US Dry Cask Dose Comparisons

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Mission: Implementation of Dry Cask on-site Storage for Spent Fuel

- Post-Fukushima Tier II US NRC recommendation was to safely move spent fuel from LWR from Wet Storage to Dry Cask Storage On-site
- Special license is grant to each utility to perform the work entitled: “Dry Cask Storage Campaigns”
- For Example, D. C. Cook 1,2 granted license to start dry cask storage in summer of 2014
- Campaign may only occur from May to October due to winter weather restrictions
- D.C. Cook 1,2 has completed campaigns in 2014 (16 casks) and 2016 (16 casks)

Standard RWP Titles Encouraged

- Standardized RWP titles were encourage for new major radiological work orders to allow better comparisons of dose
- Dose optimization can be achieved by the sharing of good dose reduction practices and lessons learned

ISOE Reference Dose Data Used

- An Armenian presentation at the 3rd European Workshop authored by V. Atoyun and A. Muradyan discussed doses to staff during spent fuel transport and storage
- The paper provided 16 tasks for the work order
- Tables 1-3 provided calculated doses, actual doses and neutron/gamma dose fields
- One lessons learned was that actual doses were lower because estimated doses were based on 3 year of storage in pool: actual time was 10 years prior to spent fuel transport to dry storage

Cook ALARA Conceptual Design

Dry Cask Campaign Defined

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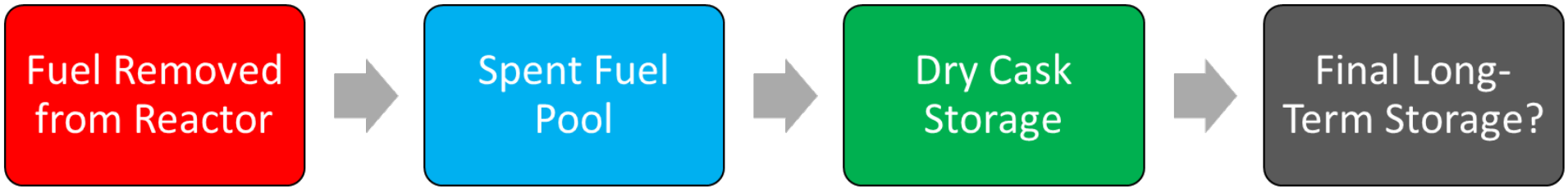
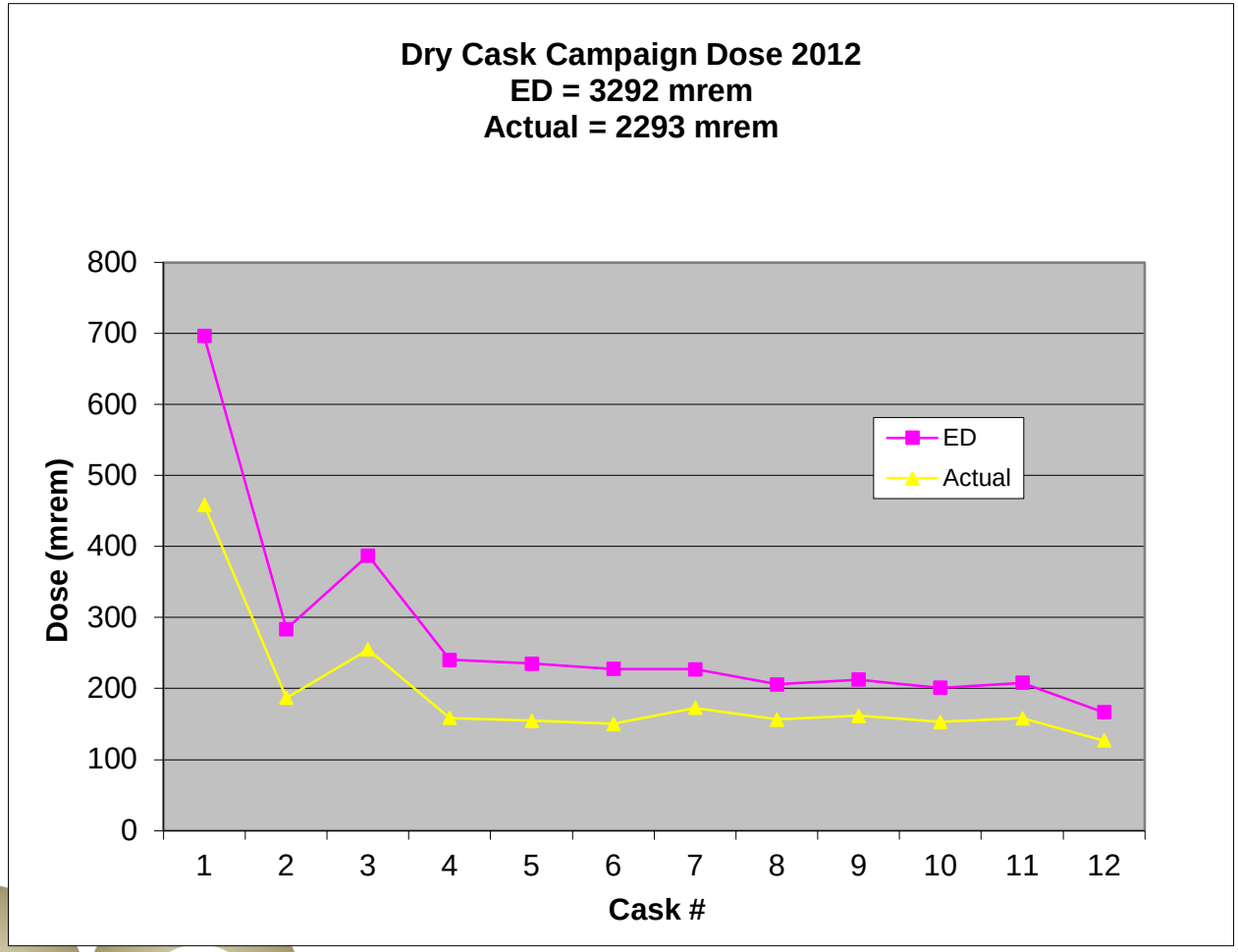
- What is the process of storing spent fuel?



- How can the radiation exposure to workers be limited?

DC Cook Dose History

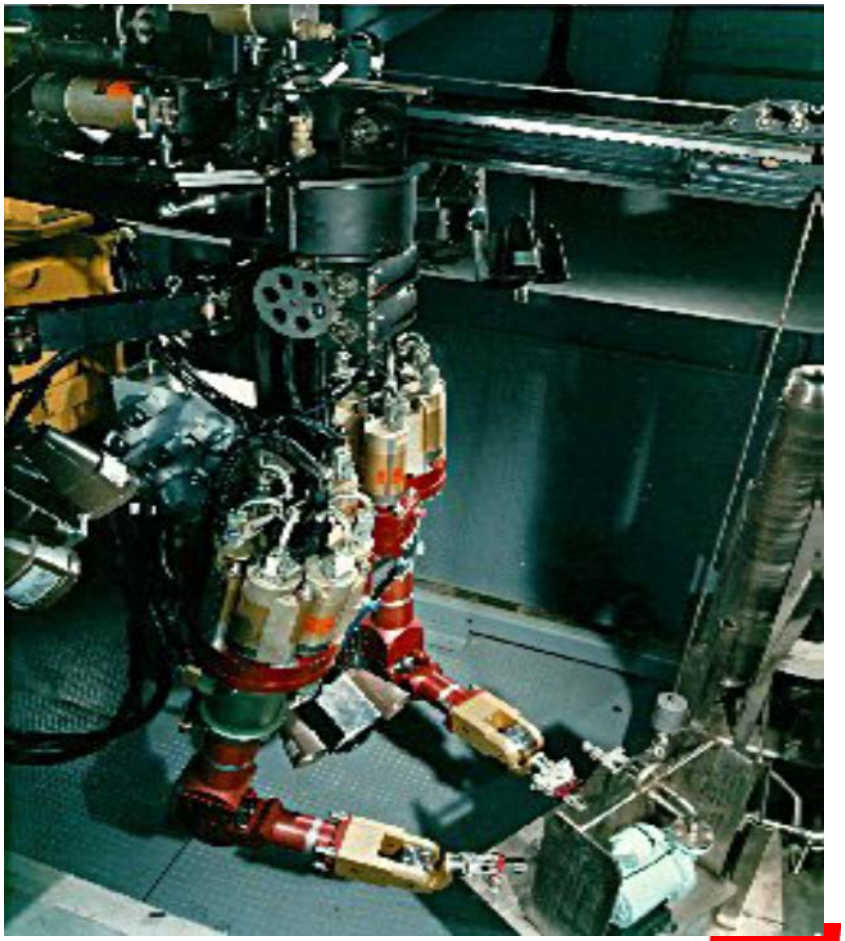


DC Cook Procedure Changes

- Fuel Rod Repositioning
- Increase Distance
- Decreasing Time
- Crowd Control
- Shielding

Increasing Distance

- How can we increase the distance between source and employee?
- Remote Welding Technologies
- Automated Welding Technologies
- Remote Transportation



Definition of Dry Cask Terms

- Multi-Purpose Canister (MPC)
- Fuel is loaded inside this canister
- HI-TRAC
- Transport Cask
- Reused for each loading process
- HI-STORM
- Final cask
- Placed on storage pad in ISFSI (independent spent fuel storage installation)

DC Cook RWP Dose Summary

Task (MPC 12-16)	Number of Workers	Duration	Person Hrs	Eff. Dose Rate	Est. mrem
Mobilize Equip./Prep Cask	10	12	120	0.02	2.4
Load Fuel in MPC	3	20	60	0.5	30
Decon/Movement	10	4	40	1	40
Welding/Processing	6	50	300	0.4	120
Transfer MPC to HI STORM	10	10	100	0.75	75
Place on ISFSI Pad	5	5	25	0.4	10
TOTAL					277.4

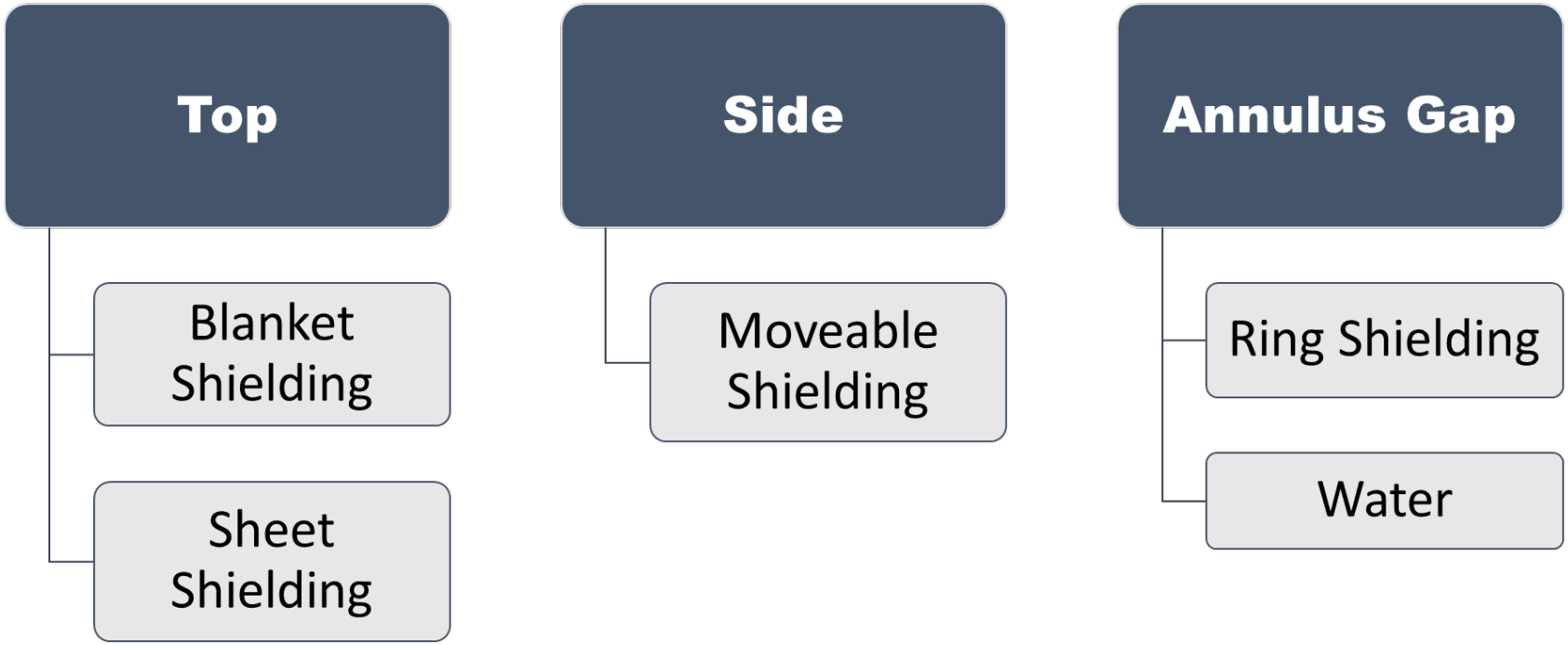
Cook RP Survey Data

Location relative to HI-TRAC	Gamma dose rate (mrem/hr)	Neutron dose rate (mrem/hr)
SIDE, after annulus drain	12-15	15-20
TOP, center, after annulus drain	20-25	65-70
TOP, annulus	700-800 O.C.	
TOP, annulus	200-350 @ 30 cm	20-30

D.C. Cook Planning

- D.C.Cook ALARA group developed the RWP tasks based on the work order activities
- ALARA staff worked with laborers to examine each task and solicit ALARA suggestions
- Paraffin shielding was added to the top and sides of the cask to reduce neutron dose rates
- Time lapse video was taken of each task during the loading and welding of the dry cask
- Significant reduction in dose per cask was achieved after the workers and RP technicians carefully critiqued the time lapse videos

Shielding Package Analysis



Cook Economic Analysis

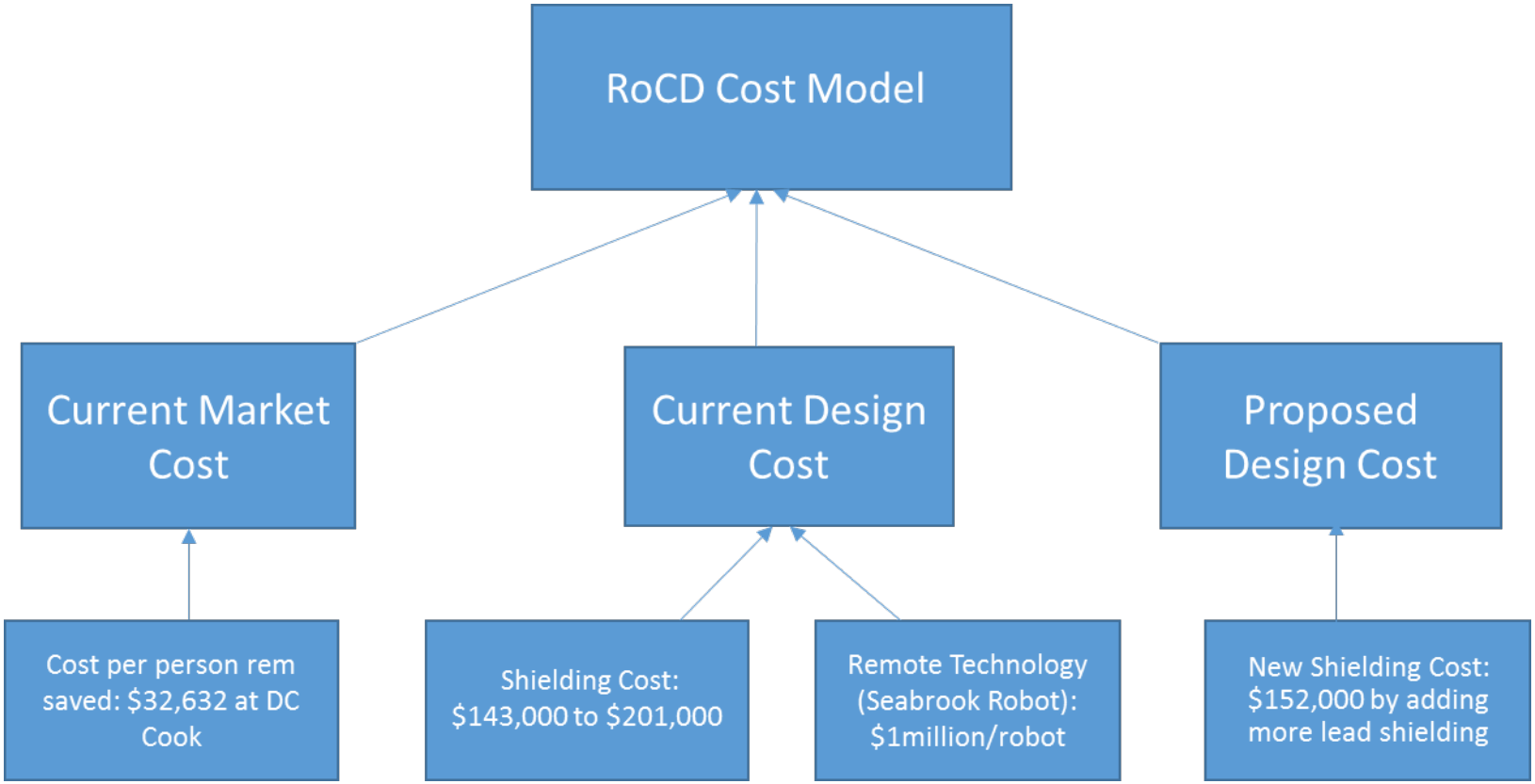
➢What is importance of ALARA?

- Since 1990's, the criteria of saving cost by saving dose has been considered heavily
- "Reasonable" takes into account the economics and ease of implementation
- In present, the ALARA-based credit for the reduced total population dose of 1 person-rem is $1000

➢Budget for dose reduction:

- Our client, DC Cook nuclear power plant, currently spends $32,632 per person rem saved
- It costs from $10,000 to $80,000 per person rem saved which varies from different plants and utility companies
- In average, the cost per person rem saved is $23,976 for all 99 nuclear reactors

Cost Modeling



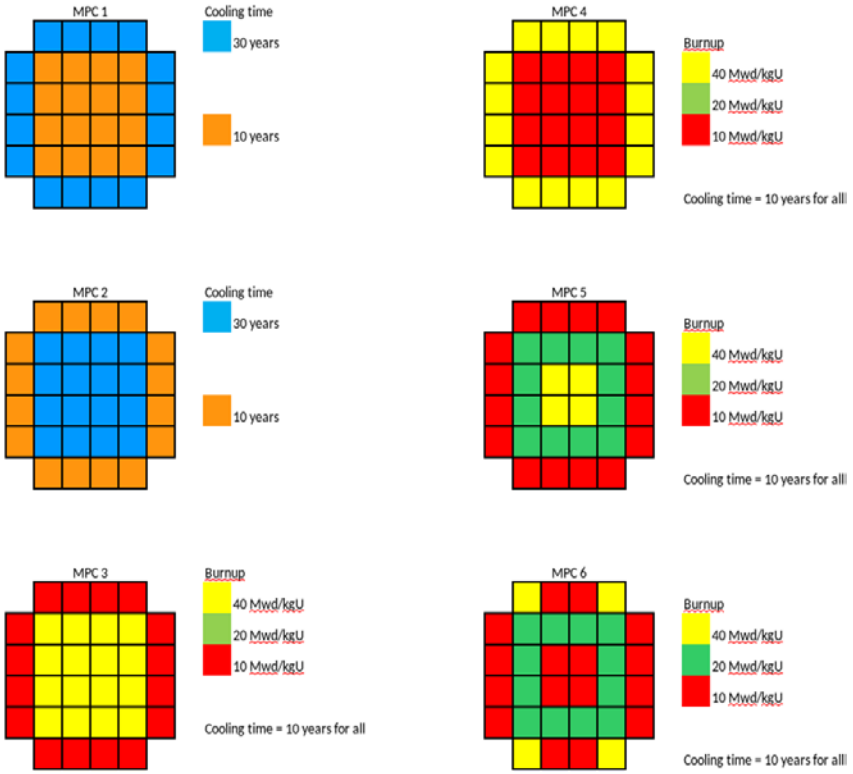
Shielding Materials Economics

Material	Density (g/cm^3)	Cost by weight ($/g)	Cost by volume ($/cm^3)	Thickness required to achieve 90% dose reduction (cm)
Tungsten	19.25	0.0295	0.5679	1.81
Bismuth	9.87	0.0283	0.2793	2.86
Lead	11.34	0.0002	0.0023	3.23
Iron	7.874	0.0002	0.0016	4.88

Serpent Neutron Model

- MPC geometry assumptions
  - Thermal and burnup limits met
  - 17x17 Westinghouse Standard fuel assemblies
  - Each fuel assembly is assumed to have 264 identical fuel pins + 25 guide tubes
  - All fuel is 3.6% initial enrichment.
  - Neutron absorbing material is on each fuel storage cell wall (no gaps in corners)
  - The final boundary of the model is the outer edge of the outermost fuel storage cells
- Burnup calculation assumptions
  - Default neutron population, fuel at 900 K, non-fuel at 600 K
  - Gap between fuel and cladding ignored

Neutron Modeling



ALARA Sharing with Other RPMs

- **D.C.Cook shared the dose savings with Perry and Palisades site**
- **After implementing the time lapse video analysis,**

1. **Cook achieve 26 mrem per cask**
2. **Perry achieved 47 mrem per cask**

Braidwood

2011 Braidwood (3 Casks) - Dose Estimate 1.050 Rem / Actual 0.721 Rem

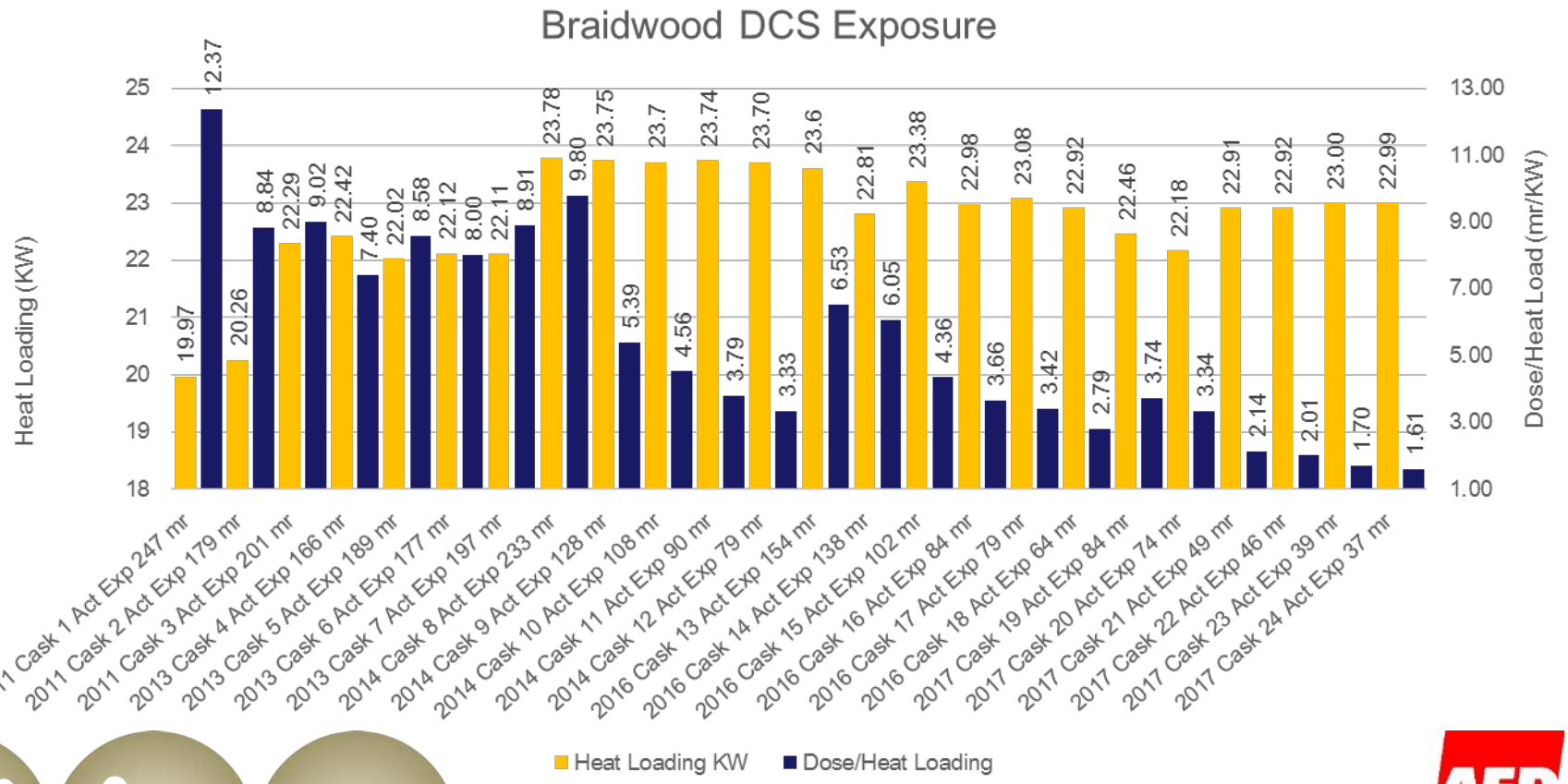
2013 Braidwood (4 Casks) - Dose Estimate 0.808 Rem / Actual 0.755 Rem

2014 Braidwood (5 Casks) - Dose Estimate 0.940 Rem / Actual 0.638 Rem

2016 Braidwood (6 Casks) - Dose Estimate 0.870 Rem / Actual 0.621 Rem

2017 Braidwood (6 Casks) – Dose Estimate 0.599 Rem / Actual 0.329 Rem

Braidwood Dry Cask Exposure History



2011 Initial Exposure

- Cameras were used to monitor remote welding operations and general work area activities.
- LDWA areas were clearly marked with postings and green flashing lights.
- Lead shielding was installed on Dry Pit Hand rail.
- Temporary / Permanent FP skimmer & FPC system were in service prior to start of work and maintained during the duration of the Dry Cask Storage campaign. Dose rates on the refuel bridge were .3 mrem/hr & around the spent fuel pool .2 mrem/hr. Dose rates without Temporary / Permanent FP skimmer & FPC system running were 1.5 mrem/hr on the refuel bridge & around the spent fuel pool .5 mrem/hr.

2013 Braidwood Dose Reduction Improvements

- Cameras were used to monitor remote welding operations and general work area activities.
- LDWA areas were clearly marked with postings and green flashing lights.
- Lead shielding was installed on Dry Pit Hand rail.
- Temporary / Permanent FP skimmer & FPC system were in service prior to start of work and maintained during the duration of the Dry Cask Storage campaign. Dose rates on the refuel bridge were .3 mrem/hr & around the spent fuel pool .2 mrem/hr. Dose rates without Temporary / Permanent FP skimmer & FPC system running were 1.5 mrem/hr on the refuel bridge & around the spent fuel pool .5 mrem/hr.

2016 Dry Cask Improvements

First time at Braidwood using the unrestrained stack-up configuration

This configuration reduced workers time in the area during download activities and saw 35% reduction in exposure when compared with the 2014 campaign

<Restrained

Unrestrained>

2016 Shielding Improvements

Radiation Protection Technician designed a new type of shielding to used in the annulus area

Saved 5 to10 mrem per cask

New Specialty shielding was made to fit in the gaps between the cleats to accommodate using the new unrestraint stack up configuration.
To reduce welders the top of the MPC annular gap were uniquely exposure during weld activities Hot Spots around identified

Braidwood Station

2016 Overall Performance

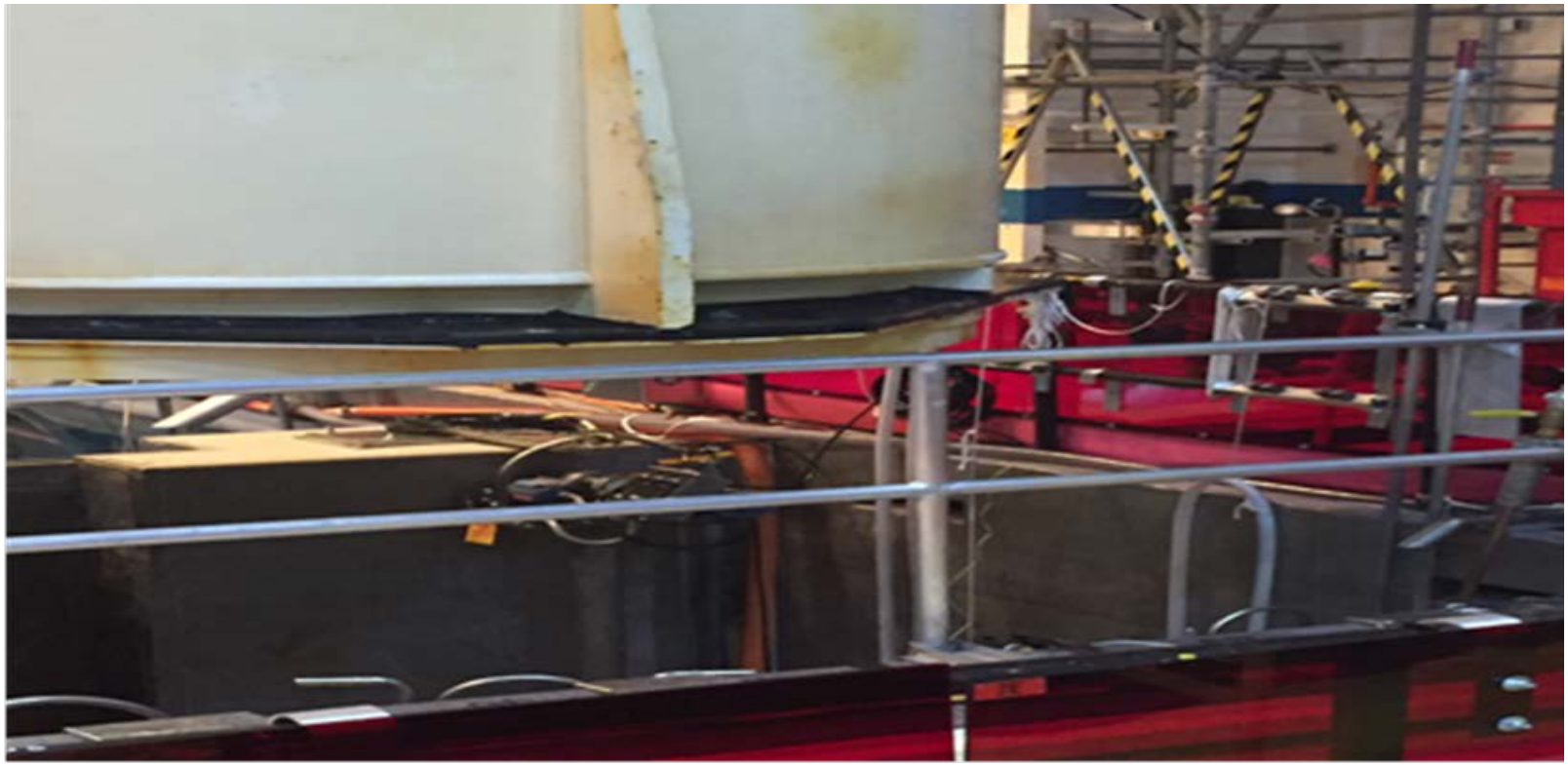
- The weld machine was installed on top of the multi-purpose cask (MPC) in lowest dose area
- Decon of the lower area of the Hi Trac was performed prior to annulus / MPC drain down.
- An RP Job guide was created to outline what the daily Dry Cask activities would be, and identify what equipment, RP resources, and surveys would be required to support the activities.

Clear View Shielding Added in 2017

- Clear View shielding was used on the portable shield rack which saved approximately 4 mrem for each cask

2017 Shielding Improvements

Shielding was installed in the sling basket. This reduced dose rates for the worker when accessing the top of the MPC
The Hi Trac bottom ledge was taped, this reduced the decon time



2017 Improvement Summary

- A long-handled pole was used to smear the pool lid, this could be performed from a distance while in a low dose area.
- Wiped down the Spent Fuel Handling Tool frequently during fuel load decreased dose rates on the tool.
- During fuel moves / the fuel handlers rotated crews.
- The new weld machine used by PCI reduced the welding time and lowered the overall welder's exposure, between both welds that saved approximately 2 hrs of welding time.

Thank You

Questions?

View Looking South