SUMMARY

Nuclear System for Sn-CLIFF

Presented by

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Presented at the

APEX Project Meeting

Phoenix, Arizona

November 7-9, 2001

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System Description

Sn has very low vapor pressure and is deal for CLIFF application.

SiC is one of the few structural materials which are compatible with Sn.

LiPb is a good tritium breeder and is compatible with SiC to > 800C.

A 2 cm layer of flowing Sn is used for first wall protection.

Sn is exit from the CLIFF region with a emperature of 550C.

LiPb exit the blanket regime with a emperature of 800C.

A He cycle with efficiency exceeds 55% can be designed.

Unique Issues

r a system with a liquid wall, those are the ique issues:

The interaction of the liquid wall with magnetic field (MHD effetcs)

Discussed with Task-II.

Interaction with plasma

Special session on Monday.

Issues unique to the system such as first wall temperature control, material selection, Na activation and its impact to safety, and impact of Sn-Cliff to tritium breeding, etc.

Coolant temperature

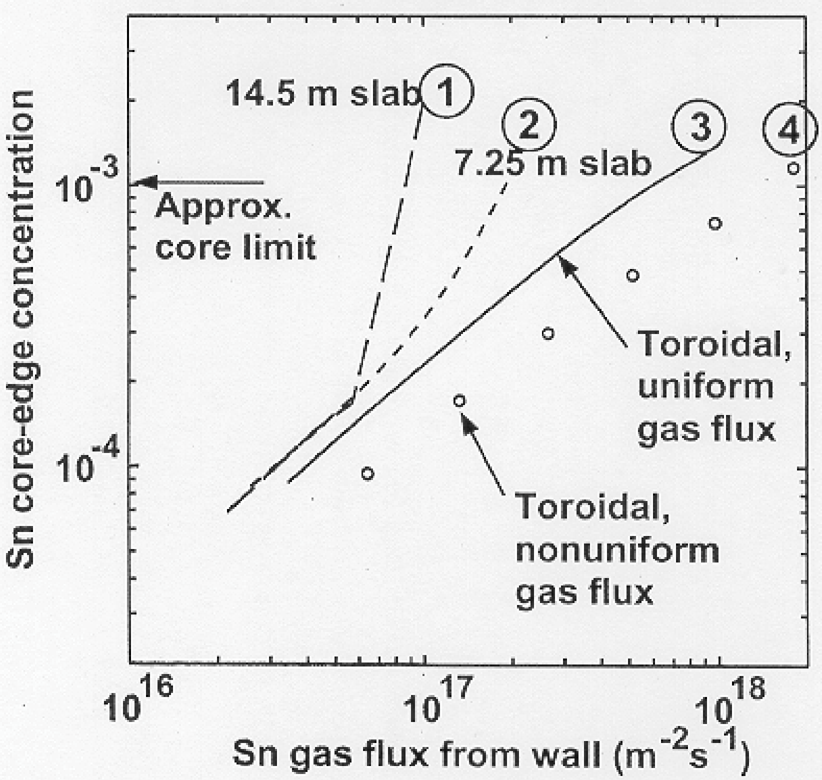
e to the high allowable temperature for Sn,
required coolant velocity is very modest:

Velocity	Inlet T	Oulet T	Surface T
4 m/s	337C	537C	737C
6 m/s	417C	557C	737C

A coolant with those temperature range
n be used with a blanket coolant, with a
nperature of 540 to 800C, to design a He
cle with cycle efficiency of >55%.

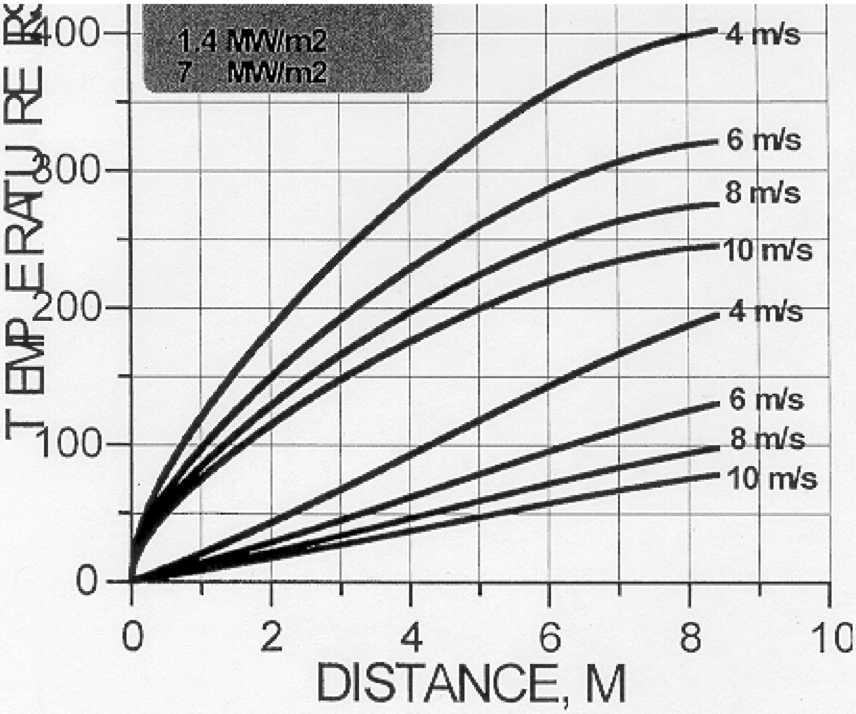
lts show substantial model sensitivity

Core Sn concentration for 4 case with increasing detail for CLIFF



Corresponding wall temperature limits

Case	1	2	3	4
T_w [K]	1010	1030	1070	1100



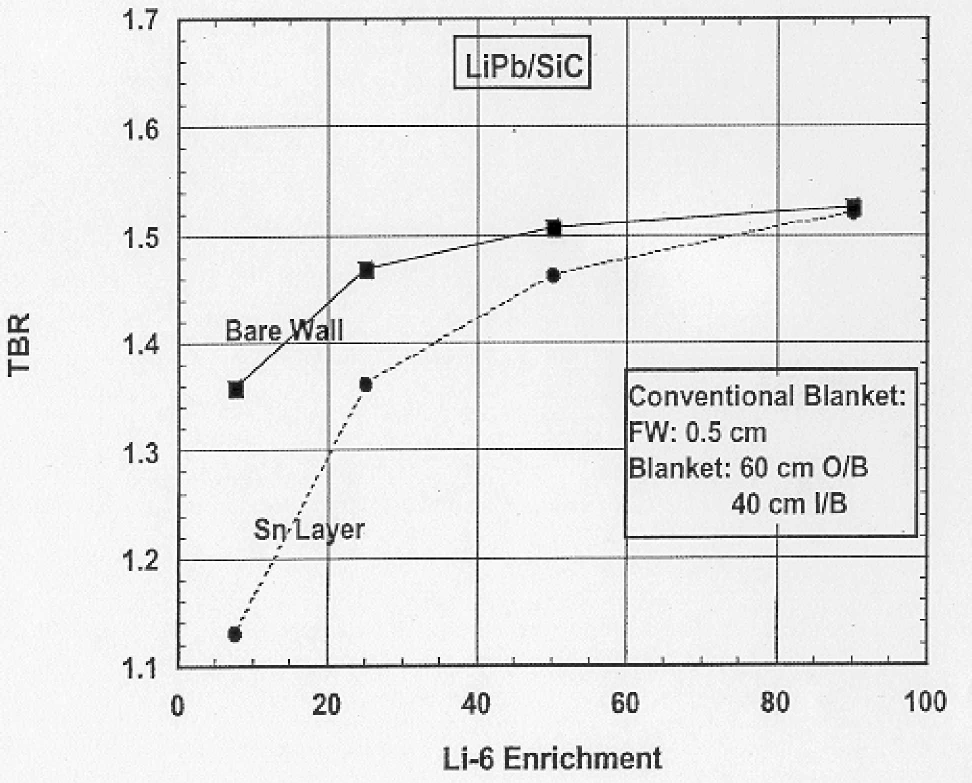
ure 2. Calculations of the temperature rise in Sn CLiFF

BR always increases with
ing Li-6 enrichment

red to the bare solid wall, the
of the inclusion of Sn layer
on TBR largely depends
enrichment

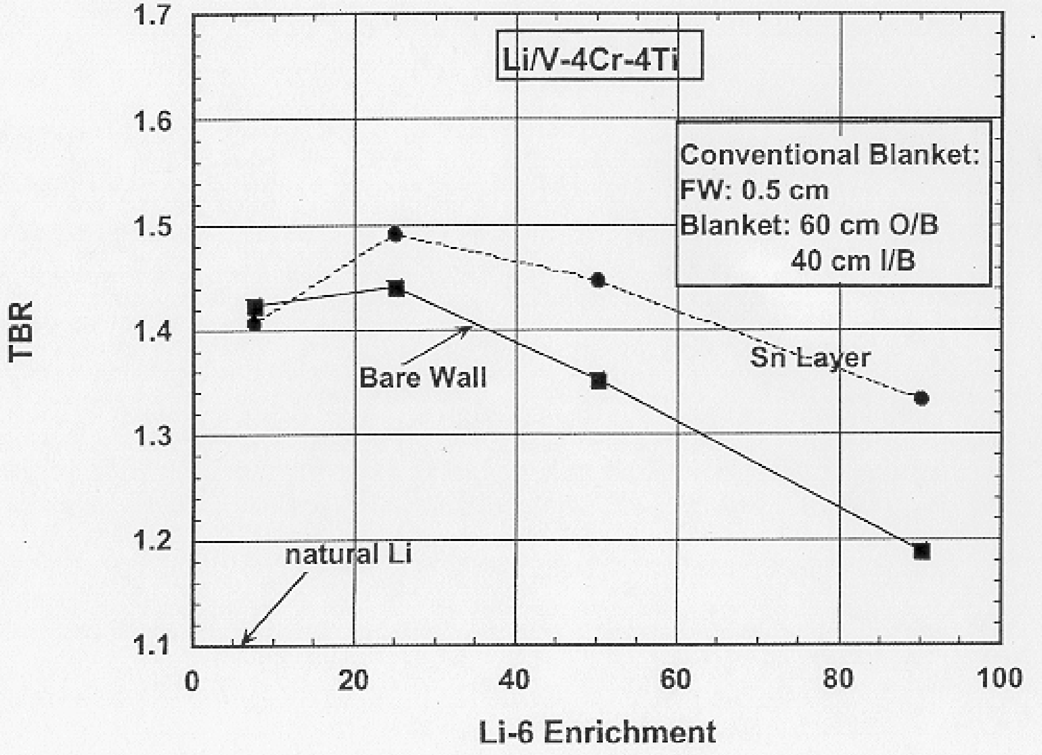
, decrease at 90%Li-6
lecrease at 25%Li-6

y use enrichment lower than
6 because the large TBR. In
, the decrease in TBR upon
inclusion can be ~10% at


Impact of Inclusion of a Liquid Layer in Front of Solid Wall
On Local Tritium Breeding Ration

atural Li-6, including
r improves local TB.
e (n,2n) cross-section,
ften spectrum,
the Li-6 enrichment at
gives the largest TBR.

R at natural Li-6 is
.2% and increasing
ent to ~25% can more
nsate for this loss.



Impact of Inclusion of a Liquid Layer in Front of Solid Wall
On Local Tritium Breeding Ration

eryllium Multiplier

est TBR in the bare wall
natural lithium

ısion of the Sn layer
; TBR. The improvement
on Li-6 enrichment. It
es at ~**50%** Li-6
ent

Impact of Inclusion of a Liquid Layer in Front of Solid Wall
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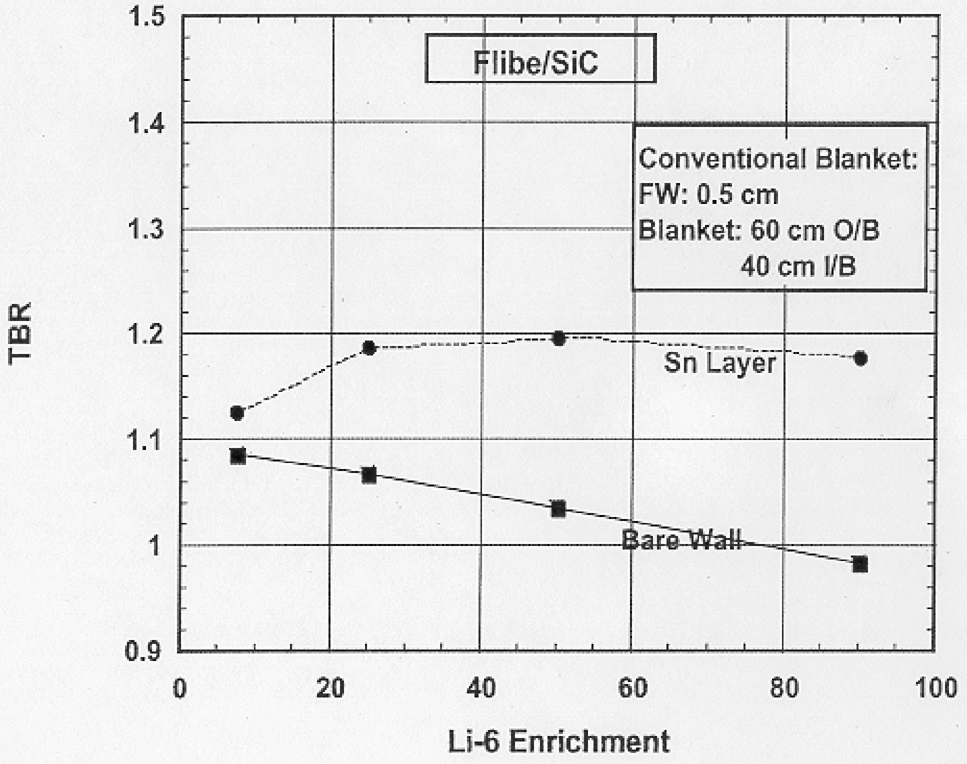
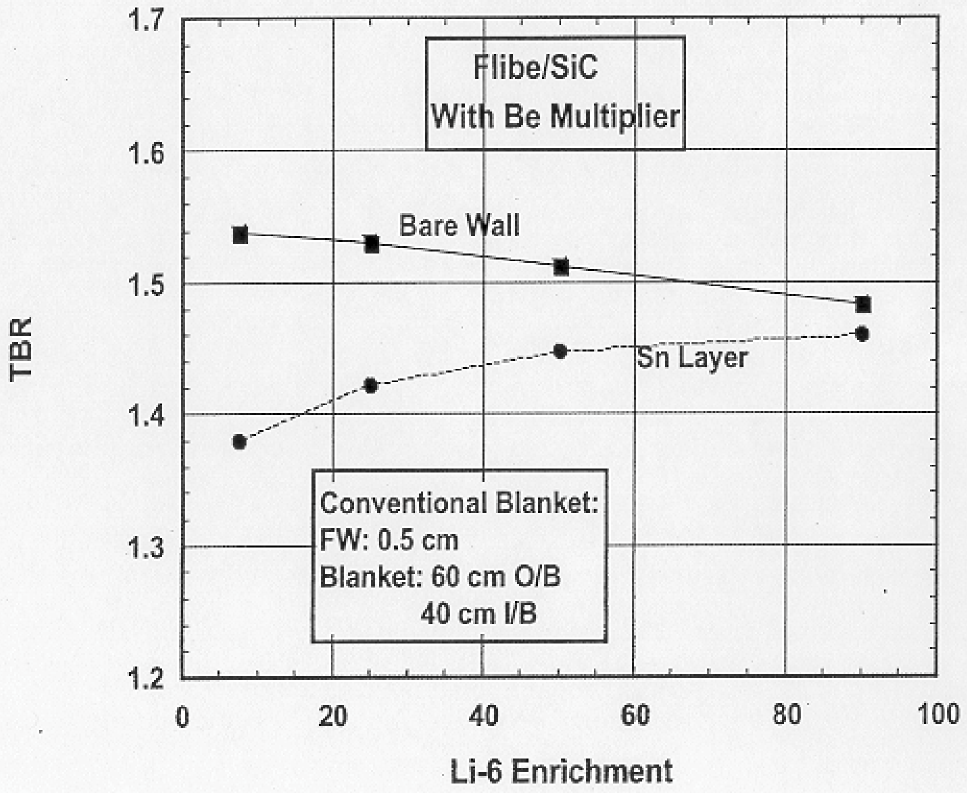


ium Multiplier

:t of the Sn layer
s the largest at natural
loss in local TBR is
is enrichment.

n TBR due to the
of the Sn layer decreases
enrichment. The
loss is ~ 1.4% at

Impact of Inclusion of a Liquid Layer in Front of Solid Wall
On Local Tritium Breeding Ration



1 easily more than compensated for by varying the
·ichment of Li-6

E.g. Li/V: use 25% Li-6
Li-Pb/SiC: use 90% Li-6

In the later case we may operate at lower Li-6 enrichment (~20%) with penalty of ~10% loss and still have adequate tritium breeding

systems with marginal local TBR (e.g. Flibe/SiC), the ·lusion of the Sn layer improves TBR if no Be multiplier is ·ed. The improvement depends on Li-6 enrichment. It ·ximizes at **~50%** Li-6 enrichment with improvement of 5%.

f a Be multiplier is used with Flibe, The impact of the ·n layer inclusion is the largest at natural Li-6. The loss n local TBR is ~10% in this case. The loss in TBR due o the inclusion of the Sn layer decreases with Li-6 ·nrichment. *The minimum loss is ~ 1.4% at 90%Li-6*

Assumptions Used in the Analysis

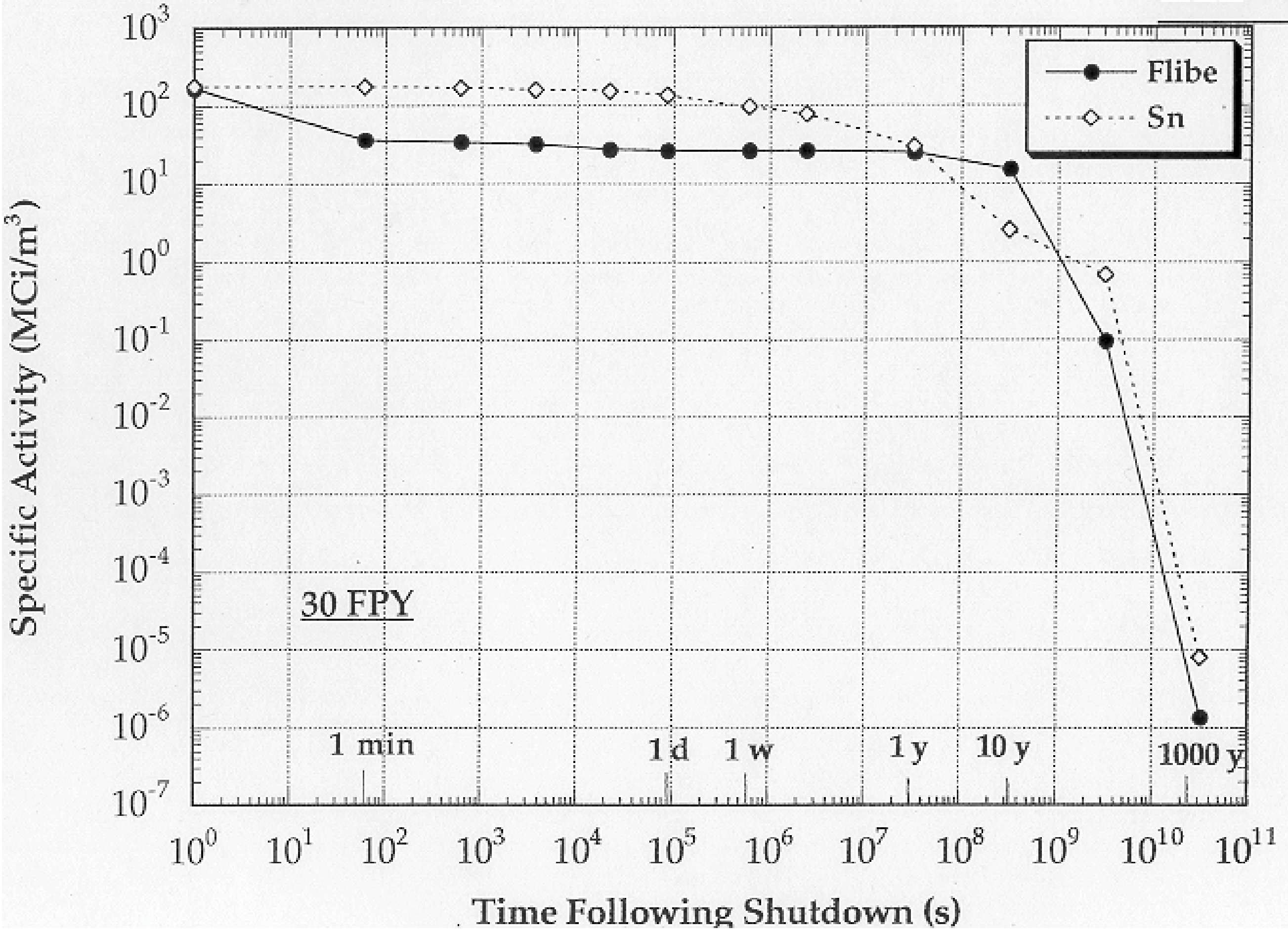
n liquid wall concept uses a 2-cm thick layer of Sn as a first wall

alysis used pure Sn (no impurities)

ssumed to spend only 20% of the time inside the reactor (1 s in and 4 s out)

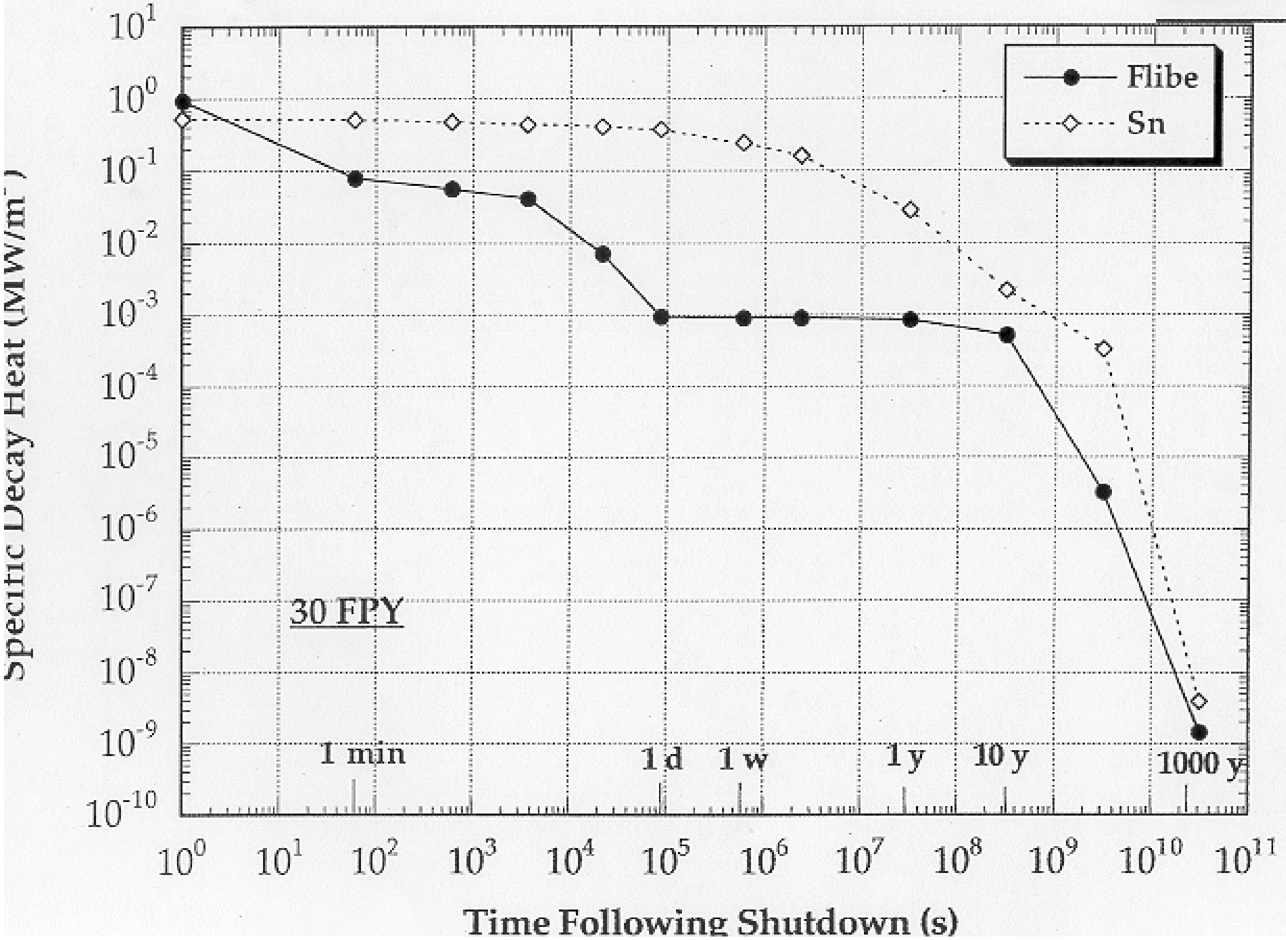
Specific Activity Induced in the Liquid Wall

University of
Wisconsin



Specific Decay Heat Induced in the Liquid Wall

University of
Wisconsin



Summary

duces larger amount of activity and decay heat than Flibe

nitial high level of activity and decay heat generated by Flibe during the
ninute following shutdown is caused by the short lived isotopes;
$_{1/2}$ = 7.13 s), ^{6}He($T_{1/2}$ = 807 ms), ^{8}Be($T_{1/2} = 7 \times 10^{-17}$ s)

wo antimony isotopes, ^{122}Sb($T_{1/2}$ = 2.7 d) and ^{124}Sb($T_{1/2}$ = 60.2 d) are the main
e of decay heat during the first week following shutdown

nerates large number of radioistopes that may cause high level of off-site dose
g an accident

npact of Sn Activation on Sn-CLIFF Safety

case accident scenario is a vacuum vessel (VV) bypass accident
ced by complete-loss-of-power accident (CLOPA) that results in a
f-flow accident (LOFA) coupled with a failure of the VV by an
d plasma disruption (loss-of-vacuum accident, LOVA)

zation of radio-nuclides is by vaporization of Sn film that adheres to
t first walls (FW)

y isotopes are In-114m, Sb-124, Sb-122, and Sn-119m

V temperature of 1000 °C, the off-site dose exceeds the no-
ation limit of 10 mSv within 1 minute.

ndium and antimony isotopes are removed during operation to
ntrations of 0.1, 0.185, and 0.0483 PPM, respectively, the time to
d the no-evacuation limit to 2 hours (facility isolate much easier)

on predicted isotope production rates, these allowable
ntrations could be achieved by processing 0.1 % of the coolant flow
nimum efficiency of 4% - vapor pressure driven separation appears

lated by Molokov and by us for the Sze test case. We can repeat calculations for variants and I can supply to Sze a resistor theory model that works reasonably well rst estimates.

entrance effect will not, however, be electrically decoupled from the nozzle region. del that has the entrance region coupled to the complex geometry nozzle has not yet developed, although presumably the Hypercomp tool should have this capability. It east 1 year away. The core flow code of Buhler at FZK may also have this bility in the high field region. It won't be able to go to zero magnetic field accurately IT field may have to be assumed outside the coils. I think the Molokov analysis with re flow code did this as well.

estimate of the flow contraction and bend effects in the nozzle region could be now using experimental correlations. This would be a very rough estimate. Again, code could be used for this work I think. We have that code here (not latest version) e no longer have experience running it. To get it restarted would take some months ort by a staff member.

ischarge: Can we use the reduction of the magnetic field at the exit region to pump e liquid for discharging? Is this pumping sufficient?

is calculable in the near term (such calculations underway now by Gao at UCLA) ning axisymmetry and purely toroidal field. This will be the first guess at the flow in annel, with pipe wall effects and other field component effects added at a later There should be results for this at the November meeting. The effectiveness of the etic propulsion effect will be evaluated. The swing of the toroidal field from ive to negative may provide some difficulties for magnetic propulsion.

ree flowing: If the free flowing liquid is entering the first wall region with a certain elocity, will the MHD effects reduce the velocity? or the gravitation force will ccelerate the velocity?

along the wall. We need to redo initial simple toroidal only, and surface-normal calculations with Sn, as well as axisymmetric calculations with 3 components. This will be done by Sergey and available at the November meeting.

work on 3 component, 3 D geometry effects will require new modeling at UCLA. a code based on parabolized Navier-Stokes is underway, as well as Hypercomp The UCLA model may be available in 6 months, Hypercomp 1 year.

A has plans to assess 2D turbulence effects but this has low priority since it may not erly beneficial. For now, pure conduction is assumed in calculated velocity profiles.

elocity profile: What is the velocity profile for the CLIFF/divertor if we use only onduction for heat transfer?

ates of velocity profiles will be provided in 3 and used in 4.

low distribution: How can we be certain that the flow distribution on the OB-CLIFF ill diverge along poloidal direction on the top of the first wall, and converge on the ottom? Will the flow be stable?

riments are planned for this effect both in MTOR and FLIHY. Some data may be able by November meeting. Calculations using parabolized NS model at UCLA are st 6 months away.

hannel flow: How can we calculate the pressure drop and velocity profile if we hange VXB (from parallel to perpendicular) or even with no change of VXB (when elocity turns, while perpendicular to B).

red in 1 for the complex nozzle geometry.

Conclusions

Sn-CLIFF provide a very large design window for the first wall coolant.

High power conversion efficiency can be achieved.

With a 2 cm CLIFF, tritium breeding is sufficient with different type of breeding material.

Sn has high after heat and activation.

Transmutation products continues clean up process needs to be developed to assure safety.

Work on MHD effects on CLIFF, and asma-liquid wall interaction issues have to continued.