Analytical Results of Field Measurements for ^{14}C in Gaseous Effluents From Nuclear Power Plants

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^{14}C Chemical Forms

- Organic carbon
  - Methane
  - Ethane
  - Ethylene
  - Other short chain hydrocarbons
- Inorganic Carbon
  - Carbon dioxide
  - Carbon monoxide
  - Bicarbonate, Carbonate
  - Particulate (?)

Significance – Principal Radionuclide

- Regulatory Guide 1.21, Rev 2
  - a radionuclide is considered a principal radionuclide if it contributes either
    - (1) greater than 1 percent of the 10 CFR Part 50, Appendix I, design ***objective dose*** for all radionuclides in the type of effluent being considered, or
    - (2) ***greater than 1 percent of the activity*** of all radionuclides in the type of effluent being considered.
  - Once principal radionuclides are identified…monitored IAW the sensitivity levels in the ODCM

Significance – Principal Radionuclide (cont'd)

- From RG 1.21 for ^{14}C
  - Because the production of C-14 is expected to be relatively constant at a particular site,
    - if sampling is performed for C-14 (instead of estimating C-14 ...), the sampling frequency may be adjusted to that interval that allows adequate measurement and reporting of effluents.
    - If estimating C-14 based on scaling factors and fission rates, a precise and detailed evaluation of C-14 is not necessary. It is not necessary to calculate uncertainties for C-14 or to include C-14 uncertainty in any subsequent calculation of overall uncertainty.
  - Lack of requirement for uncertainty estimate for calculated ^{14}C *contradicts guidance* from MARLAP as cited in the RG...

Requirements for Sampling Effluents- Liquids

- Sample preservation is a necessity
- Liquid samples
  - Inorganic
    - Alkali– Inorganic converted to HCO_3^- and CO_3^{2-}
    - Reduce temperature
  - Organic carbon requires investigation for proper preservation in liquids

Requirements for Sampling Effluents - Solids

- Solid Samples
  - Carbon chemical form is not certain
  - May be combination of organic, inorganic and particulate
    - Ship immediately after sampling
    - Refrigerate (minimize loss of volatiles)
    - Analyze immediately upon receipt

Requirements for Sampling Effluents- Gases

- Already discussed in first presentation by Jim Holtzclaw.

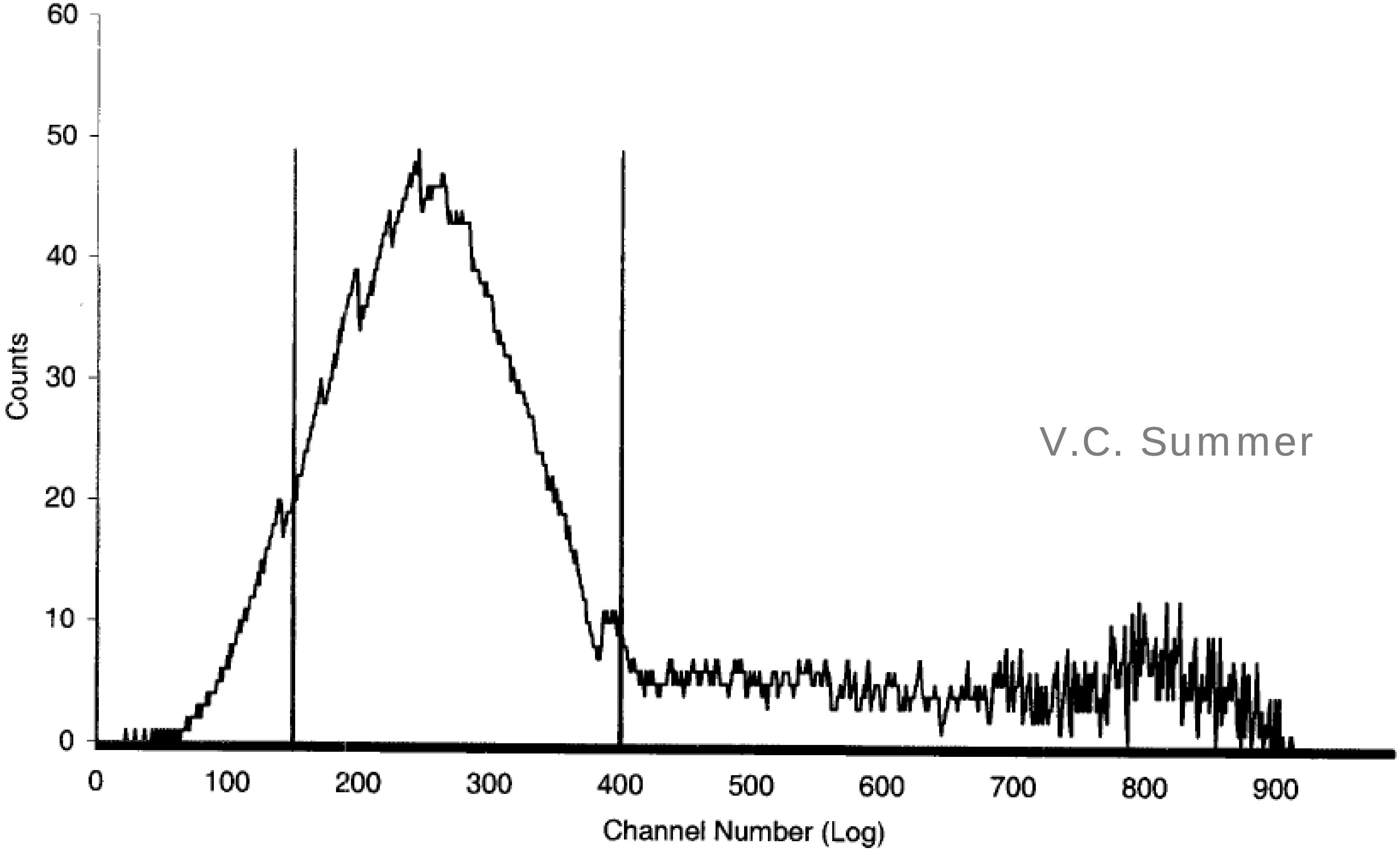
Analytical Capabilities

- Analysis for ^{14}C is done by Liquid Scintillation Counting
  - Sample Preparation – removes radionuclide impurities
  - E_{max} = 156 keV
  - Detection Efficiency = ~95 %

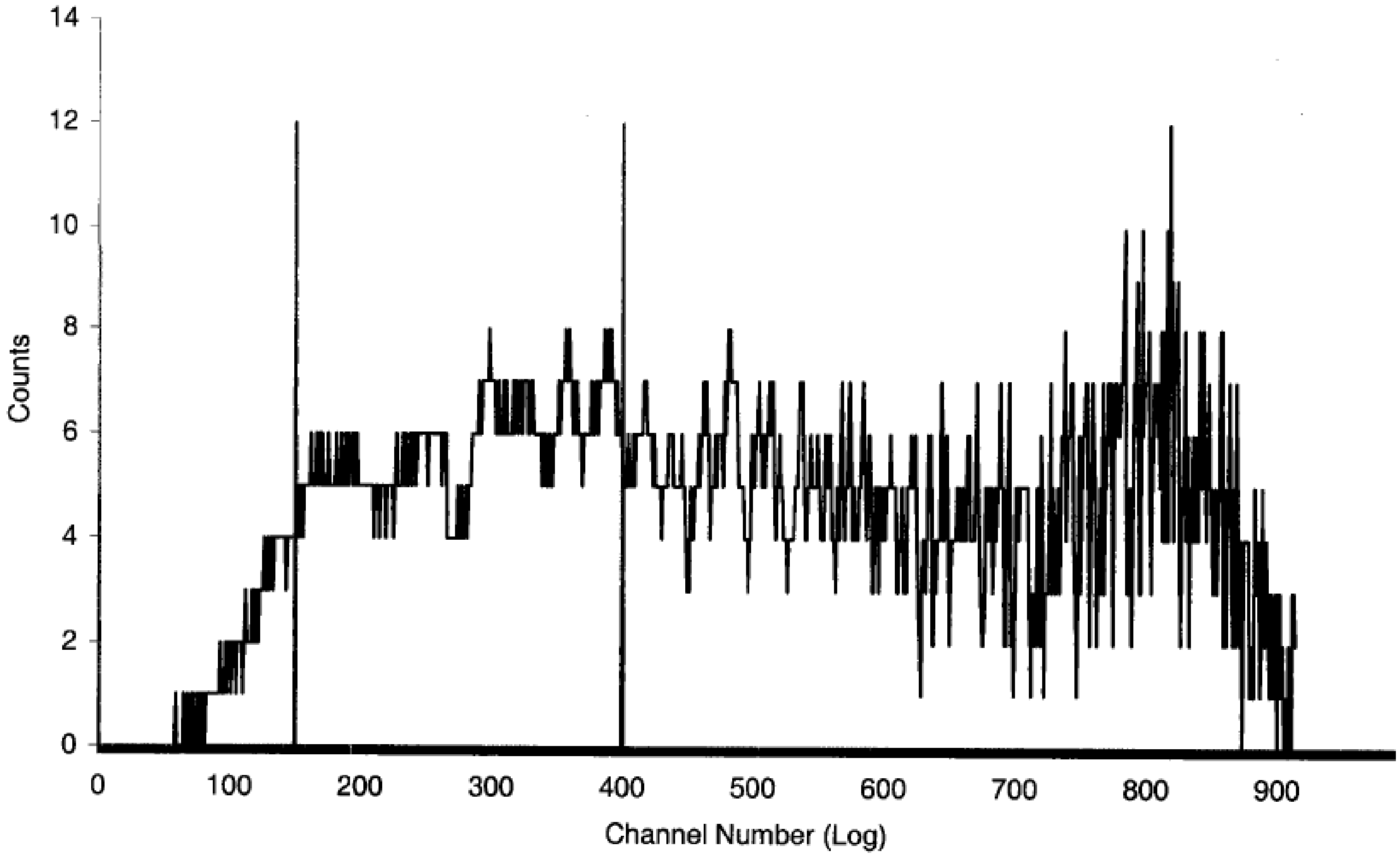
- Analysis can also be done by GPC by precipitating $BaCO_3$.
  - Not as effective at contamination removal
  - Limited ability to assess contamination potential

^{14}C Sample Spectrum Plant Vent

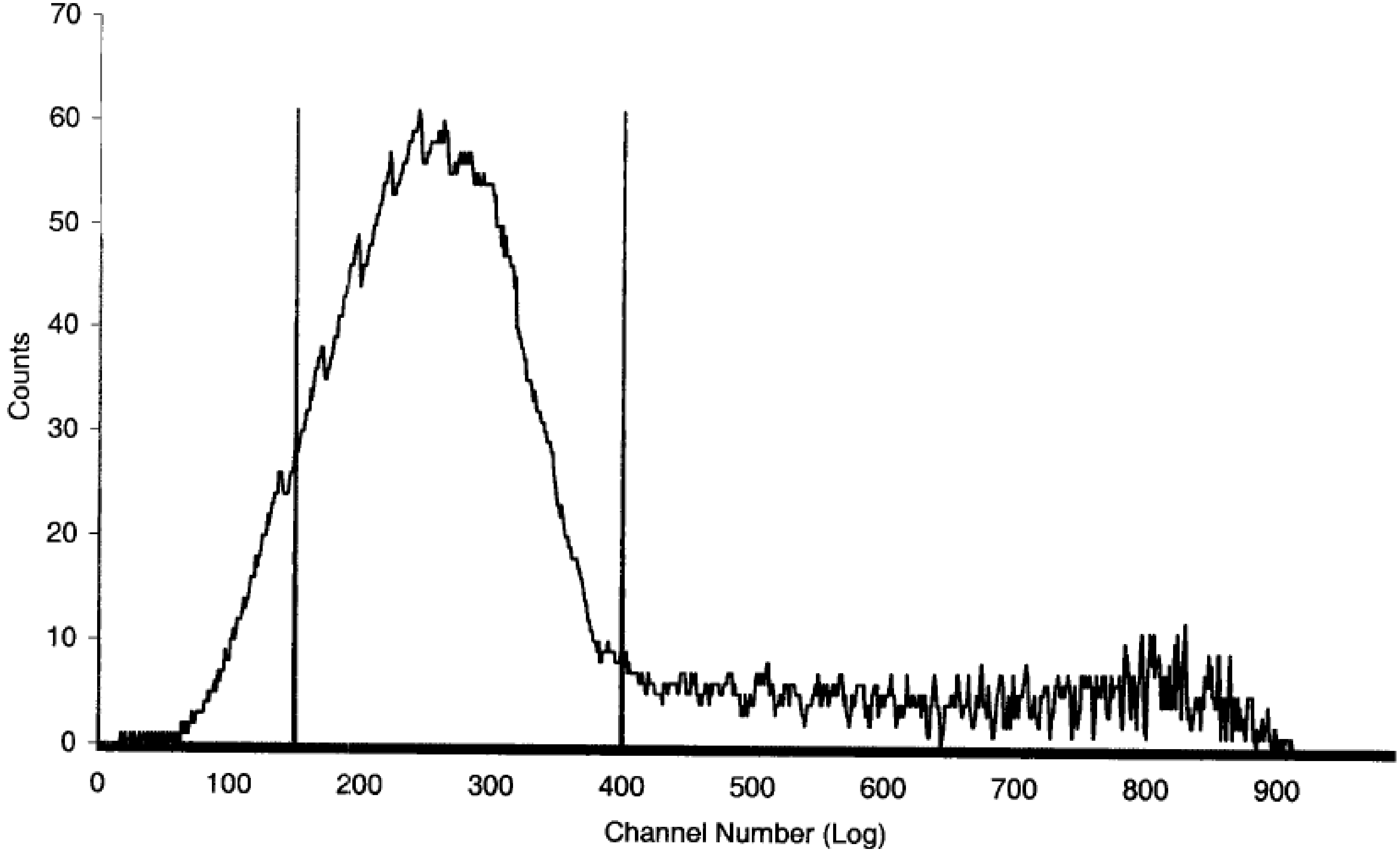
(1.39 pCi/L, 36 L sample, 120 min count time)



^{14}C Method Blank Spectrum



LCS – Ascarite Spiked with ^{14}C Standard



Analytical QC Data

^{14}C in sucrose
Method Blank = -1.33 ± 4.0x10^{-11} µCi/mL

QC	Filter blank, µCi/mL	Ascarite Blank (Total) µCi/mL	Ascarite Blank (Inorganic) µCi/mL	LCS, µCi/mL	LCS-Dup, µCi/mL
Lab	-3 ± 4.1 x10^{-11}	-2.9 ± 7.8 x10^{-11}	3.0 ± 8.8 x10^{-11}	1.11 ± 0.08 x10^{-9}	1.11 ± 0.07 x10^{-9}
Plant	---	1.1 ± 11 x10^{-11}	-7.2 ± 15 x10^{-11}	1.83 ± 0.52 x10^{-9}	1.87 ± 0.50 x10^{-9}

Analytical Results

V.C. Summer

Location	Total, µCi/mL [µCi/ft^3]	% Organic	% Inorganic	Annual flow, ft^3
Plant Vent	$(1.40 \pm 0.18)\times10^{-9}$ $[(3.98 \pm 0.51)\times10^{-5}]$	99.3	0.7	1.1×10^{11}
Waste Gas #1	$(4.86 \pm 0.84)\times10^{-3}$ $[(1.38 \pm 0.24)\times10^{2}]$	91.9	8.1	775 to 3192 for both
Waste Gas #3	$(5.62 \pm 0.14)\times10^{-3}$ $[(1.60 \pm 0.04)\times10^{2}]$	93.1	6.9	↓

Uncertainty at 2 sigma

Analytical Results

Location	Total, µCi/mL [µCi/ft^3]	% Organic	% Inorganic	Annual flow, ft^3
Plant Vent	$(-6.34 \pm 7.11)x10^{-11}$ $[(-1.8 \pm 2.0)x10^{-9}]$	---	---	
Waste Gas B	$(1.02 \pm 0.06)x10^{-2}$ $[(2.88 \pm 0.17)x10^{2}]$	84.6	15.8	

Uncertainty at 2 sigma

Analytical Results

Diablo

Sample Point	**Total, µCi / mL**	**CO_2 , µCi / mL**	**%**	**Organic, µCi / mL**	**%**
U1-CTMT	$5.2x10^{-7}$	$3.96x10^{-8}$	7.6	$4.8x10^{-7}$	92.4
U2-CTMT	$1.62x10^{-6}$	$4.12x10^{-8}$	2.5	$1.58x10^{-6}$	97.5
U1- PV	$2.46x10^{-9}$	$1.75x10^{-10}$	7	$2.29x10^{-9}$	93
U2 – PV	$3.35x10^{-9}$	$1.31x10^{-9}$	39	$2.05x10^{-9}$	61
U2-WG-Dis	$4.45x10^{-4}$	$4.7x10^{-6}$	1	$4.40x10^{-4}$	99
WGDT	$1.88x10^{-3}$	$2.06x10^{-5}$	1	$1.86x10^{-3}$	99

Uncertainty at 2 sigma

Sample Locations

- Plant Vent
- Containment
- Waste Gas Decay Tanks
- Waste gas header during discharge
- FSB Vent header
- Auxiliary Building vent header
- RCS
- Waste Liquid

What Happens to ^{14}C Concentration if a Fuel Defect Develops?

- ^{14}C formed by activation of oxygen in the UO_2 (3.5 Ci per year - 1,000 MWe)
- Fuel also has some nitride (15 Ci per year - 1,000 MWe)
- Nitrogen in Fuel clad (30 Ci per year - 1,000 MWe)
  - Release to RCS is based on number and type of defects, escape capacity from cladding
- SFP?

Reference: "CARBON-14 PRODUCTION IN NUCLEAR REACTORS", W. Davis, ORNL/NUREG/TM-12 (1977)

Use of Marker Gamma Emitters

- Can Gamma ray emitters be used as a marker for estimating ^{14}C activity?
  - Radionuclide would need to:
    - Be directly related to neutron flux
    - have relatively constant concentration over the fuel cycle
    - be measured with sufficient accuracy to identify changes based on the ratio
    - Measured during normal and fuel defect cycles

Use of Marker Gamma Emitters

- Candidates
  - ^{16}N
  - ^{133}Xe (RCS)
  - ^{41}Ar (containment)
  - Others?