Task-III Nuclear System

Summary

Presented by

Dai-Kai Sze

UCSD

And the APEX Task-III

APEX E-meeting

Feb. 5-7, 2002

Mission of the Task

- To assess engineering issues associated with a flinabe CLIFF.
- To establish an acceptable temperature window for both the CLIFF and the divertor.
- To develop numerical codes for heat transfer calculations, including the MHD effects on heat transfer, and heat transfer improvement.
- To develop engineering solutions to subsystem such as the nozzle design and penetration cooling.
- To develop divertor design compatible with the CLIFF design.
- To assess the impact of the plasma to the stability of CLIFF.
- To do the engineering calculations such as tritium breeding, activation and safety assessment.

CLIFF temperature window

- The upper temperature limit of the CLIFF system is the allowable interface temperature between the CLIFF and the plasma.
- The lower temperature limit is the melting temperature of the CLIFF coolant.
- The temperature difference between those two limits must be large enough to allow heat transfer, heat transport, and maybe power conversion.

- The design in progress is based on flinabe and AFS.
- The melting temperature of flinabe is ~ 240 to 310C, much lower than flibe.
- The allowable temperature for AFS is about 800C.
- The suggested interface temperature between flinabe and AFS is suggested to be 700C.
- Those temperatures provide us a large temperature window for the CLIFF design.

CLIFF Temperature limit

ITER slab	**Tw = 390C**
ARIES-RS, uniform Tw	**Tw = 450C**
ARIES-RS, nonuniform Tw	**Tw = 480C**

Tw in = 300C, Tw out = 480C

For more detail information, see Rognlien's presentation on 2/5.

CLIFF heat transfer

- MHD effect on the flow thickness is very small.
- Turbulence in the near-surface regime is affected by the field more siginificantly.
- The heat transfer DT is 90C with the following parameters:

  Velocity 10 m/s

  Height 2.3 cm

  Distance 8 m

  Surface heat flux 1.4 MW/m2

- This DT can be reduced by another 30C due to

  Surface wave

  Poloidal heat flux variation

  B radiation

Temperature Summary

- **The maximum allowable surface temperature is 480C.**
- **The heat transfer DT is 60C. Thus, the coolant exit temperature is 420C.**
- **The coolant inlet temperature is 300C.**
- **Those temperatures give us a comfortable temperature window for flow fluid and power conversion.**

Team Effort

This is a good team effort:

- **Discover flinabe gives us a much lower melting temperature.**
- **New work from Tom increases the allowable surface temperature from 390 to 480C.**
- **Heat transfer calculation (Sergey), poloidal heat flux distribution (Mohamed) and B penetration reduces the heat transfer concerns.**

All three part of the work are necessary to give us a comfortable CLIFF temperature window.

For more detail heat transfer calculations, see the attached VG's from Sergey.

PENETRATIONS IN LIQUID WALL FLOWS

—— Curve Plate and Thin Liquid Wall

Initial Reference Case Parameters of Penetration

V_{in} (m/s)	10.0		
Flow length	8 m		
Flow Thickness (m)	0.02		
G_y (m^2/s)	9.8		
Wall Roughness (m)	10^{-5}		
Fluid-Wall Contact Angle	0		
Penetration Dimension (m)	A	B	H
	0.15	0.5	0.02

What happened?

- **Fluid can cover the back wall completely.**
- **There are still some splash droplets and fluid thickness is too thin at a very samll spot at downstream.**

What can do done:

Modify the penetration shape to reduce splash droplets.

Using buffer to control fluid thickness at downstream.

For more detailed results from Huang, see the attached document.

Flibe Transmutation

- Flibe transmutation rates have been calculated for Li, Be and F.
- This results are important to calculate thermodynamics for a flibe blanket.
- From mass balance point of view, there is no free F in the blanket.
- This result is important because F will attack all the structural material.
- The TF concentration increase per coolant pass is 5.5 appb. (F/flibe)
- The allowable TF concentration in flibe with FS blanket is about 100 appb, based on very prelminary calculations.
- Total transmutation rate, including other elements, will be calculated.
- This will establish the chemical state of a flibe blanket, and provide parameters for the JUPITER-II experiment at INEL.

Conclusions

Some very encourage results have been obtained for a blanket based on flinabe:

- **Based on the information we have, we have obtained a “comfortable” temperature window for the CLIFF, based on flinabe and AFS.**
- **Work on the penetration cooling progress well. The splashes have reduced and the dry area has been eliminated .**
- **Initial calculations show that there will be no free F in a flibe blanket based on the mass balance.**
- **Allowable TF concentration is much higher than the TF concentration increase per coolant pass.**
- **More detailed works are needed to confirm those conclusions.**