# Activation Analysis of the Thick Liquid Metal Concepts

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UCLA

# Decay Heat Induced in the Li/V First Wall and Blanket

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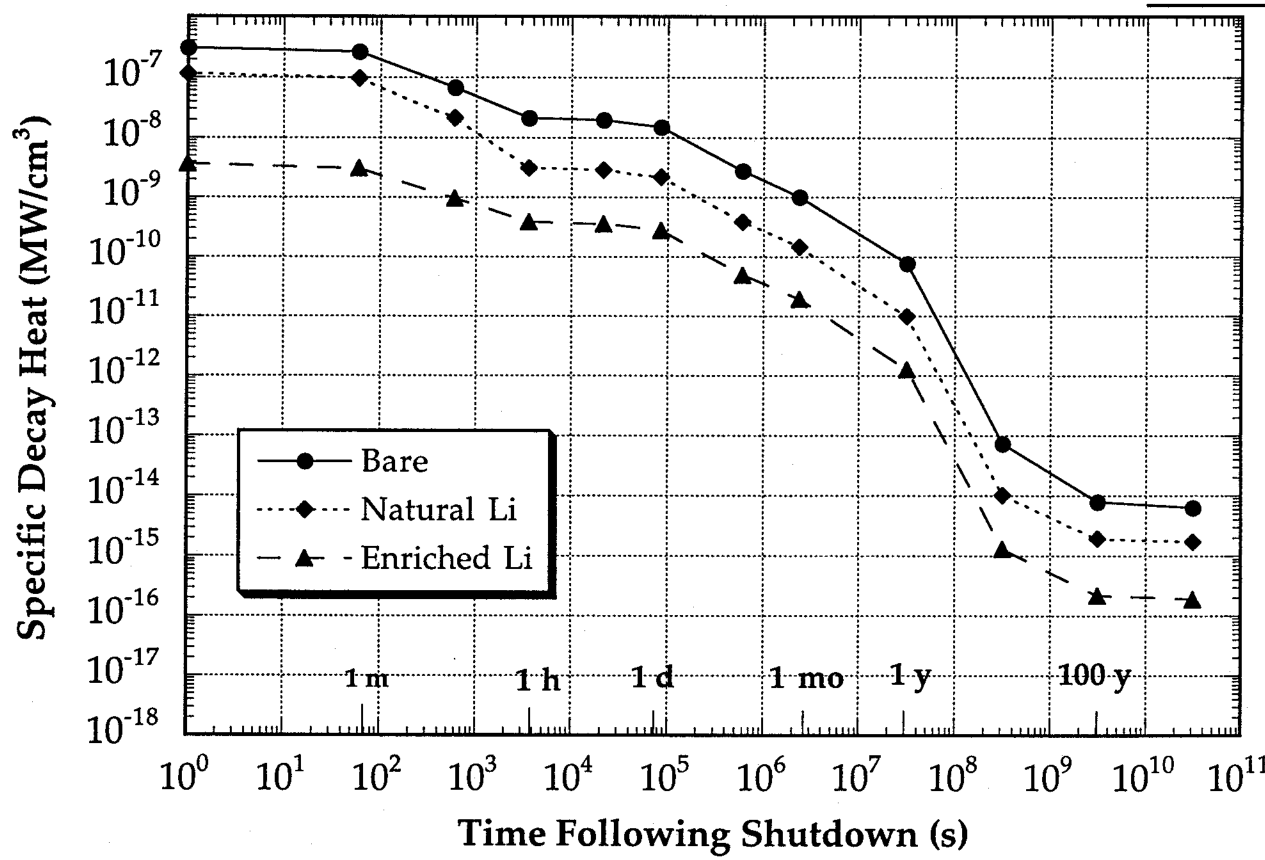

# Decay Heat Induced in the Li/V TFC

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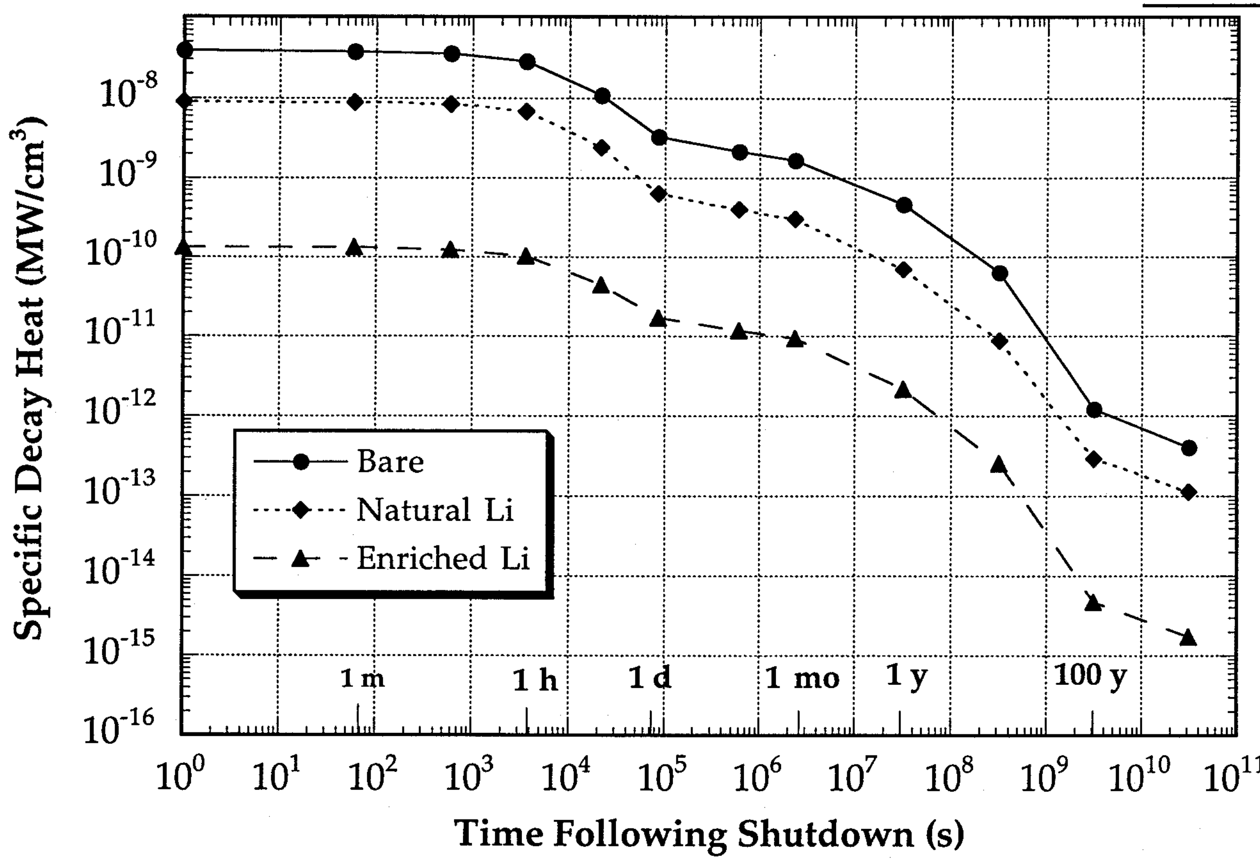

# Integrated Decay Heat Induced in the Li/V First Wall and Blanket

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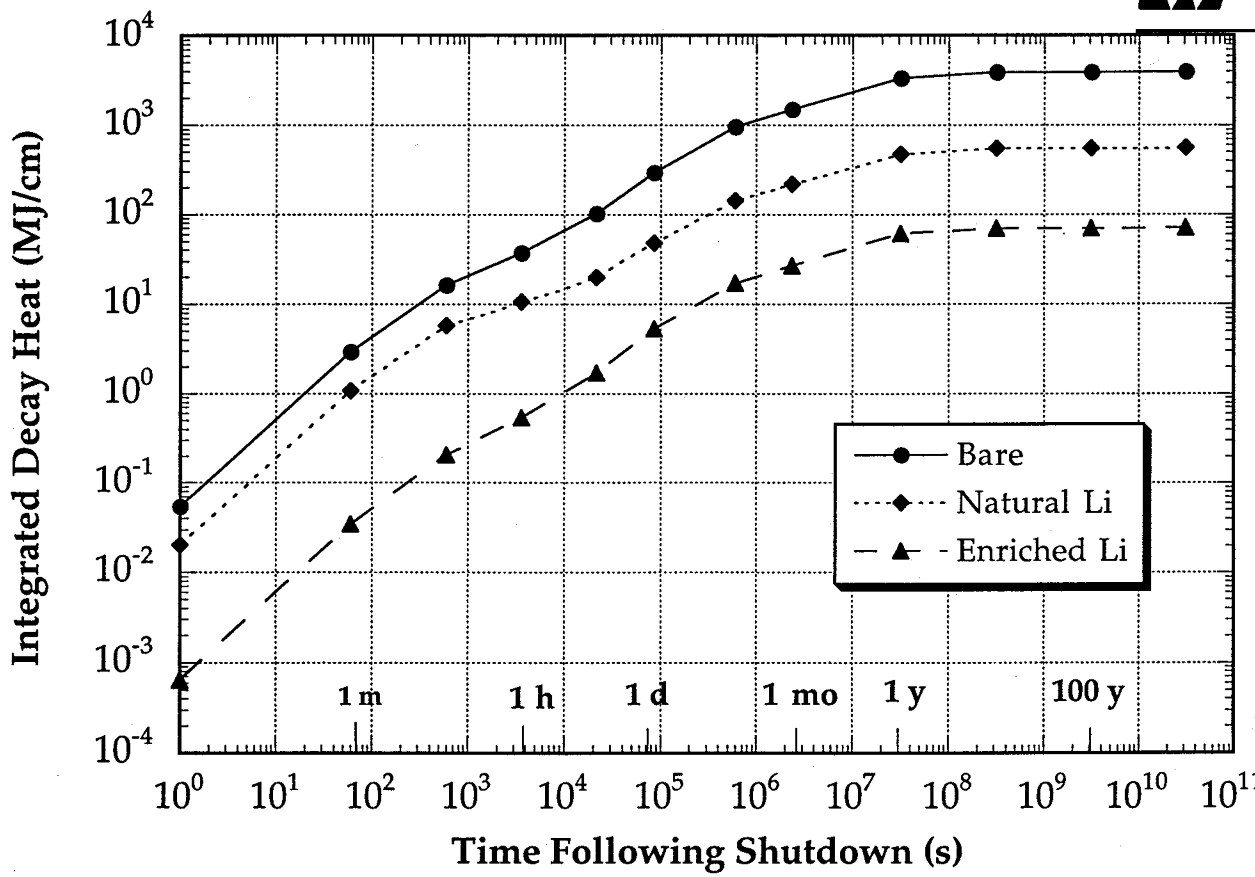

# Activity Induced in the LiPb/SiC First Wall and Blanket

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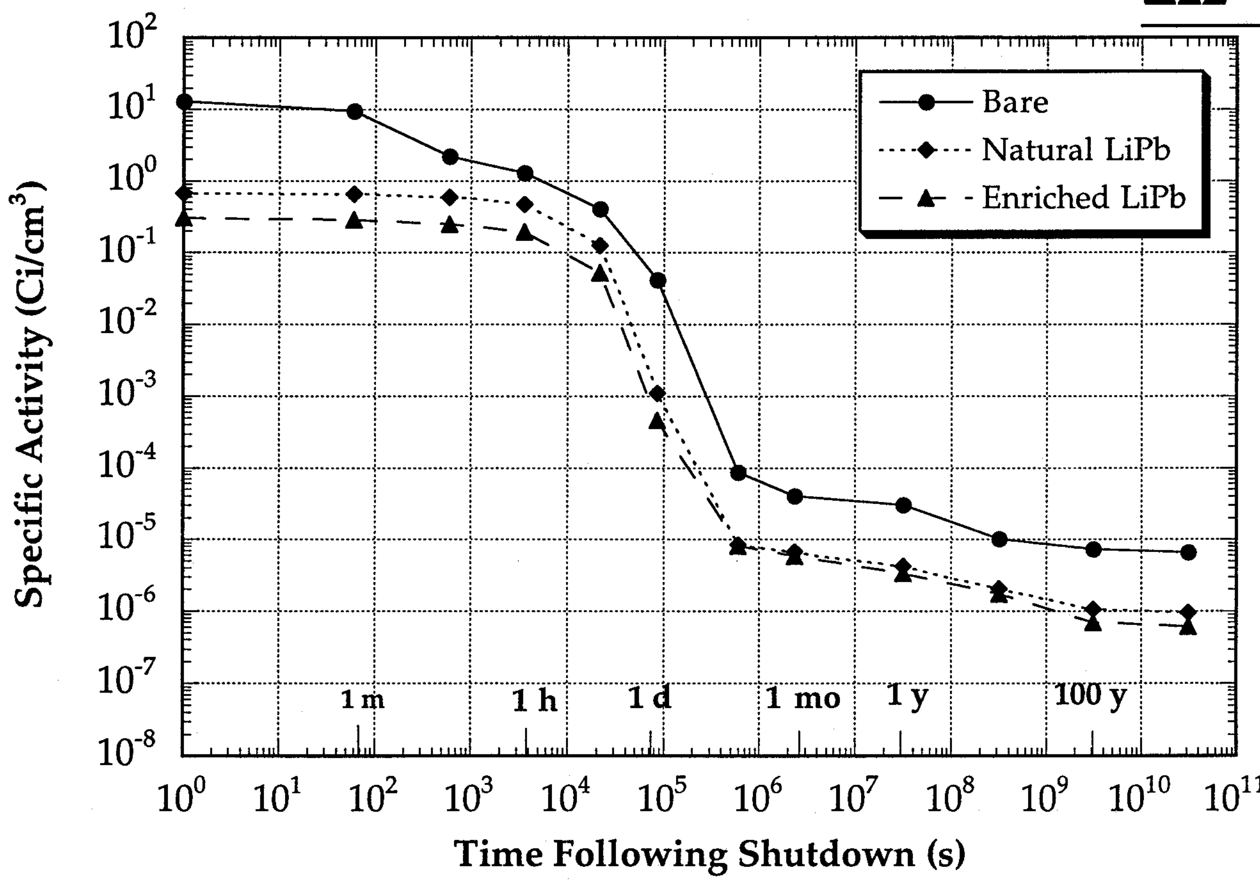

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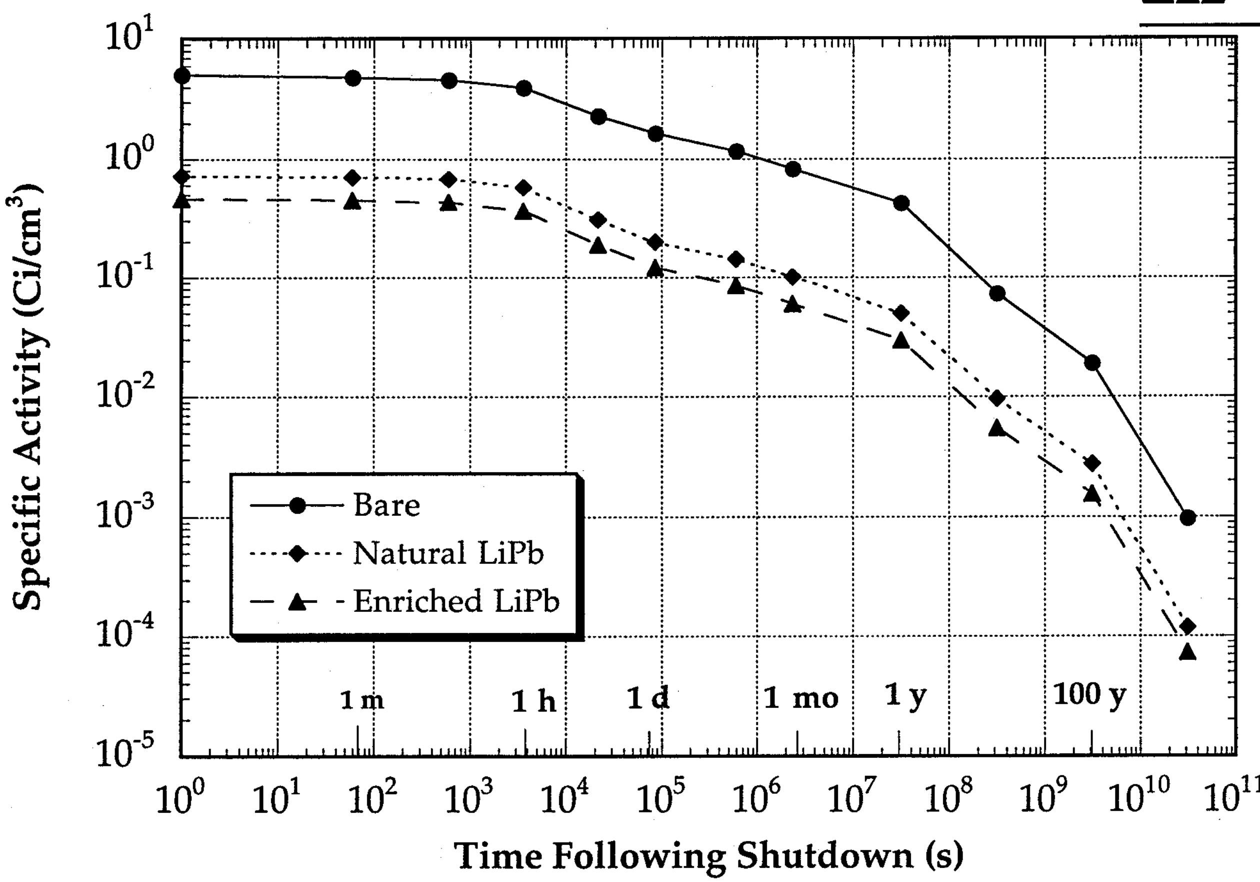

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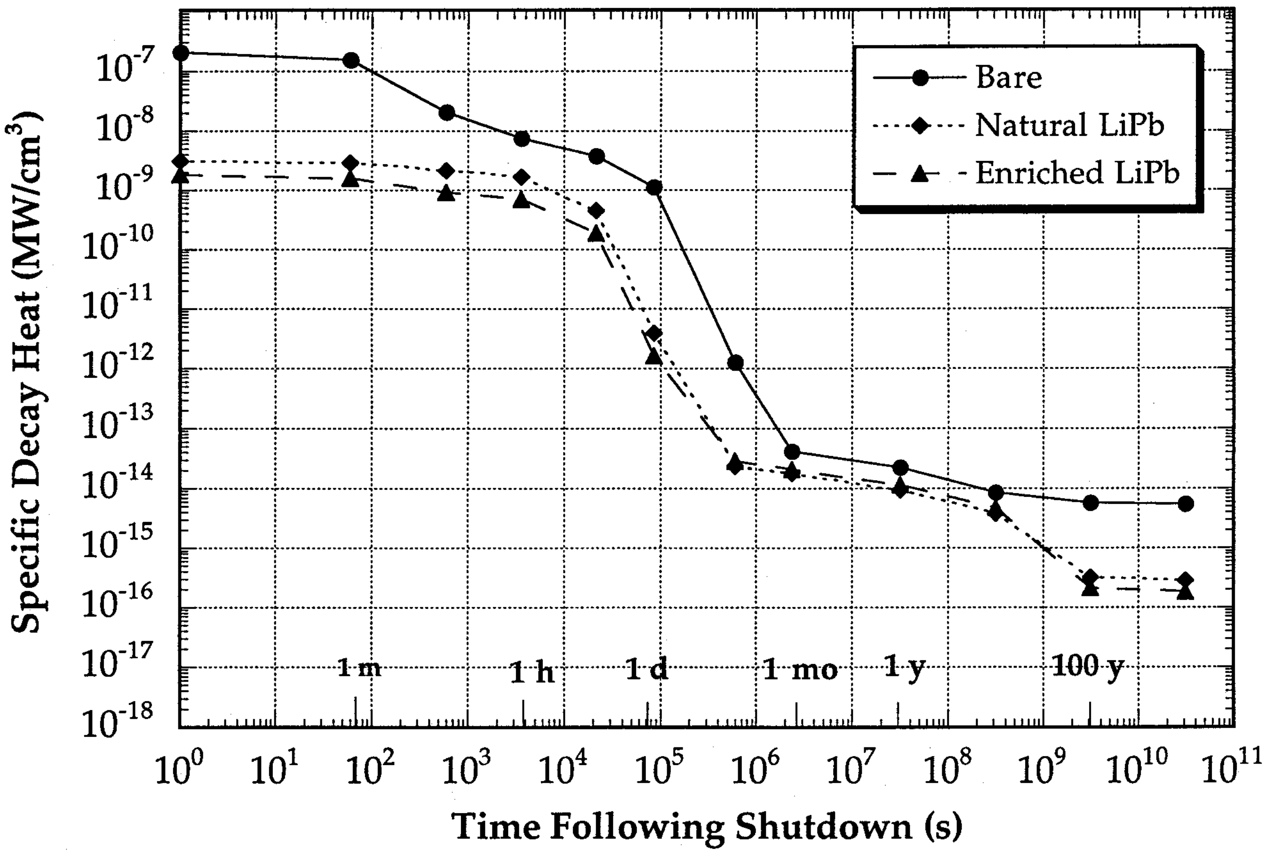

# Decay Heat Induced in the LiPb/SiC TFC

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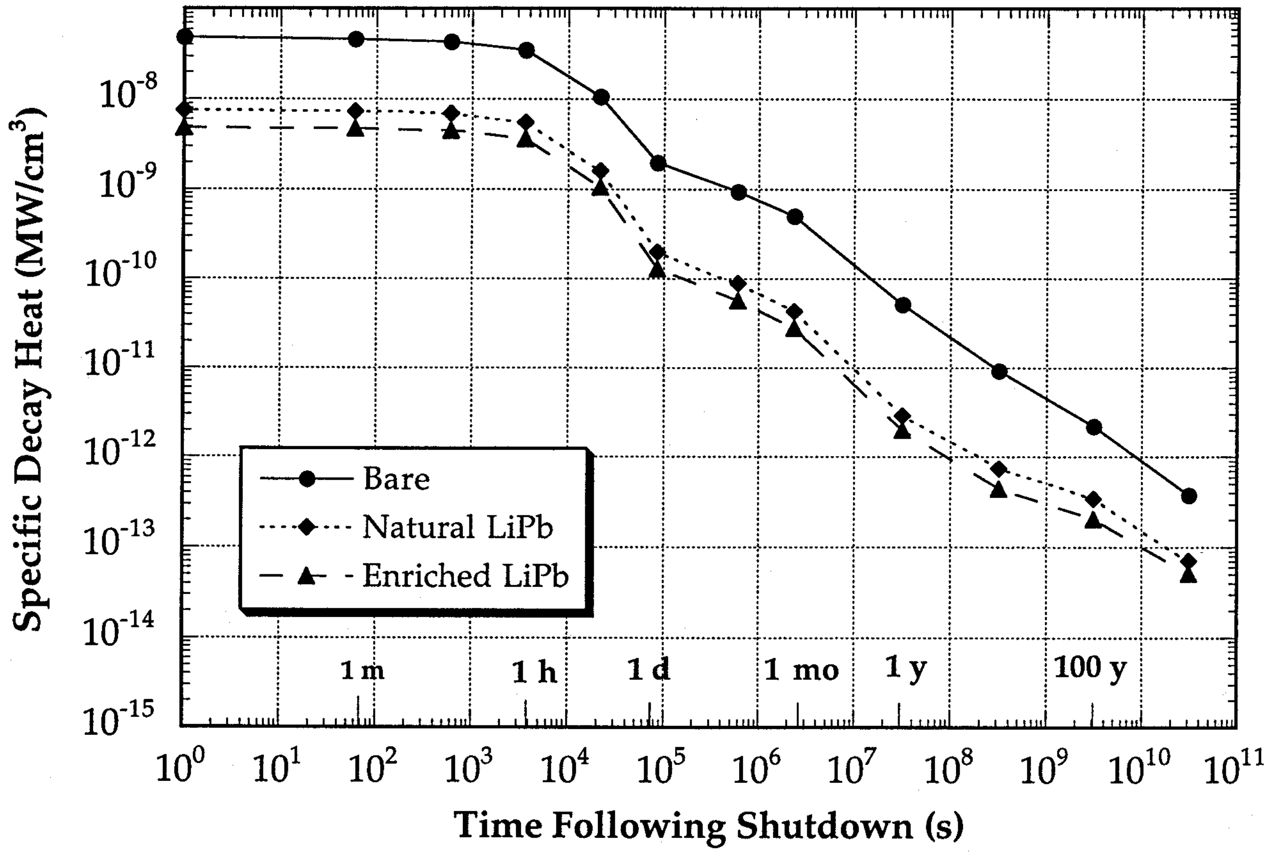

# Integrated Decay Heat Induced in the LiPb/SiC First Wall and Blanket

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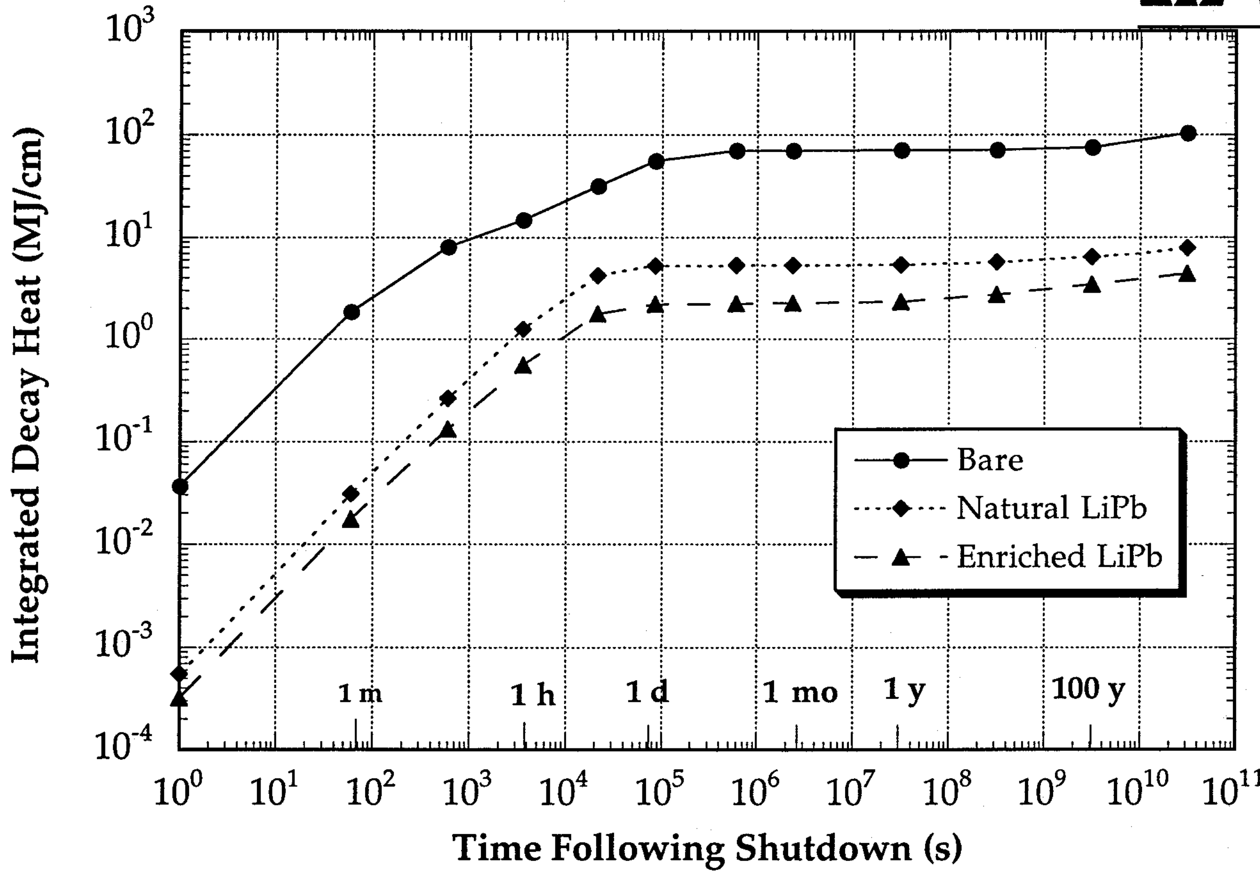

# Dominant Nuclides Following Shutdown

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| Time Following Shutdown | Activity | Decay Heat |
|---|---|---|
| ***Flibe/FS*** | | |
| < 1 week | $^{55}Fe$, $^{185}W$ | $^{54}Mn$, $^{182}Ta$ |
| > 1 year | $^{55}Fe$, $^{54}Mn$ | $^{54}Mn$, $^{60}Co$ |
| ***Li/V*** | | |
| < 1 week | $^{51}Cr$, $^{49}V$ | $^{48}Sc$, $^{46}Sc$ |
| > 1 year | $^{49}V$, $^{45}Ca$ | $^{46}Sc$ |
| ***LiPb/SiC*** | | |
| < 1 week | $^{24}Na$, $^{55}Fe$ | $^{24}Na$ |
| > 1 year | $^{14}C$, $^{55}Fe$ | $^{54}Mn$, $^{26}Al$ |

# Waste Disposal Ratings

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- WDR for Class C waste are calculated using the 10CFR61 and Fetter waste disposal limits
- The ORNL steel (9Cr-2WVTa) composition used in the analysis include a 0.5 wppm of niobium as impurity
- Waste disposal ratings are given after 1 year following shutdown
- Waste disposal ratings are given for compacted wastes

# Calculational Procedures

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- Neutron flux was generated by the ONEDANT code using FENDL cross section data
- Average neutron wall loading of 7 $MW/m^2$ at the inner wall of the first wall
- Radioactivity calculations were performed using the DKR-PULSAR code with FENDL-2 activation cross section library
- Operation time is 30 FPY
- The following three first wall/blanket options were assessed:
  - ORNL ferritic steel with: no flibe, natural flibe and enriched flibe
  - V-4Cr-4Ti with: no Li, natural Li and enriched Li
  - SiC composite with: no LiPb, natural LiPb and enriched LiPb
- Waste disposal ratings for Class C waste were calculated using the 10CFR61 and Fetter waste disposal limits
- Early doses inventories were calculated using Sv/TBq values produced using the MACCS2 code assuming a ground release, atmospheric stability class F, 2 km site boundary and 1 m/s wind speed

# Waste Disposal Ratings Using Fetter Limits

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| Option | WDR | Dominant Nuclides |
|---|---|---|
| ***Flibe/FS*** | | |
| Bare | 1.57 | $^{192m}Ir$, $^{94}Nb$ |
| Natural Flibe | 0.49 | $^{192m}Ir$, $^{94}Nb$ |
| Enriched Flibe | 0.038 | $^{192m}Ir$, $^{94}Nb$ |
| ***Li/V*** | | |
| Bare | 1.05 | $^{26}Al$, $^{94}Nb$ |
| Natural Li | 0.4 | $^{94}Nb$ |
| Enriched Li | 0.01 | $^{94}Nb$ |
| ***LiPb/SiC*** | | |
| Bare | 6.15 | $^{26}Al$ |
| Natural LiPb | 8.1e-4 | $^{14}C$, $^{108m}Ag$ |
| Enriched LiPb | 5.24e-4 | $^{14}C$, $^{192m}Ir$ |

# Waste Disposal Ratings Using NRC Limits

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| Option | WDR | Dominant Nuclides |
|---|---|---|
| ***Flibe/FS*** | | |
| **Bare** | **0.69** | $^{94}Nb$ |
| **Natural Flibe** | **0.15** | $^{94}Nb$ |
| **Enriched Flibe** | **0.0156** | $^{94}Nb$ |
| ***Li/V*** | | |
| **Bare** | **1.49** | $^{14}C$, $^{94}Nb$ |
| **Natural Li** | **0.6** | $^{14}C$, $^{94}Nb$ |
| **Enriched Li** | **0.037** | $^{14}C$, $^{94}Nb$ |
| ***LiPb/SiC*** | | |
| **Bare** | **0.27** | $^{14}C$ |
| **Natural LiPb** | **0.043** | $^{14}C$ |
| **Enriched LiPb** | **0.028** | $^{14}C$ |

# Early Dose Inventory

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| Option | Dose (Sv/cm Height) | Dominant Nuclides |
|---|---|---|
| ***Flibe/FS*** | | |
| **Bare** | 19.65 | $^{54}Mn$ |
| **Natural Flibe** | 0.99 | $^{54}Mn$, $^{182}Ta$ |
| **Enriched Flibe** | 0.27 | $^{54}Mn$ |
| ***Li/V*** | | |
| **Bare** | 8.47 | $^{48}Sc$, $^{46}Sc$ |
| **Natural Li** | 1.22 | $^{48}Sc$ |
| **Enriched Li** | 0.156 | $^{48}Sc$ |
| ***LiPb/SiC*** | | |
| **Bare** | 0.38 | $^{24}Na$ |
| **Natural LiPb** | 0.043 | $^{24}Na$ |
| **Enriched LiPb** | 0.0068 | $^{31}Si$ |

# Conclusions

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- Using a flowing layer of flibe results in reducing the level of activity and decay heat generated in the ferritic steel structure by more than an order of magnitude and using enriched flibe results in a further reduction of less than an order of magnitude

- Using a flowing layer of Li results in reducing the level of activity and decay heat generated in the vanadium structure by a factor of three and using enriched Li results in a further reduction of more than an order of magnitude

- Using a flowing layer of LiPb results in reducing the level of activity and decay heat generated in the SiC structure by more than an order of magnitude and using enriched LiPb results in a further slight reduction of induced radioactivity

- The flibe/ferritic steel option provide the TFC with the highest shielding protection resulting in a TFC with the lowest level of induced activity and decay heat among the three options considered

# Conclusions (Cont.)

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- The use of a flowing layer is essential to allow for the disposal of the first wall and blanket structures, of any of the 3 options, as LLW if Fetter waste disposal limits are used

- The use of a flowing layer is only essential for the Li/V option to allow for the disposal of the first wall and blanket structures as LLW if NRC waste disposal limits are used

- The 316 SS TFC will not qualify for disposal as Class C waste except for the ferritic steel/enriched flibe option

- The off-site dose inventory calculations indicate that using a flowing layer results in a significant reduction of off-site doses

- The LiPb/SiC option produced the least off-site dose inventory

- The new FENDL-2 cross section data shows an order of magnitude lower production of $^{24}Na$ in SiC, resulting in a much lower off-site doses contribution from SiC

# Activity Induced in the Flibe/Ferritic Steel First Wall and Blanket

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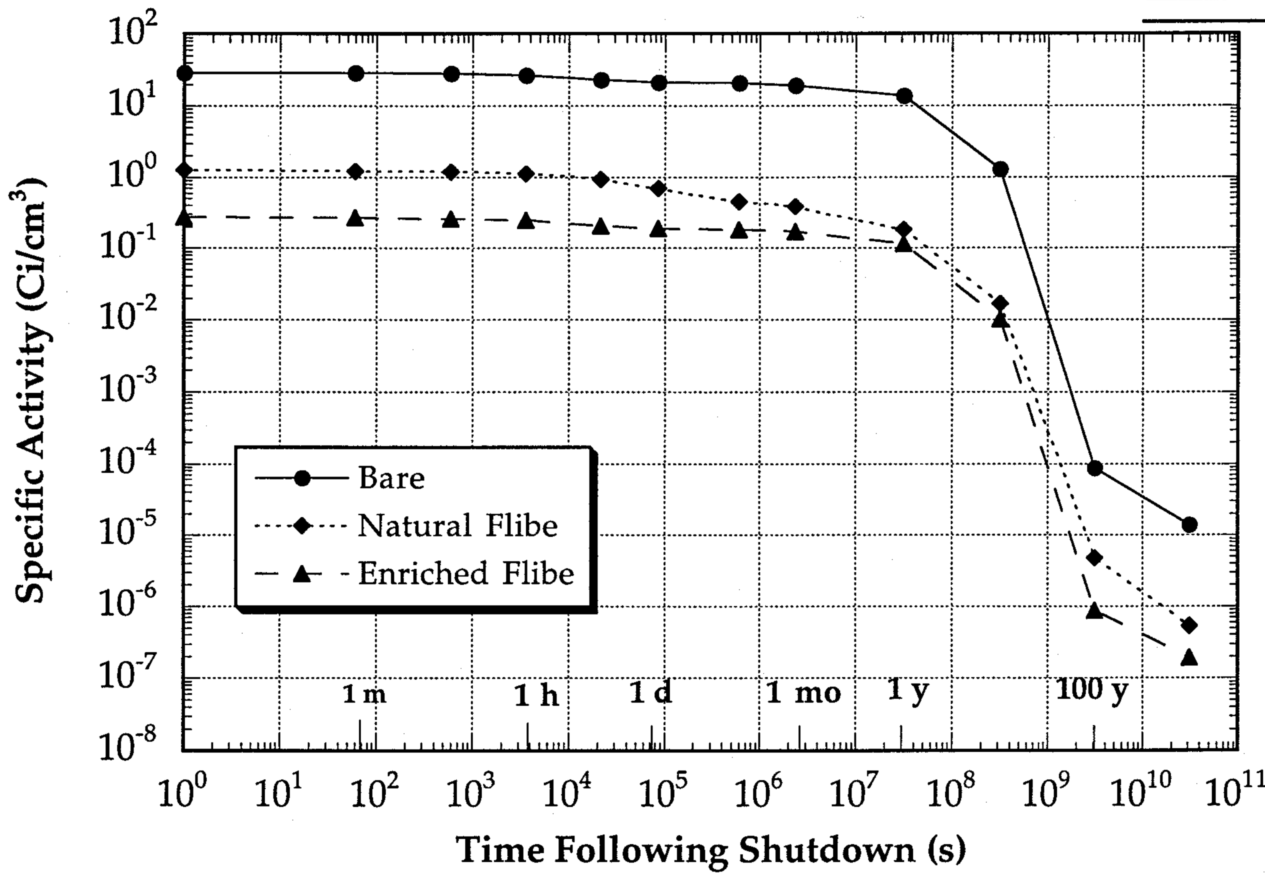

# Activity Induced in the Flibe/Ferritic Steel TFC

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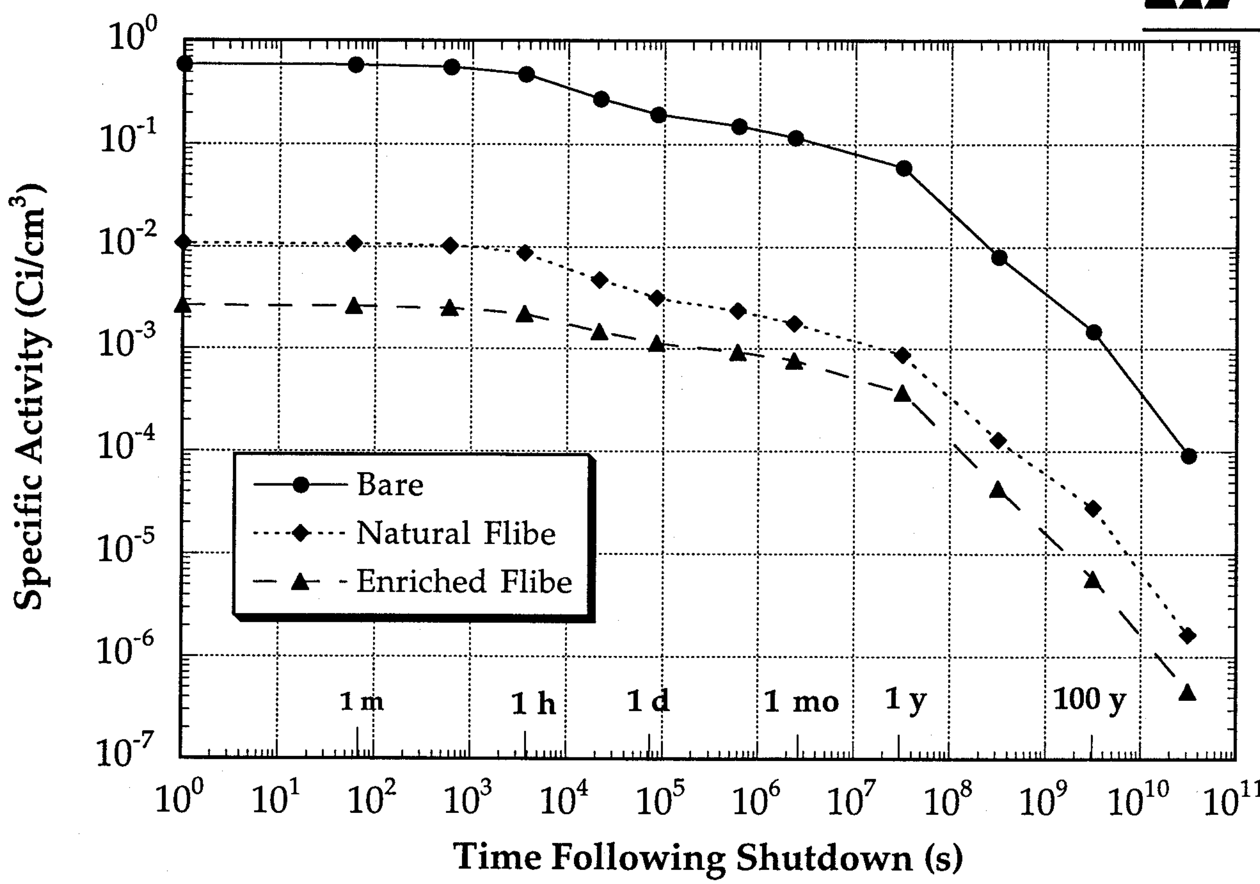

# Decay Heat Induced in the Flibe/Ferritic Steel First Wall and Blanket

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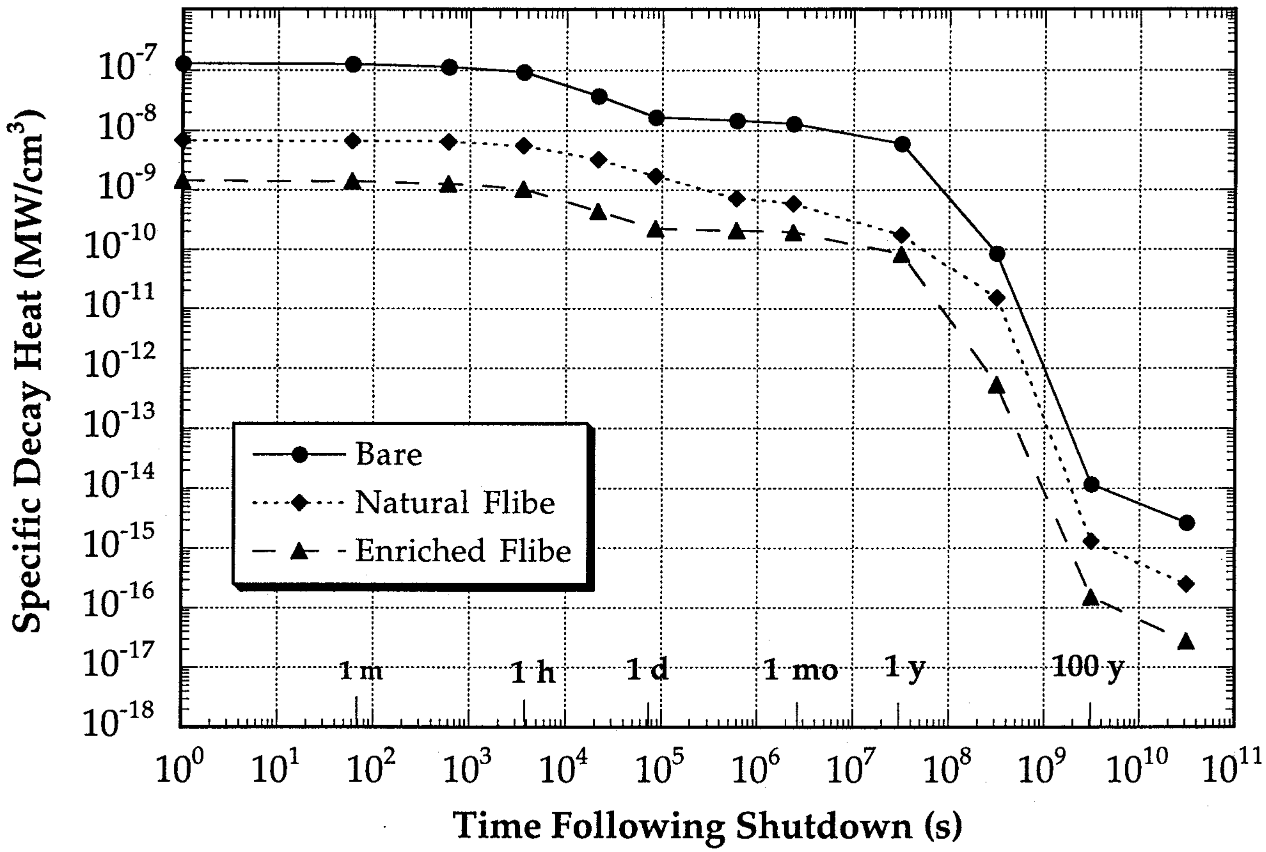

# Decay Heat Induced in the Flibe/Ferritic Steel TFC

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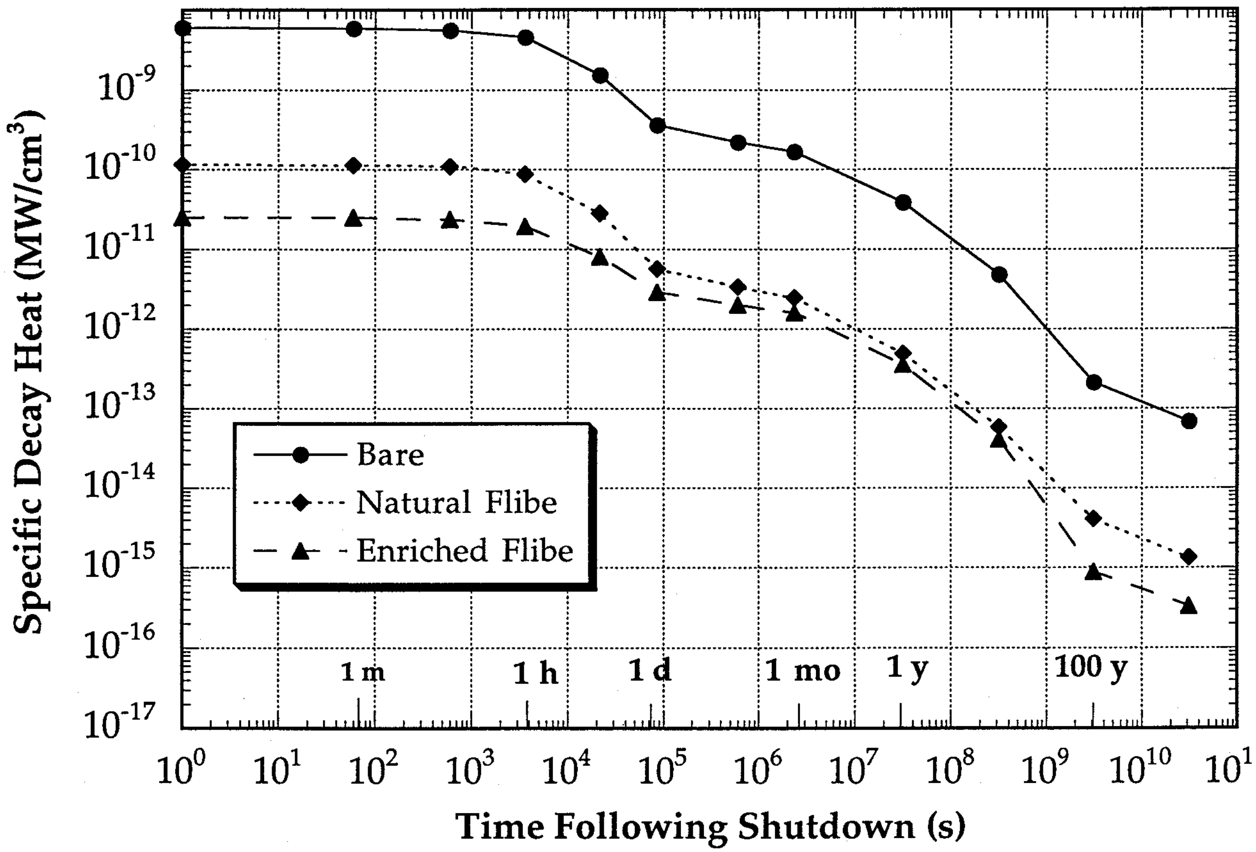

# Integrated Decay Heat Induced in the Flibe/Ferritic Steel First Wall and Blanket

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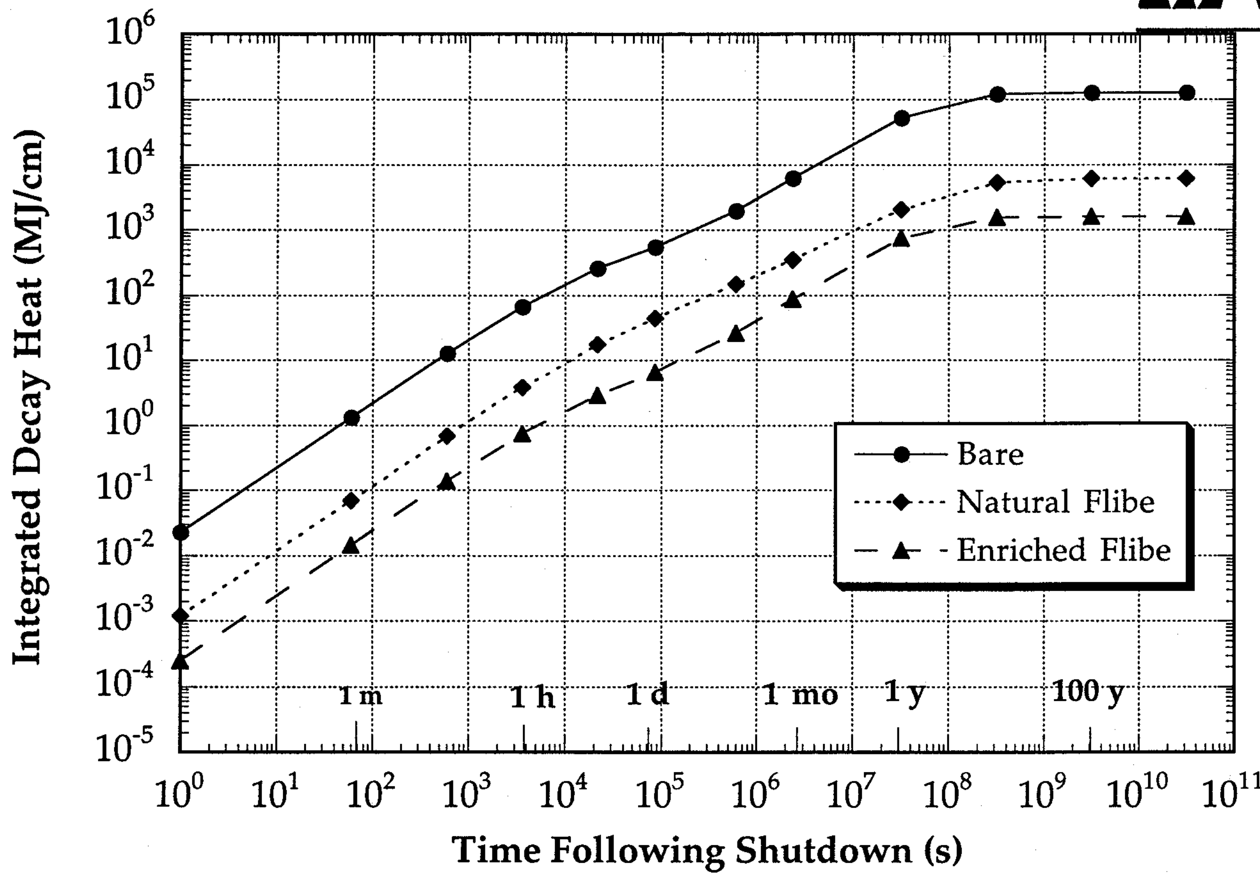

# Activity Induced in the Li/V First Wall and Blanket

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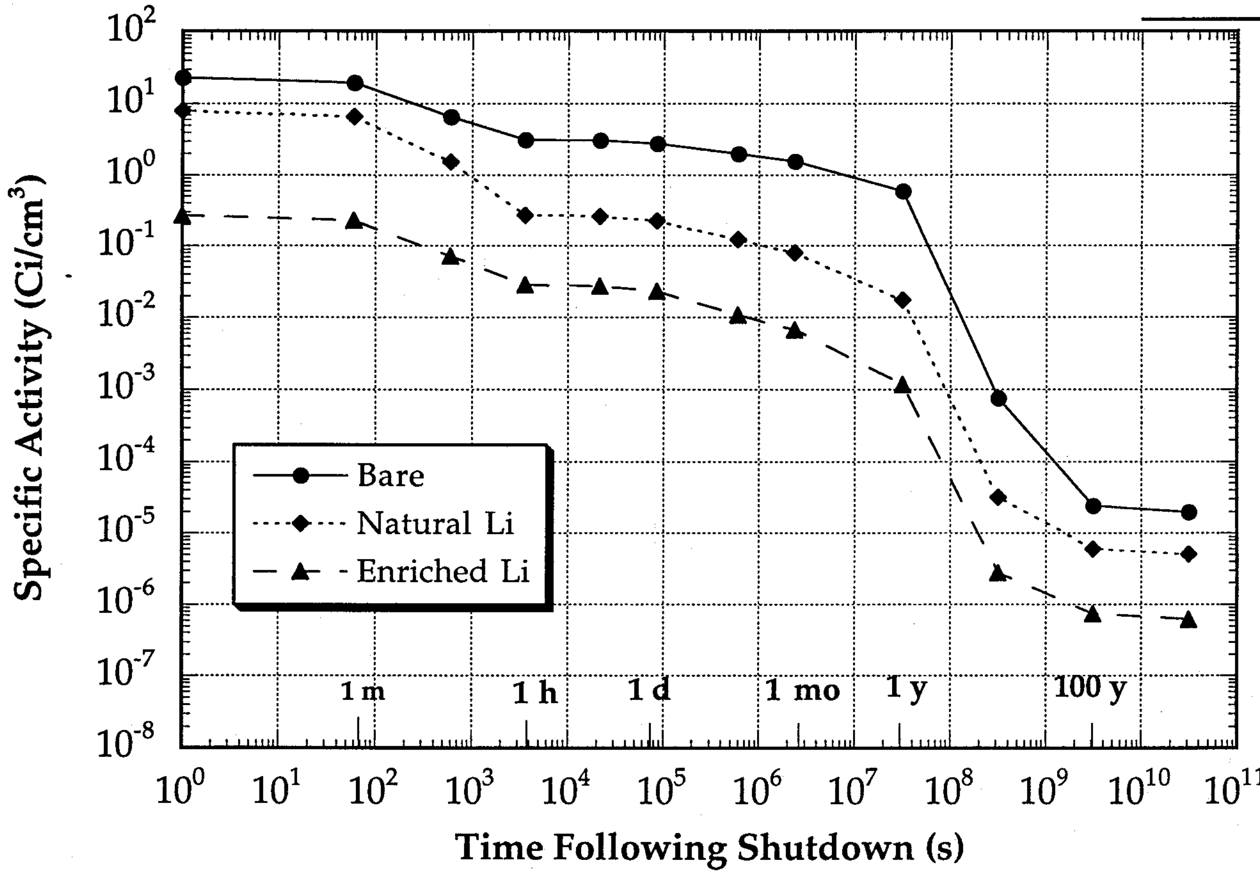

# Activity Induced in the Li/V TFC

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