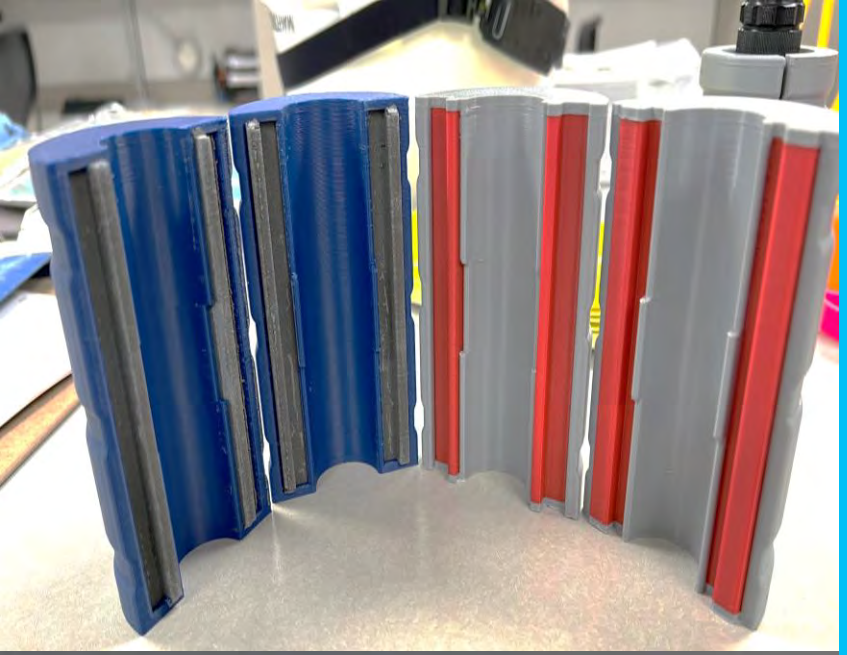
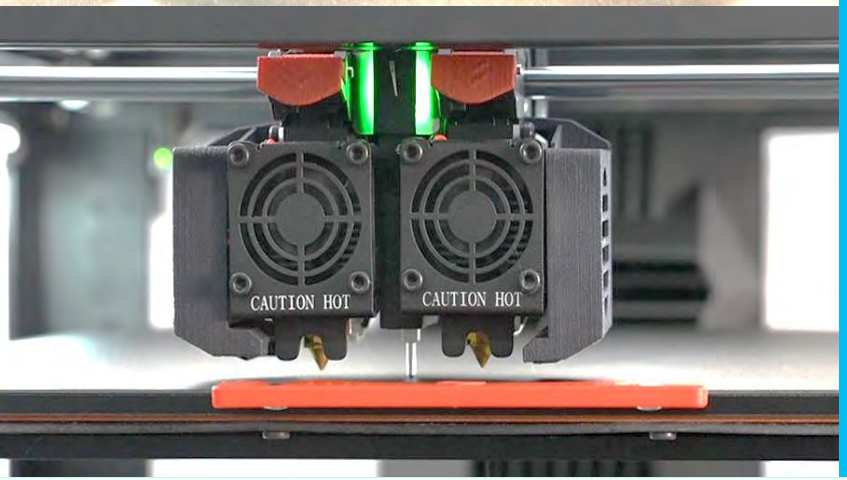
RP ALARA Presentations

A. RP ALARA Presentations

1. 3D Printing
2. WANO 10 Method

3D Printed Shielding





3D Printed Shielding

DCPP RP ALARA

PG&E Together, Building a Better California

OE: IRIS 586757 3DP Tungsten Shielding

DCPP RP ALARA

PG&E Together, Building a Better California

Bruce Power

INPO IRIS 586757

- Bruce Power introduced to INPO an innovation in radiation shielding in 2023.
- Leveraged 3D printing technology with a tungsten-infused filament for radiation shielding applications.

SAPN 51242803

- INPO directed DCPP to evaluate use of 3D printing technology in everyday applications to include 3D shielding.
- DCPP ALARA concluded that routine use of this technology could occur under $20,000.

DCPP Goal

Routine Use

- Leverage 3D printing technology in a low-cost and repeatable manner with minimal effort by the end-user.

Technology Overview

DCPP RP ALARA

Together, Building a Better California

Fused Filament Fabrication (FFF)

FFF Description

- Additive manufacturing process that uses thermoplastic material to create 3D objects.
- Deposits of automatically arranged melted plastic builds a 3D object layer by layer.
- Also known as “Fused Deposition Modeling”.

Printers

- A host of printers exist that utilize the FFF process ranging from simple machines on Amazon to the industrial machines at Raise 3D and beyond.
- DCPP uses the Raise 3D Pro3 Plus H/S and Bambu X1E printers for our project.

Cost & Benefit Analysis

Procurement & Implementation

PG&E

Together, Building a Better California

Costs

Cost of Procurement & Implementation

Item	Vendor	Purchase Type	Cost
Raise 3D Pro 3 H/S Printer	Raise 3D	Initial	$7,599.00
Printer Materials	Raise 3D	Initial	$3,468.87
Miscellaneous Materials	Raise 3D	Supplemental	$4,081.37
Bambu X1E Printer	Matter Hackers	Initial	$4,000.00
SolidWorks Software	Hawk Ridge	Initial	$8,000.00
Tungsten Filament	Virtual Foundry	Initial	$2,400.00
Tungsten Filament	Virtual Foundry	Supplemental	$6,788.97
Total			**$36,338.21**

NOTE: Costs do not include time spent learning about software or 3D printing.

Disadvantages

Disadvantages

- High learning curve for new users.
- Front end software appears very expensive
- Constant misalignment of nozzles led to grinding through multiple build plates.
- Factory misalignment of nozzles identified after 2-months of troubleshooting.
- Routine maintenance is required (not advertised).

Disadvantages

- Buyer is required to perform all maintenance.
- Vendor on-site work is extremely expensive (thousands for just a visit).
- Vendor support is limited to emails and phone calls that significantly delays printer repair.
- High cost for tungsten filament ($800/kg-filament).
- **Print time and design complexity are proportional**.

Advantages

Advantages

- High potential for a significant reduction of costs/time for material use.
- Easily repeatable builds after design/product are stabilized.
- Simple process to print out 3D Objects after design completion.
- Most builds can be finished within a 12-hour shift.

Advantages

- Engineering has agreed to re-evaluate use of shielding on in-service systems that use fitted shielding.
- Relatively simple knowledge transfer and training on printer use and daily checks.
- Maintenance is relatively simple after learning.

Applications

Everyday Materials

- Sample carriers
- Source holders
- Portal monitor source holders
- Instrument calibration tools.
- Probe cover for floor frisking

Shielding Applications

- Shielded
  - Sample Carriers
  - Source Carriers
  - Frisker Probes
  - Frisker Caves (in dev)
  - Straight Pipes
  - Elbows
  - Tee-connections
  - Brackets

Shielding Effectiveness

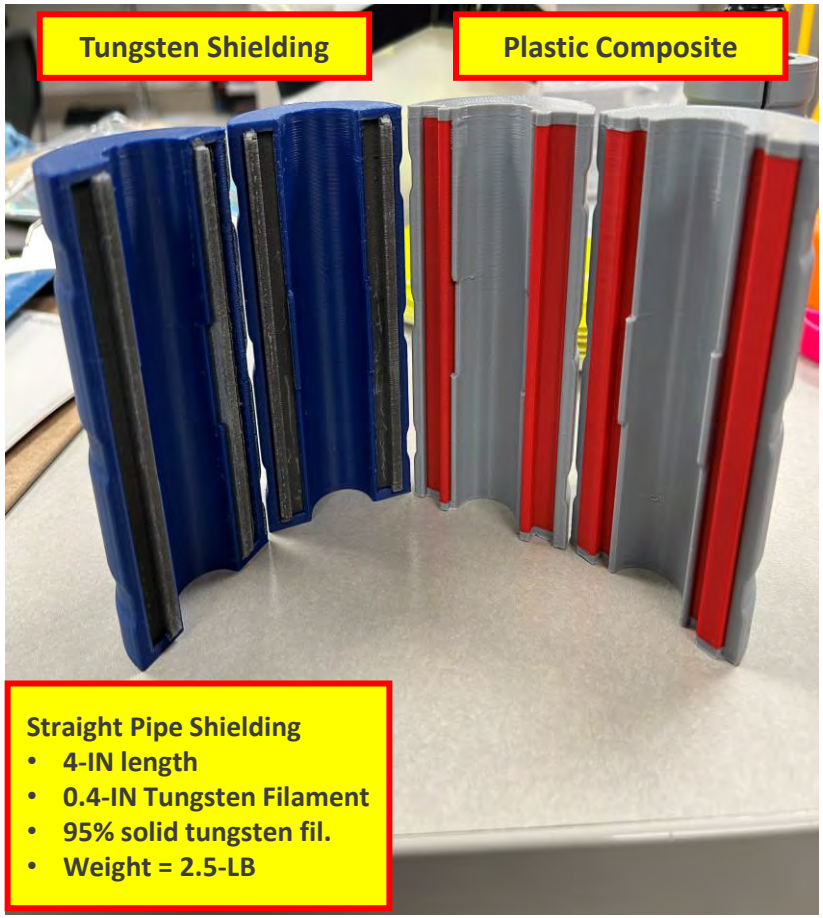
Tungsten Application

PG&E

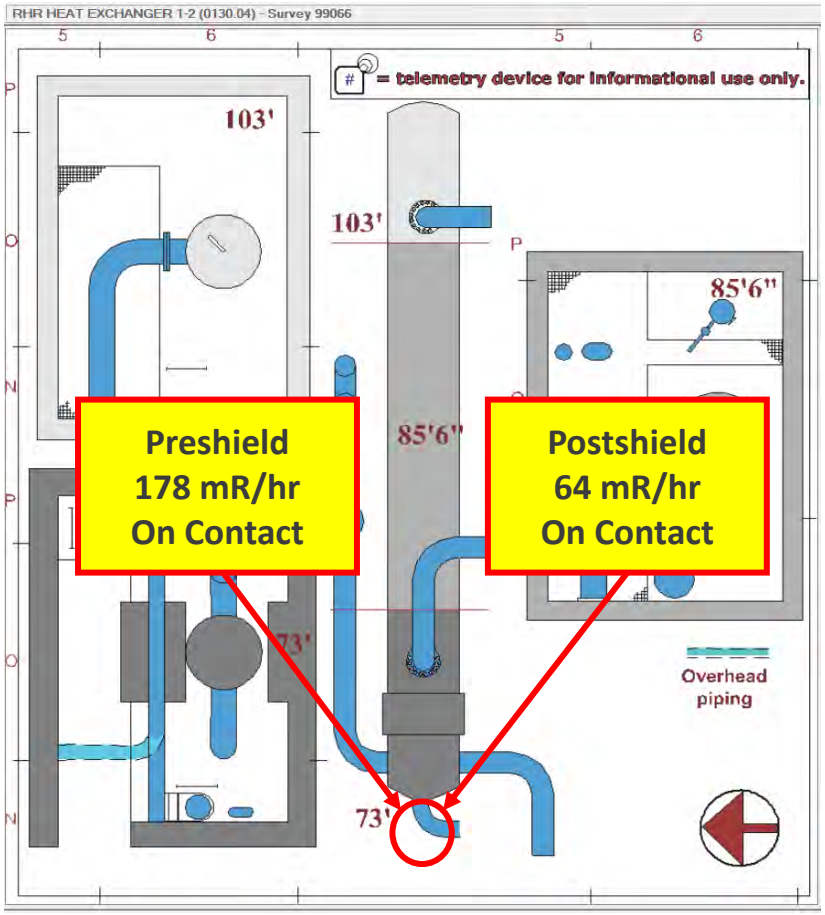
Together, Building a Better California

Radiation Shielding

3D Printed Parts



RHR HX Pipe Drain



Final Thoughts

DCPP 3D Printing

PG&E

Together, Building
a Better California

3D Printed Radiation Shielding

Feasibility

- Experience is essential for proper builds and cost management.
- Once designs are set, builds are reliably repeatable.
- Routine maintenance is essential for consistent performance.
- Convenience of 3D Printing makes the effort worthwhile.
- The opportunity to shield hotspots on in-service systems is worth the effort.
- Successful performance leads the way to further enhancements in the process.

Questions, Comments, Recommendations?

Contact Felix Martinez at

felix.martinez@pge.com

WANO 10 Method

Constellation

Transition to WANO Method 10 for RP

Introduction

- INPO transitioned to Method 10 on January 1st 2025
  - This change was made to align INPO and WANO
  - Site Collective Radiation Exposure (CRE) will be the only input to Station INPO Index
    - RPI will still be tracked by INPO but have no link to Station INPO Points

- Current Method - Radiation Protection Index- (RPI)
  - 6 different inputs – Total of 100 Points
    - CRE – 20 Points
      - Previous 24 months online CRE + last outage CRE / 2 = 2yr rolling average
      - 2 yr average < 110 Rem = 20 Points, >220 Rem = 0 Points
    - Dose Control (LHRA) – 30 Points
    - Dose Control (HRA) – 21 Points
    - RAM Control (PA) – 10 Points
    - RAM Control (RCA) – 4 Points
    - Contamination Control – 5 Points
    - RAM Shipping – 10 points
  - 7.5 Points attributed to Station INPO Index Points
    - RPI >90 Points = 7.5 Station INPO Points

Constellation

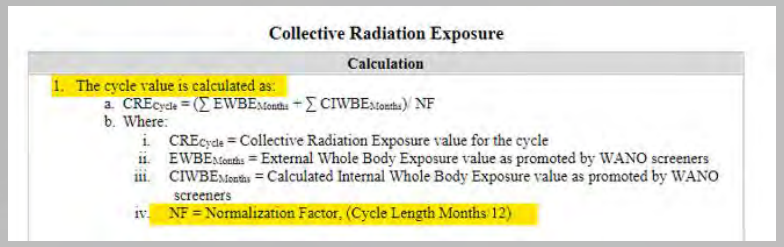
Radiation Protection Index (RPI)

Radiation Protecion Index	Jan-24	Feb-24	Mar-24	Apr-24	May-24	Jun-24	Jul-24	Aug-24	Sep-24	Oct-24	Nov-24	Dec-24
CRE Points BWR (20 Points)	18.126	18.000	14.101	14.040	13.900	13.989	14.369	14.409	16.338	16.281	16.250	16.249
Dose Control Event Points (30 Points)	30	30	30	30	30	30	30	30	30	30	30	30
Dose Control INPO Points (21 Points)	21	21	21	21	21	21	21	21	21	21	21	21
RAM PA Points (10 Points)	10	10	10	10	10	10	10	10	10	10	10	10
RAM RCA Points (4 Points)	4	4	4	4	4	4	4	4	4	4	4	4
Contamination Control Events Index (5 Points)	5	5	5	5	5	5	5	5	5	5	5	5
RPI RAM Shipping (10 Points)	10	10	10	10	10	10	10	10	10	10	10	10
RPI Value	98.126	98.000	94.101	94.040	93.900	93.989	94.369	94.409	96.338	96.281	96.250	96.249
RPI Points	Jan-24	Feb-24	Mar-24	Apr-24	May-24	Jun-24	Jul-24	Aug-24	Sep-24	Oct-24	Nov-24	Dec-24
Unit 1 RP Index	100	100	100	100	100	100	100	100	100	100	100	100
Unit 2 RP Index	98.1	98.0	94.1	94.0	93.9	94.0	94.4	94.4	96.3	96.3	96.2	96.2
Station RP Index	99.1	99.0	97.1	97.0	97.0	97.0	97.2	97.2	98.2	98.1	98.1	98.1
INPO Point Value	Jan-24	Feb-24	Mar-24	Apr-24	May-24	Jun-24	Jul-24	Aug-24	Sep-24	Oct-24	Nov-24	Dec-24
Unit 1 INPO Points (Max 7.5)	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50
Unit 2 INPO Points (Max 7.5)	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50
Station INPO Points (Max 7.5)	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50

Constellation

INPO Method 10

- Method 10
  - Only one input
    - Collective Radiation Exposure
      - Cycle CRE (Online and Outage)/ NF = Cycle Average
      - Total dose for previous cycle duration (18 months or 24 months)
      - Normalized by dividing cycle duration by 12 (NF)
  - 10 Points attributed to Station INPO Index Points
    - BWRs
      - Cycle Average <120 Rem = 10 Points
      - Cycle Average >220 Rem = 0 Points
    - PWRs
      - Cycle Average <60 Rem = 10 Points
      - Cycle Average >80 Rem = 0 Points



Collective Radiation Exposure

Calculation
1. The cycle value is calculated as:
a. $CRE_{Cycle} = (\sum EWBE_{Months} + \sum CIWBE_{Months}) / NF$
b. Where:
i. CRE_{Cycle} = Collective Radiation Exposure value for the cycle
ii. $EWBE_{Months}$ = External Whole Body Exposure value as promoted by WANO screeners
iii. $CIWBE_{Months}$ = Calculated Internal Whole Body Exposure value as promoted by WANO screeners
iv. NF = Normalization Factor, (Cycle Length Months/12)

WANO Performance Indicator Index

WANO Performance Indicator Index - Method 10

Definition
This indicator is calculated using a weighted combination of performance indicators. **Guidance/Key Insights to Understand:** • WANO specifies points redistribution- if up to half of the contributors are missing, the remaining indicators will ALL be weighted more heavily with a common multiplier to compensate for the missing contributor's points. • WANO specifies contributing indicators are rounded to the value displayed, contrary to PICs normal behavior where rounding only happens displaying the final value on the website. • Each indicator is assigned a point value based on its value. • Point earned are interpolated between the full and no points thresholds. • The point values for individual indicators are summed to determine the overall index for a unit. • This indicator is a Unit Level Indicator. • This indicator first calculated Jan 1996.

Performance Indicator	Duration	Points	Full Points	No Points
High Pressure Injection Unavailability (indicatorid: 101500)	36M	10	0.02	0.03
Heat Removal Unavailability (indicatorid: 101501)	36M	10	0.02	0.03
Emergency AC Power Unavailability (indicatorID: 101502)	36M	10	0.025	0.035
Unplanned Scram Rate (indicatorID: 101801)	24M	15	0.5	1
Forced Loss Rate (indicatorID: 101498)	Cycle	15	1.25	4
Unit Capability Rate (indicatorID: 101798)	Cycle	10	98	93
Total Industrial Safety Accident Rate (indicatorID: 101800)	Cycle	5	0.05	0.5
Collective Radiation Exposure (indicatorID 101495)	Cycle	10	BWR: 120 PHWR:80 PWR: 60	BWR: 220 PHWR:140 PWR: 120
Fuel Reliability (indicatorID 101505)	Index	10	BWR: 300 PHWR:0.0005 PWR: 0.0005	BWR: 3000 PHWR:0.005 PWR: 0.005
Chemistry Performance (indicatorID 101496)	Cycle	5	1.01	1.2

Data Requirements:

At least 50% of contributing indicators must have a calculated value for the month.

Page 1 of 2

Radiation Protection Index (RPI)

BWR Method 10 CRE Point Calculator

2 yr Average <120 Rem = 10 Points 2 yr Average >220 Rem = 0 Points

Unit 1				Unit 2			
Month	Total Monthly Dose (Outage and Online)	Cycle Average	Method 10 CRE Points	Month	Total Monthly Dose (Outage and Online)	Cycle Average	Method 10 CRE Points
Jan-24	0.806	77.52	10.00	Jan-24	4.018	120.29	9.97
Feb-24	0.872	77.29	10.00	Feb-24	8.143	120.94	9.91
Mar-24	0.674	77.18	10.00	Mar-24	184.423	141.47	7.85
Apr-24	3.871	77.86	10.00	Apr-24	4.308	141.79	7.82
May-24	1.032	71.67	10.00	May-24	5.030	142.55	7.74
Jun-24	1.294	71.56	10.00	Jun-24	1.974	142.06	7.79
Jul-24	0.856	71.58	10.00	Jul-24	1.394	139.97	8.00
Aug-24	0.833	71.70	10.00	Aug-24	2.469	139.75	8.02
Sep-24	1.379	72.17	10.00	Sep-24	1.709	127.52	9.25
Oct-24	1.182	72.49	10.00	Oct-24	2.779	127.78	9.22
Nov-24	1.173	72.69	10.00	Nov-24	2.027	127.96	9.20
Dec-24	1.163	72.46	10.00	Dec-24	2.197	127.96	9.20
Jan-25	1.163	72.01	10.00	Jan-25	2.917	126.90	9.31
Feb-25	1.163	71.53	10.00	Feb-25	2.917	127.58	9.24
Mar-25	1.163	23.01	10.00	Mar-25	2.917	128.18	9.18
Apr-25	127.643	76.98	10.00	Apr-25	2.917	128.97	9.10
May-25	1.163	77.02	10.00	May-25	2.917	128.30	9.17
Jun-25	1.163	77.17	10.00	Jun-25	2.917	127.83	9.22
Jul-25	1.163	77.39	10.00	Jul-25	2.917	128.06	9.19
Aug-25	1.163	77.34	10.00	Aug-25	2.917	128.67	9.13
Sep-25	1.163	77.35	10.00	Sep-25	2.917	126.35	9.36
Oct-25	1.163	77.39	10.00	Oct-25	2.917	126.60	9.34
Nov-25	1.163	77.53	10.00	Nov-25	2.917	127.40	9.26
Dec-25	1.163	77.79	10.00	Dec-25	2.917	127.74	9.23

PWR Method 10 CRE Point Calculator

2 yr Average <60 Rem = 10 Points 2 yr Average >120 Rem = 0 Points

Unit 1				Unit 2				
Month	Total Monthly Dose (Outage and Online)	2-Year Average	Method 10 CRE Points	Month	Total Monthly Dose (Outage and Online)	Monthly Dose	2-Year Average	Method 10 CRE Points
Jan-24	0.290	27.44	10.00	Jan-24	0.21	122.90	0.00	
Feb-24	0.140	26.84	10.00	Feb-24	0.22	119.59	0.04	
Mar-24	0.140	26.47	10.00	Mar-24	0.17	47.99	10.00	
Apr-24	28.980	39.70	10.00	Apr-24	0.13	46.22	10.00	
May-24	0.620	33.31	10.00	May-24	0.12	44.54	10.00	
Jun-24	0.250	32.67	10.00	Jun-24	0.18	43.15	10.00	
Jul-24	0.130	32.34	10.00	Jul-24	0.12	40.42	10.00	
Aug-24	0.350	32.21	10.00	Aug-24	0.34	39.14	10.00	
Sep-24	0.118	32.05	10.00	Sep-24	0.118	26.11	10.00	
Oct-24	0.232	16.68	10.00	Oct-24	0.232	26.20	10.00	
Nov-24	0.187	16.73	10.00	Nov-24	0.187	26.25	10.00	
Dec-24	0.111	16.70	10.00	Dec-24	0.111	26.20	10.00	
Jan-25	0.146	16.68	10.00	Jan-25	0.146	26.22	10.00	
Feb-25	0.139	16.66	10.00	Feb-25	0.139	26.24	10.00	
Mar-25	0.132	16.67	10.00	Mar-25	0.132	26.25	10.00	
Apr-25	127.643	80.43	3.96	Apr-25	0.126	13.57	10.00	
May-25	1.163	80.91	3.91	May-25	2.917	3.32	10.00	
Jun-25	1.163	81.40	3.86	Jun-25	2.917	4.72	10.00	
Jul-25	1.163	81.93	3.81	Jul-25	2.917	6.13	10.00	
Aug-25	1.163	82.43	3.76	Aug-25	2.917	7.46	10.00	
Sep-25	1.163	82.91	3.71	Sep-25	2.917	8.82	10.00	
Oct-25	1.163	83.40	3.66	Oct-25	2.917	10.21	10.00	
Nov-25	1.163	83.92	3.61	Nov-25	2.917	11.60	10.00	
Dec-25	1.163	84.46	3.55	Dec-25	2.917	13.01	10.00	

INPO Method 10 Monthly Data Requests

Month:																							
Station	BWD		BYR		CC		CPS	DRE		FITZ	GN	LAS		LIM		NMP		PB		QC		Fleet Totals
Unit	U1	U2	U1	U2	U1	U2	U1	U2	U3	U1	U1	U1	U2	U1	U2	U1	U2	U2	U3	U1	U2	
INPO Method 10 (Unit)	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	0.00	10.00	10.00	10.00	9.29	10.00	10.00	10.00	6.70	
INPO Method 10 (Site)	10.00		10.00		10.00		10.00	10.00		10.00	10.00	5.00		10.00		9.65		10.00		8.35		9.42
RPI (Unit)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	80.0	92.0	100.0	100.0	96.4	100.0	100.0	100.0	91.0	
RPI (Site)	100.0		100.0		100.0		100.0	100.0		100.0	100.0	90.0		92.0		98.2		100.0		95.5		97.98
Business Plan Goals																						
Annual Goal	33.60	3.50	3.00	35.60	4.00	50.00	156.00	177.40	21.60	27.00	2.80	23.30	192.00	23.00	192.00	147.00	40.00	28.00	152.00	205.00	20.00	1536.80
Annual Stretch Goal																						0.000
Year to Date Actuals																						
BP Goal through the end of the current month (O.3)																						0.000
Actual																						0.000
Status On-track/Off-track to BP	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Online Emergent Dose																						0.000
Outage																						
Outage Business Plan Goal (Month)																						0.000
Outage Stretch Goal (Month)																						0.000
Outage Estimate (Month)																						0.000
Outage Actual (Month)																						0.000
Outage Projected Emergent (Month)																						0.000
Current Month																						
Monthly Business Plan Goal (0.3)																						0.000
Monthly Estimate (SAC)																						0.000
Monthly Actual																						0.000
Status On-track/Off-track to BP Goal	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Status On-track/Off-track to SAC Estimate	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Site Historical Best Low Dose Month Performance																						
Record Month	03/2022		07/2020		12/2020		08/2020	07/2020		12/2019	05/2021	11/2019		10/2015		08/2016		12/2016		11/2016		
Record Dose Value	0.116		0.127		0.083		0.401	1.608		0.648	0.047	2.508		0.841		1.893		1.336		1.594		
Site Historical Best Low Dose Outage Performance																						
Record Refuel Outage Number	A1R18		B1R24		CC2R24		C1R16	D3R25		R22	G1R39	L1R18		Li1R18		N1R26		P3R23		Q1R27		
Record Dose Year	2015		2021		2021		2016	2018		2014	2015	2020		2020		2021		2021		2021		
Record Dose Value	16.766		17.016		38.521		16.490	69.808		90.745	26.492	112.025		64.124		70.072		86.550		104.144		
Site Historical Best Low Dose Year Performance																						
Record Year	2019		2021		2021		2020	2020		2014	2022	2020		2015		2021		2021		2021		
Record Dose Value	27.152		21.518		40.506		13.217	115.000		151.9	1.870	179.220		121.954		124.709		144.783		136.238		