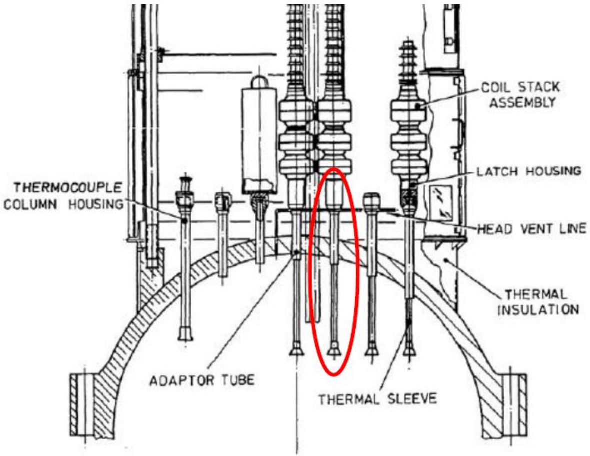
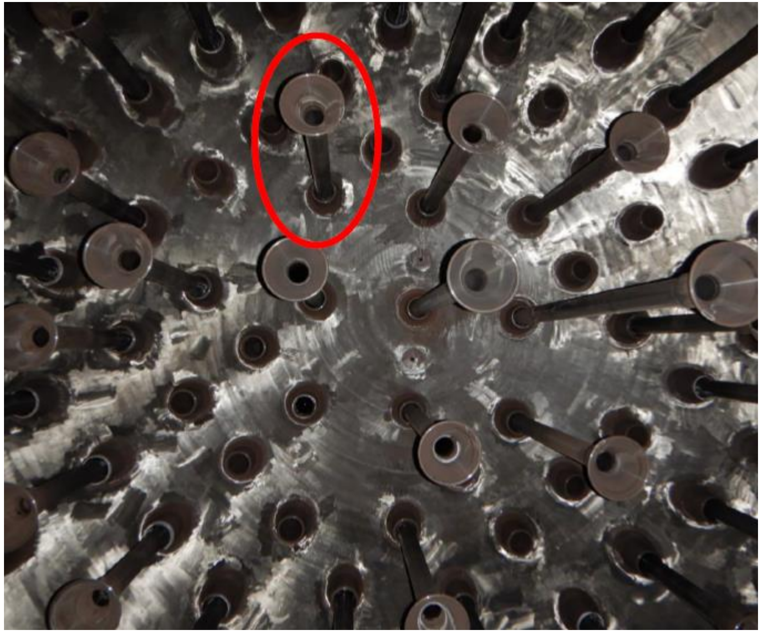
Sizewell B Thermal Sleeve Replacement

Radiological Protection Aspects

Location and function of thermal sleeves



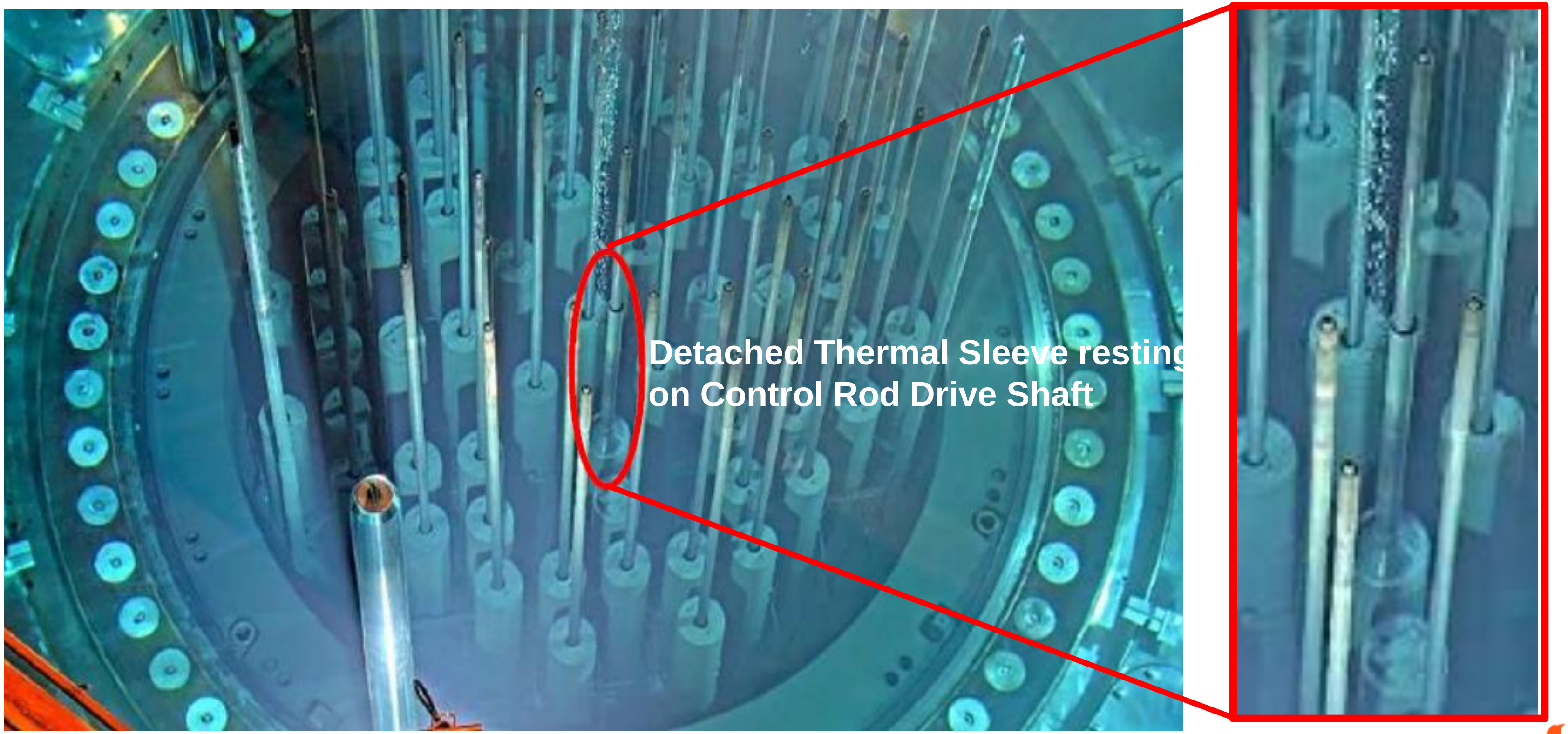


Thermal sleeves protect the Control Rod Drive (CRD) Mechanisms (CRDM) from thermal transients, provide a lead-in alignment for the CRD shafts and protect the CRDMs from the RPV Head cooling spray.

Operating Experience

- Westinghouse had issued two Nuclear Safety Advisory Letters that warned of the potential for separation of thermal sleeves, due to either vibration or thermally induced fatigue.
- Sizewell's RPV Head was replaced in 2006. The analysis indicated that Sizewell was not at short-term risk because the RPV Head at Sizewell had a relatively short operating life of less than fifteen Effective Full Power Years.
- Nevertheless Sizewell decided to carry out laser scanning of thermal sleeves in RO17, to validate the fatigue models.

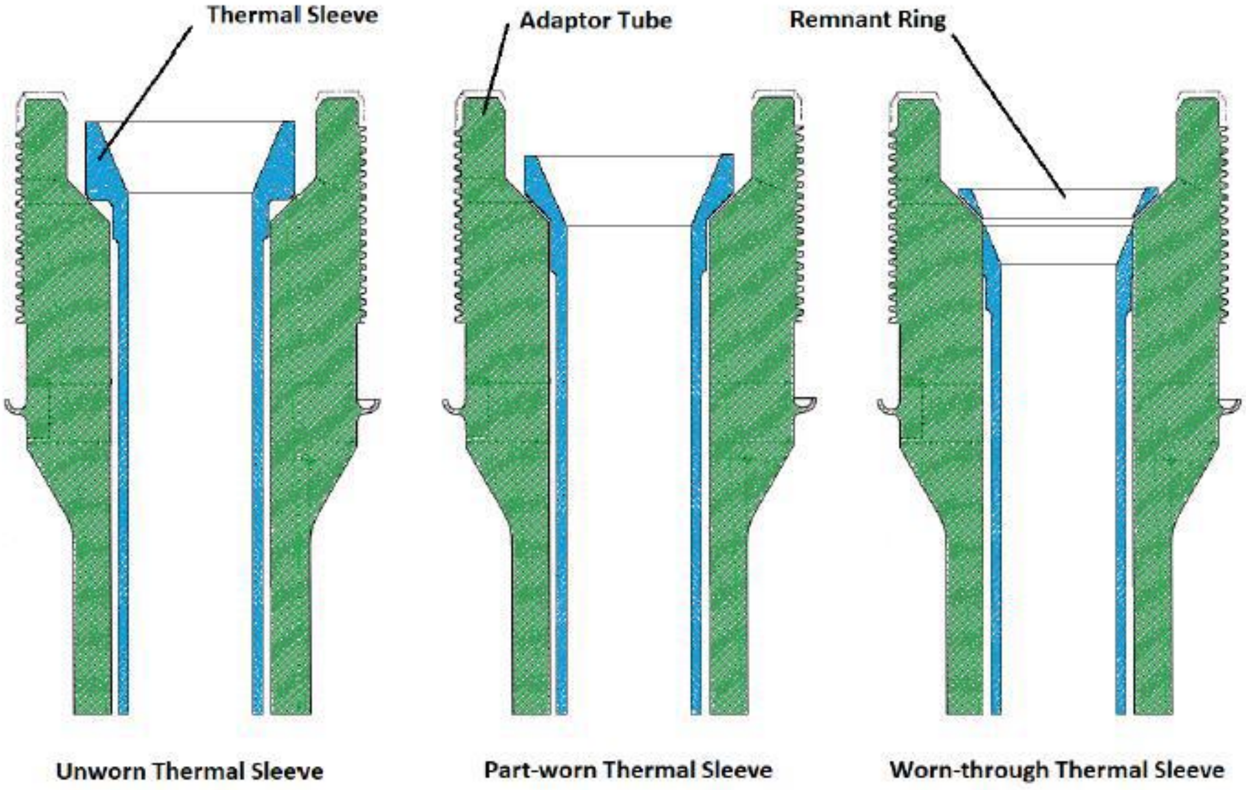
Discovery of detached thermal sleeve after RPVH lift



Recovery Strategy

- Recover the detached thermal sleeve from the Upper Internals.
- Investigate the extent of condition.
- Determine the probable cause of failure.
- Implement a repair for any detached or degrading thermal sleeves.
- Develop a suitable safety case to justify return to power and longer term operation.

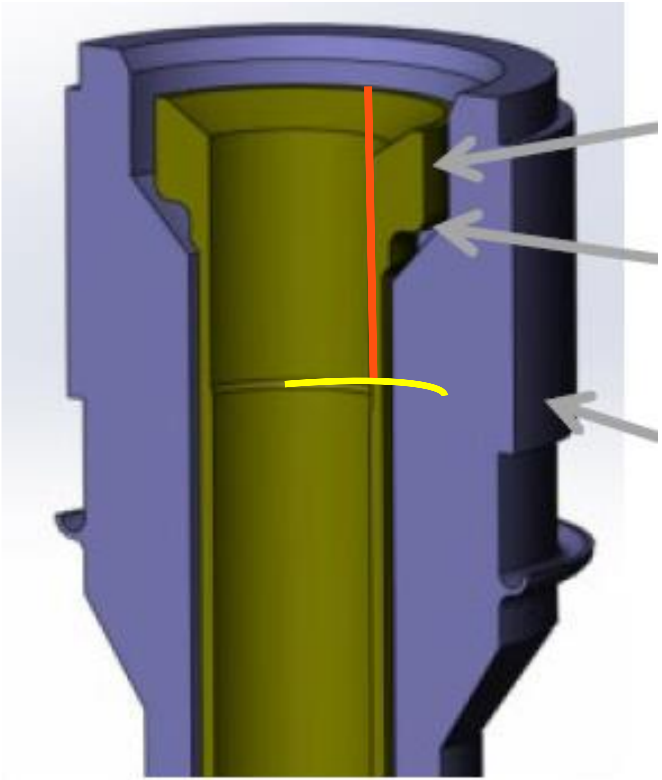
Probable Failure Cause - What Had Happened?



Extent and Type of Repairs

- Laser scanning and analysis indicated that fifteen thermal sleeves required replacement. One thermal sleeve had already separated from the RPVH and was recovered from the Upper Internals. A second sleeve was removed by hand during an investigative “jump” beneath the RPVH.
- “Top down” approach would require significant dismantling of nuclear safety significant components, cutting and rewelding of pressure boundary welds, required a longer time to implement and cost more both in terms of actual technique and in terms of lost generation (~£2m per day).
- The proposed “under head” repair separates the existing thermal sleeves by Electrical Discharge Machining (EDM), inspections of the open penetrations, then installation of compressible thermal sleeves. These required no welding.
- (Both were ~140 vs 190 man.mSv collective dose).

Sleeve Removal: EDM Cut Locations



Three vertical EDM cuts "Alpha Cuts" at 120° apart - shown in red.

Three circumferential EDM cuts of 120 ° - shown in yellow.

Alpha cuts longer duration than beta cuts

Sleeve Replacement

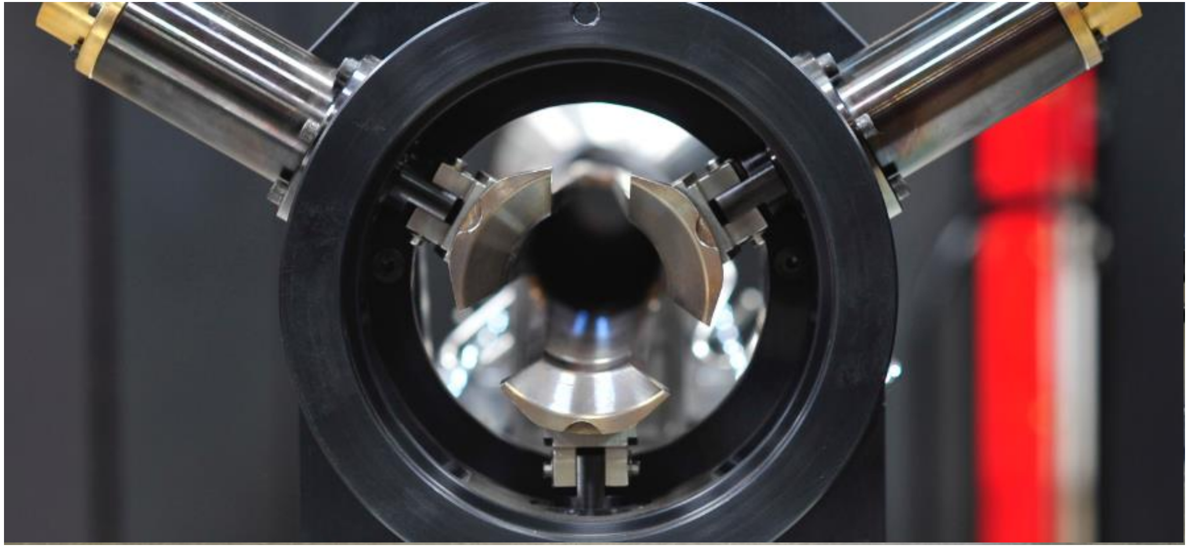
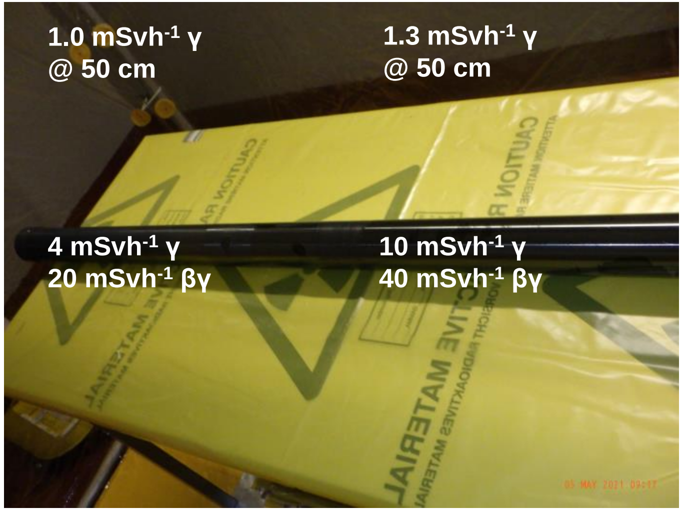
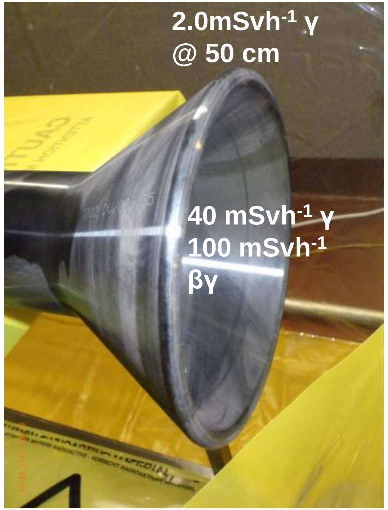


Image courtesy Westinghouse Thermal Sleeve Wear website (https://info.westinghousenuclear.com/blog/comprehensive-solutions-for-thermal-sleeve-wear)

Compressible end of the sleeve is held under tension until fully inserted. When the tension is released the sections at the compressible end spread out like an opening flower.

Radiological Hazard - Thermal Sleeve Source Term





Swabs of recovered sleeve over approximately 3000 cm^2 were full scale deflection by Mini 900 / HP260 (2k cps scale). Dose rate of swabs 0.8 to 2.0 mSv/hr in contact.

Radiological Hazard - Under RPV Head Source Term

Radiological Protection Challenges

- Management of whole body doses.
- Evaluation and management of doses to the lens of eye.
- Containment of airborne activity, generated under the RPV Head, during aggressive tasks, including wet work during cutting (cooling fluid for EDM).
- Handling and storage of old thermal sleeves.

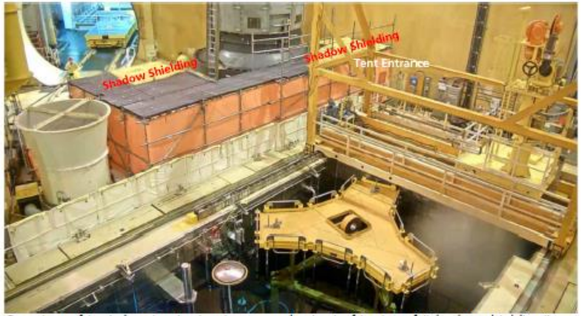
Radiation Dose Control Measures

- Team trained extensively on mock-up at vendor’s works before deployment to Sizewell – unfortunately RP staff could not participate because of Covid restrictions on travel to USA.
- Use of Remote Monitoring – use of multiple cameras, teledosimetry and wireless communications. RP deployed a camera underneath the RPVH which was invaluable in managing doses and in identifying opportunities for dose reduction.
- Use of shadow shielding on the tent roof and walls – to reduce the radiation shine from the RPVH structure above the bolting ring, given the anticipated high number of worker hours in the tent waiting between under head tasks.

Management of Eye Doses

- Eye doses were assessed by eye (Hp (3)) dosemeters positioned on inside of RPE.
- Eye dosemeters were read after early entries to verify doserates to the lens of the eye and to establish the ratio to whole body doses. Dosemeters were repeatedly read until the whole body to eye dose ratio was clearly established and the variance in eye dose results understood.
- For the latter phase of the project eye doses were able to be controlled using the whole body dosemeter to eye dose ratio, allowing the eye dosemeter wear period to be extended. Throughout project doses were systematically assessed by eye dosemeters.

RPVH Storage Stand Tent

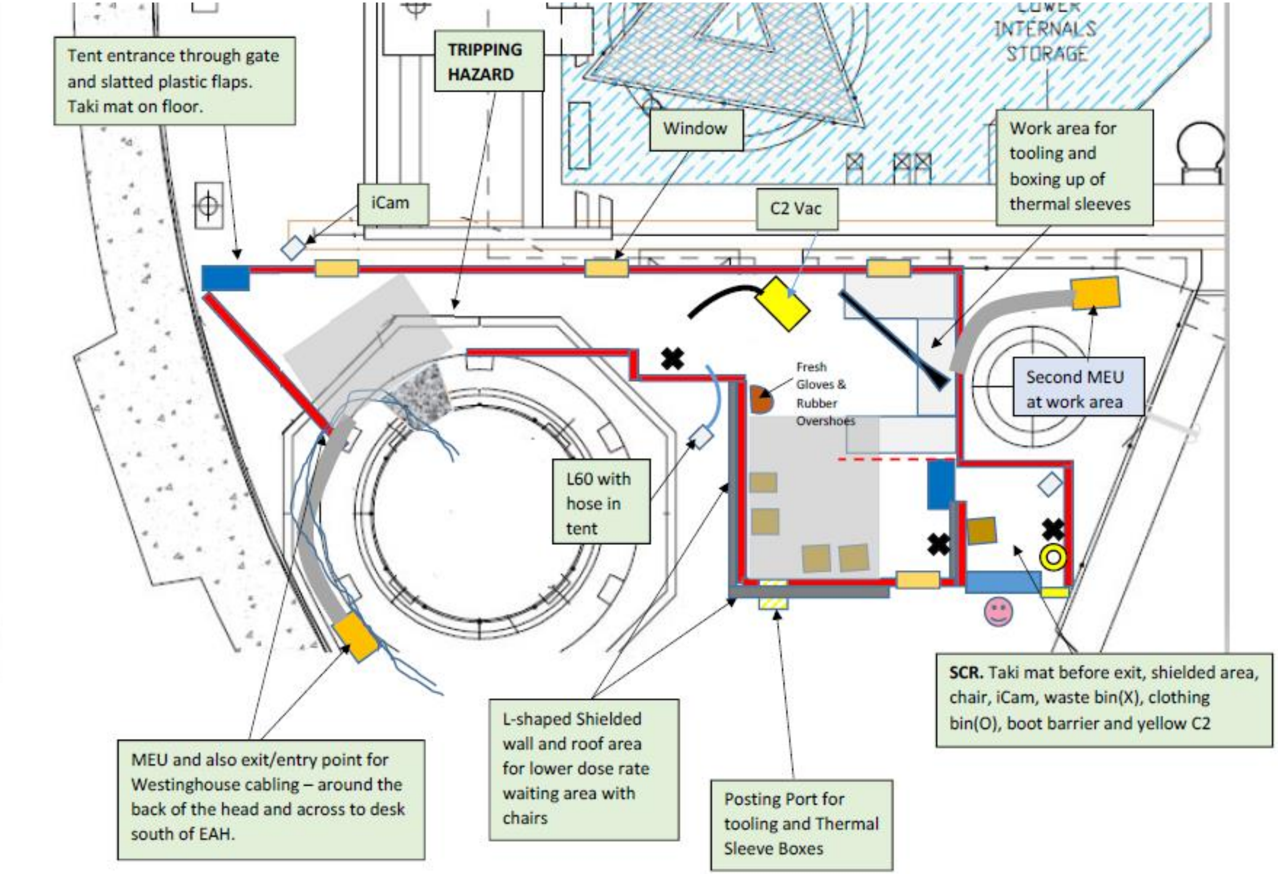


Overview of tent showing tent entrance and extent of tent roof "shadow shielding"

Overview of tent showing tent exit and location of EDM/Inspection work station

Given the size of the tent two filtered extract units were employed, one close to the RPVH storage stand doors and the other extracting from the undressing/low doserate waiting area.

RPVH Storage Stand Tent



Handling and Storage of removed thermal sleeves

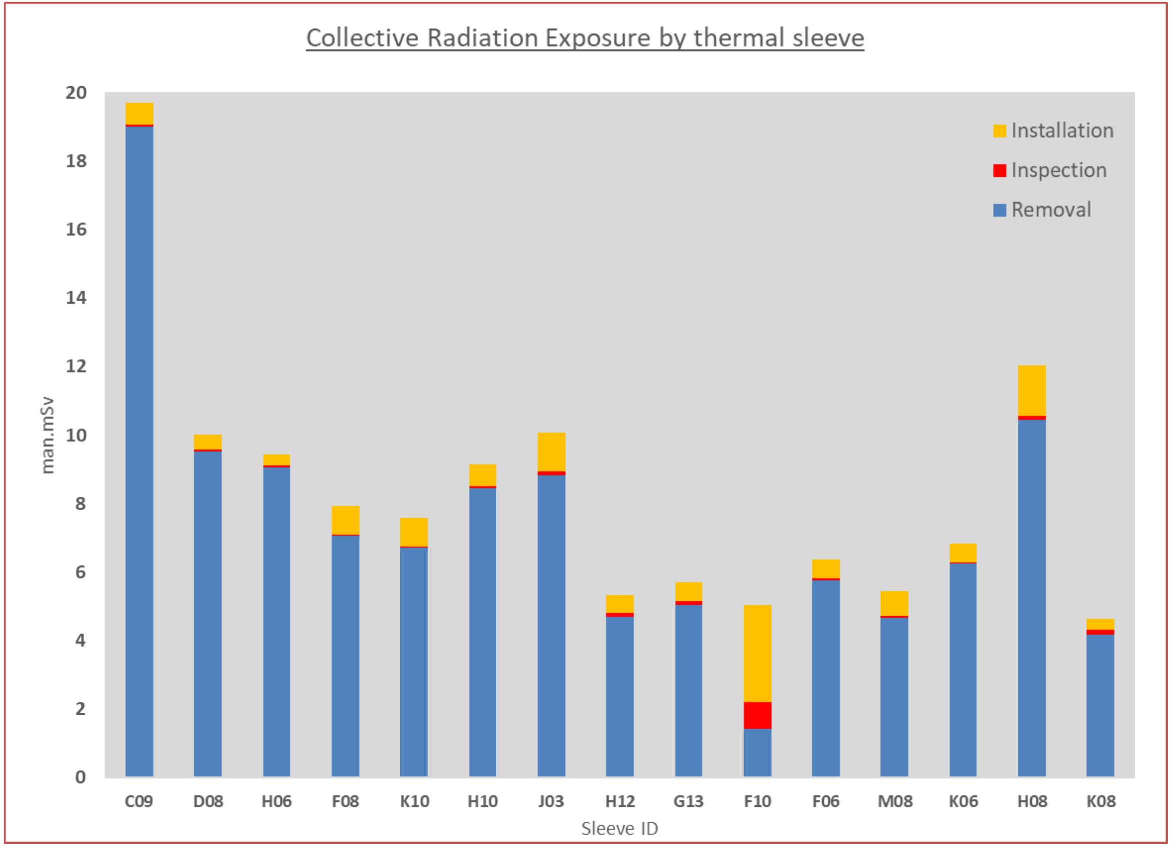
Bespoke aluminium containers were made to move and store the removed thermal sleeves. With good preparation the doses for loading and moving the containers were very low and the risk of contamination spread was minimised.

Under Head Jumps

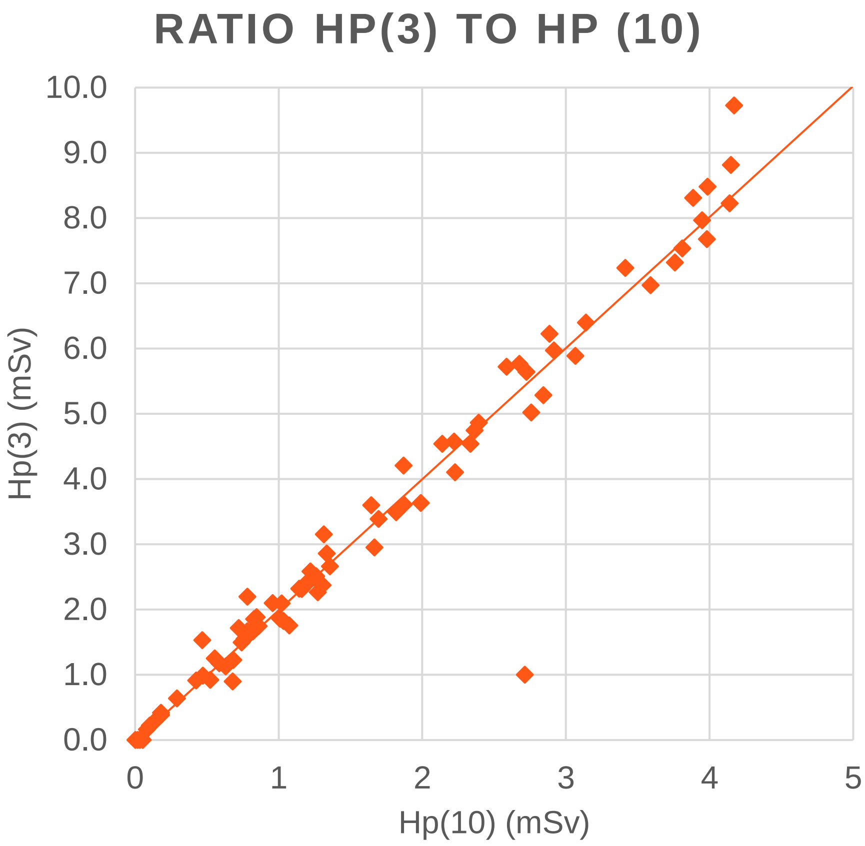
- The following clip shows a typical under head ‘jump’ to install a new thermal sleeve into a prepared and inspected penetration.

Thermal Sleeve Repair at Sizewell B

Radiation Dose for under-RPVH tasks



Radiation Doses to the Lens of the Eye



- Comparison of whole body and eye dosemeter data showed a very consistent 2:1 ratio between Hp (3) and Hp (10).
- This ratio is similar to the ratio of gamma doserate measured at different elevations under the RPV Head.
- In one case, for a relatively low whole body dose, the dose received outside of the RPVH may have affected the reliability of the ratio. Alternatively the worker did not wear their eye dosemeter for an entry!

Under RPVH Tasks; Durations & Doses

No of Workers	Total number of entries	Total time under RPVH (mins)	Mean worker time under RPVH (mins)	Under RPVH CRE (man.mSv)	Mean worker individual dose for under RPVH tasks (mSv)	Mean individual dose for a single under RPVH entry (mSv)
Thermal Sleeve Removal and Installation Tasks						
25	653	1153	46	119	4.75	0.181
CRDM Penetration Housing Inspections						
5	32	34	6:45	1.94	0.39	0.06

Overall RP Performance Metrics

Indicator	Goal	Actual
CRE (man.mSv)	175	135.1
Maximum Individual Dose (mSv)	6.0	5.91
Maximum Dose to lens of eye (mSv)	15	12.2
No of PCEs	N/A	3[(1)]

Notes
(1) All PCEs were EPRI level 1.

Lessons Learned

What went well	What could have been better
Collaborative and open relationship between lead contractor and RP	RP participation during Mock Up training
Use of Remote Monitoring with multiple cameras (including under RPVH)	Use of optimised and fixed height work platforms
Detailed Post Job Brief after first sleeve removal to gather operating experience and to identify opportunities for improvement	Modify tool lengths for site specific RPVH storage stand arrangements to allow workers to be lower when under RPVH
Remote Monitoring output in Lead Contractor’s project management office, with ability, via OCC, to talk directly to under RPVH workers using VOIP.	

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Thank You

