

Clearance Issues and Radwaste Volume for ARIES-AT

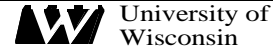
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With inputs from
M. Sawan (UW), D. Petti (INEEL)

Web address:
http://fti.neep.wisc.edu/FTI/ARIES/MAR2000/clear_lae.pdf

ARIES Project Meeting
20-21 March 2000
UCSD

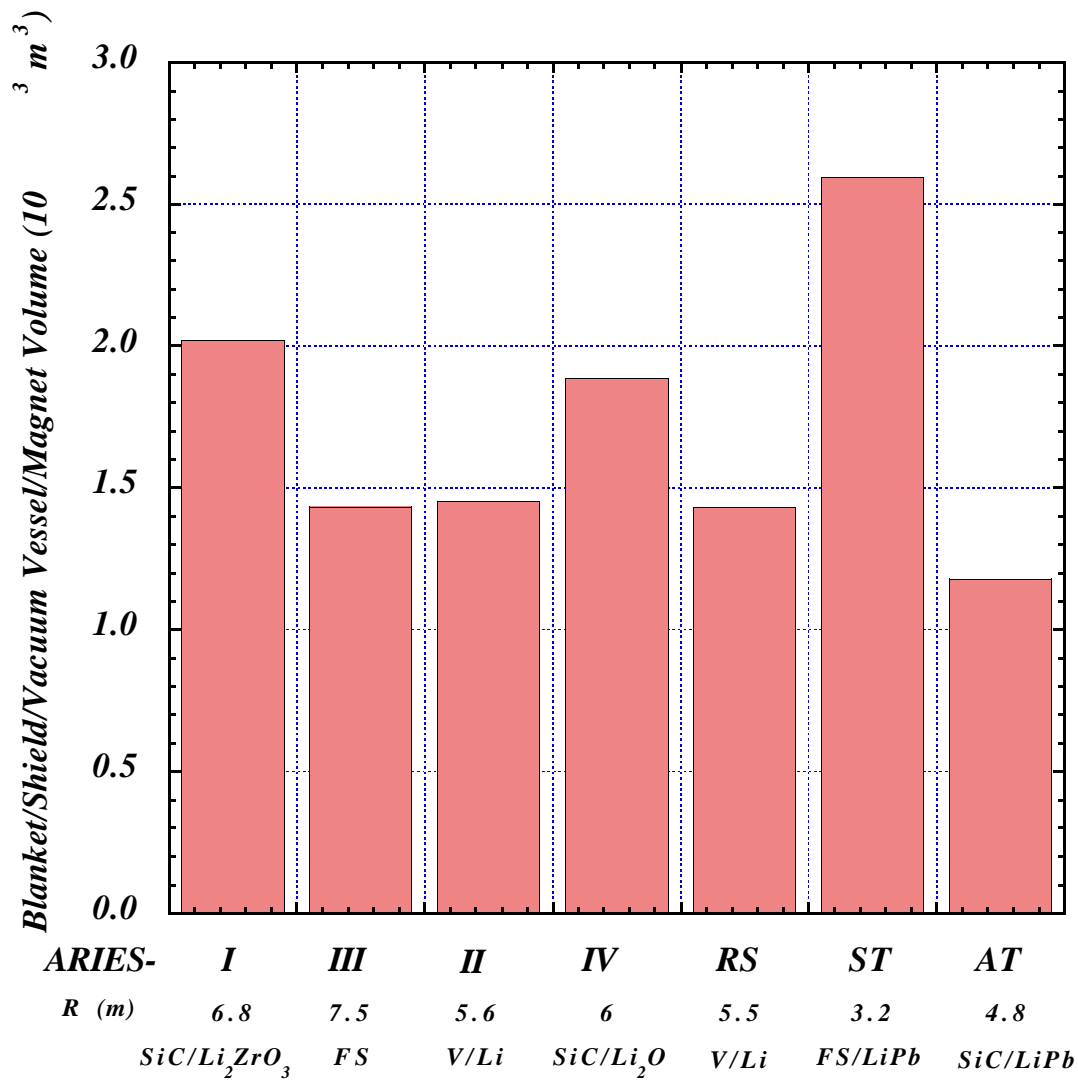
Background Information



- In ARIES studies, serious effort was devoted to reduce machine size and radwaste volume by operating at high power density, optimizing radial build, and segmenting replaceable components
- Recently, an effort was launched in US and Europe to further reduce the volume of fusion waste by clearing outer components
- To clear a nuclear component from regulatory control, it should have a Clearance Index (CI) of one or less. A storage period of 50-100 y is allowed
- At end of storage period, individual constituents* of each component will be recycled and released by industry for reuse, meaning CI for individual constituent should not exceed one. This could cause problems. Entire component may be cleared, but individual constituents may not
 - ⇒ Need new approach for handling cleared components
- Shield design (thickness and composition) controls clearance level of outer components. Our current shielding philosophy is to clear as many components/constituents as design allows for reasonable cost and at no significant increase in waste volume.
- IAEA developed CIs for 1,654 isotopes of interest to nuclear applications
- In US, NRC has not developed clearance standards for nuclear materials. Will US clearance limits be more restrictive than IAEA's?
- This is the first set of clearance calculations for ARIES designs. For Snowmass meeting (7/99), D. Petti (INEEL) generated CI for ARIES-RS in-vessel components except magnet. Recent UW analysis by P. Wilson indicates CI of 600 for ARIES-RS magnet, meaning it is not cleared.
- Benchmarking of UW and INEEL clearance calculations showed excellent agreement

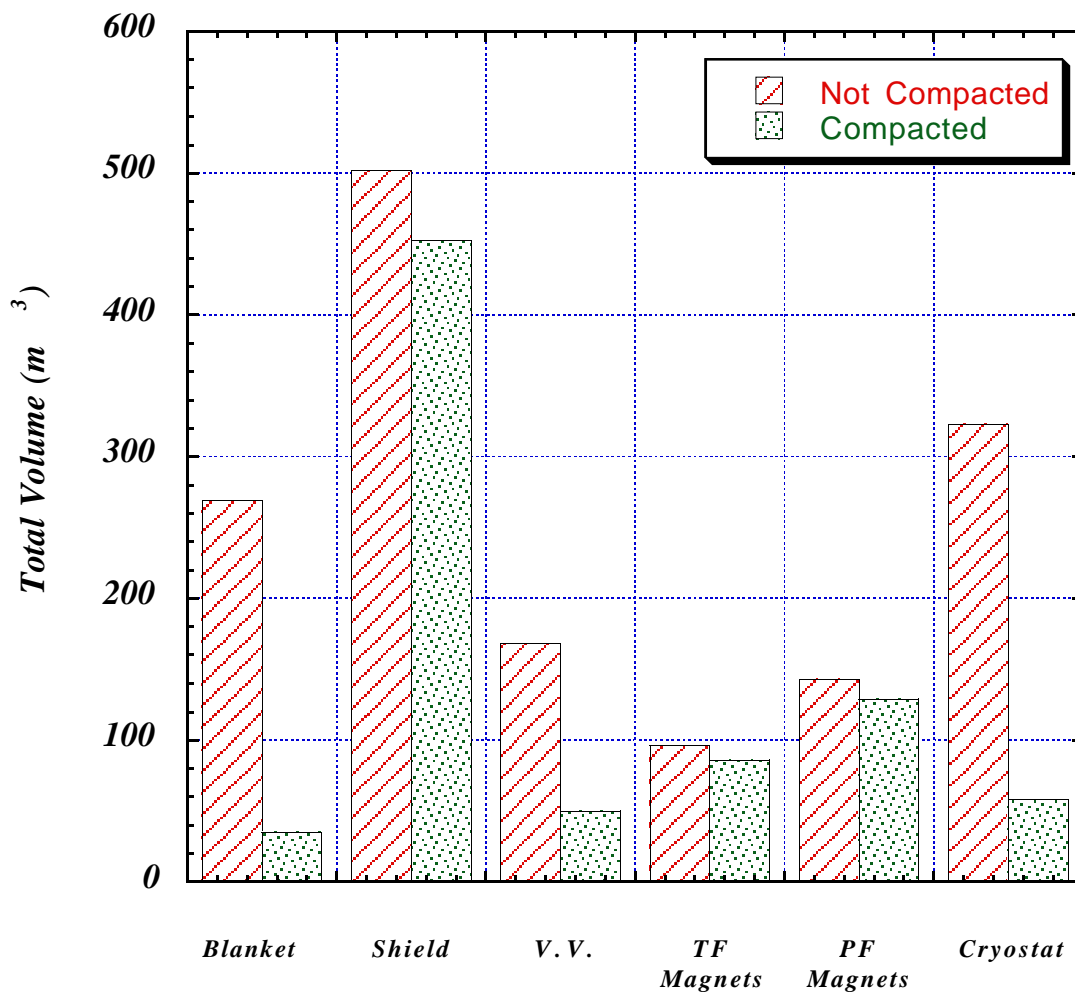
* Such as SS, conductor, structure, filler,...

ARIES-AT Generates Small Volume of Radwaste*



* not compacted

ARIES-AT Volume of Radwaste



- **Total** volume of radwaste is **1500 m³** (**810 m³** compacted)
- **Shield** generates **~50%** of compacted waste
- **OB components** generates **~60%** of compacted waste

SiC Shielding Capability

- From the shielding viewpoint, **metals are superior to SiC**
- Shield made entirely out of SiC/SiC composites (400 \$/kg) will be fairly **thick**, extremely **expensive**, and lead to **large machine**
- **SiC structure must be used in shield to recover heat at high temperature (HT)**. (Shield contains 15-20% of nuclear heating that must be recovered to improve power balance)
- **Recommendations for optimal shield design:**
 - Divide the shield into HT and LT components (the latter could contain few % of heating)
 - Limit use of SiC structure to HT components
 - Use **steel filler** with SiC structure **for better shielding**
 - Employ more efficient, expensive **WC and/or B₄C** filler for IB shield /V.V. **to reduce machine size** (**monitor decay heat of WC**)
 - Use **water** to cool LT shield and V.V. **to improve shielding performance**
 - **Optimize composition** of shield and V.V.; trade filler for water
 - Size blanket to protect shield for plant life and **reduce radwaste stream**
- **If implemented correctly, design will have attractive features:**
 - **Compact machine**
 - Competitive cost
 - **Low radwaste volume/mass**

Impact of Shielding Materials on IB Radial Build and LOCA Temperature



Shield Filler	SiC	B-FS	WC	WC/B-FS (reference)
IB Shield Thickness (cm)	72	54	42	49
Δ Shield (cm)	+23	+5	-7	0
Peak IB V.V. Temp during LOCA* @ 2days	460	520	1540	770

- **SiC** results in low temp during LOCA but **leads to large machine and waste**
- Compact design employs **WC** for shielding. However, WC generates **high short-term activity, decay heat, and LOCA temp** that raise many **safety concerns**
- Reference **ARIES-AT** design employs **WC** for LT shield and **B-FS** for HT shield, resulting in acceptable temp during LOCA

* Assuming no heat sink on IB side

Impact of Shielding Materials on Volume/Mass/Cost of OB Shield/V.V. (May 99 Presentation)



(5/99 ARIES-AT Design)

Fillers	FS	B-FS (reference)	WC
Thickness (cm)			
HT Shield*	15	15	15 [#]
LT Shield**	30	20	---
V.V.***	30	30	30
Total	75	65	45
Volume^{##} (m ³)			
HT Shield	50	50	50
LT Shield	105	70	--
V.V.	110	108	105
Total	~270	~230	~160
Mass⁺ (Tonnes)			
HT Shield	320	320	580
LT Shield	700	470	---
V.V.	730	710	1140
Total	1750	1500	1720
Cost (M\$)			
HT Shield	16	16	45
LT Shield	23	16	---
V.V.	28	28	75
Total	67	60	120

- WC shield/VV is 20 cm thinner than reference B-FS shield/VV
- WC reduces volume of shield/VV by 30% but increases mass by 15% and double cost

WC shield is recommended for IB side only, not for OB

* 15% SiC structure, 10% LiPb coolant, 75% filler

V.V. reweldability limit is not met

** 15% FS structure, 15% H₂O coolant, 70% filler

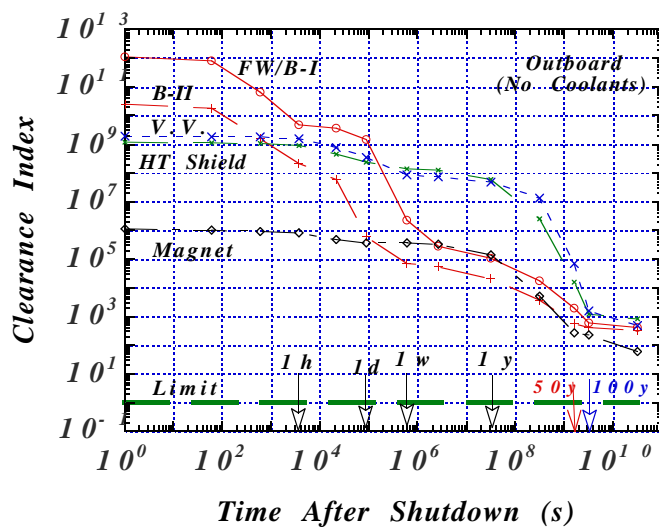
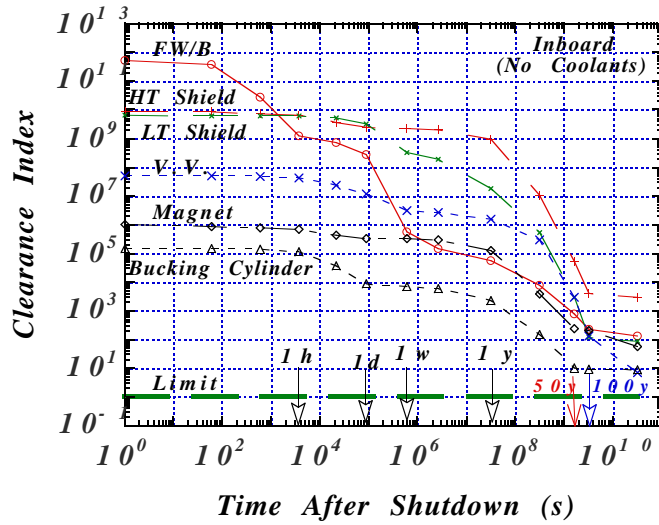
*** 25% FS structure, 15% H₂O coolant, 60% filler

Assuming 8 m effective height

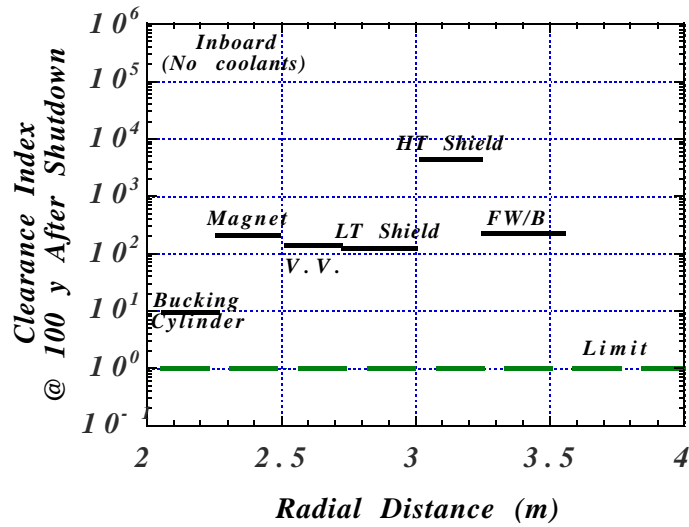
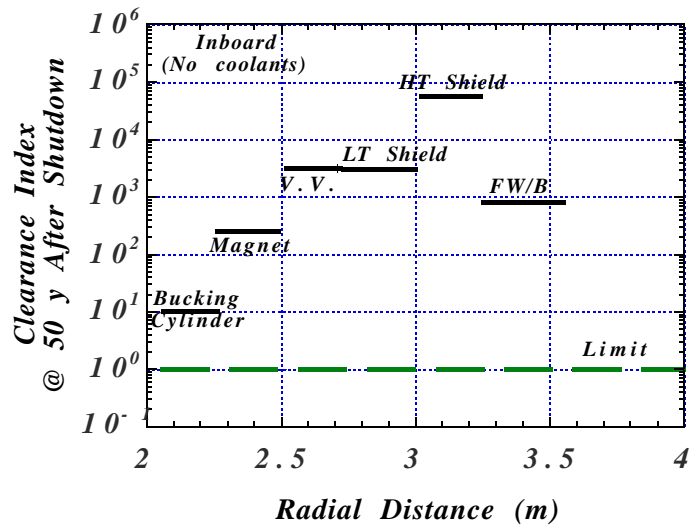
+ Mass is now economic driver for waste disposal rather than volume

ARIES-AT Clearance Index

Variation of CI with Time After Shutdown

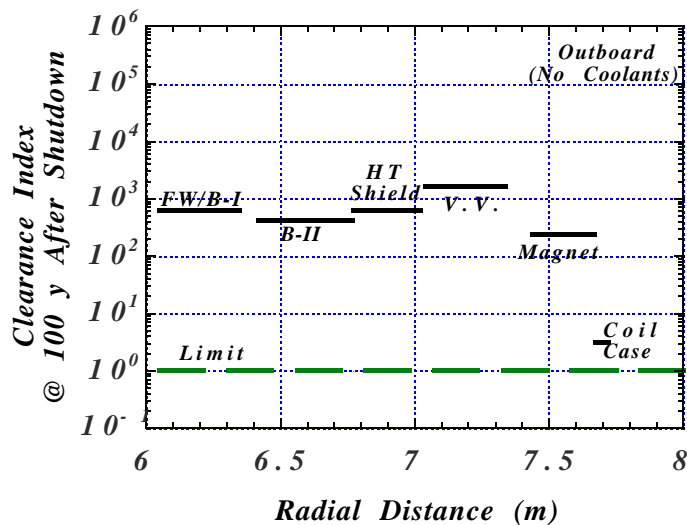
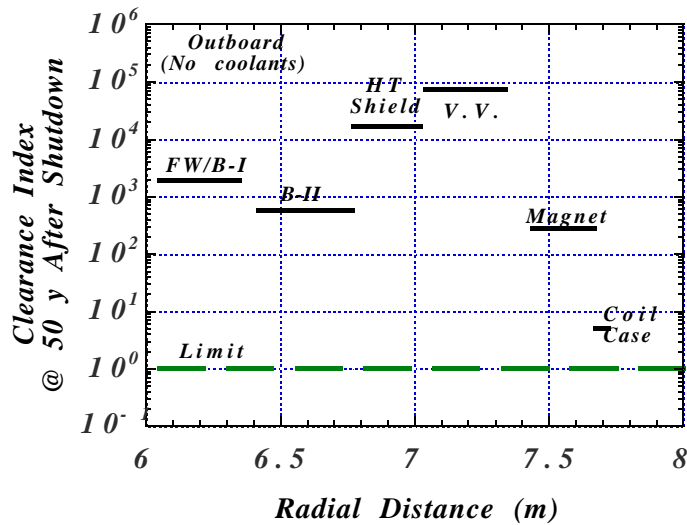


Clearance Index @ 50 y and 100 y (IB Components)



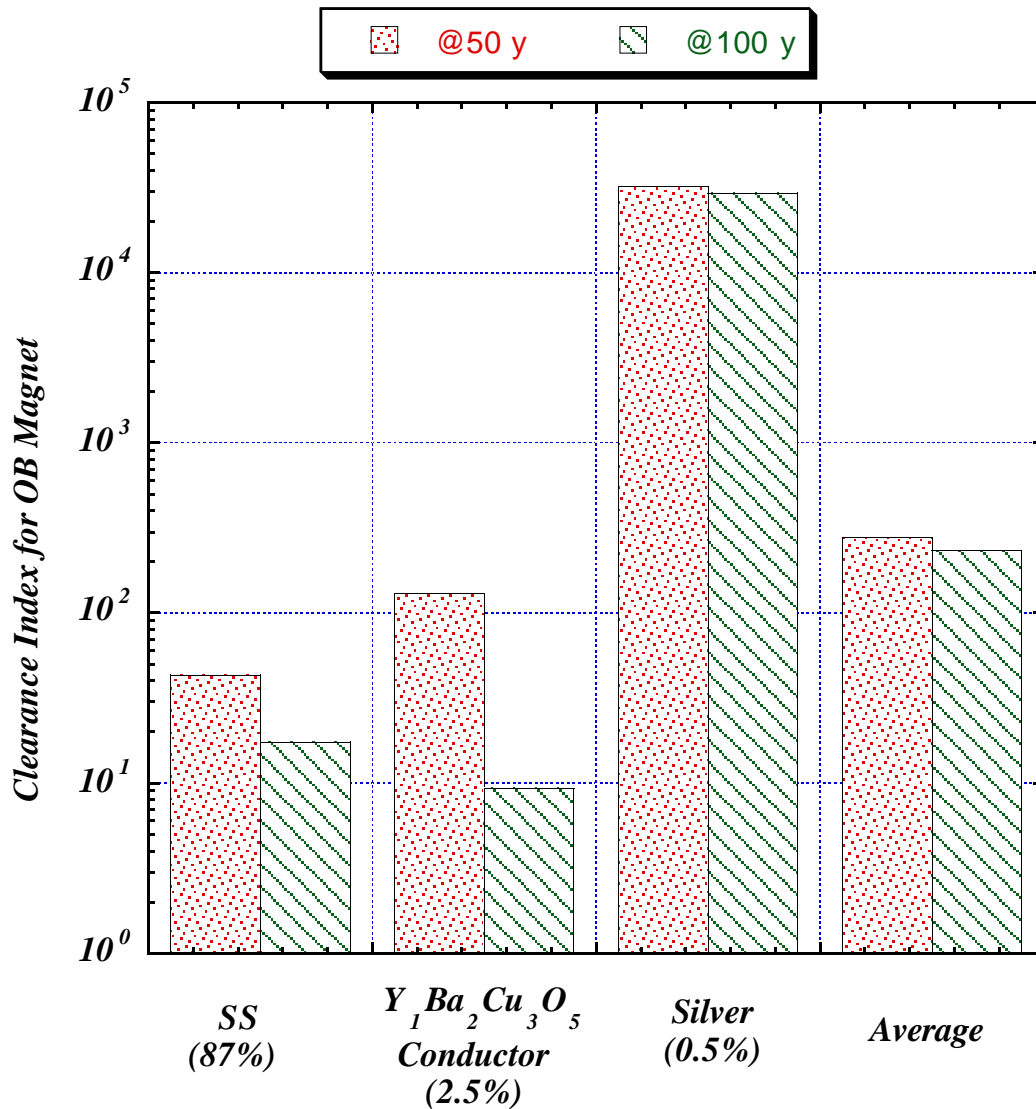
All IB components have $CI > 1$ @ 50 and 100 y after shutdown

Clearance Index @ 50 y and 100 y (OB Components)



All OB components have $CI > 1$ @ 50 and 100 y after shutdown

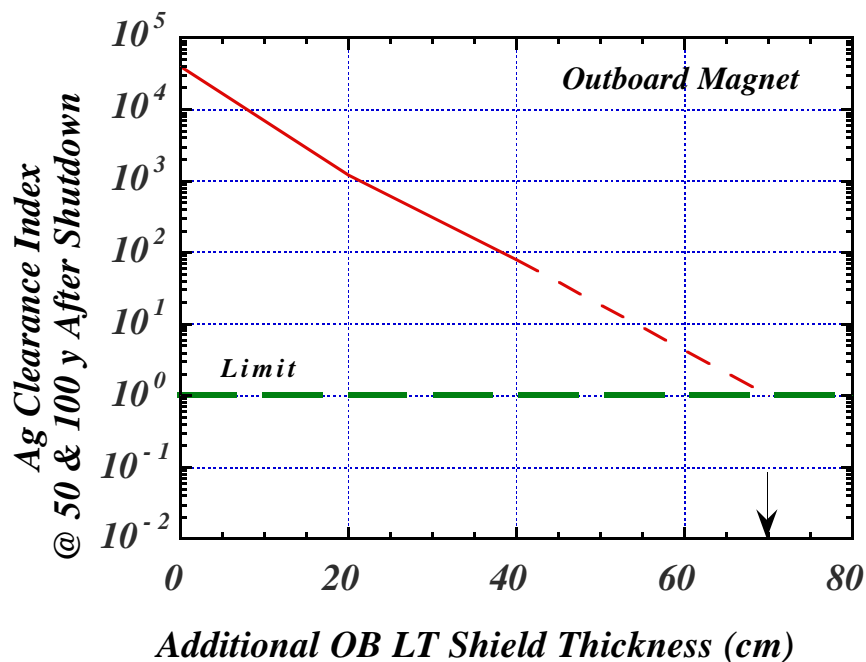
Clearance Index for OB Magnet Constituents*



- **Ag** is magnet constituent, not impurity
- **Ag** is major contributor to magnet CI even though volume fraction is only 0.5%!
- Average magnet CI drops to 45 w/o Ag

* w/o impurities. To be considered in future calculations

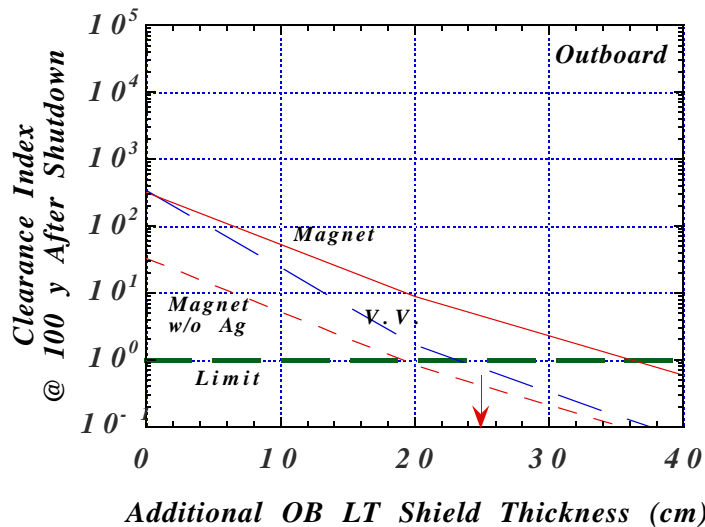
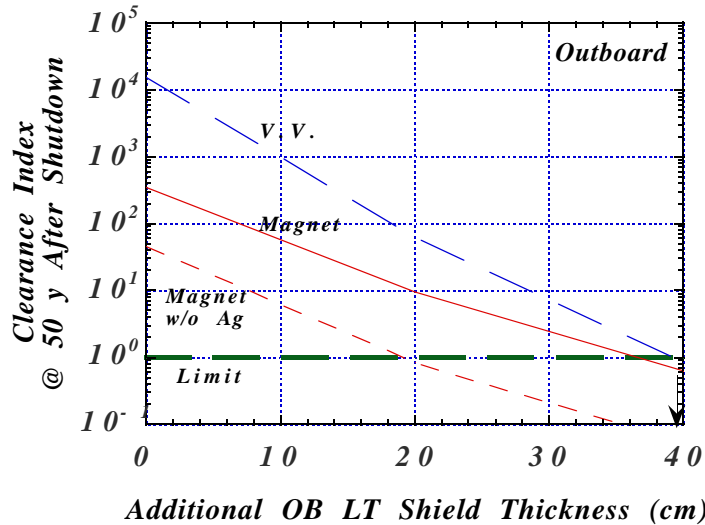
Fairly Thick Additional LT Shield Needed to Clear Ag Constituent of OB Magnet



- Volume of **Ag** in 16 TF magnets is only **0.5 m^3**
 - **70 cm thick additional OB shield ($\sim 160 \text{ m}^3$)** is required to clear **0.5 m^3** of **Ag**
- ⇒ If thinner shield is needed to clear other magnet constituents, **separate Ag and dispose as nuclear waste**

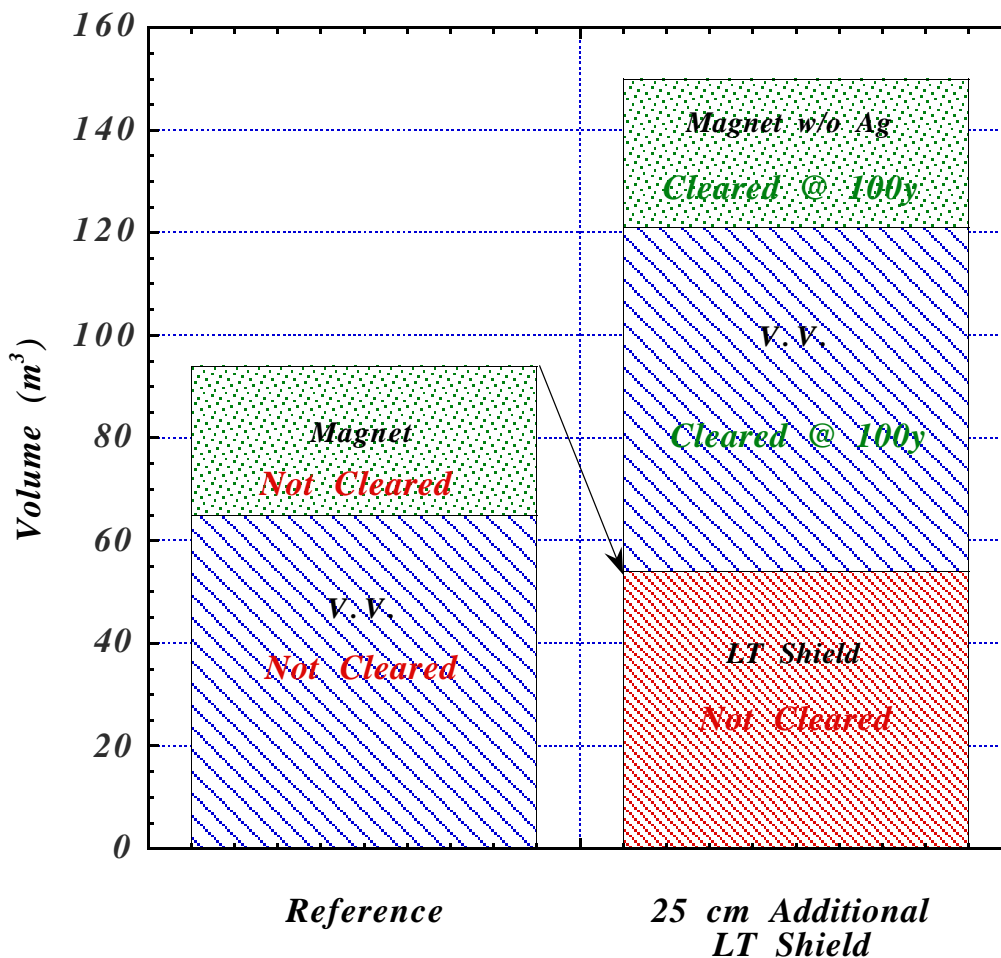
25 cm Thick Additional LT Shield* Needed to Clear Constituents of OB V.V.* and Magnet (w/o Ag) @ 100 y

*40 cm Shield Clears Both V.V. and Magnet
or 20 cm Shield Clears Magnet only*



* LT shield and V.V. composition is 25% FS, 40% H₂O, 35% B-FS

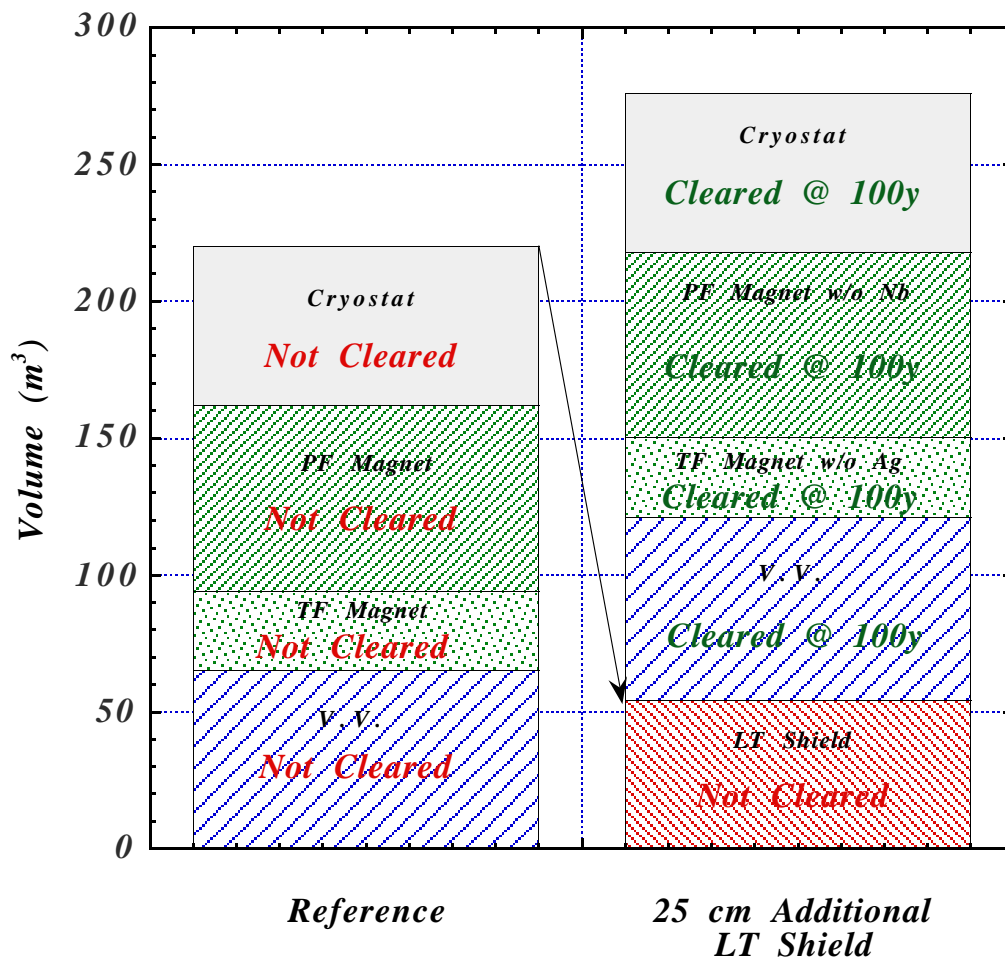
Impact of Additional 25 cm OB Shield on Volumes* of V.V. and TF Magnet



- 25 cm additional OB shield reduces waste volume of LT shield + V.V. + magnet by 40%, but generates more waste + cleared metals

* Compacted waste.

Impact of Additional 25 cm OB Shield on Volumes* of V.V., TF & PF Magnets, and Cryostat*

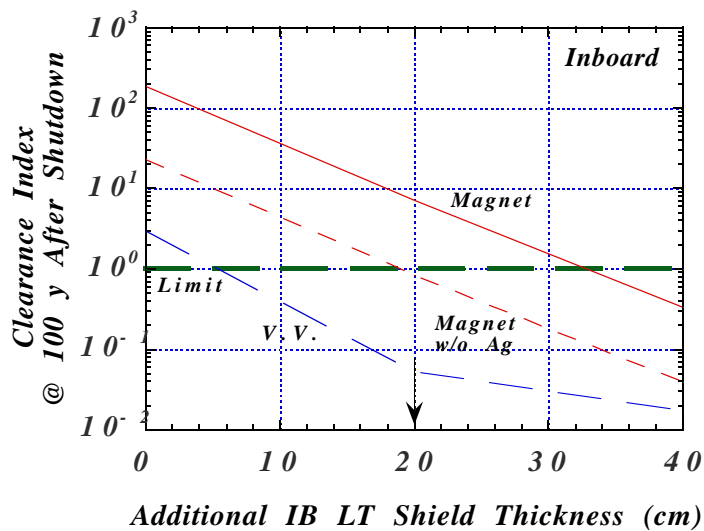
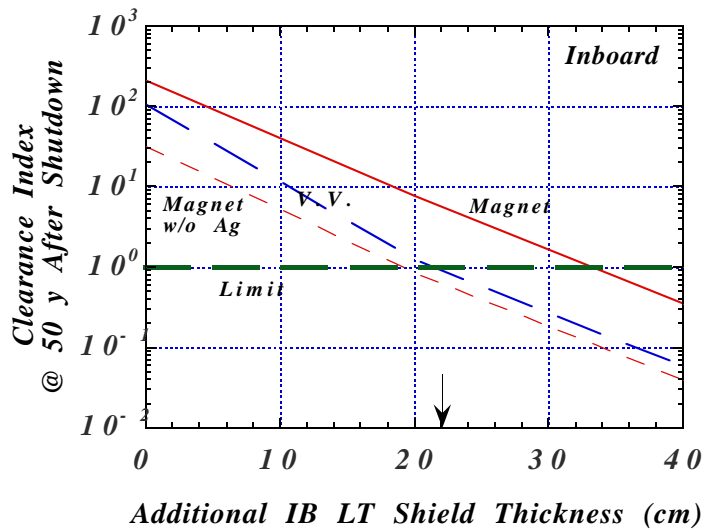


- 25 cm additional OB shield reduces waste volume of LT shield + V.V. + magnets + cryostat[#] by factor of 4, but generates more waste + cleared metals

* Compacted waste

[#] Those components comprise 20% of total FPC compacted volume

20 cm Additional LT Shield Needed to Clear Constituents of IB V.V.* and Magnet (w/o Ag)



- Reduction in IB waste volume is small while impact of additional 20 cm shield on overall machine size and waste is large ⇒ **Do not clear IB components**

* Extra LT shield and V.V. composition is 35% FS, 25% H₂O, 40% WC

Observations and Conclusions

- **ARIES-AT is compact** and generates the least amount of waste compared to previous ARIES designs
- Adding **25 cm shield on OB** to clear ex-vessel components **reduces total waste by 15%**, but **generates more waste + cleared metals** and **increases COE**
- Adding more **shield on IB will negatively impact total volume of waste and economics**
- Compact designs are more attractive than large designs with cleared components generating more waste + cleared metals
- **Status of cleared metals is uncertain.** Is there a market for cleared metals? Will cleared metals be restrictively released to nuclear facilities? Could cleared metals be released to commercial market or industry as clean scrap?
- At present, **US market** for recycled nuclear waste **is very limited.** **Environmentalists** continue to oppose the release of recycled radioactive metals to commercial market, claiming that any amount of radiation in metal for consumer use is too much. **Steel Industry of North America** voiced its opposition on 1/6/00 in a statement: SSINA members have not and well not accept scrap that is known or perceived to be radioactively contaminated and will continue to monitor and reject materials that violate the industry “zero tolerance” policy.
- If **US industry tolerance** for activity of cleared metal is too low (if not zero), **NRC** clearance limits will be much more severe than IAEA’s
 - ⇒ Much thicker additional shield to clear outer components, no significant reduction in waste volume, and higher COE
- If there is **no market for cleared metals**, will fusion require 3 types of repositories for Class C waste, Class A waste, and cleared metals? If so, **do not clear any component** and minimize fusion waste by design.