Radwaste Management Issues

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Contents

- Comparison of waste volumes generated by various devices: ITER, ARIES-AT, PPCS (Model-C), VECTOR, ARIES-CS, and ESBWR (fission)

- Disposal/recycling/clearance critical issues:
  - Disposal cost
  - Cost of recycled materials
  - Physical properties of recycled materials
  - Radioisotopes buildup by subsequent reuse
  - Clearance index of Type-04 concrete vs. EU PWR concrete
  - Recycling dose of 2 mm W tiles on FW

- Recent publications

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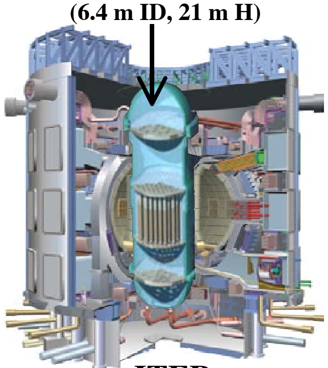
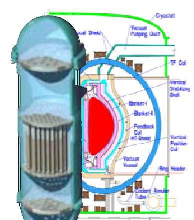
Radwaste Volume Comparison

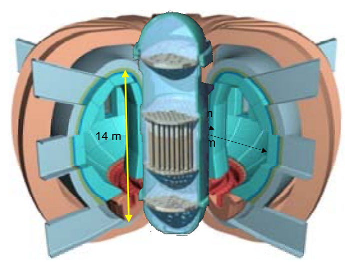
ESBWR Vessel (6.4 m ID, 21 m H)



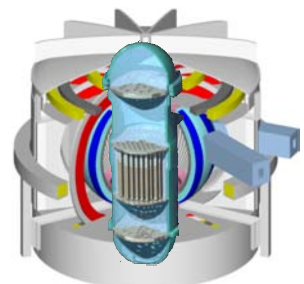
ITER



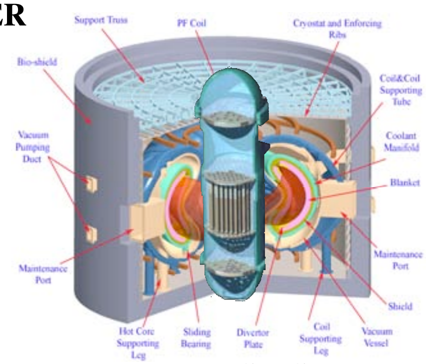
ARIES-AT



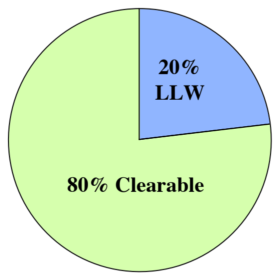
PPCS



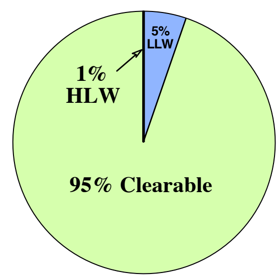
VECTOR



ARIES-CS

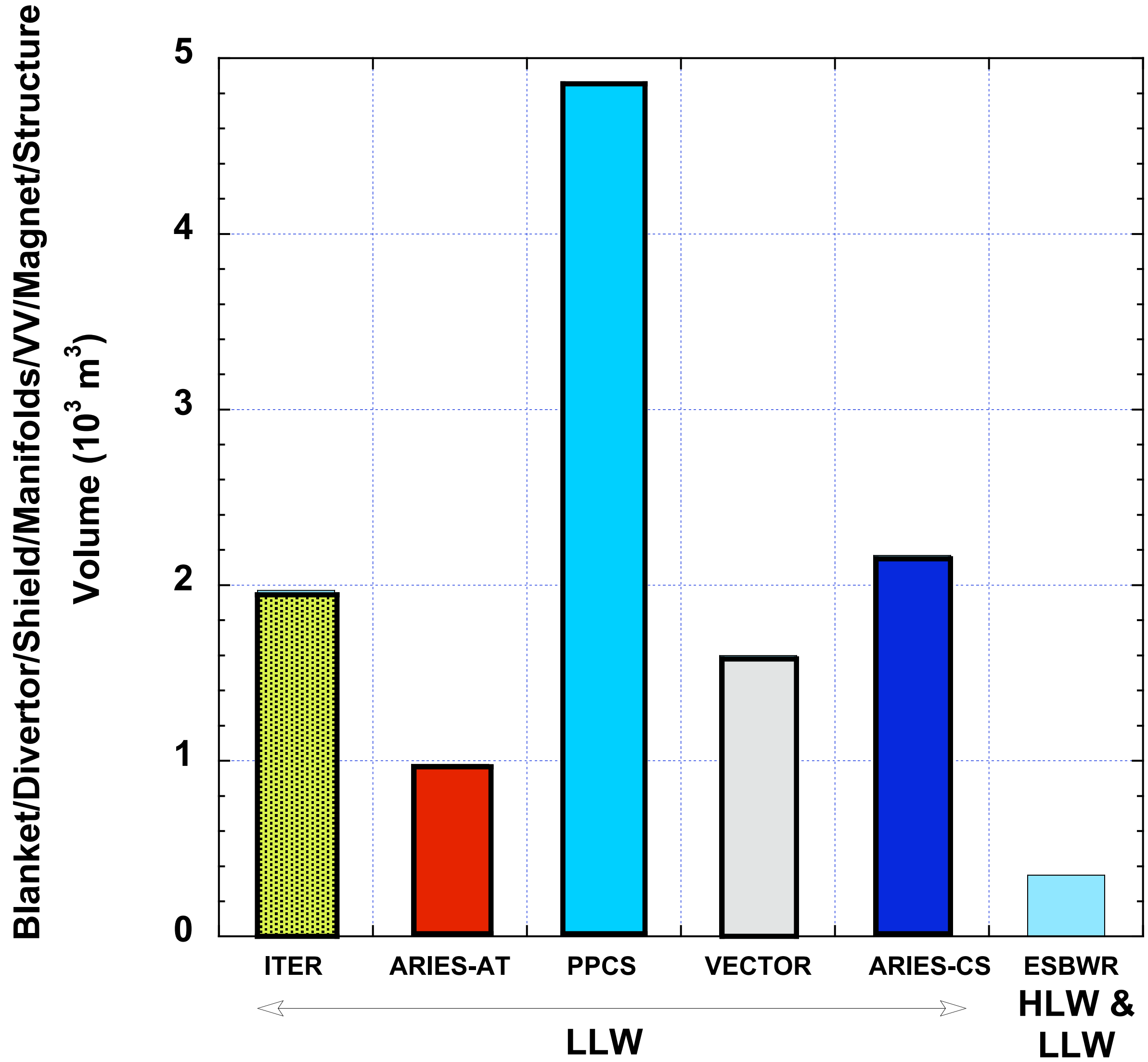


Fusion



Fission

Radwaste Volume Comparison (Cont.)



Radwaste Volume Comparison (Cont.)

Design	ITER	ARIES-AT	PPCS	VECTOR	ARIEC-CS	ESBWR
		US	EU	J	US	US
Concept	←	Tokamaks		→	Stellarator	Fission
Major radius (m)	6.2	5.2	7.5	3.2	7.75	
Minor radius (m)	2.0	1.3	2.5	1.4	1.7	
Volumes (m^3):						
FW, blanket, and divertor	---	270	1391	483	494	
Shield	360*	160	238	678	436	
Manifolds	---	---	385	---	318	
Vacuum vessel	580	295	1188	82	362	
Magnets and structure	1030	256	1663	356	558	
Fission core and vessel	---	---	---	---	---	~350
Total	~1970	~980	~4870	~1600	~2170	~350

* Includes divertor volume.

Disposal Issues

- Large volume to be disposed of (7,000 - 8,000 m^3 per plant, including bioshield)
- Immediate or deferred dismantling?
- High disposal cost (for preparation, packaging, transportation, licensing, and disposal).
- Limited capacity of existing LLW repositories*
- Need for fusion-specific repositories designed for T-containing activated materials
- Political difficulty of building new repositories*
- Tighter environmental controls
- Radwaste burden for future generations.

* Covered in Radwaste Management presentation - 6/07 ARIES meeting.

Disposal Cost

- **Waste disposal costs** (in 2003 $) at U.S. disposal sites are typically:
  - ~$3 per cubic foot for **Class A** LLW
  - ~$300 per cubic foot for **Class C** LLW

- This waste disposal cost is only ~15% of total waste life cycle cost. Other costs include waste characterization, packaging, interim storage, and transportation

- **Total waste life cycle cost** (in 2003 $):
  - ~$20 per cubic foot for **Class A** LLW
  - ~$2,000 per cubic foot for **Class C** LLW

- Many nuclear facilities are currently storing their LLW and HLW onsite because of limited and expensive offsite disposal options.

Recycling Issues

- Development of radiation-hardened RH equipment (10,000 Sv/h)*
- Large interim storage facility
- Energy demand for recycling process
- Cost of recycled materials
- Radiochemical or isotopic separation processes for some materials (e.g., LiPb), if needed
- Efficiency of detritiation system
- Any materials for disposal? Volume? Waste level?
- Properties of recycled materials? Any structural role? Reuse as filler?
- Aspects of radioisotopes buildup by subsequent reuse and radiotoxicity buildup
- Recycling plant capacity and support ratio
- Acceptability of nuclear industry to recycled materials
- Recycling infrastructure.

* Ref.: R. Pampin, R.A. Forrest, R. Bestwick, Consideration of strategies, industry experience, processes and time scales for the recycling of fusion irradiated material, UKAEA report FUS-539 (2006).

Cost of Recycled Materials
(Example)

- INL recycled cask shielding with GTS-Duratek firm in 2001 to fabricate 100 tons of activated Pb bricks for nuclear industry use as accelerator target shielding wall at Idaho Accelerator Center on campus of Idaho State University

- Each shielding brick weighed ~26 pounds (12 kg)

- Estimated cost of Pb LLW disposal was ~$5/pound while cost of recycling was ~$4.3/pound including fabrication into brick shapes

- Cost to purchase brand new shielding bricks rather than obtain recycled bricks was estimated to be $46 per brick (~$1.8/pound)

- Savings:
  - Recycling versus disposal cost
  - Disposal volume
  - Not requiring purchase of new Pb bricks.

Physical Properties of Recycled Materials (Example)

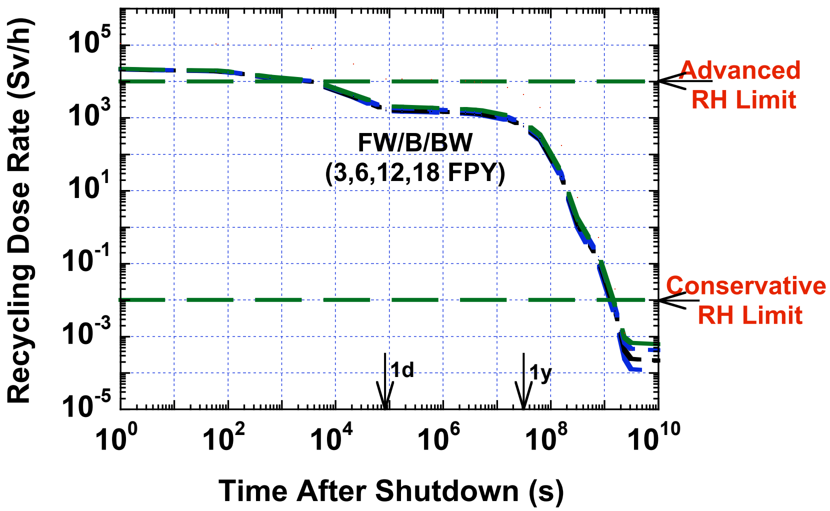
- SS recycling has been carried out at INL **and** Westinghouse Savannah River Company
- In 1996, INL fabricated small shielding casks out of recycled SS, sized to accommodate 30-gallon or 55-gallon waste drum containing transuranic waste (TRU) that read 50 mSv/h. Casks reduced dose to < 2 mSv/h allowing contact handling.
- Casks were designed, built, and tested for strength and impact
- Casks were put in service at Radioactive Waste Management Complex at INL
- Prototype casks functioned well and are still in use

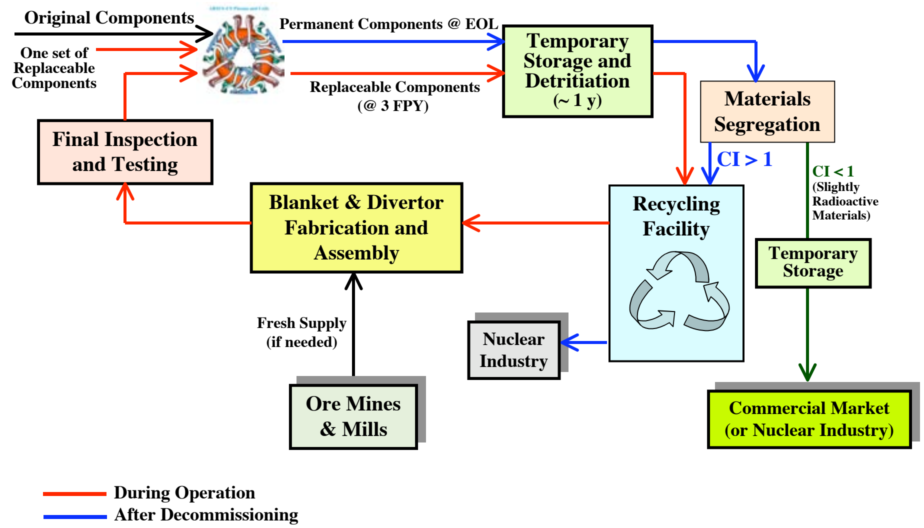
Physical Properties of Recycled Materials (Cont.)

- Both INL and WSRC found that **slag** from melting tends to collect some, or majority, of radionuclides
- When slag was removed from the melt, the resulting ingots contained only very low levels of radioactivity
- Slag would be sent to LLW disposal, but as greatly reduced volume
- Composition adjustments after slag removal produced metal alloys with properties very similar, or equal, to those of fresh alloys.

No Recycling Dose Buildups up to 50 y

(Example: ARIES-CS blanket; MF82H Structure)



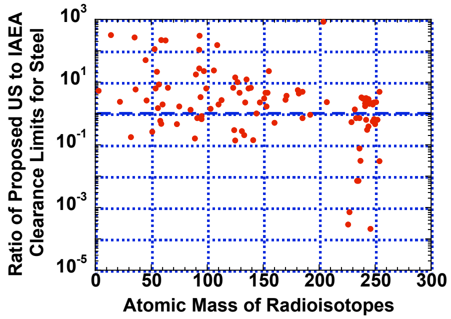


Assumptions:

- 3 FPY irradiation
- 1 y storage
- 2 y fabrication, assembly, and testing
- No slag removal
- Multiple reuse for blanket (highly irradiated component).

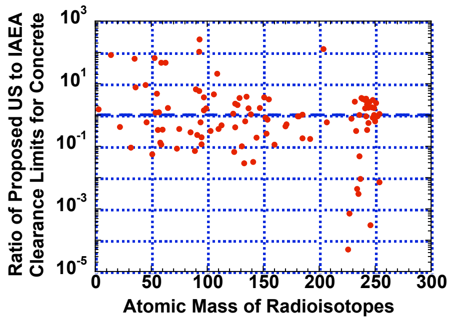
Clearance Issues

- Discrepancies between NRC & IAEA clearance standards



- Impact on CI prediction of missing radioisotopes (such as ^{10}Be, ^{26}Al, ^{32}Si, $^{91,92}Nb$, ^{98}Tc, ^{113m}Cd, ^{121m}Sn, ^{150}Eu, $^{157,158}Tb$, $^{163,166m}Ho$, ^{178n}Hf, $^{186m,187}Re$, ^{193}Pt, $^{208,210m,212}Bi$, and ^{209}Po).

- Need for fusion-specific clearance limits



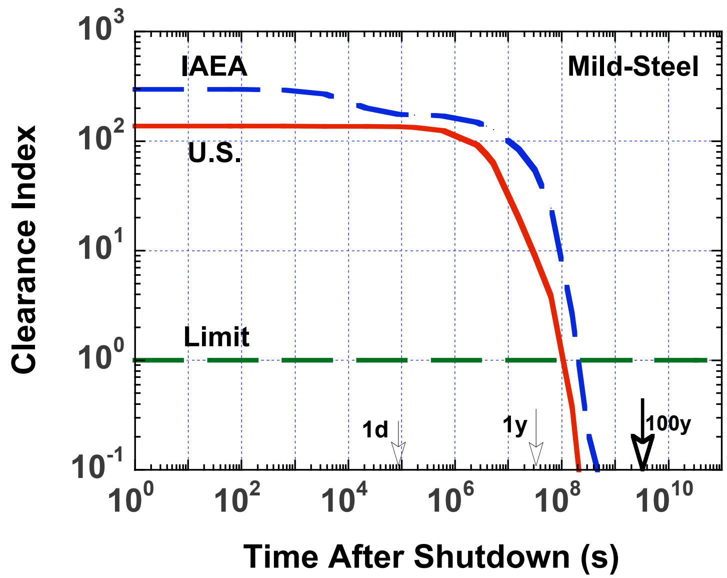
- Large interim storage facility

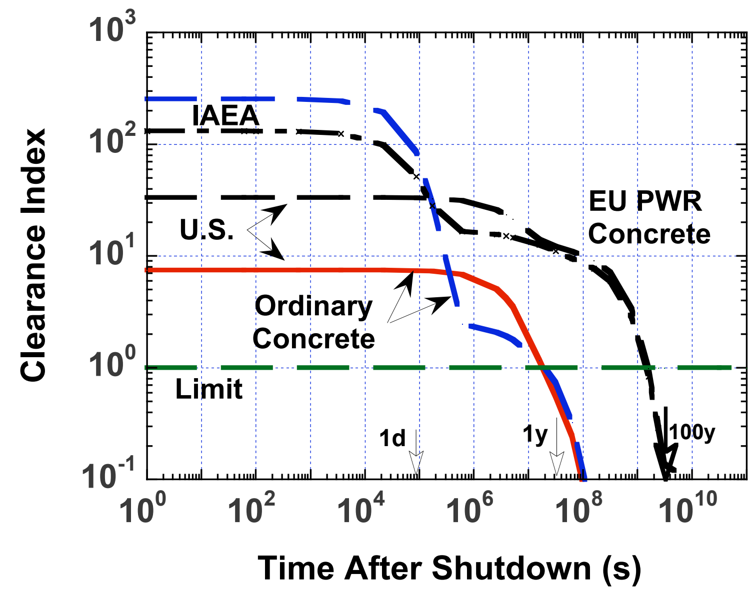
- Clearance infrastructure

- Availability of clearance market (none anywhere in the world, **except** in Germany, Spain, and Sweden. Currently, U.S. industries do not support unconditional clearance claiming it could erode public confidence in their products and damage their markets).

Clearable Bioshield

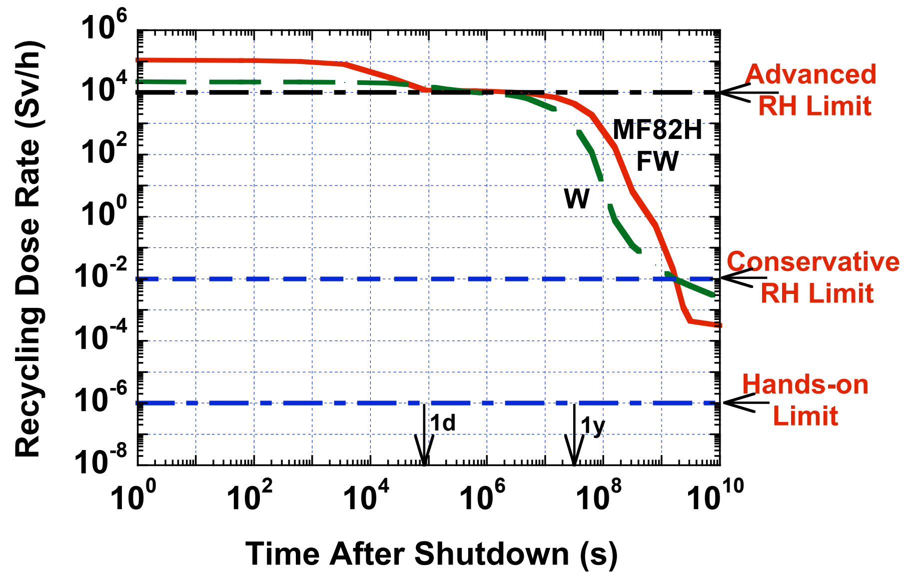
(85% concrete, 10% mild steel, 5% He)





EU PWR concrete requires longer cooling period of ~50 y
mainly for CI of ^{152}Eu (from 0.09 wppm Eu impurity) to drop below one

Impact on Recycling Dose of 2 mm W tiles on FW



- Recently, many plasma physicists called for attaching 2 mm W tiles to FW to enhance the plasma performance
- W exihibits slightly lower recycling dose than steel-based FW.

Recent Publications

FDM-1333:

– L. El-Guebaly, V. Massaut, K. Tobita, and L. Cadwallader,
"**Evaluation of Recent Scenarios for Managing Fusion Activated Materials: Recycling and Clearance, Avoiding Disposal**," University of Wisconsin Fusion Technology Institute Report, UWFDM-1333 (Sept. 2007).
Available at: http://fti.neep.wisc.edu/pdf/fdm1333.pdf

ISFNT-8 paper (invited):

– L. El-Guebaly, V. Massaut, K. Tobita, and L. Cadwallader,
"**Goals, Challenges, and Successes of Managing Fusion Active Materials**," to be published in Fusion Engineering and Design.