Scoping Study of Safety & Environmental Attractiveness of Target Materials

by

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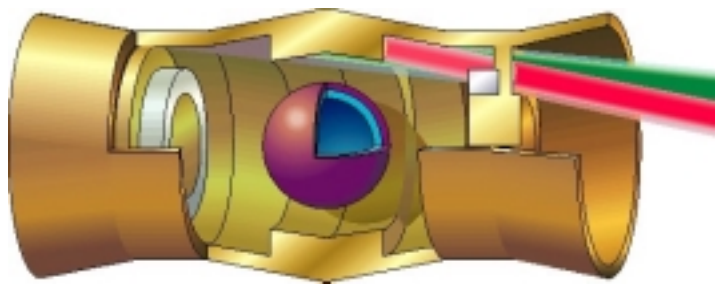
Elements have been rated for their S&E attractiveness when used in IFE targets

- Neutron activation calculations were performed:
  - used spectrum and flux experienced by the high-Z material in the close-coupled[1] target
  - assumed weekly (batch) irradiation of material for 30 years
  - considered all elements from lithium to bismuth



Close-coupled target

[1] D. A. Callahan-Miller and M. Tabak, "Increasing the Coupling Efficiency in a Heavy Ion Inertial Confinement Fusion Target," *Nucl. Fusion* **39** (Nov. 1999) 1547.

Three criteria have been adopted to rank the elements

- Accident dose < 5 mSv (50% of the 10 mSv limit—rest allocated to tritium)

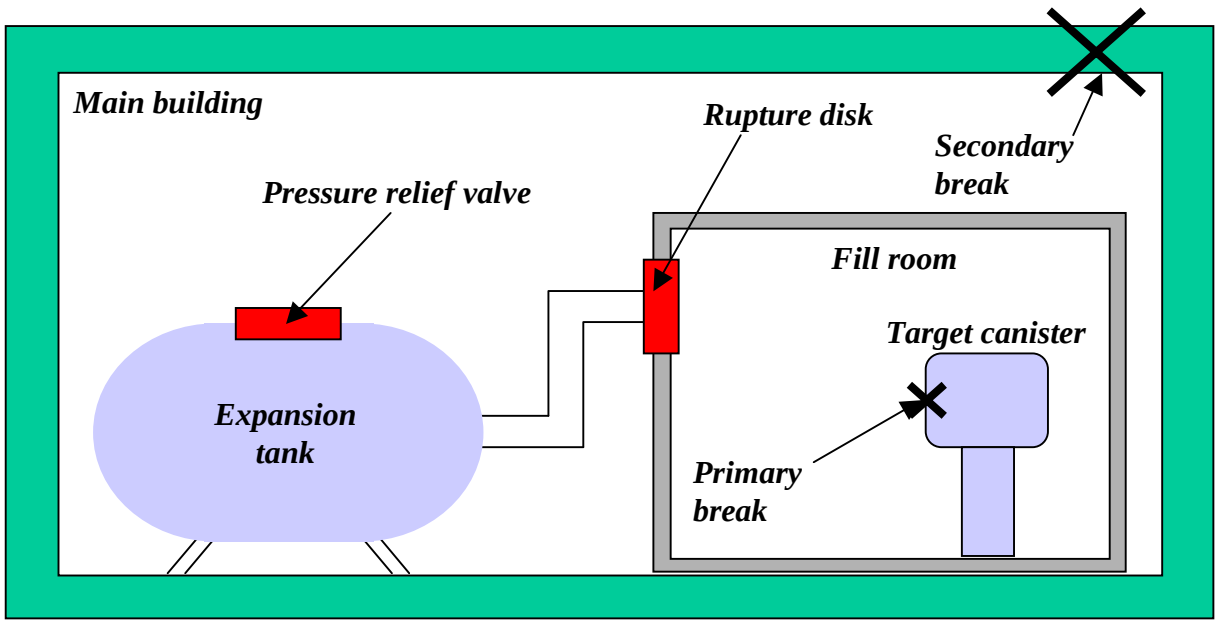
- Contact dose rate < 114 Gy/hr after 1 week:
  - gives total dose of 30 MGy in 30 years
  - European Fusion Technology Programme[1] uses lifetime dose limit of 30 MGy (3×10^8 rad) as a reference value for components subjected to high radiation fields
  - this limit probably can be relaxed significantly:
    - consider more radiation resistant components
    - allow replacement of sensitive components according to economics

- Waste disposal rating < 1 after 30 years of weekly irradiation

[1] J. Benner and W. Till, *Nucl. Eng. Int.* **35** (1990) 38.

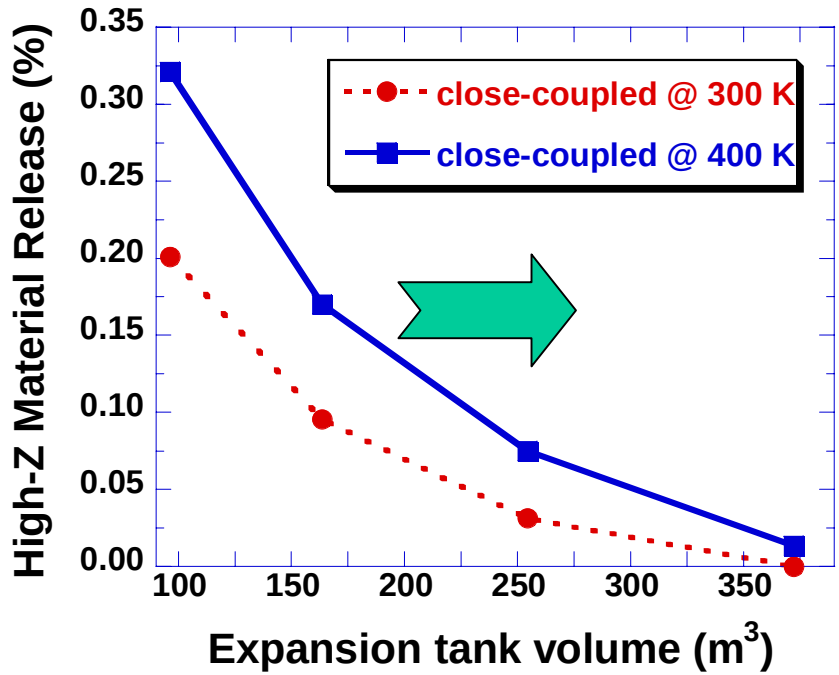
A simple MELCOR model has been used to estimate accident release fractions

- We have modeled the failure of a single canister:
  - Canister break area of 1 cm^2 assumed
  - Fill room pressurizes and rupture disk breaks at $\Delta p = 10$ kPa
  - Material flows into expansion tank; pressure relief valve opens at $\Delta p = 10$ kPa
  - Material fills main building and has opportunity to leak via 1 m^2 break in wall
  - Material assumed to be a fine particulate with PSD of 0.1-10 μm
  - Chemistry is not treated



Particulate results

- Worst-case release only ~ 0.3%
- Tritium results likely to push design to larger expansion tank; particulate release probably limited to < 0.1%
- Larger PSD (1-10 μm) produces 4× lower release
- Allocation of 50% of the 10 mSv limit to the high-Z material:
  - all elements except Co, Ni, Br, Cd, In, Te, and Eu qualify if release limited to 0.3%
  - All elements qualify if release limited to 0.05%—a more realistic PSD would help



Combined results

- Accident dose results: all elements except Co, Ni, Br, Cd, In, Te, and Eu meet 5 mSv limit if release limited to 0.3% of inventory (72 out of 79 pass)
- Contact dose rate results: 27 elements pass
- Waste disposal rating results: 48 elements pass
- 17 elements simultaneously pass all three criteria
- Increasing the contact dose rate limit by 3× (~ 100 MGy lifetime dose) expands the list to 25 elements

Future work

- Look at ways to expand list of acceptable elements; consider factors (e.g., chemistry) that could shrink the list

- Higher contact dose rates might be tolerable:
  - higher lifetime dose limit to components
  - change-out of sensitive components
  - need to examine extraction, recycling, and manufacture process

- ***Cold assembly*** would greatly reduce the threat of large-scale mobilization of high-Z material (and reduce plant tritium inventories by 10-30×)

- Larger expansion tank may be cost-effective

Summary of S&E characteristics of potential target materials

Element	Code	Element	Code	Element	Code
Li	**P**	Be	**P**	B	**P**
C	**P**	N	W	O	**P**
F	**P**	Ne	**P**	Na	C
Mg	C	Al	CW	Si	P
P	**P**	S	**P**	Cl	W
Ar	W	K	W	Ca	W
Sc	C	Ti	C	V	C
Cr	C	Mn	C	Fe	C
Co	CA	Ni	CWA	Cu	C
Zn	C	Ga	**P**	Ge	C
As	C	Se	CW	Br	CWA
Kr	W	Rb	C	Sr	C
Y	C	Zr	C	Nb	CW
Mo	CW	Ru	CW	Rh	CW
Pd	CW	Ag	CW	Cd	CW
In	C	Sn	P	Sb	C
Te	CWA	I	C	Xe	C
Cs	C	Ba	C	La	**P**
Ce	C	Pr	**P**	Nd	C
Sm	CW	Eu	CWA	Gd	W
Tb	CW	Dy	W	Ho	W
Er	CW	Tm	CW	Yb	**P**
Lu	C	Hf	C	Ta	C
W	C	Re	CW	Os	CW
Ir	CW	Pt	W	Au	C
Hg	**P**	Tl	C	Pb	**P**
Bi	CW				

C = failed contact dose rate criterion (dose < 30 MGy for 30 years, continuous exposure);
W = failed waste management criterion (WDR < 1);
A = failed accident dose criterion (early dose < 5 mSv for 0.3% release);
P = passed all criteria.