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Understanding Radiation Fields Through Electronic Dosimetry

Revised SRMP and BRAC Programs

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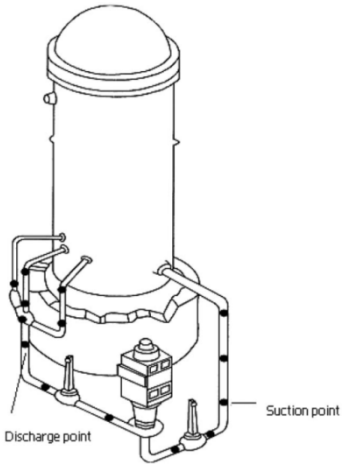
Standard Radiation Monitoring Programs
BRAC and SRMP

Dose rates representative of activity incorporation into piping oxide films during operating cycle.

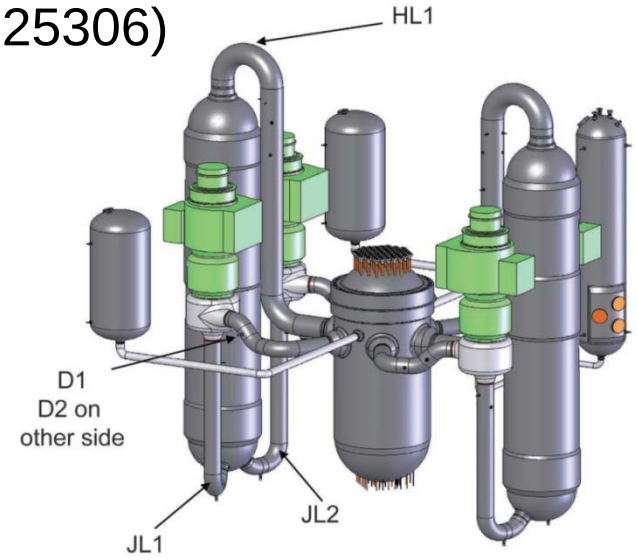
BWR Radiation Level Assessment and Control

- 1977 – current
- Long running data collection program
- 2012 Benchmarking Report (1025319)



PWR – Standard Radiation Monitoring Program

- 1978 to 1996, 2005 – current
- 2012 Benchmarking Report (1025306)



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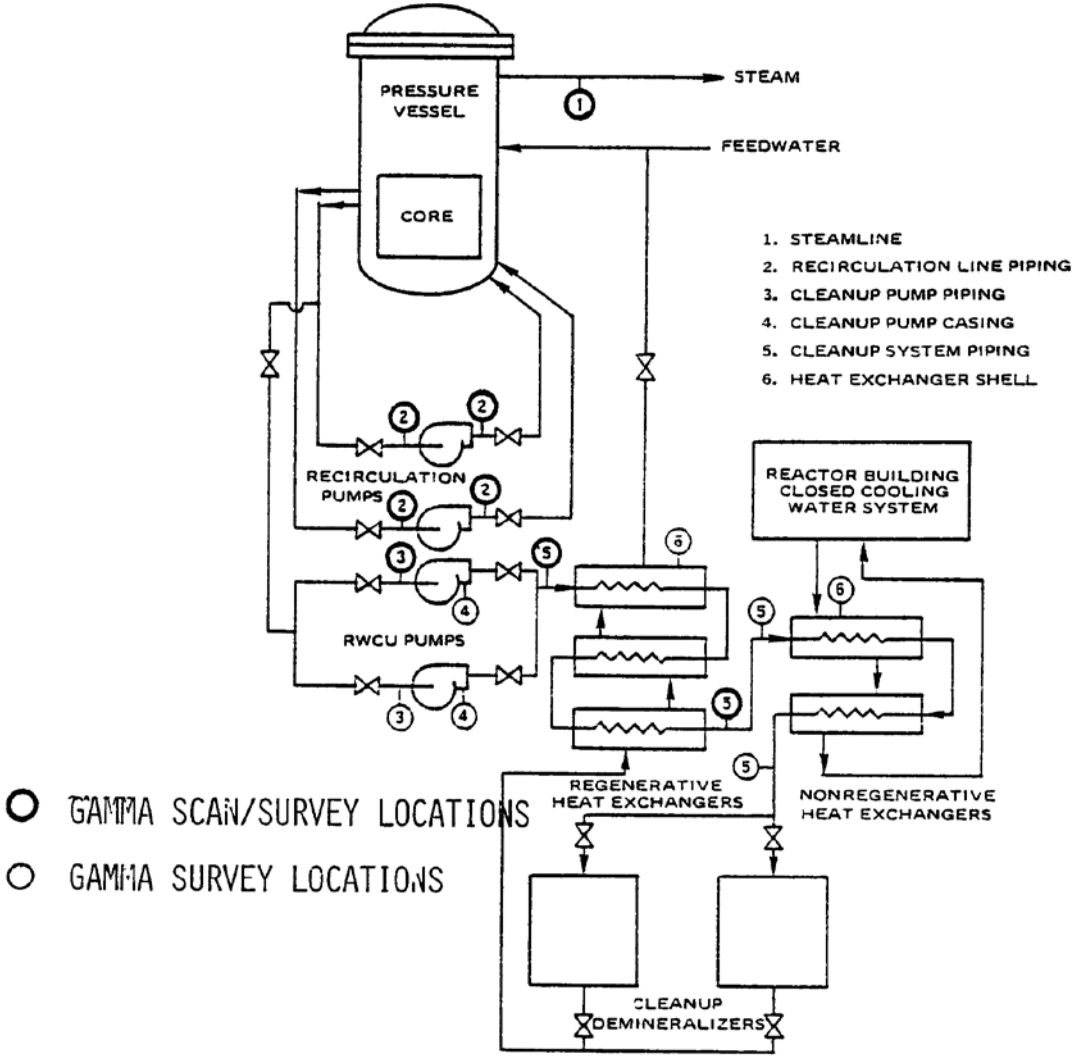
BWR Radiation Level Assessment and Control Program (BRAC)

Purpose: To establish a standard systematic approach to dose rate monitoring with the goal of developing a predictive BWR radiation buildup model

Survey Locations

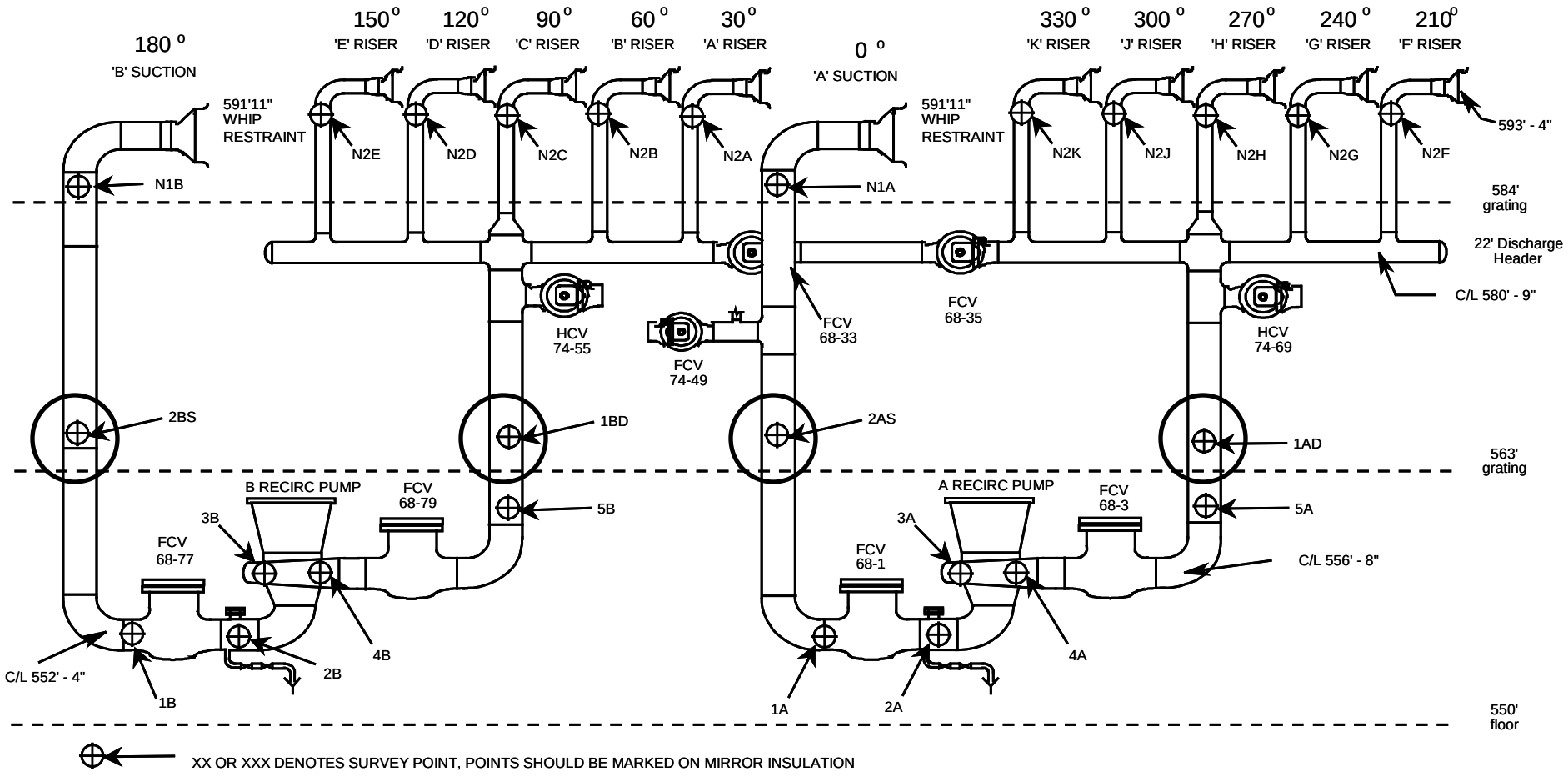
- Recirc and RWCU systems
- Main steam lines
- Moisture separator reheater
- Undervessel



* GE Document, NEDC-13361-01 and NEDC-12688

Standard BRAC Points

Majority of Data



BWR Performance Monitoring. EPRI, Palo Alto, CA: 2002. 1003600. and *Cobalt Reduction Sourcebook*. EPRI, Palo Alto, CA:2010. 1021103.

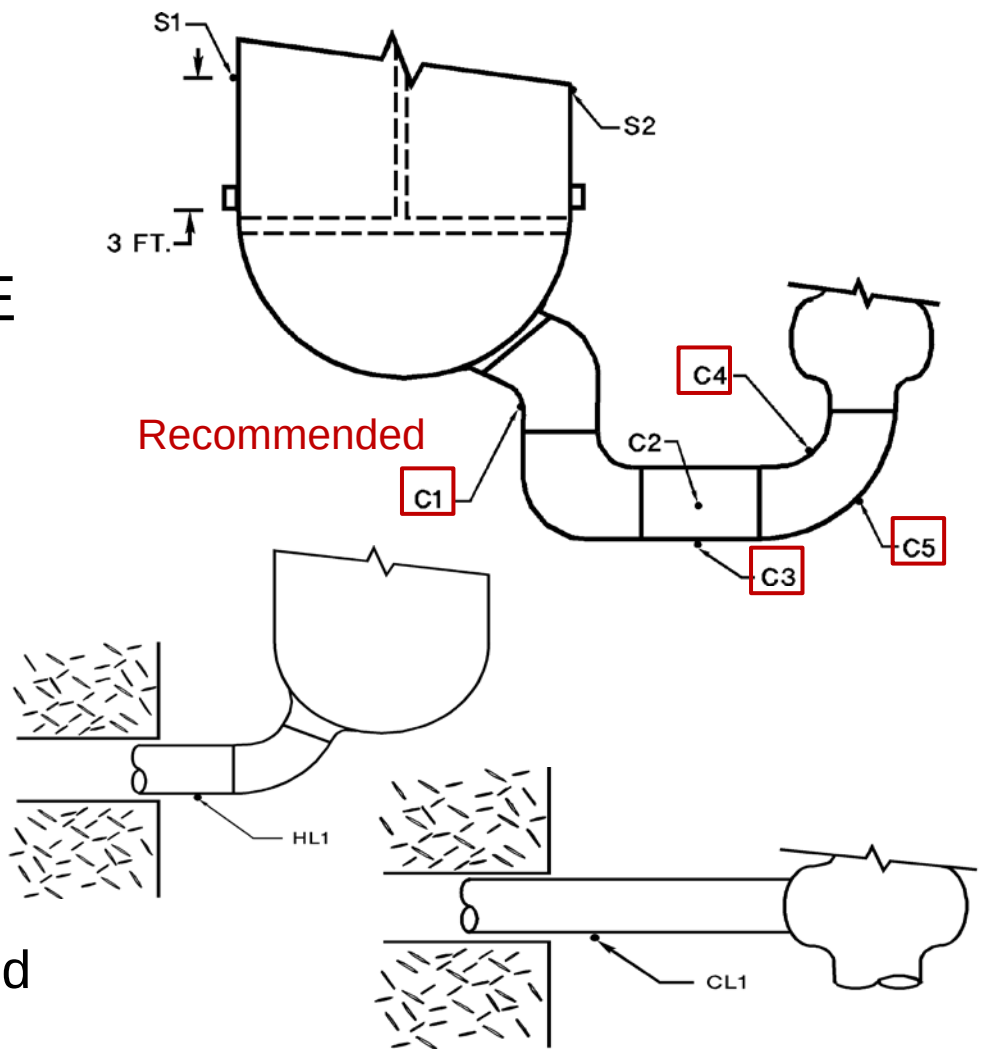
PWR Standard Radiation Monitoring Program
Original and 2007 Version (Current)

- **Goals:** Provide meaningful, consistent and systematic approach to dose rate measurements for making comparisons to other plants and identifying plant features, materials, and operational techniques that help control radiation fields.
  - In 1996, lack of industry interest and reduced funding limited the SRMP scope then reinstated 2007 (RP 2020 Initiative)
- Procedures available for all three western PWR designs, Westinghouse, Combustion Engineering, and Babcock & Wilcox
- Categories for locations include 'Required Points,' 'Recommended Points,' and 'Optional Information.'
- Majority of data collected by conventional (unshielded) probe

Application of the EPRI Standard Radiation Monitoring Program for PWR Radiation Field Reduction. EPRI, Palo Alto, CA: 2007. 1015119.

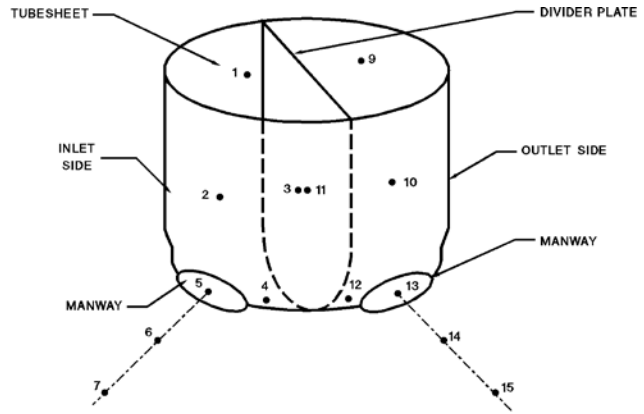
Required SRMP Points (1015119)
Loop Piping

- Required for All Designs
  - Straight section of crossover/crossunder piping, side of pipe
- Required only for W and CE
  - Bottom of hot leg piping between SG inlet and reactor vessel shield
  - Bottom of cold leg piping between RCP and reactor vessel shield
- Required only if previously collected
  - Outside of SG, hot leg and cold leg sides



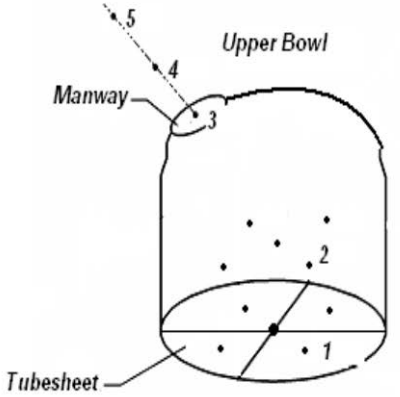
Required SRMP Points (1015119)
Channel Head

Westinghouse



- Required for W and CE
  - Midpoint of tubesheets
  - Channel Head Centers
  - Center of Divider Plate (W), Stay Cylinder (CE)
  - Bottom of Channel Head

Babcock & Wilcox

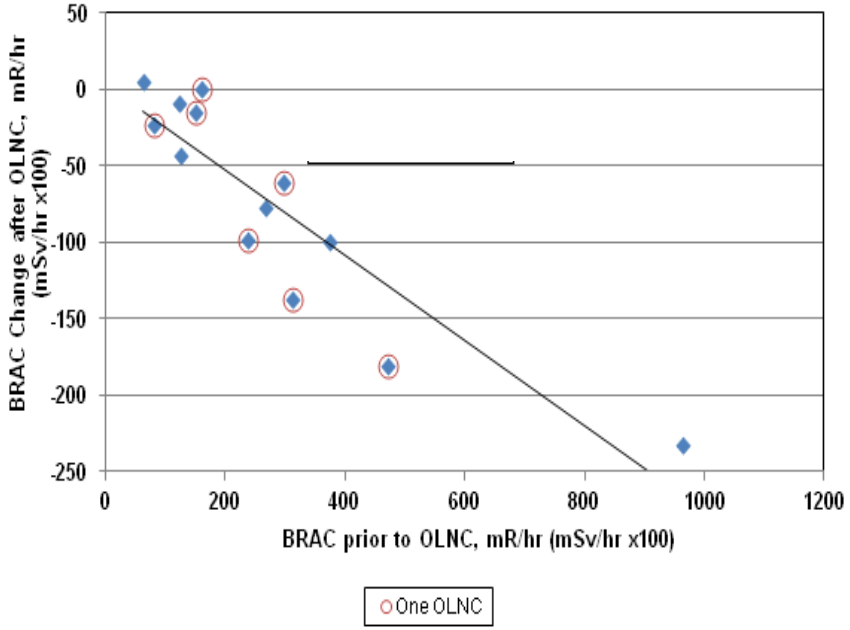


- Required for B&W
  - Highest general area dose rate and contact with the center of the tubesheet (upper & lower bowls)
  - 30 cm above highest dose rate tubesheet point of upper/lower bowl

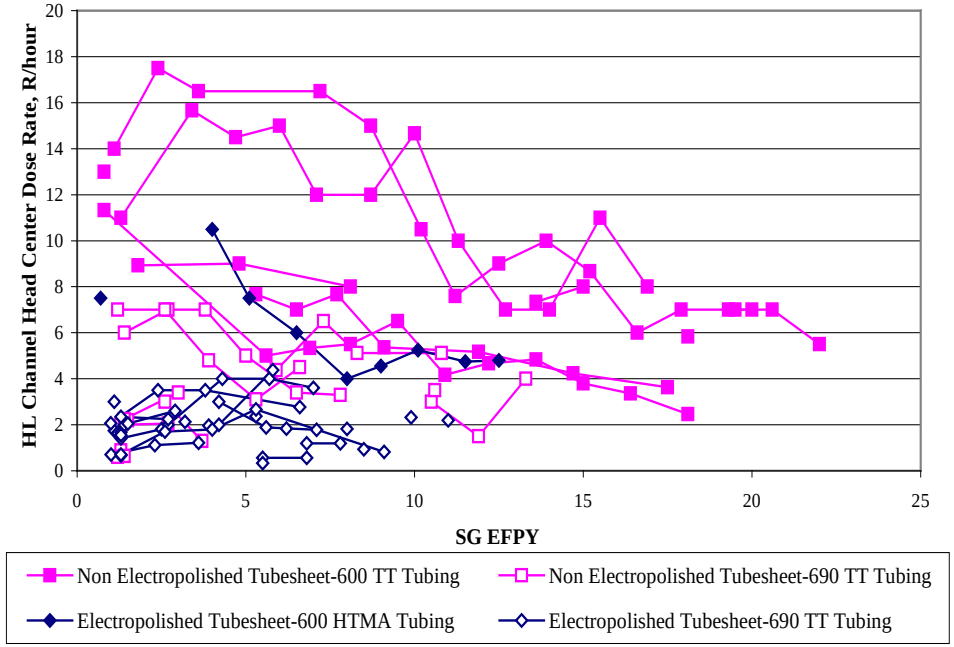
Gross Dose Rates Data (Contact Dose Rates)

Impact of BRAC/SRMP Programs

BRAC Change After OLNC and BRAC Prior to OLNC[1]



SRMP Channel Head Dose Rate reductions with SG channel head electropolishing[2]



1. *Impact of Chemical Injections on Boiling Water Reactor Dose Rates: Interim Report.* EPRI, Palo Alto, CA: 2012. 1025308.
2. *Plant Specific Recommendations for PWR Radiation Source Term Reduction*. EPRI, Palo Alto, CA:2009. 1019225.

Radiation Surveys

Key Link to Source Term Management Efforts

- **BRAC and SRMP are representative of activity incorporation into piping oxide films during operating cycle**
- **BUT BRAC/SRMP dose rate measurements do not always correlate with cumulative radiation exposure (CRE) at many plants (complicated by time in field)**
  - Chemical source term management technologies may not be uniformly effective (all locations and all nuclides)
  - New technology exists to evaluate plant radiation field evolutions and also reduce work dose associated with data collection
  - Numerous work locations beyond the recirculation piping

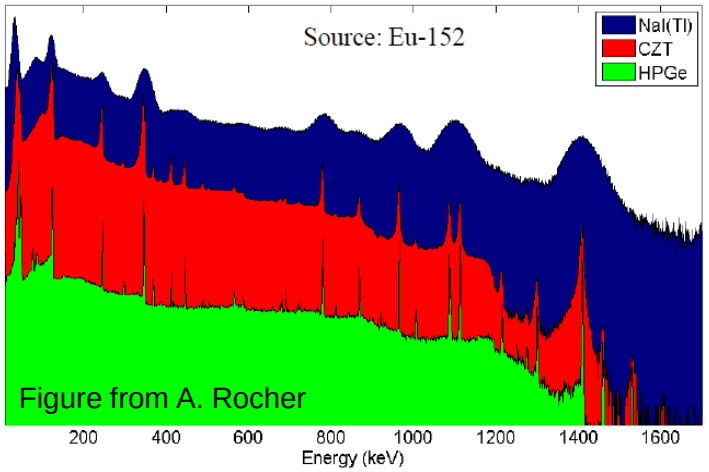
Beyond Contact Dose Rates

Gamma Spectroscopy and Electronic Dosimetry

ISOTOPIC CONTRIBUTIONS TO DOSE RATES

- The impact of small chemistry, operations, materials changes on an isotopic deposited activity can be large and complex.[1]

Spectral Resolution : HPGe – CZT – NaI

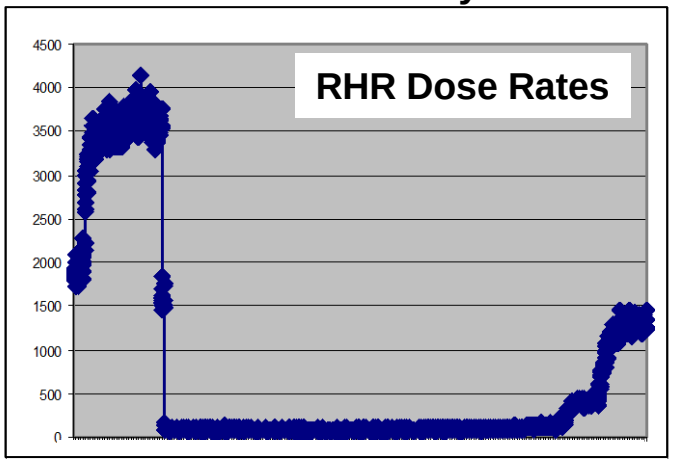


[1]*PWR Activity Transport and Source Term Assessment: Surface Activity Concentrations by Gamma Scanning.* EPRI, Palo Alto, CA: 2011. 1023027.

TIME DEPENDENT DOSE RATES

- Dose rates throughout the plant can impacted during shutdown due to movement of particulate activity.[2]

Electronic Dosimetry Data



- [2]*Impact of PWR Operational Events on Particulate Transport and Radiation Fields.* EPRI, Palo Alto, CA: 2012. 1025305.

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Availability of Advanced Radiation Field Data

Gamma Spectroscopy

- High Purity Germanium (HPGe)
  - Industry standard but expensive
  - PWR: >40 outages* plus a few international units collect at every outage
  - BWR: >260 outages (supplements with coupons being developed)
- Cadmium-Zinc-Telluride (CZT)
  - New technology and less expensive
  - EDF utilizing since 2006 throughout their fleet
  - Collection increasing, but limited standardization of procedure (shielding, collimation, post-processing, etc.)

Time-Dependent Dose Rates

- Installed Electronic Dosimetry
  - PWR: common practice in US, but no limited standardization
  - BWR: *very limited*. Only 1 US plant is known to collect and only for most recent outages

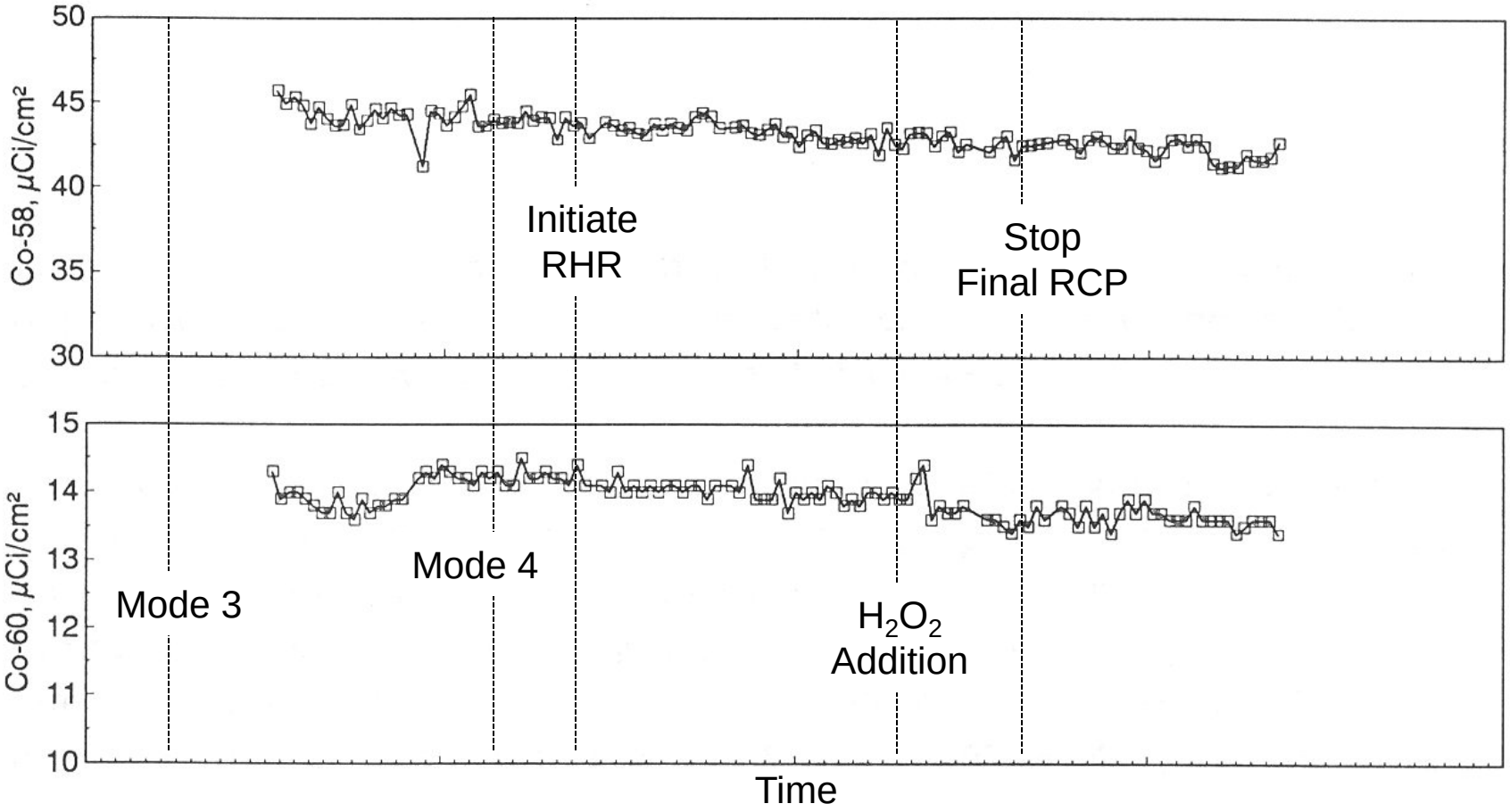
Expanded collection required for full utilization of data

**PWR Activity Transport and Source Term Assessment: Surface Activity Concentrations by Gamma Scanning.* EPRI, Palo Alto, CA: 2011. 1023027.

Gamma Spectroscopy

Soluble Activity Incorporation

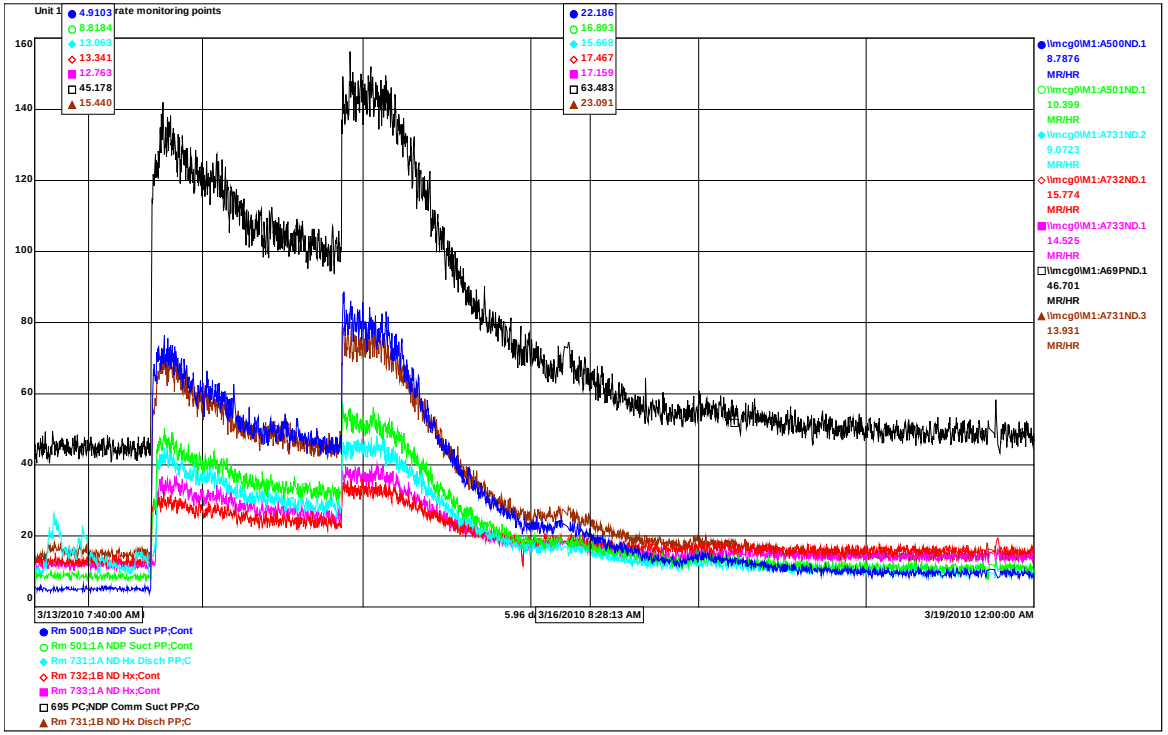
Westinghouse PWR
Crossover Piping Activity Shutdown Transient



Pressurized Water Reactor Activity Transport and Source Term Assessment: Surface Activity Concentrations by Gamma Scanning. EPRI Palo Alto, CA: 2011. 1023027.

Installed Remote Technology (EDs)
Improved Understanding of Operational Maneuvers

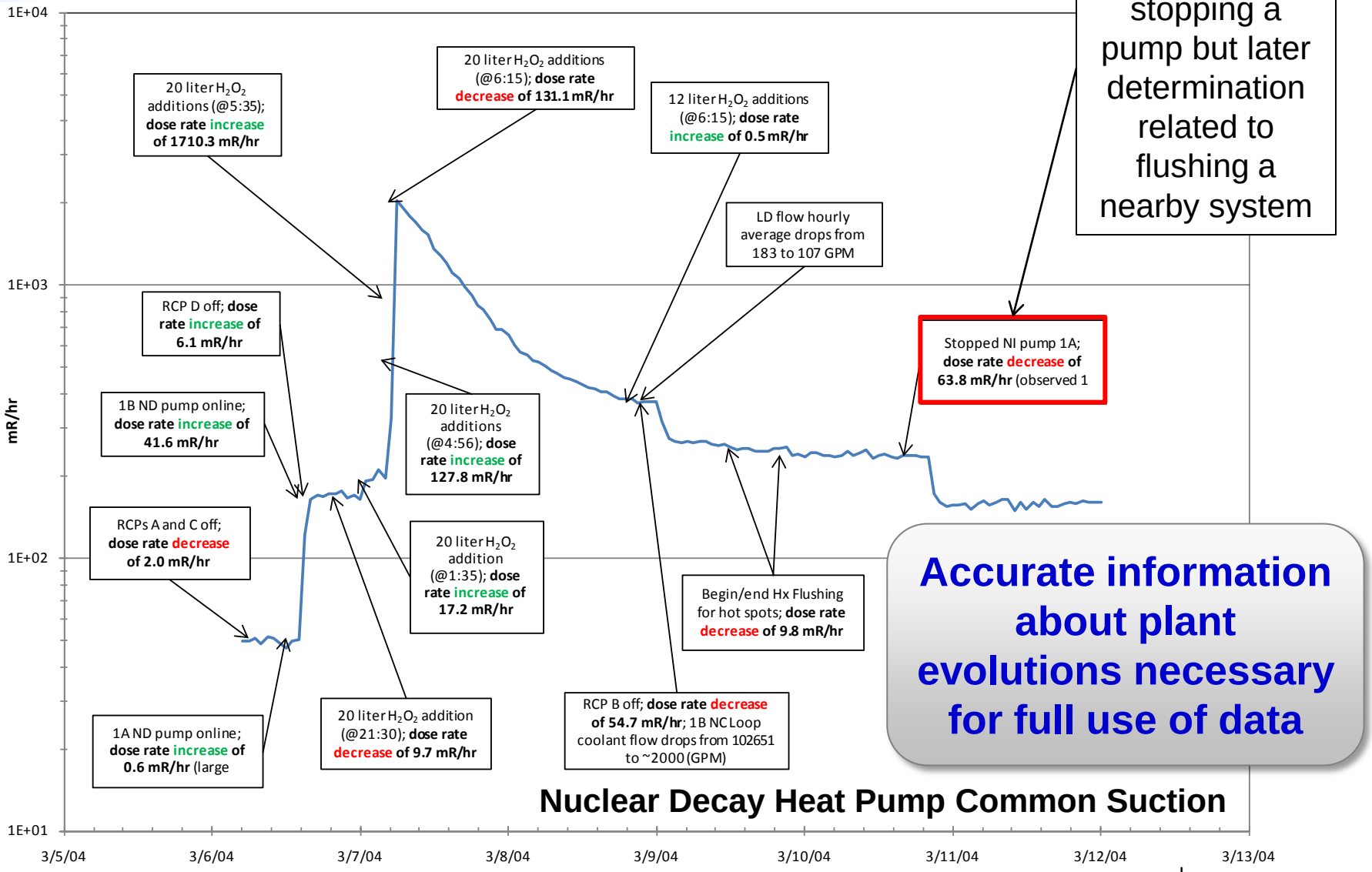
- Provides time dependent information about changes in dose rate
- Expands understanding of impact of operations and corrective actions



**See D. Wells presentation from 2013 NA-ISOE ALARA Symposium*

Impact of PWR Operational Events on Particulate Transport and Radiation Fields. EPRI, Palo Alto, CA: 2012. 1025305.

Installed Remote Technology in PWRs
Electronic Dosimetry



Accurate information about plant evolutions necessary for full use of data

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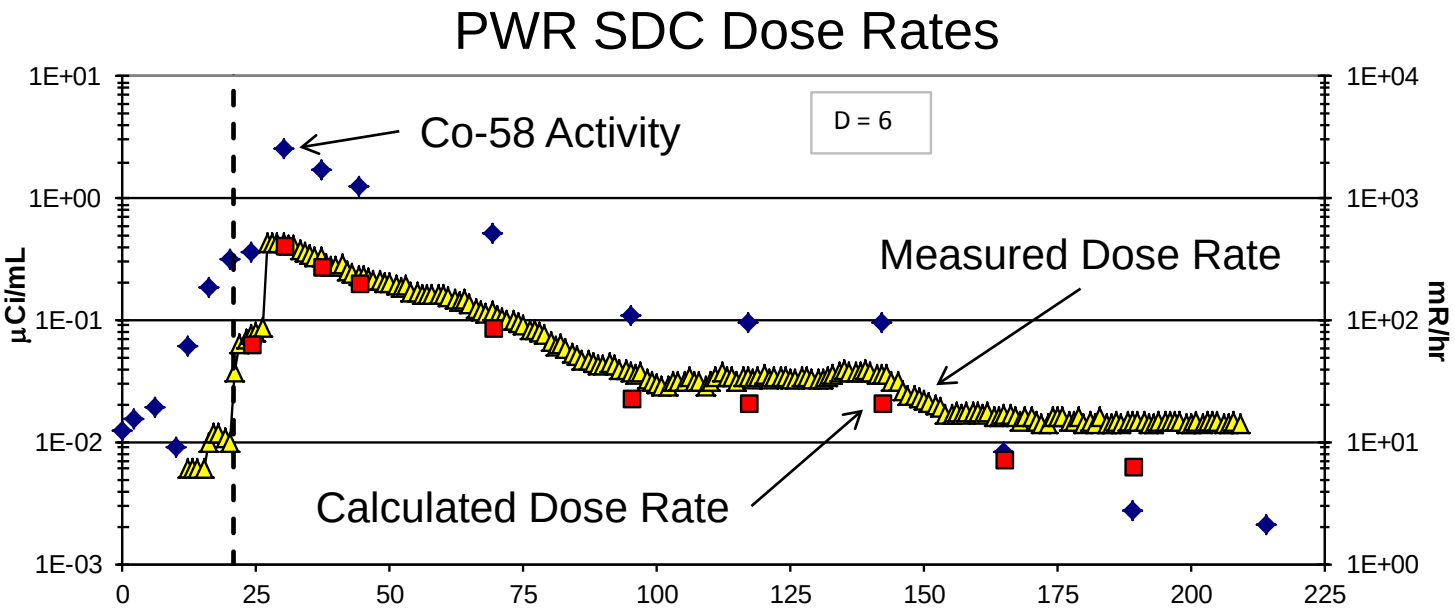
Installed Remote Technology (EDs)

Improved Understanding of Particulate Transport



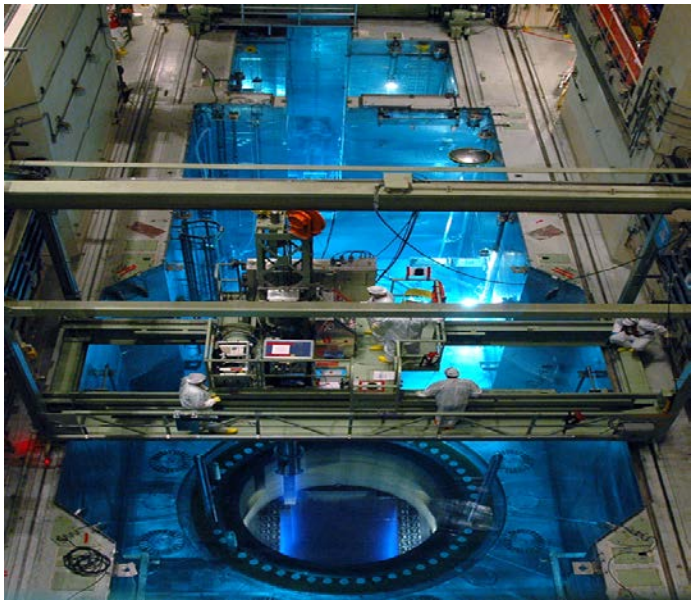
- Measured data corrected for activity of the coolant
- Calculated data shows impact of particulate transport
  - Observed to calculated delta demonstrates impact of particulate dropout

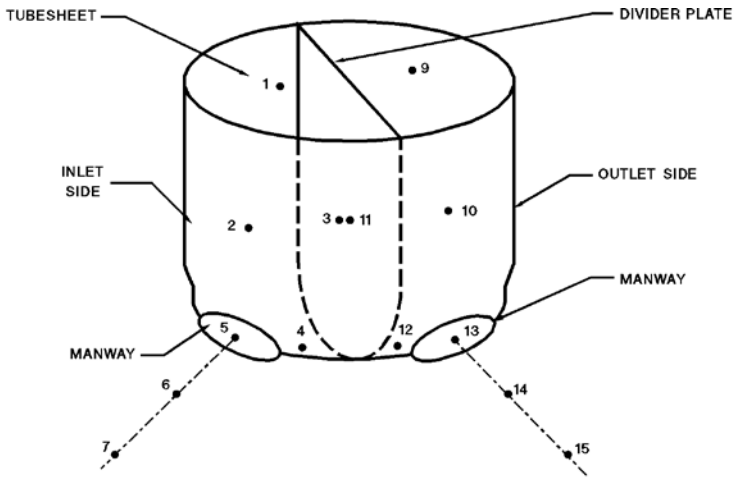
**See D. Wells presentation from 2013 NA-ISOE ALARA Symposium*

Impact of PWR Operational Events on Particulate Transport and Radiation Fields. EPRI, Palo Alto, CA: 2012. 1025305.

Beyond High Flow Regions of the Plant
Collection Locations

- Current BRAC & SRMP describe dose rates in high flow rate systems
- Other locations more dominated by other transport mechanisms





Revised program must balance need for additional data, dose to collect data, and burden on plant staff

Data Collection Categories

- **Required** are surveys for which data that must be taken.
- **Highly Recommended** are surveys that are strongly requested and are considered *'best practices*,' but may be skipped in cases of personnel safety, poor accessibility, or significant ALARA impact.
- **Recommended** surveys are those that are requested, but may be skipped in cases of personnel safety, poor accessibility, or significant ALARA impact.
- **Optional** surveys include information that is requested if available. The data can be of particular use to plants having specific dose issues.

Data Collection Type and Categories
SRMP/BRAC Revision

- Originally required, recommended, optional only used for locations – extend category to type of data.
- **Required**
  - Most locations contact dose rates only required type
- **Highly recommended (best practice)** – *required locations*
  - Electronic dosimetry (ED) – installed as soon as possible and remaining in place until 2 weeks after startup where possible
  - Gamma spec at time of contact dose rates
- **Required ED**
  - General area, i.e. refuel bridge and undervessel (BWR)

Provide General Guidance for Gamma Spectroscopic Analysis

Highly recommended at most required locations.

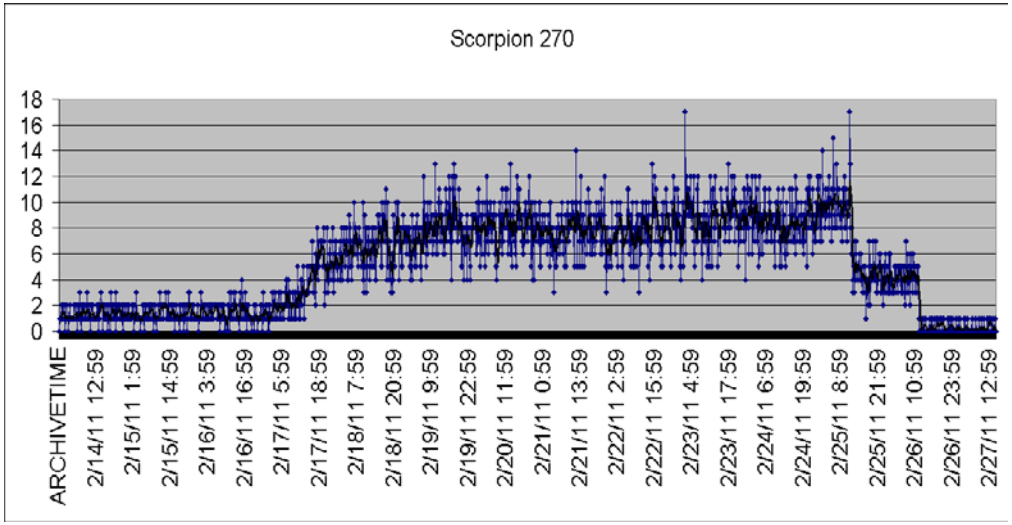
- Establish steps necessary for collection of isotopic data regardless of detector
  - Energy/channel calibration
  - Shielding requirements
- Allow for data collection with available detectors

Detector	Type	Resolution at 622 keV (Cs-137)
Sodium Iodide, NaI(Tl)	Scintillation	~44 keV
Lanthanum Bromide, La(Ce)Br_3	Scintillation	18.5 keV
Cadmium-zinc-telluride, CZT	Solid state	10-20 keV
High Purity Germanium, HPGe	Solid state	1.7 keV

Expand Utilization of Installed Electronic Dosimetry

Highly recommended at most required locations.

- Installation Details
  - As soon as possible and kept in place through restart where possible
  - Recommended to leave ED installed throughout operation where possible



- Data Details
  - Raw data anticipated: dose rate vs. timestamp (no additional clean up required)
  - Electronic data files are fine – export to tab-delimited text file if using uncommonly used software

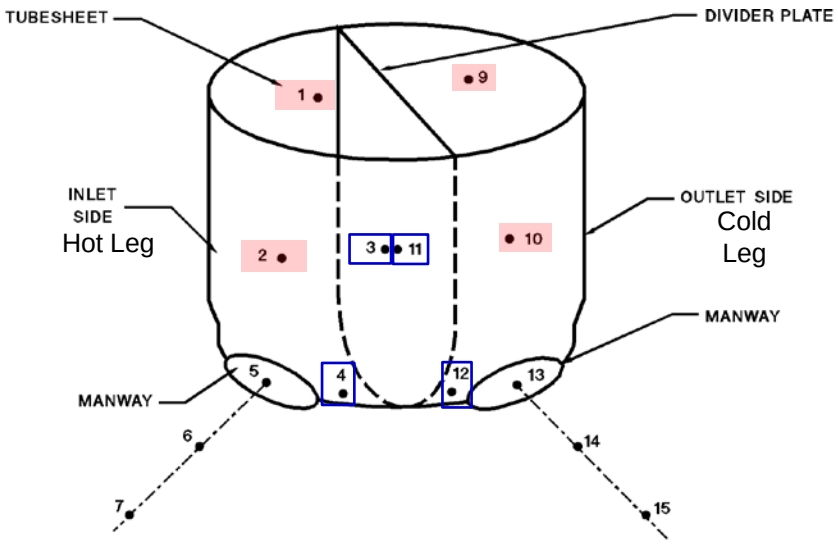
EPRI PWR Standard Radiation Monitoring Program (SRMP)

2013 Revision

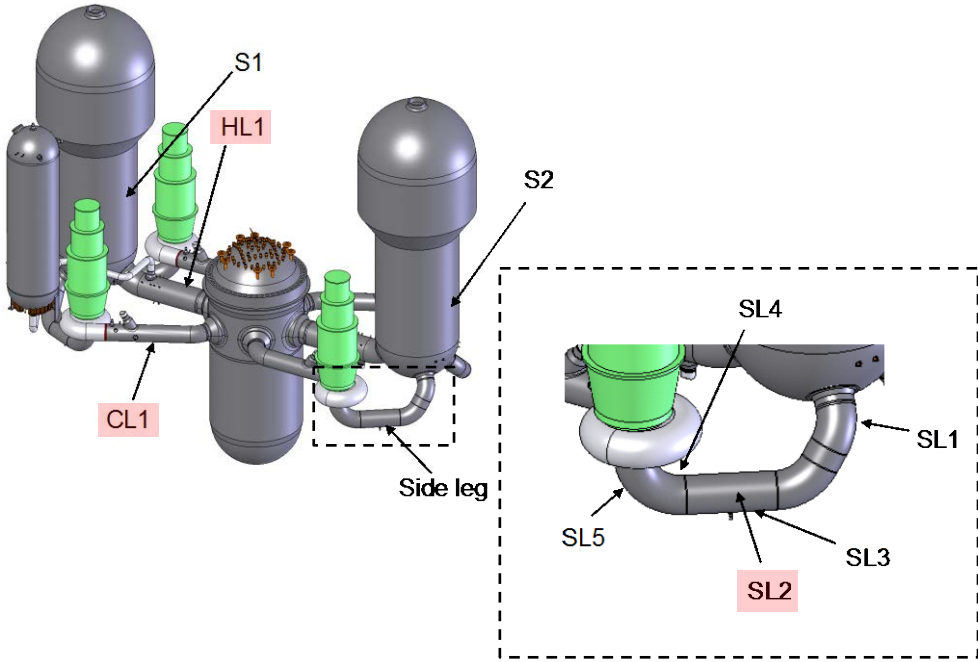
High Flow Reactor Coolant Loop

Required Loop Piping and Steam Generator Points

Steam Generator Locations



Loop Piping Locations



- Retain 4 of current 8 required SG points as required (change to recommended)

Figure Key

Required Location

Recommended (New)

- Retain 3 points per loop (hot, side of center crossover, and cold legs) – all designs

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Revised PWR-SRMP

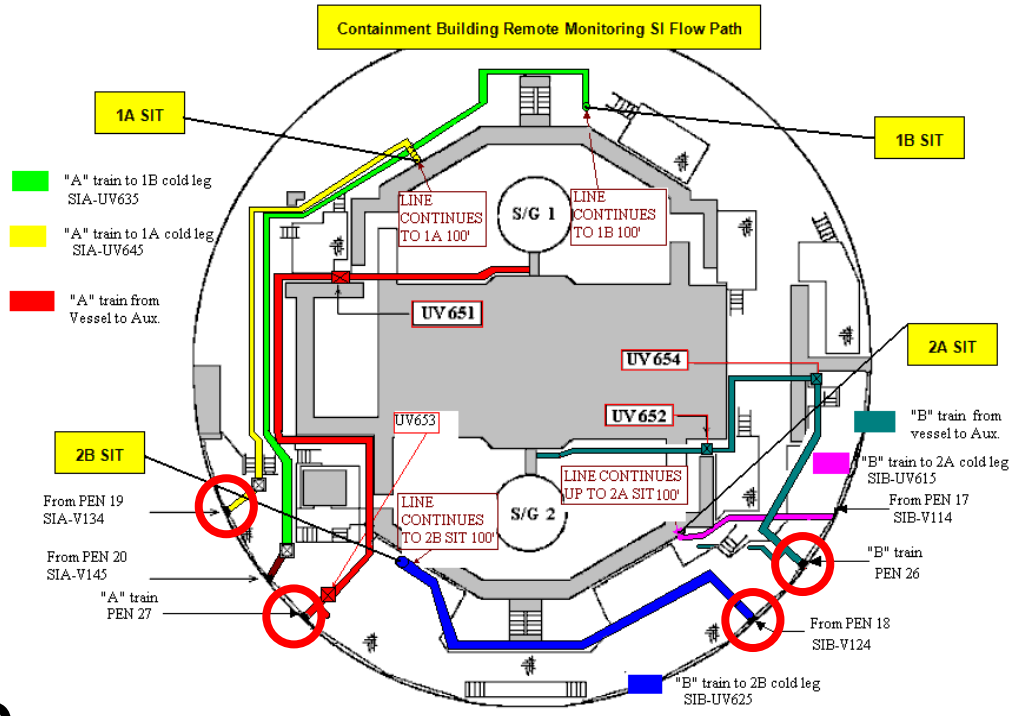
Auxiliary System Data

REQUIRED – CDR

- Letdown/CVCS system (inlet and return)
- RHR/Decay Heat (inlet and return)
- Pressurizer surge line
- Refueling bridge (ED)

HIGHLY RECOMMENDED

- ED & GSA at required locations
- SG outer surface (CDR)
- Pressurizer spray (CDR)



CDR = Contact Dose Rate

GSA = Gamma Spectrum Analysis

ED = Electronic Dosimetry

GA = General Area

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EPRI BWR Radiation Level Assessment and Control (BRAC) Program

2013 Revision

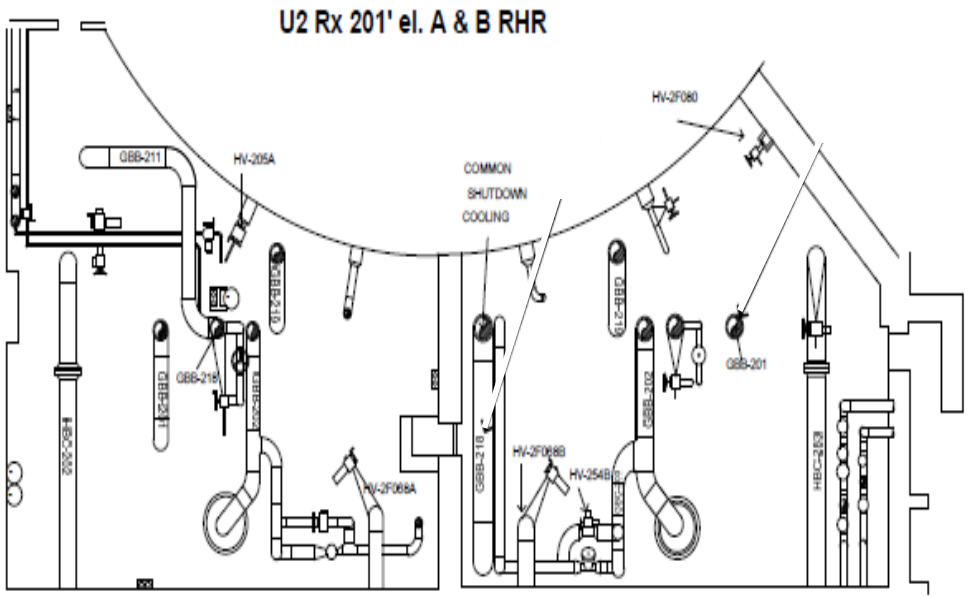
Revised BRAC Program

REQUIRED - CSP

- Recirc Piping
- Undervessel (GA)
- Bottom Head Drain Line
- RWCU inlet
- RHR SDC header
- Refueling bridge (ED)

HIGHLY RECOMMENDED

- ED &/or GSA at some required locations
- Main steam line



CSP = Contact Shielded Probe

GSA = Gamma Spectrum Analysis

ED = Electronic Dosimetry

GA = General Area

Project Status and Summary

- The program structure was finalized December 2012 *(tables are attached to the presentation materials)*
  - Revision expands not only locations for data collection, but also types of data to collect – *contact dose rates, gamma spec, electronic dosimetry, and general area*
- Document describing in more detail the programs will be released in 2013
  - Procedures and templates for data collection
  - Specifics of locations

Source Term and Radiation Field Reduction Workshop 2013
Focus: *Detectors and technology for radiation monitoring*

July 9-11, 2013 – Palo Alto, CA

Together…Shaping the Future of Electricity

Table 7-5
General Description of SRMP Radiation Survey Locations (All Design Types)

Data Set	Description	Location	Survey Type				Notes
			Contact Dose Rate[1]	Electronic Dosimetry (ED)[4]	Gamma Spectrum Analysis (GSA)[6]	General Area (GA) Dose Rate	
RCLP	RCLP cold leg	Design specific, cold leg piping between Reactor Coolant Pump and Reactor Vessel	Required (2,3)	Highly Recommended (5)	Highly Recommended	n/a	
	RLCP hot leg	Design specific, hot leg piping between Reactor Vessel and Steam Generator inlet	Required (2,3)	Highly Recommended (5)	Highly Recommended	n/a	
	RLCP crossover	Design specific, crossover piping between Steam Generator outlet and Reactor Coolant Pump	Required (2,3)	Highly Recommended (5)	Highly Recommended	n/a	Straight section of crossover piping, side of pipe
	RLCP supplemental crossover (W and CE only)	Design specific, additional locations on crossover piping between Steam Generator outlet and Reactor Coolant Pump	Recommended (2,3)	n/a	n/a	n/a	Locations cover the elbows and the bottom of the piping
	Steam Generator outer surface on hot leg side (W and CE only)	Outside of Steam Generator, hot leg side, approximately 1 meter above top of Channel Head Tube Sheet and approximately midway between secondary side hand-hole cover and hot leg piping (90 degrees radially from the no-tube lane)	Highly Recommended (2)	n/a	n/a	n/a	RCS level should be above the measurement point, preferably 100% full and the secondary side should be ≥ 20% full.
	Steam Generator outer surface on cold leg side (W and CE only)	Outside of Steam Generator, cold leg side, approximately 1 meter above top of Channel Head Tube Sheet and approximately midway between secondary side hand-hole cover and cold leg piping (90 degrees radially from the no-tube lane)	Highly Recommended (2)	n/a	n/a	n/a	RCS level should be above the measurement point, preferably 100% full and the secondary side should be ≥ 20% full.
SGCH	SGCH center (hot & cold leg)	Design specific, center of Channel Head or 30 cm from Tube Sheet contact in hot and cold leg Channel Heads	n/a	n/a	n/a	Required (7)	

Data Set	Description	Location	Survey Type				Notes
			Contact Dose Rate[1]	Electronic Dosimetry (ED)[4]	Gamma Spectrum Analysis (GSA)[6]	General Area (GA) Dose Rate	
SGCH	SGCH Tube Sheet contact (hot & cold leg)	Design specific, in contact with Tube Sheet in hot and cold leg Channel Heads	Required (7)	n/a	n/a	n/a	
	SGCH divider (hot & cold leg)	Design specific, in contact with divider/stay plate in hot and cold leg Channel Heads	Recommended (7)	n/a	n/a	n/a	
	SGCH bottom (hot & cold leg) (W and CE only)	Bottom of hot and cold leg Channel Heads	Recommended (7)	n/a	n/a	n/a	
	SGCH manway entrance (hot & cold leg)	Center plane of manway entrance to Channel Head (hot & cold leg)	n/a	n/a	n/a	Recommended (7)	
	Outside SGCH manway entrance, 30 cm (hot & cold leg)	30 cm from plane of manway entrance to hot and cold leg Channel Head	n/a	n/a	n/a	Recommended (7)	
	Outside SGCH manway entrance, 1 m (hot & cold leg)	1 meter from plane of manway entrance to hot and cold leg Channel Head	n/a	n/a	n/a	Recommended (7)	
AUXS	Pressurizer Spray Line	Design specific, in contact with the horizontal section of pipe near cold leg tap or the horizontal section of pipe near the Pressurizer Head	Highly Recommended (2,8)	n/a	n/a	n/a	At least one contact dose rate survey at one of the two specified locations is highly recommended. Contact dose rates at both locations are recommended.
	Pressurizer Surge Line	Design specific, in contact with horizontal section of pipe near hot leg/vessel tap	Required (2,8)	n/a	n/a	n/a	
	Reactor Vessel Closure Head	Plant specific location	n/a	Optional	n/a	n/a	
	Refueling Bridge	Top of handrail, midway across refueling bridge, near operator	n/a	Required (5)	n/a	n/a	The approximate distance between installed electronic dosimeter and refueling water surface should be noted with the survey.
	CVCS/MU&P Letdown Line	Auxiliary building, nearest to location where pipe exits containment	Required (2)	Highly Recommended (5)	Highly Recommended	n/a	

Data Set	Description	Location	Survey Type				Notes
			Contact Dose Rate[1]	Electronic Dosimetry (ED)[4]	Gamma Spectrum Analysis (GSA)[6]	General Area (GA) Dose Rate	
AUXS	CVCS/MU&P Return Line	Auxiliary building, nearest to location where pipe enters containment	Required (2)	Highly Recommended (5)	Highly Recommended	n/a	
	CVCS/MU&P Heat Exchanger	On outer shell of Heat Exchanger	Recommended (2)	Recommended (5)	n/a	n/a	This location corresponds to the Non-Regenerative Heat Exchanger if the NSSS design also has a Regenerative Heat Exchanger
	RHR/SDC/DH Letdown Line	Auxiliary building, nearest to location where pipe exits containment	Required (9)	Highly Recommended (10)	Highly Recommended	n/a	
	RHR/SDC/DH Return Line	Auxiliary building, nearest to location where pipe enters containment	Required (9)	Highly Recommended (10)	Highly Recommended	n/a	
	RHR/SDC/DH Heat Exchanger	On outer shell of Heat Exchanger	Recommended (9)	Recommended (10)	n/a	n/a	
	DH Pump Suction (B&W only)	Suction line for Decay Heat pump	Optional (9)	n/a	n/a	n/a	

Additional Notes

1. It is strongly recommended that contact dose rate surveys are performed with a directional shielded probe (e.g., Eberline HP 220A). At a minimum, the survey should indicate whether or not the probe was shielded. Contact dose rates may also be reported using electronic dosimeter data, provided the reported value is consistent with Notes 2 and 3 (below).
2. Contact dose rate should be taken as soon as possible after the forced oxidation cleanup end point concentration in the primary coolant is reached (e.g., within 24 hours of reaching 0.05 μCi/ml).
3. Survey data taken while the Steam Generator manway covers are not in place should be noted clearly.
4. For contact dose rate measurements, installation of electronic dosimeters (probes) under shielding is ideal. Always indicate whether or not the probe was placed under or on top of shielding.
5. Electronic dosimeters should be installed as soon as possible and kept in place as long as possible. Where applicable, installation should occur prior to evolutions associated with forced oxidation (i.e., hydrogen peroxide addition or other coolant oxygenation measures). Out-of-containment dosimeters should be left in place for at least 2 weeks following startup and, if possible, throughout operation (recommended). The objective of this data collection is to monitor changes in dose rate with time and plant evolutions.
6. Indicate the type of device used (i.e., HpGe, LaBr, CZT, etc.), along with detector size, resolution, and any shielding specifics. Also indicate the date at which the measurement was taken (absolute or relative to plant shutdown).
7. Dose rates are measured prior to primary side inspection or maintenance of the Steam Generator.
8. Dose rate measurements before and after shielding package installation at shutdown may be reported instead.
9. Contact dose rate as soon as possible (i.e., within 24 hours) following RHR/SDC/DH isolation during plant startup.
10. Electronic dosimeters should be installed prior to shutdown operations involving the RHR/SDC/DH system (i.e., flushing or placing the system into service) and kept in place for at least 2 weeks following startup. It is recommended that dosimeters at these locations be left in place during operation. The objective of this data collection is to monitor changes in dose rate with time.

Table 4-1
Revised BRAC Radiological Survey Program

Description	Location	Survey Type				Survey Timing
		Contact-Shielded Probe (CSP)	Gamma Spectrum Analysis (GSA)	Electronic Dosimetry (ED) (1)	General Area (GA)	
Reactor Recirculation System Piping	Pump Suction and Discharge Vertical Piping	Required	Highly Recommended	Optional (2)	N/A	7 to 10 days after shutdown
Reactor Recirculation System Piping	Vertical riser piping to N2 nozzles (above ring header, below elbow)	Recommended	Optional	Optional (2)	N/A	7 to 10 days after shutdown
Under Vessel	Two feet below shoot-out-steel centerline.	N/A	N/A	Highly Recommended	Required	After TIP tubing removed. If ED is installed, locate so that it does not interfere with work activities and does not have to be relocated.
Reactor vessel bottom head drain line	Vertical section of piping upstream of first isolation valve.	Required	Recommended	Optional	N/A	CSP and GSA: 7 to 10 days after shutdown
RWCU Inlet Piping	Vertical piping adjacent to inboard containment isolation valve	Required	Highly Recommended	Highly Recommended	N/A	CSP and GSA: 7 to 10 days after shutdown
RWCU Pumps	Vertical pump suction piping	Recommended	Optional	Recommended (3)	N/A	Plant specific
RWCU Heat Exchangers	Inlet head on RHE and/or inlet head on NRHE	Optional	Optional	Recommended (3)	N/A	Plant specific
Main Steam Piping	Main steam piping adjacent to outboard MSIVs	Highly Recommended (4)	Recommended (4)	N/A	N/A	Prior to flooding main steam lines

Description	Location	Survey Type				Survey Timing
		Contact-Shielded Probe (CSP)	Gamma Spectrum Analysis (GSA)	Electronic Dosimetry (ED) (1)	General Area (GA)	
RHR SDC Header	Vertical piping on SDC header, outside of drywell	Required	Highly Recommended	Highly Recommended (5)	Optional	CSP and GSA: 7 to 10 days after shutdown. ED setup prior to first start of SDC.
RHR Pumps	Vertical pump suction piping (preferred)	Recommended	Optional	Recommended (5)	Optional	CSP and GSA: 7 to 10 days after shutdown.
RHR Heat Exchangers	Heat exchanger shell (near reactor coolant inlet and/or exit nozzle) (5)	Recommended	Optional	Optional (5)	Optional	CSP and GS: 7 to 10 days after shutdown.
Refuel Bridge	Plant specific location on refuel bridge	N/A	N/A	Required (6)	Required (6) (7)	Setup ED prior to commencing fuel moves.
IVVI Work platform	Near platform floor	N/A	N/A	Recommended (8)	Recommended (9) (10)	When performing IVVI from platform

Notes.

1. In all cases ED should be installed as soon as possible prior to the activity commencing and should remain in service until the activity is completed or until the end of the outage. Care must be taken to ensure that the remote monitoring equipment is adequately secured so that it does not become a foreign material issue and does not interfere with work activities.
2. Consider when performing chemical decontamination.
3. Use of ED for RWCU outside of drywell is recommended. Plants to choose specific locations; not necessarily the locations specified in table.
4. For plants that observe significant increases in MCO towards EOC and/or observe increases in reactor coolant Co-60 concentrations toward EOC or following an OLNC application.
5. Use of ED at select RHR system locations during an outage is beneficial in identifying transient conditions
6. If possible, use same survey location each outage. Report approximate height of survey point above water level (cavity flooded) with survey data.
7. Required, only if ED cannot be setup on the refuel bridge (at waist level midpoint of bridge). Optional otherwise.
8. If possible, use multiple dosimeters around platform circumference. Note if shielding installed on platform floor. Pre and post flush.
9. Recommended, only if ED cannot be setup on the IVVI work platform. Note if shielding installed. Pre and post flush. Optional otherwise.
10. If performing manual general area surveys, consider performing at multiple worker locations (floor level, knee level, waist level, chest level, head level)