
3-May
4-May
5-May
6-May
7-May
8-May
9-May
10-May
11-May
12-May
13-May
14-May
15-May
16-May
17-May
18-May
19-May
20-May
21-May
22-May
23-May
24-May
25-May
26-May
27-May
28-May
29-May
30-May
31-May
1-Jun
2-Jun
3-Jun
4-Jun
5-Jun
6-Jun
7-Jun
PVTotal C-14
FHBTotal C-14
FHBTotal C-14 (corr)
Plant Vent Flow (cfm)
Lower Cavity Fill
Core Unload
Core Reload

U1 Refueling Cavity Level vs C-14 Results



U1 Containment Atmosphere (calculated)
C-14 During 1R17



Plant Vent C-14 (pCi/L)

(raw results)

Date	Comment	Total	CO_2	$\%CO_2$
4/19/12	Normal Ops (2 days before 1R17)	1.94	0.13	6.44
4/21/12	Containment Purge (1 day pre 1R17)	56.0	2.50	4.46
4/23/12	Mode 5	4.24	0.38	9.01
4/24/12	H_2O_2 Add to RCS (forced oxygenation)	---	---	---
4/25/12	RCS Cleanup	4.49	0.23	5.03
4/27/12	Fill Lower Cavity from LHUT 0-1	8.27	1.79	**21.6**
4/28/12	Rx Head Lift / Cavity Fill	34.6	14.2	**41.0**
4/30/12	36 hrs. into 72 hr. Core Offload	6.43	3.65	**56.8**
5/03/12	Upper cavity drained, Lower cavity filled Rx Head on Vessel	10.8	5.49	**50.8**
5/04/12	Same as 5/03/12	7.46	4.69	**62.9**

Fuel Handling Building C-14 (pCi/L)

(raw results)

Date	Comment	Total	CO_2	$\%CO_2$
4/24/12	H_2O_2 Add to RCS	---	---	---
4/25/12		11.4	1.70	14.9
4/27/12	Fill Lower Cavity (should not affect FHB)	24.3	3.21	13.2
4/30/12	36 hrs into Core Offload	9.13	10.0	**109[1]**
5/03/12	Cavity drained / Head on Vessel	26.0	30.3	**116[1]**
5/04/12	Core fully offloaded to SFP	24.4	27.7	**113[1]**

[1] Essentially 100% CO_2. Attribute >100% to sampling differences/accuracy.

Gas Decay Tank C-14 (pCi/L)
(raw results)

- 5/4/12
  - Forced Oxygenation and Core Offload Complete

GDT	Total	CO_2	$\%CO_2$
1-1	6.03E+06	5.05E+04	0.84
1-2	5.01E+6	3.39E+3	0.07
1-3	6.49E+06	3.57E+04	0.55

Containment Atmosphere C-14 (pCi/L)
(calculated)

- Flow weighted based upon Plant Vent result
- Subtract Fuel Handling Building
- Assume no C-14 from Auxiliary Building

Date	Condition	Total	$\%CO_2$
4/21/12	Containment Purge (1 day pre 1R17)	312	5
4/23/12	Mode 5	12	5
4/25/12	RCS Cleanup	27	<1
4/27/12	Fill lower cavity	12	31
4/28/12	Rx Head Lift / Cavity Fill	103	38
4/30/12	36 hrs. into 72 hr. Core Offload	15	39
5/03/12	Upper cavity drained, Lower cavity filled, Rx Head on Vessel	22	<1[1]
5/04/12	Same as 5/03/12	11	<1[1]

[1] Calculated value may be influenced by high FHB $\%CO_2$

Plant Vent Normal Ops Comparison

(no containment discharge occurring)

Year	Condition	Total C-14 (pCi/L)	%CO_2
2010 – U1	Normal Ops (70% thru cycle)	2.3	8
2010 – U2	Normal Ops (37% thru cycle)	2.1	34[1]
2012 – U1	Normal Ops (100% thru cycle)	1.9	6

[1] Need to sample U2 Plant Vent in 2012 to determine if 34% CO_2 is consistent

Containment Atmosphere Comparison C-14 During Operation (pCi/L)

Date	Total	CO_2	$\%CO_2$
U1 - 4/26/10 (70% thru cycle)	480	40	8
U2 - 4/27/10 (37% thru cycle)	1580	41	3
U1 - 4/21/12 (100% thru cycle)	310	14	5

Gas Decay Tank Comparison

Year	Condition	Total C-14 (pCi/L)	%CO_2
2010 – GDT 2-1	Normal Ops (37% thru cycle)	4.4E+05	0.02
2012 – GDT 1-1 GDT 1-2 GDT 1-3	Outage	6.03E+06 5.01E+6 6.49E+06	0.84 0.07 0.55

Approximate Plant Vent C-14 Ci Discharged per Year per Unit

- Assumptions (per Unit)
  - 52 discharge periods per year
  - 5E+10 L/vent
  - 2.1 pCi/L C-14
  - 1E-12Ci/pCi

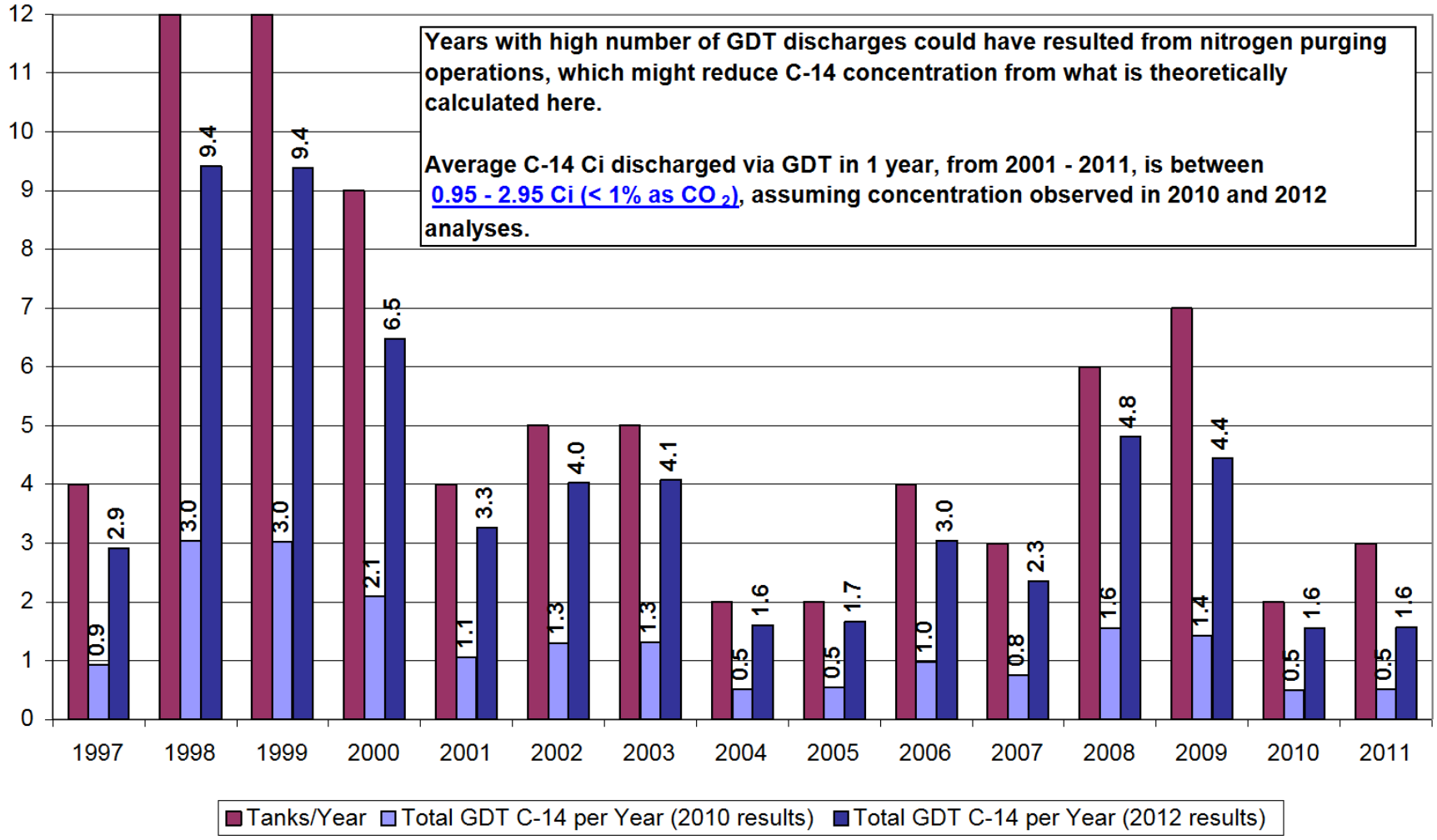
= **5.5 Ci C-14/year/Unit**

Approximate Containment C-14 Ci Discharged per Year per Unit

- Assumptions (per Unit)
  - 52 vents per year
  - 1.7E+06 L/vent
  - 790 pCi/L C-14
  - 1E-12 Ci/pCi

= **0.07 Ci C-14/year/unit**

DCPP GDT Discharges and Theoretical C-14 Ci Discharged per Year
Based upon 2010 / 2012 Sampling



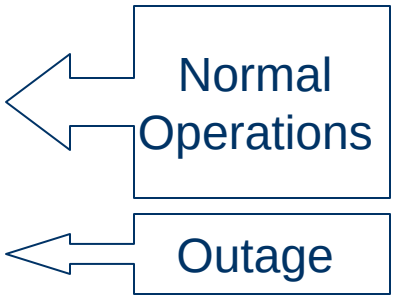
C-14 In DCPP Solid Radwaste (Ci)

Year	Resin	Filters	Total
2000	1.0	0.0	1.0
2001	0.4	3.2	3.6
2002	0.7	3.9	4.6
2003	0.0	4.0	4.0
2004	2.7	3.7	6.4
2005	1.0	0.0	1.0
2006	0.1	1.9	2.0
2007	0.1	2.1	2.3
2008	3.7	2.7	6.4
2009	0.3	2.9	3.2
2010	4.2	1.3	5.5
2011		1.5	
Average/Year =	**1.3**	**2.3**	**3.6**

Single Unit C-14 Mass Balance

(Based upon 10-year average parameters)

- C-14 Generated
  - 12 C-14 Ci/EFPY per Unit
  - ~0.93 Capacity Factor per Unit per year
  - = **11.2 Ci C-14 generated per Unit per year**
- C-14 Removed
  - 5.5 (PV)
  - 0.06 (Cnt)
  - 2.1 (GDT)
  - 1.8 (Solid Radwaste)
  - 1.8 (outage GRW)



  - **= 11.2 Ci C-14 (fairly rough approximation, but pretty close)**

Conclusions

- Analysis results for 2010 and 2012 are fairly consistent for normal operation GRW
- Outage evolutions definitely contribute higher than normal C-14 concentrations for short periods of time.
- The % of C-14 in CO_2 form increases with when systems are opened. H_2O_2 likely plays a role.
- For some plants, removal of C-14 in solid radwaste may be significant.
- A mass balance calculation for C-14 appears to account for a majority of the isotope generated.