US Field Trial of CZT Detector Technology for Source Term Monitoring and ALARA

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Presented by:
Dr. Frederic J. Mis

Presentation Outline

- What is CZT?
  - Development History for Nuclear Power Plants (NPP)
- Why Use It?
- How to Use it?
  - Brief Overview of CZT Operation
- First US Field Trial Results
- Future

What is CZT?

Cadmium Zinc Telluride (CZT) Gamma Spectroscopy

- New Gamma Spectroscopy Technology
  - Identifies Isotopes in Energies between 100 keV to 1800 keV
  - Isotopes ID for NPP:
    - Co-58, Co-60, Ag-110m, Cs-137, Sb-124 &122, Cr-51, Fe-59, Mn-54, Zn-65
- Small and Lightweight
- Portable
- Cost Effective
- No Cooling Required
- Done during Refueling Outages
  - 2 days of measurement
  - 3 days of analysis (normally)

Électricité de France (EDF) Leadership

- Developed by Commissariat à l'énergie atomique (CEA)
  - Licensed to Canberra

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- EdF Plant Aging Program
  - Deployed to all 58 EdF Nuclear Plants
  - Standard Protocols Measurements ALL RFOs

- Purpose:
  - Source Term Changes
  - EPD's and Instrument Cal
  - ALARA
  - Effective Dose Equivalent
  - Component Degradation
  - Dose Reduction Actions

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EDF Protocol and Data Sharing

- Standardized EDF Protocol
  - Being Implemented in US NPP
  - Exelon, AEP, FENOC, Dominion Taking US Leadership.
    - Exelon committed to the process over the next 4 years as an assessment tool for determination of source term reduction success. Others above following suit.
  - 8 Specific Locations
    - CVCS Pipe In/Out; Regen HX; SG HL/CL Pipe;
    - US Plants Augmented: RCP Flange; CVCS HX, SI Check Valves
- IAEA/ISOE Data Base
  - NATC MOU for Data Upload - EdF and US NPP
  - Permits Comparison of Plant Performance
    - **Different Source Term reduction strategies and their impacts are measured promptly!**

CZT Device and Analysis

- Major Components
  - 3 Probes: 20 mm^3, 60 mm^3 500 mm^3
  - Collimator
  - Inspector 2000: Real Time Acquisition and Storage of Gamma Energy Spectrum

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CZT Device and Analysis

- CZT Output:
  - Gamma Energy Emission
  - Isotopic Identification
- Needs
    - Pipewall thickness and diameter
    - Insulation material, if any
    - Station ion chamber results
- Results from MicroShield output,
  - Deposited activity in μCi/cm2
  - Dose contributions from each radioisotope
    - *This results in an understanding of the impact of cycle chemistry and shutdown crud contribution!*

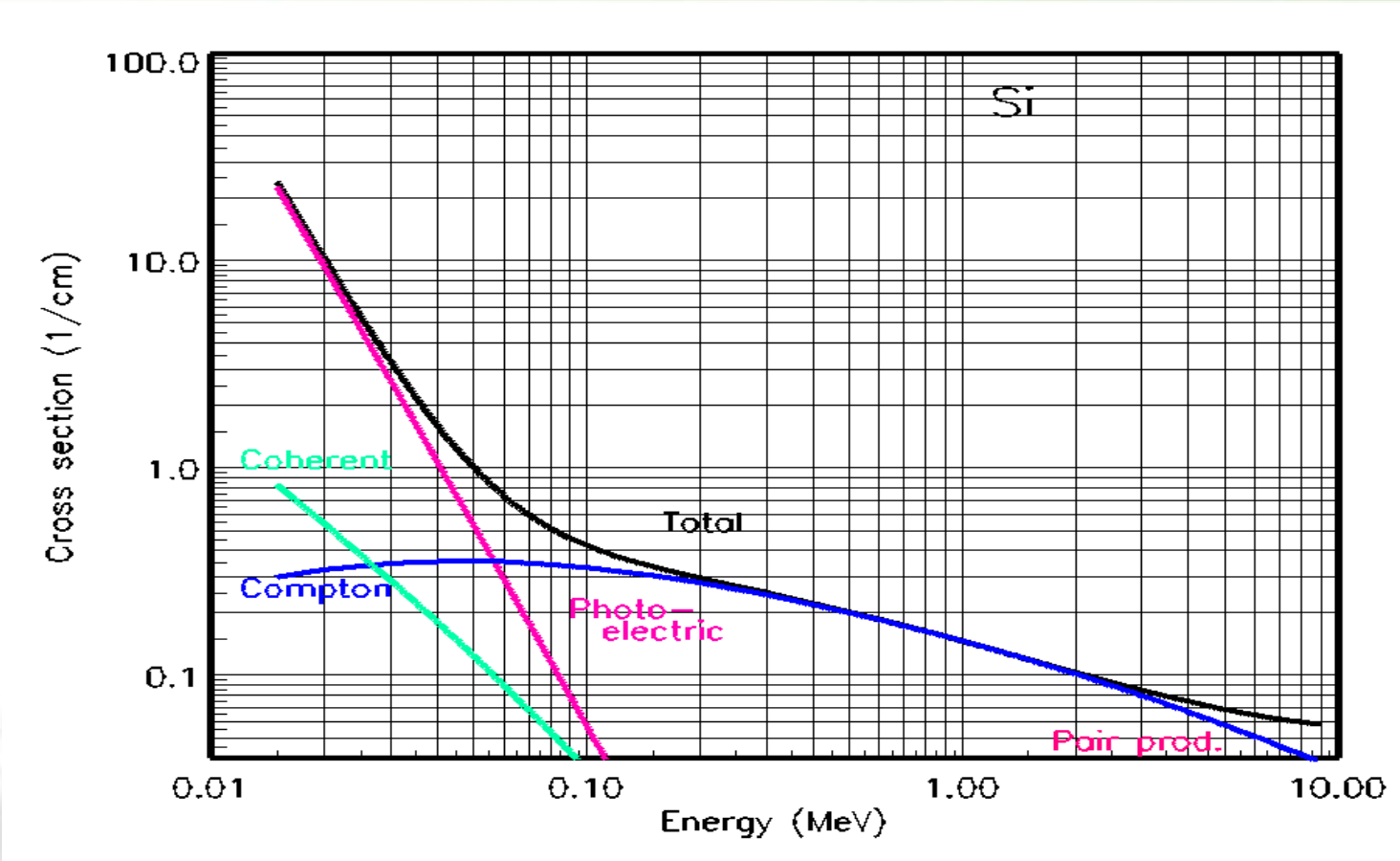
Strength Added to RP and Chemistry Programs

- Source Term Reduction
  - Tracking Performance RFO to RFO
  - Sister Plant Comparison
    - ❑ Including 58 EdF Units for data analysis
- Dosimetry
  - Electronic Dosimetry calibration verification
- ALARA
  - Shielding
  - Areas Identified for Dose Reduction
- Instrument Calibration
- Component Aging
  - Isotope Signature

Importance of Calibrating to the Station Energy Spectrum

- Chemistry Source Term Initiatives
  - Can have a profound impact on the response on a plants dosimetry!
  - Shift in Isotopic Mix, Co-58, Co-60 impact results!
- Cs-137 single point calibrations:
  - Found significant differences between DLRs and Electronic Dosimetry (ED), with the EDs under-responding!
  - Over-Corrected ED responses confuse workers, leading to poor confidence in dosimetry results and potential later challengs.
- INPO has issued AFIs when there is a large gap between ED and DLRs,
  - When DLRs and ED see the same spectrum, and are calibrated appropriately, then the difference between the two should be less than 3%.

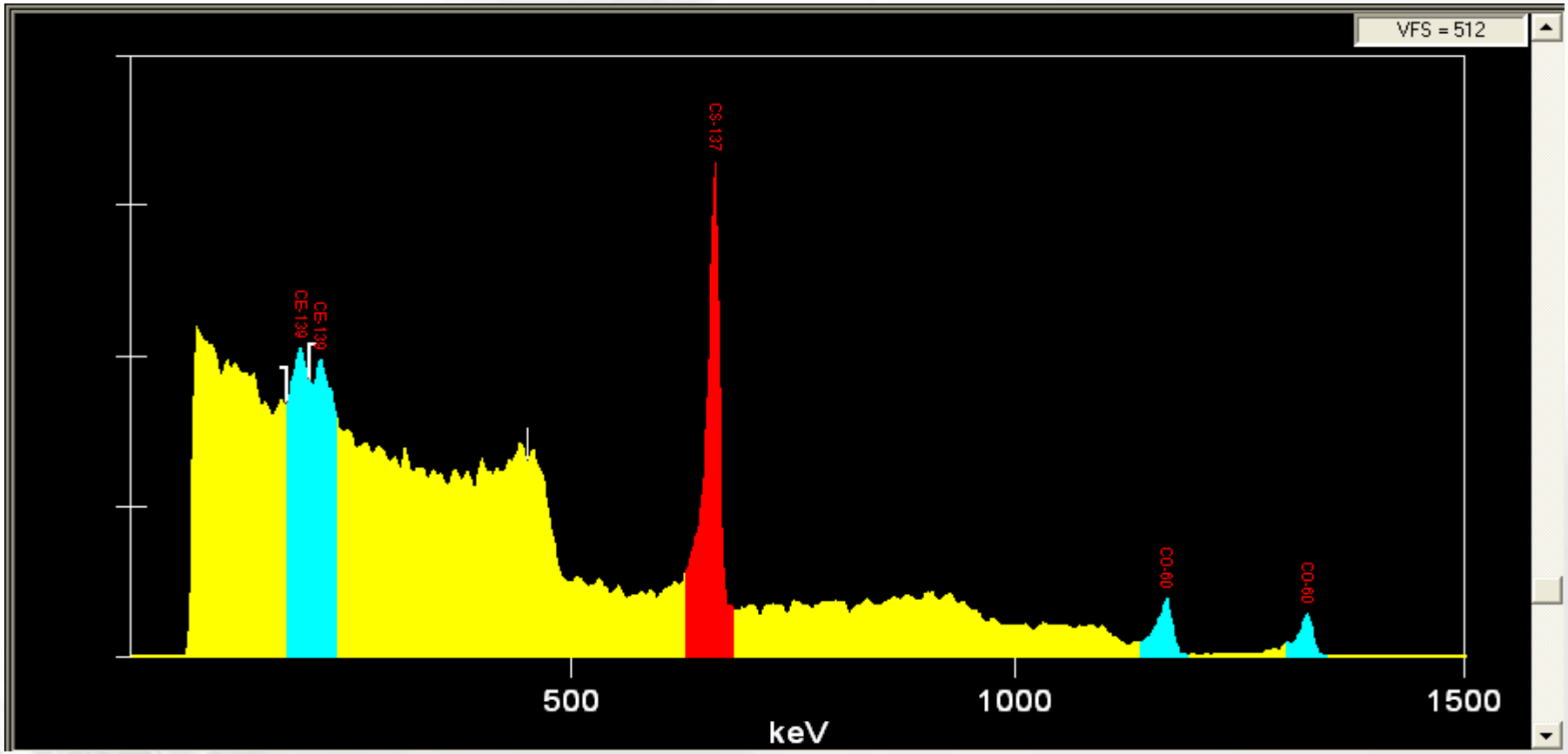
The basis of the Co-60 silicon under-response is shown in the response curve below;



Description of Methods for Measurement, cont.

- CZT detector utilizes high atomic numbers in its form in combination with a sufficient band-gap of about 1.47 eV in order to allow operation at room temperature.
- For power plant operations, the ability to have a hand held, easily positioned detector is a premium
  - spaces are tight, or
  - positioning is difficult due to pipe placement, shielding, or
  - other equipment is challenging the operator's ability to perform quality measurements.

A Calibration Spectrum of CZT Crystal, 50 uCi Cs-137, 1 uCi of Co-60



Operating Characteristics of the CZT Vs. GeLi and NaI

- CZT Cs-137 and Co-60
  - FWHM of about 11.5 keV
  - about 1.7 % of peak energy for Cs-137, less for Co-60
- GeLi detector
  - FWHM of less than 0.5% of peak energy
  - but is significantly better than a NaI,
  - which has a value of, about 7% of peak energy depending on the detector volume and the photon energy.

Operating Characteristics

- No Cooling Required
  - Therefore no risk of having the detector compromised because of a lack of adequate cooling
  - The resolution is sufficient for determination of key power plant radioisotopes,
    - cobalts and cesiums, as well as Fe-59, Zn-65 and radioiodines
- Temperature variability will shift the spectrum
  - Best practices are to perform a spectrum analysis prior to and after use if temperatures are more than 10 degrees C different than calibration conditions.

Operating Characteristics

- Collimation/shielding of the detector
  - necessary in radiation fields in excess of 1 mSv/hr, (100 mRem/hr).
  - Angular response on small bore piping can add 31% uncertainity to Co-58 deposited activity
  - No angular dependency without Collimator on Large Bore or Cast Piping
- Different size detectors are available based on field conditions.
  - The crystals which make up the detectors are time consuming to grow, and are expensive.
  - They are sensitive to temperature changes
    - Best practices include peak validation before each days activities.

Braidwood A1R15 CZT Results

Component Measured	Co-58 Value using CZT detector [nCi]	Co-60 Value using CZT detector [nCi]	Co-58 to Co-60 ratio	Dose Rate @ Survey Pt [mR/hr]	Co-58 Deposited Activity [uCi/cm2]	Co-60 Deposited Activity [uCi/cm2]
S/G cold leg, B Loop	1,200	270	4.4 to 1	75	**30.0**	**2.317**
S/G hot leg, B Loop	4,600	575	8.1 to 1	90	**42.0**	**2.70**
SI Check Valve 8948A	8,670	410	21.2 to 1	95	**4.11**	**0.123**

- Braidwood Unit 1: Final Outage Dose 64.329 REM, 32 days
  - 4 Loop Inconel 690 SG, Electropolished Channel Heads
  - pH 7.4, 2 mos. zinc Injection, LISV, 1st NPE/PRC-01M
  - Experienced 2 hard trips from 100% power, 1 cold shutdown within 2 months of the A1R15 refueling outage.

Beaver Valley 1R20 CZT Results

Component Measured	Co-58 Value using CZT detector [nCi]	Co-60 Value using CZT detector [nCi]	Co-58 to Co-60 ratio	Contact Dose Rate [mR/hr]	Co-58 Deposited Activity [uCi/cm2]	Co-60 Deposited Activity [uCi/cm2]
C S/G cold leg	430	290	1.5:1	50	**13.0**	**2.10**
C S/G hot leg	410	270	1.5:1	50	**14.5**	**3.50**
B S/G cold leg	214	1164	1.84	40	**11.5**	**2.3**
SI check valve	440	357	1.2:1	65	**1.75**	**0.77**

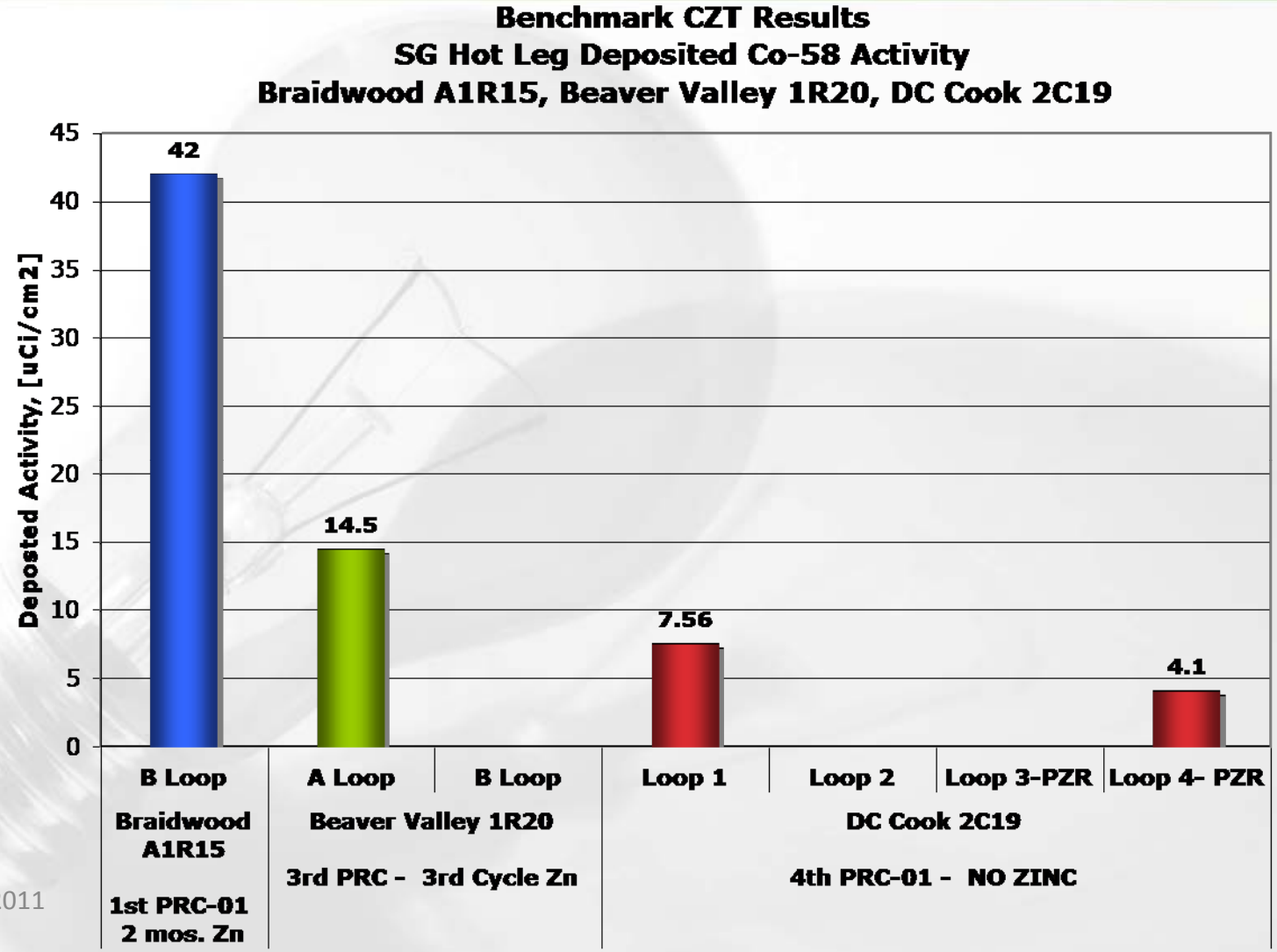
- BVPS 1R20: Final Outage Dose 53.65 REM, 32 Days
  - 3 Loop Inconel 690 SG
  - Loop Isolation Valves
  - Zinc Injection Plant, 3 cycles; 3rd PRC-01M

DC Cook- 2C19 CZT Results

Component Monitored	Co-58 Value using CZT detector [nCi]	Co-60 Value using CZT detector [nCi]	Co-58 to Co-60 ratio CZT ratio	Contact Dose Rate [mR/hr]	Co-58 Deposited Activity [uCi/cm2]	Co-60 Deposited Activity [uCi/cm2]
Unit 2, S/G cold leg 1	270	200	1.34	15	**4.60**	**1.82**
Unit 2, S/G cold leg 2	217	150	1.45	16	**5.34**	**1.86**
Unit 2, S/G cold leg 3	376	207	1.81	27	**11.4**	**2.6**
Unit 2, S/G cold leg 4	100	40	2.41	28	**12.9**	**2.5**
Unit 2, S/G hot leg 1	333	200	1.66	24	**7.56**	**1.70**
Unit 2, S/G hot leg 4	100	102	1.04	17	**4.11**	**1.40**

- DC Cook 2C19: 45.95 REM 52 Day RFO
  - 4 Loop Inconel 600 SG, 33% smaller Containment than Braidwood/Byron
  - No Zinc Injection; 4th RFO PRC-01M

Benchmarking
Source Term Reduction



Future

- US Utilities Purchasing and Integrating Technology
  - NATC Coordinating Measurements per EdF Protocol and
  - ISOE Database: Data Access and Exchange for Benchmarking
- Planned Spring 2011 Plants Conducting CZT
  - Several Plants Participating
  - A number of repeat sites, since information was useful for the first sites investigated (Unit 1 compared to Unit 2, fuel failure history impact,etc.)

Questions?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