C-14 Airborne Environmental Sampling

Christopher Whitener – Duke Energy, McGuire

John Knemeyer and Martin Wright – PG&E, Diablo Canyon

Mike Roberts – SCANA, V.C. Summer

James Westmoreland and Bob Wills - GEL

Jim Key – Key Solutions, Inc.

Presented at the 2013 RETS-REMP Workshop

Westminster, CO / July 24-27, 2013

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C-14 Is Now On The Scene

- Largest dose contributor to member of public as a result of effluent releases.
- Required to monitor environmental impact.
  - 10 CFR (Part 20, Part 50 Appendix A, General Design Criteria 64, Part 50 Appendix I)
- Currently NOT monitoring
  - When Released
  - In Environment
  - In Human Food Chain

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Concern

- No Impetus For Direct Monitoring
  - Guidance does not require the REMP to monitor C-14.
  - Hard to justify any added expense if “not required to do it.”
- Compliance with guidance (or lack of guidance) does not equate to compliance with regulations….

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10 CFR 50, Appendix A General Design Criteria 64

- Means shall be provided for monitoring the reactor containment atmosphere, spaces containing components for recirculation of loss-of-coolant accident fluids, effluent discharge paths, and the plant environs for radioactivity that may be released from normal operations, including anticipated operational occurrences, and from postulated accidents.

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10 CFR 50, Appendix I, Section IV.B – Establish Surveillance and Monitoring Program To

1. Provide Data on ***Measurable*** Levels of Radioactive Material Released in Liquid and Gaseous Effluents
2. Provide Data on ***Measurable*** Levels of Radioactive Material Released in the Environment
3. Identify Changes in *Principal Exposure Pathways*

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C-14 Regulatory Check Off List

Regulation	YES	NO
Data On Measurable Levels in Effluents?		x
Data On Measurable Levels in Environment?		x
Monitor Principal Exposure Pathway?		x

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C-14 and REMP

- Do We Need To Monitor?
  - YES
- How Do We Monitor?
- Where Do We Monitor?
- When Do We Monitor?

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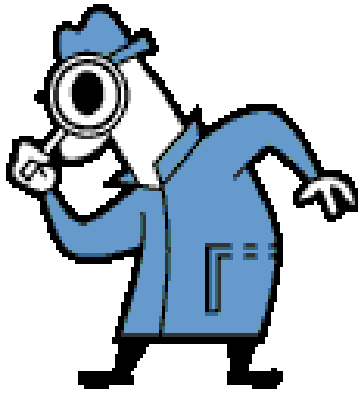
How To Monitor

- C-14 Dose Impact Due To Incorporation Into Human Food Chain via Photosynthesis
  - No dose of significance via liquid pathways.
- Need To Monitor
  - Atmosphere OR
  - Food Stuffs



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Where to Monitor

- In Plant
  - Continuous monitoring for BWRs
  - WGDT and MPV for PWRs
- In Environment
  - In transit
- In Food Product
  - Human Food Chain

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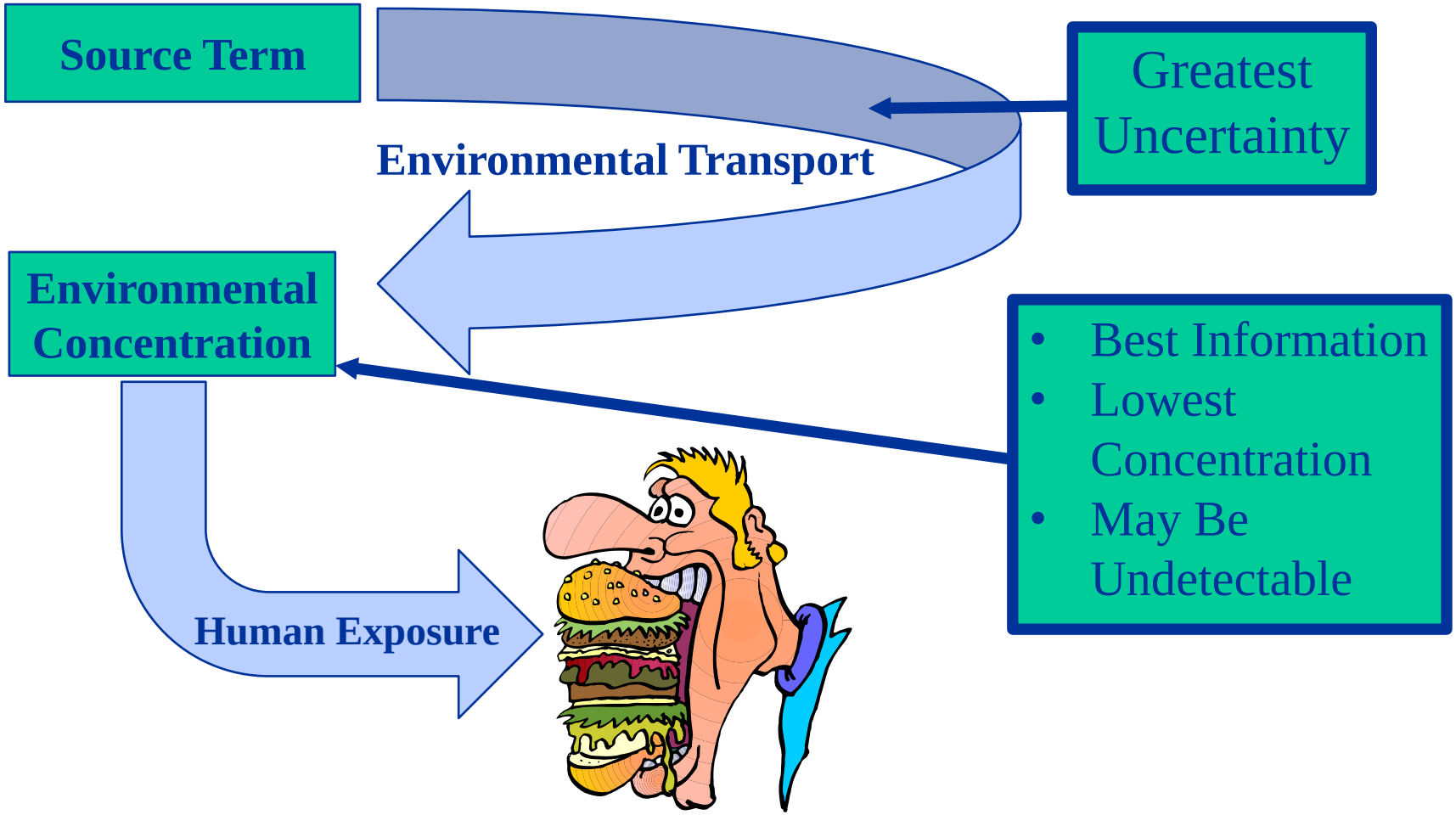
Where to Monitor?



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Monitor As Released

- Advantages
  - Measure at Location of Highest Concentration
  - Better Analytical Data (least uncertainty in source term)
- Disadvantages
  - Must Model Transport to Determine Environmental Concentration
  - Must Model Incorporation Into Human Food Chain
  - Environmental Transport Model Process Introduces Greatest Uncertainty

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Monitor In Transit

- Advantages
  - Careful Selection of Monitoring Location Eliminates Need to Model Environmental Transport
- Disadvantages
  - Lower Concentrations
  - May Be Hard to Quantify or Undetected
  - May Still Be Necessary to Model Incorporation into Food Chain

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Monitor – In Human Food Chain

- Advantages
  - Least Uncertainty
  - Direct Measurement of Consumed Food
- Disadvantages
  - Lowest Concentrations
  - Typically Undetected

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When To Monitor

Monitoring Frequency Should Be Based On:

- Dose Impact
  - High Impact = More Frequent Monitoring
- Variability in Concentration
  - High Variability = Continuous or Frequent Monitoring
- Variability in Release Rates
  - High Variability = Continuous or Frequent Monitoirng

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When To Monitor C-14

- Monitoring Should Be Frequent or Continuous
  - High Dose Impact
  - High Variability in Concentration over Time
  - High Variability in Release Rate over Time

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GEL

Is There Simple Way To Monitor for C-14?

- Air Sample Cartridge
- Same Dimensions as Iodine Charcoal Cartridge
- Same Kind of REMP Air Samplers as in Common Use – Except
  - Flow Rate Must Be Kept Low ~ 1 liter/min
  - Current Pump Flow Rates May Not Be Stable if Throttled Back

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Cartridge Specifications

- Similar configuration as Iodine cartridges
- Uses a proven solid sorbent
- No shipping restrictions

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Cartridge Performance

- >99.9% retention of CO_2
  - flow rates from 0.5 to 2 liters per minute
  - optimal flow 1.0 liter/min for 7 day interval
  - Currently 1 pCi/m^3 typical limit of detection

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Special Considerations

- Precautions
  - Not compatible with Iodine REMP pumps (1 cfm)
  - Higher flow rates can saturate cartridge with CO_2.
- Air collection locations
  - Avoid Areas With Potential for High CO_2
    - Diesel generators produce ~12% CO_2 exhaust (v/v)
    - Colocation with Coal Plants
    - Cartridge Could Saturate

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Advantage of REMP Air Sampling for C-14

- Sampling Performed Weekly.
  - REMP food products sampled (per BTP) Only:
    - At time of harvest.
    - Monthly during growing season.
- Weekly sampling and fast turn around allow for early intervention.
  - Sampling not seasonally dependent.
  - REMP food sampled only portion of year.

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Is This a Practical Approach?

- Are The Achievable C-14 LLDs Useful?
  - At start of study ~ 6 pCi/m^3 for airborne C-14
  - Current LLDs ~ 1 pCi/m^3
- Compare To LLDs in Guidance?
  - No
- Compare To ***Doses*** Associated With LLDs in Guidance!

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NRC Environmental LLDs

Nuclide	Water pCi/l	Airborne pCi/m^3	Fish pCi/Kg	Milk pCi/l	Food pCi/Kg	Sediment pCi/Kg
H-3	2000					
Mn-54	15		130			
Fe-59	30		260			
Co-58	15		130			
Co-60	15		130			
Zn-65	30		260			
Nb-95	15					
Zr-95	15					
I-131	1	0.07		1	60	
Cs-134	15	0.05	130	15	60	150
Cs-137	18	0.06	150	18	80	180
Ba-140	15			15		
La-140	15			15		

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Dose Associated With LLDs Listed in Guidance

- Assumptions from Guidance
  - Constant Presence at LLD Level
    - BTP and Table 14.2.1, NUREGs 1301/1302
  - One Year Exposure Time
    - Section B, RG 1.109
  - Maximum Individual Usage
    - Table E-5, RG 1.109
- What Kind of Doses Do You Get?

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Annual Doses Associated With Environmental LLDs

Nuclide	Water mrem	Airborne mrem	Fish mrem	Milk (Infant) mrem	Leafy Veg mrem	Non-Leafy Veg mrem
H-3	0.21					
Mn-54	0.15		0.04			
Fe-59	0.74		0.19			
Co-58	0.17		0.04			
Co-60	0.44		0.11			
Zn-65	0.62		0.08			
Nb-95	0.23					
Zr-95	0.34					
I-131	4.59	1.14		4.6	*8.9*	*178*
Cs-134	3.48	0.06	0.41	3.5	0.6	*12*
Cs-137	3.63	0.05	0.36	3.6	0.6	*14*
Ba-140	0.85			0.8		
La-140	1.01			0.6		

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C-14 Cartridge LLD Comparison

Nuclide	Milk		Leafy Veg (26 kg/yr – child)		Non-Leafy (546 kg/yr – child)	
	LLD (pCi/kg)	Dose (mrem)	LLD (pCi/kg)	Dose (mrem)	LLD (pCi/kg)	Dose (mrem)
I-131	1	4.59	60	*8.92*	60	*178*
Cs-134	15	3.48	60	0.60	60	*12*
Cs-137	18	3.63	60	0.68	60	*14*
C-14	1 pCi/m^3	0.1	1 pCi/m^3	0.18	6 pCi/m^3	3.7

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Consider Actual Practice

- Leafy and Non-Leafy
  - Sample 1 x Month When Available
- $^{14}CO_2$ Air Cartridge
  - Sample Weekly Year Round
- Worst Case
  - Assume Present at LLD
  - What Does This Mean?

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What If Found Present At LLD?

- Depends on Frequency of Samples
  - Monthly (dose generated in 30 days)
    - I-131: 15 mrem
    - Cs-134: 1 mrem
    - Cs-137: 1 mrem
  - Weekly (dose generated in 7 days)
    - C-14: 0.1 mrem

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What Does All This Prove?

- Question Was: Are The Achievable C-14 LLDs Useful?
  - Yes
  - It's All About Dose
- 1 pCi/m^3 provides the ability to determine the impact of C-14 …
  - At Least As Well (If Not Better) Than the BTP LLDs for Other Radionuclides

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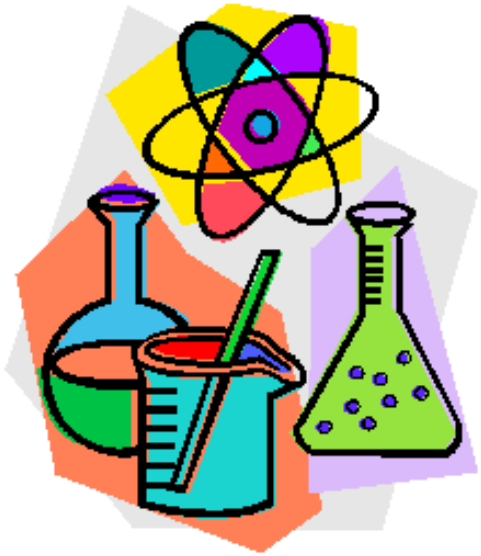
Testing – Who Participated

- **Developed Cartridge and Analytical Method**
  - **GEL**
    - **James Westmoreland and Bob Wills**
- **Field Testing**
  - **McGuire Station:**
    - **Chris Whitener**
  - **VC Summer**
    - **Mike Roberts**
  - **Diablo Canyon:**
    - **John Knemeyer and Marty Wright**
- **Technical Review and Dose Assessment**
  - **Key Solutions**
    - **Jim Key**



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Duke Energy McGuire Station

Investigator: Chris Whitener

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Why Duke Energy Participated

- Determine if our primary effluent isotope and chemical form are detectable in REMP samples.
- Obtain empirical data with C-14 in the environment related to MNS effluent.
- Use actual sampling to reduce dose reported in annual reports.

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Duke Energy

C-14 air sampling tests performed at REMP Sampling Location 120 with highest D/Q.

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Duke Energy

Location 120 Co-located With Duke and State of NC

Open station shows Duke REMP samplers

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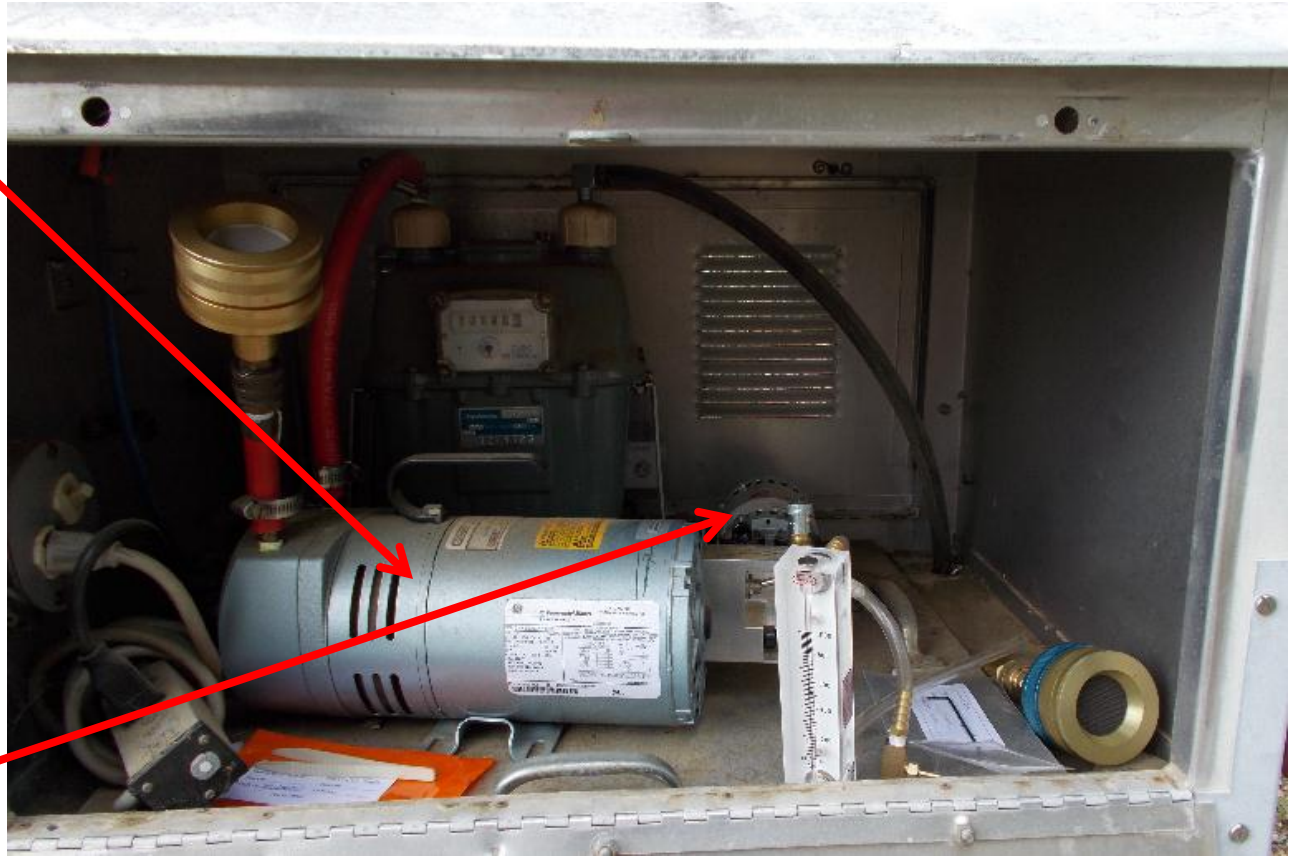
Duke Energy

Other Station Contains State of NC Sampler and C-14 Sampler

State of NC Sample Sump

Small C-14 Sample Pump in Back



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Duke Energy

- Environmental C-14 sampling occurred at McGuire REMP Location 120 from March 06, 2013 through May 2013
- Unit 1 refueling outage occurred during this time (March 16-April 20).

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Key Solutions

Duke Energy Results

Collect Date	Result (pCi/m3)	MDC (pCi/m3)	Flow Rate (cc/min)	Total Volume (liters)
8-Mar-13	-8.17E-01	6.83E-01	800	5702.4
14-Mar-13	-1.04E+00	1.28E+00	600	5535.2
21-Mar-13	-8.16E-01	1.38E+00	600	5042.0
29-Mar-13	-3.45E-01	1.13E+00	600	5896.1
5-Apr-13	-5.47E-01	1.32E+00	600	5406.0
11-Apr-13	-1.55E+00	1.59E+00	600	4570.2
18-Apr-13	-1.02E+00	1.70E+00	600	4108.2
26-Apr-13	3.39E-01	9.30E-01	600	6921.1
3-May-13	3.42E-01	1.38E+00	600	4809.4

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Duke Energy Results Comparison

Duke Energy McGuire 2012 ARERR (Max Dose is 0.875 mrem to Child Bone)

ANNUAL 2012

=== IODINE, H3, AND PARTICULATE DOSE LIMIT ANALYSIS======== Annual 2012========

Period-Limit	Critical Group	Critical Organ	Dose (mrem)	Limit (mrem)	Max % of Limit
Yr - Maximum Organ Dose	CHILD	BONE	8.75E-01	3.00E+01	2.92E+00

Maximum Organ Dose Receptor Location: 1.5 Mile NE
Critical Pathway: Vegetation

Major Isotopic Contributors (5% or greater to total)

Nuclide	Percentage
C-14	1.00E+02

which incorporates the following from the ODCM:

Ratio of the total annual C-14 release time to the total annual time during which photosynthesis occurs. This value is assumed to be 0.31, based on 70% of C-14 releases being from WGDTs, and 30% of C-14 releases being continuous from the unit vents (ref. IAEA Technical Reports Series no. 421, "Management of Waste Containing Tritium and Carbon-14", 2004).

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Duke Energy Results Comparison

- From ODCM Methodology
- MDC of 0.93 pCi/m3
- Annual dose to Child-Bone dose is 0.455 mrem
  - ~50% reduction (compared to 0.875 mrem) in reported offsite dose using this location.

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Diablo Canyon Power Plant (DCPP)

Investigators: John Knemeyer and Marty Wright

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Why DCPP Participated

- To conduct REMP sampling of effluents primary isotope.
- Use actual sampling to reduce dose reported in annual reports.
- A "zero" or "< MDC" are always good data points for possible litigation.

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Diablo Canyon

- C-14 air sampling tests at REMP sampling location 8S1 with highest D/Q.

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Diablo Canyon

- Separate weather housing with temporary power to doghouse.

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DCPP

- Installed new doghouse on temporary concrete bases to prevent wind damage.

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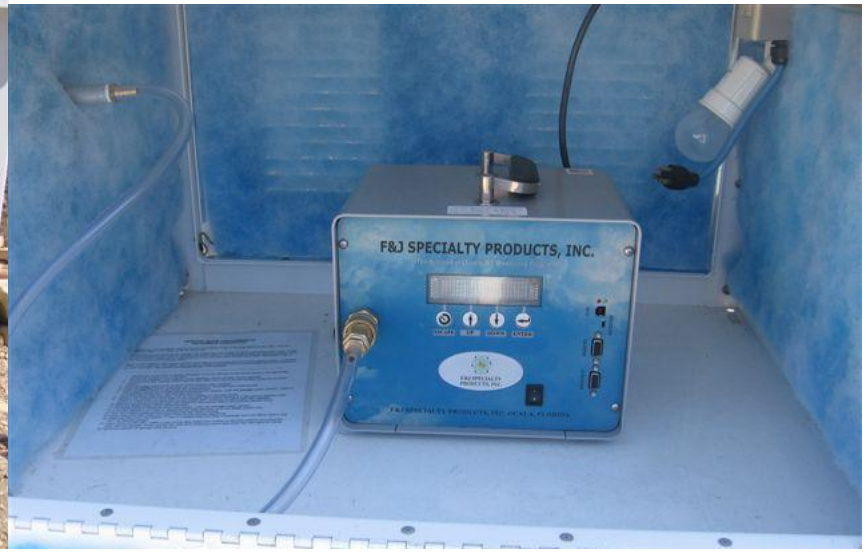
DCPP

- C14 air sampling pump is different model than our normal REMP air samplers



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DCPP

- Needed new air sampling pump procedure and pump calibration protocols for new process

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Diablo Canyon

- Environmental C14 sampling occurred at this location from Oct 2012 thru June 2013.
- Unit 2 refueling outage occurred during this time.
- Two Waste Gas Decay Tanks Released
  - 12-13-12 to 12-14-12
  - 3-26-13 to 3-27-13

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Early DCPP Results

Collect Date	Result (pCi/m3)	MDC (pCi/m3)	Flow rate (cc/min)	Total Volume (liters)
10/20/2012	0.83	5.63	500	5215.7
10/27/2012	1.78	5.27	500	5412.7
11/4/2012	-0.49	5.12	500	5183.3
11/10/2012	1.00	5.18	500	5121.3
11/17/2012	1.49	6.06	500	4557.1
11/24/2012	-2.93	4.83	500	5950.4
12/1/2012	-1.59	9.00	500	5307.5
12/8/2012	-0.17	5.29	500	5148.5
12/15/2012	-1.98	6.37	500	5340.6

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Latest DCPP Results

Collect Date	Result (pCi/m3)	MDC (pCi/m3)	Flow rate (cc/min)	Total Volume (liters)
4/6/2013	0.37	0.85	800	7640.9
4/13/2013	0.40	0.86	800	7754.7
4/20/2013	-0.30	0.97	800	7594.3
4/27/2013	0.10	0.99	800	7596.4
5/4/2013	-0.14	0.91	800	7732.9
5/11/2013	-0.27	0.71	1000	9916.6
5/18/2013	-0.10	0.75	1000	10242.1

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VC Summer Nuclear Station (VCSNS)

Investigator: Mike Roberts

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Why VCSNS Participated

- Validate previous effluent sampling conducted in 2010 and 2011.
- Determine if our primary effluent isotope was detectable in REMP samples.
- Determine if the chemical form of C-14 is changing following release.

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VCSNS

- C-14 air sampling was conducted at Environmental Sites 6 and 7 which are collocated with our Environmental Gardens.

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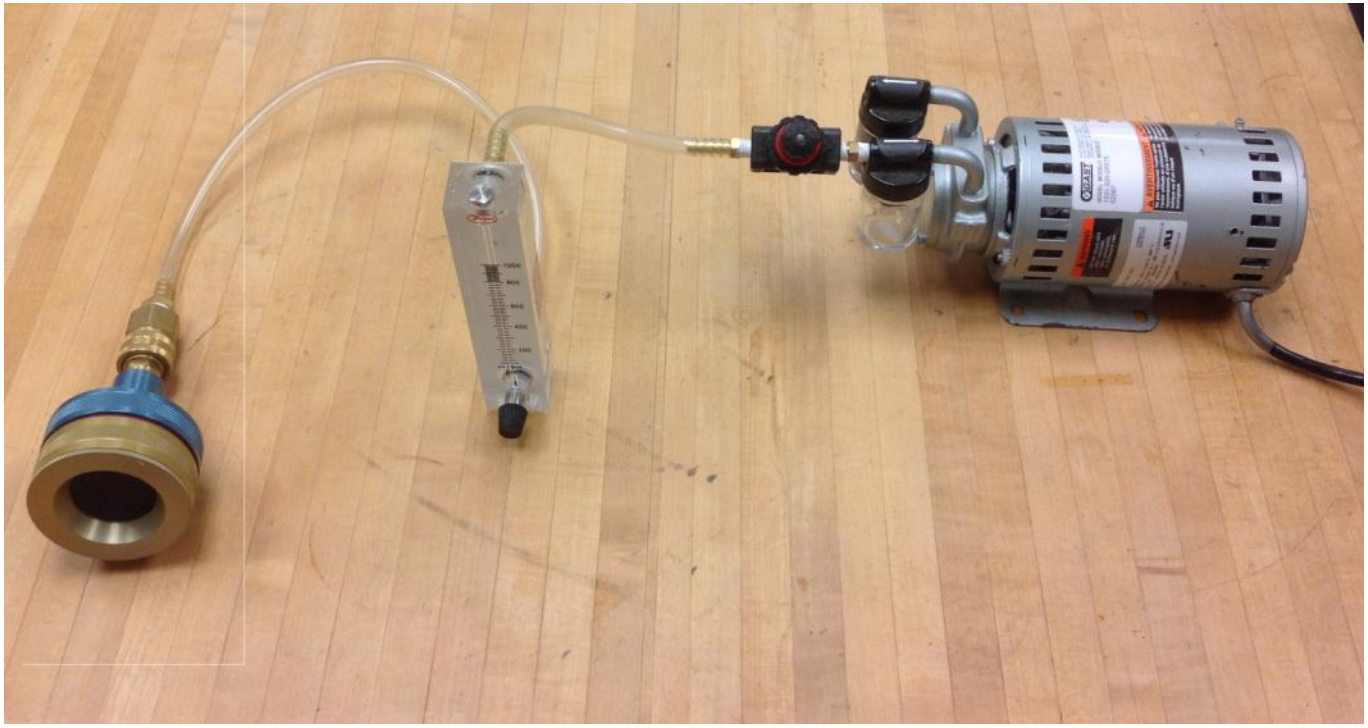
VCSNS

- We had issues with decreasing sample flow rates at one location.



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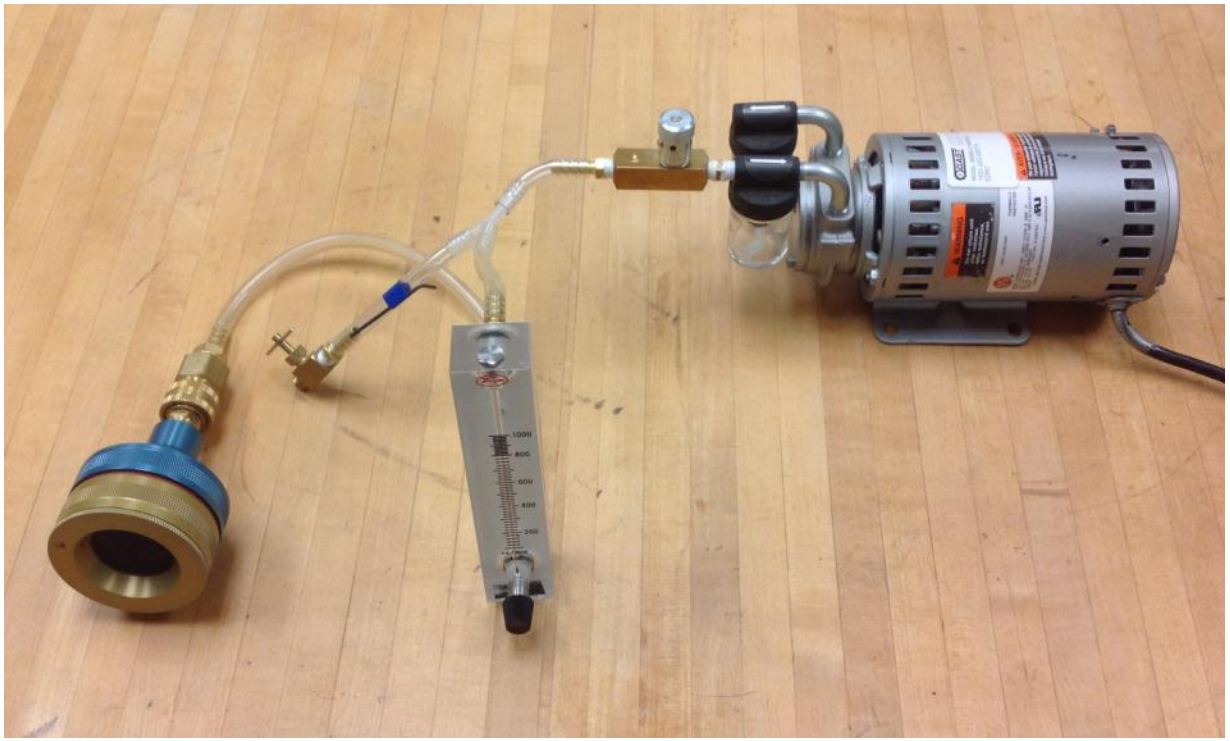
VCSNS

- Modification made to sampler with limited improvement in sample flow, but pump ran much cooler.



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Pump Observations

- Basic field pump without flow compensation
  - Used at Duke and VC Summer
  - Some drops in pressure over 7 day interval
  - Drops of 0.1-0.2 lpm were observed
- Constant flow compensation pump
  - Used at Diablo Canyon
  - No pressure drops observed
  - Available by special order from F&J

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VCSNS

- Environmental sampling occurred at two locations from Jan to March of 2013
- RCP Seal Replacement mini-outage occurred March 23 – April 2.
- No Waste Gas Decay Tank Releases during this period.

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Key Solutions

VCSNS Results Site #6

Date Collected	Result (pCi/m³)	2 Sigma Uncert	MDC	2 Sigma TPU	Initial Flow (cc/min)	Final Flow (cc/min)	Volume Received (L)
11-Jan-13	-2.62E+00	2.58E+00	4.41E+00	2.58E+00	600	300	5742
19-Jan-13	1.46E-01	1.04E+00	1.74E+00	1.04E+00	600	500	5552
26-Jan-13	-6.43E-01	8.39E-01	1.43E+00	8.39E-01	600	800	7053
2-Feb-13	-1.27E+00	1.48E+00	2.52E+00	1.48E+00	600	480	5443
9-Feb-13	-9.68E-01	9.46E-01	1.62E+00	9.46E-01	600	430	5183
16-Feb-13	-1.16E+00	7.97E-01	1.38E+00	7.97E-01	600	500	5726
23-Feb-13	-1.40E+00	1.02E+00	1.75E+00	1.02E+00	600	200	3934
2-Mar-13	-5.60E-01	7.64E-01	1.30E+00	7.64E-01	600	400	4983
9-Mar-13	2.42E-01	7.64E-01	1.27E+00	7.63E-01	600	700	5613
16-Mar-13	-3.73E-01	8.03E-01	1.36E+00	8.03E-01	600	300	4563
23-Mar-13	-3.85E-01	5.75E-01	9.78E-01	5.75E-01	500	800	6552
30-Mar-13	-2.24E-01	5.57E-01	9.43E-01	5.57E-01	800	600	7070

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Key Solutions

VCSNS Results Site #7

Date Collected	Result (pCi/m^3)	2 Sigma Uncert	MDC	2 Sigma TPU	Initial Flow (cc/min)	Final Flow (cc/min)	Volume Received (L)
11-Jan-13	-1.82E+00	1.77E+00	3.03E+00	1.77E+00	600	600	7641
19-Jan-13	-4.74E-01	1.12E+00	1.89E+00	1.12E+00	600	500	5556
26-Jan-13	-4.60E-01	8.62E-01	1.46E+00	8.62E-01	600	800	7052
2-Feb-13	-1.18E+00	1.47E+00	2.49E+00	1.47E+00	600	380	4939
9-Feb-13	-8.98E-01	7.75E-01	1.33E+00	7.74E-01	600	600	6036
16-Feb-13	-4.08E-01	9.71E-01	1.64E+00	9.71E-01	600	400	5188
23-Feb-13	-1.38E+00	1.01E+00	1.74E+00	1.01E+00	600	400	4928
2-Mar-13	-1.22E+00	8.20E-01	1.42E+00	8.19E-01	600	450	5237
9-Mar-13	-4.42E-01	8.00E-01	1.36E+00	8.00E-01	600	500	4749
16-Mar-13	2.33E-01	6.50E-01	1.08E+00	6.50E-01	600	550	5816
23-Mar-13	-5.45E-01	6.72E-01	1.15E+00	6.72E-01	300	800	5539
30-Mar-13	-1.40E-01	4.67E-01	7.88E-01	4.67E-01	800	900	8589

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Customers Experience

- GEL was extremely pro-active and very good to work with.
- C14 cartridges and analysis are very affordable.
  - Can easily add this sampling into existing REMP budget.
- Sample Turnaround Is Quick

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Customer Wish List

- Placement of C-14 filter in series with normal REMP particulate and iodine filters, so only one pump is needed per station.
- Use normal REMP style air sampling pumps to allow routine calibration, maintenance, and pump swap-out.
  - 2.55 cubic meters per hour (42.5 liters/minute)

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Conclusion

- Advantages
  - Cost
    - Cartridge and Analysis
  - Turn Around Time ~ 1 Month
  - Frequency ~ Weekly (Same as Already Doing)
  - Allows for Early Intervention
  - Actual Sampling can Reduce Annual Reported Dose
- Future
  - Continue to Evaluate for REMP Monitoring
  - In-Plant Monitoring (Unit Vent, Containment, WGDT, etc.)
  - Increase Flow Rate

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