ARIES IFE -
Some Concluding Comments on Thick Liquid Walls

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Physics &
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ARIES-IFE work and interactions with other OFES funded work on thick liquid chambers has been interesting and beneficial

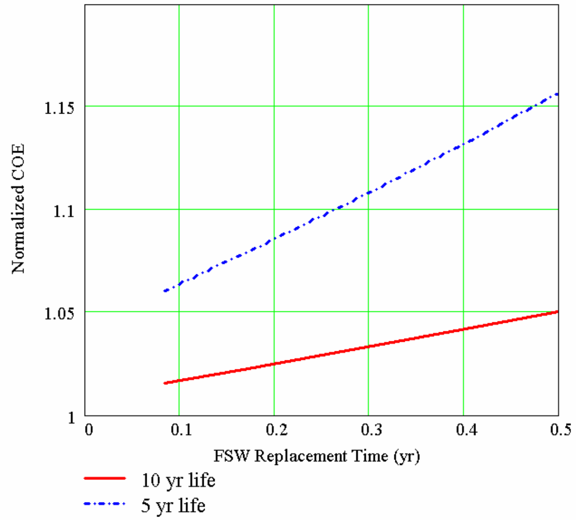
- Re-examined structural material options
- Determined economic impact of FW replacement if need
- Updated mechanical design and developed maintenance sequence
- Facilitated workshop on liquid chamber dynamics
- Produced new views on recycling target material
- Improved final focus magnet shielding designs

Structural material options were considered

- ARIES report primarily recommended FS for better neutron life
- Some prefer Ni containing alloys (e.g., 304SS) for corrosion resistance, but modified to increase rad damage life (like 316 was modified to make PCA)
- Liquid wall thickness is an important design knob
- Needs: continued development of FS and modified SS, neutron damage and corrosion tests

Economic impact of FW replacement (if required) is acceptable; goal of lifetime components remains

COE vs. replacement time for 5 and 10 yr wall lifetimes



- If wall lasts 10 yrs and takes 6 months to replace, COE only increases by 5%.

- But that may exceed acceptable plant down time for utility.

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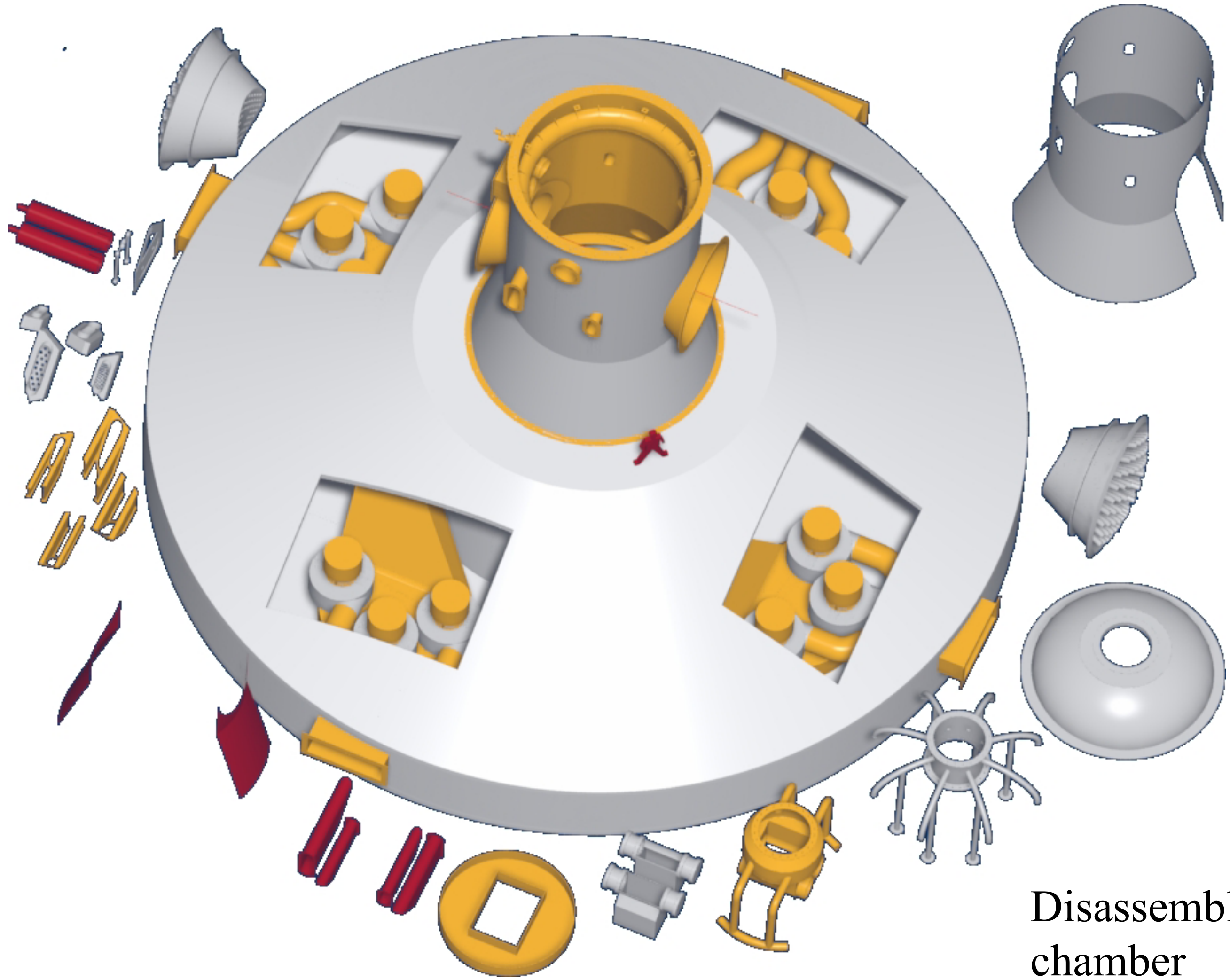
ARIES IFE and Robust Point Design study motivated new work on chamber mechanical design



Disassembled chamber

RPD-2002 fusion chamber design report just completed

A Fusion Chamber for the 2002 Robust Point Design

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ABSTRACT

A top-level overview of the mechanical design for the 2002 Robust Point Design (RPD-2002) fusion chamber is introduced. It is based on the HYLIFE-II design and includes modifications to the liquid pocket configuration and first structural wall (FSW), facilitates periodic maintenance or replacement of internal components, and is compliant with all other RPD-2002 parameters. This work has been carried out by constructing a parametric computer model capable of being updated as future changes become necessary.

INTRODUCTION

RPD-2002 is an attempt to present a self-consistent picture of a heavy ion inertial fusion energy (HIF) power plant by integrating the latest understanding of target physics, drivers and beam focusing, chamber dynamics, and radiation shielding [1]. A HYLIFE-II style 2,3] thick liquid protected fusion chamber featuring an updated pocket configuration is proposed for RPD-2002. This chamber type can make possible substantially longer chamber component lifetimes compared to what can be achieved with dry and wetted wall concepts, the ultimate goal being for them to survive the lifetime of the plant.

This document summarizes a mechanical design for the fusion chamber that is fully compatible with other plant parameters. The design also adds functionalities not found in HYLIFE-II including a capability for periodic repair or replacement of internal chamber components if radiation damage limits necessitate such action. Other chamber features have been modified to be more robust in light of recent materials failure concerns. Primary among these is the design of the FSW where the arrays of vertical tubes found in the HYLIFE-II design have been replaced by a flexible woven-wire steel mesh to mitigate stresses from neutron induced swelling.

LIQUID PROTECTION CONFIGURATION

The molten salts Flibe (Li_2BeF_4) and Flinabe ($LiNaBeF_4$) have been identified as candidates for the RPD-2002 fusion chamber thick liquid protection system. This system is composed of several distinct molten salt flows (see Figure 2). All have the general function of shielding solid components from target output x-rays and neutrons, but the specific configuration of each type of flow is dictated by its location in the fusion chamber and the physical processes it is attempting to control.

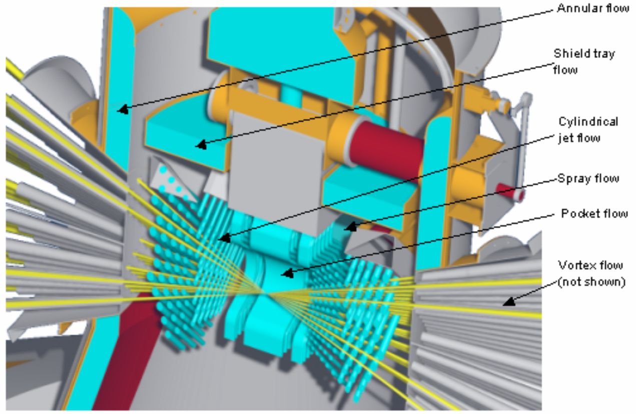

Fig. 2 Thick liquid protection system molten salt flows.

The flow producing the central pocket is produced from molten salt exiting at 12 m/s from nozzles actuating at the target injection frequency of 6 Hz. When a pocket reaches the proper location, a target is injected along its horizontal axis toward the center of the chamber where it is ignited by ion beams.

If the pocket were a monolithic flow of full density molten salt, shocks from x-ray ablated target facing surfaces and neutron isochoric heating would eject damaging high

Target material recycling was examined

- Target factory designers would like to avoid dealing with recycled, activated hohlraum materials
- Environmental assessments support feasibility of a no-recycle approach

Conclusions

- Recycling introduces activation problems, adds complexity, increases COE, and mandates remote handling in target Fab (costly, slow, complex).
- Hohlraum walls represent small waste stream for IFE-HIB (< 1% of total nuclear island waste) ⇒ recycling is not a "must" requirement for ARIES-IFE-HIB unless materials have cost/resource problems (e.g., Au and Gd).
- With or without recycling, Au and Au/Gd hohlraums result in highest COE.
- One-shot use is preferred option for all materials except Au and Gd, offering
  - Attractive safety features
  - Radiation-free target Fab
  - Less complex design
  - Lower COE
- Make hohlraum out of breeding or liquid wall materials (Pb, LiPb, Li?, Flibe?, Flinabe?) to avoid separation from liquid walls.
- To recycle Au/Gd, attractive scheme would combine controlled cooling period and efficient clean-up system to filter out small amount (cups?) of HLW. This waste could be burned in special module to avoid deep geological burial* of waste and meet ARIES Class C-only waste requirement.

* L. El-Guebaly, "Need for Special Burning Modules in Fusion Devices to Transmute Fusion High Level Waste", University of Wisconsin, UWFDM-1155 (June 2002).

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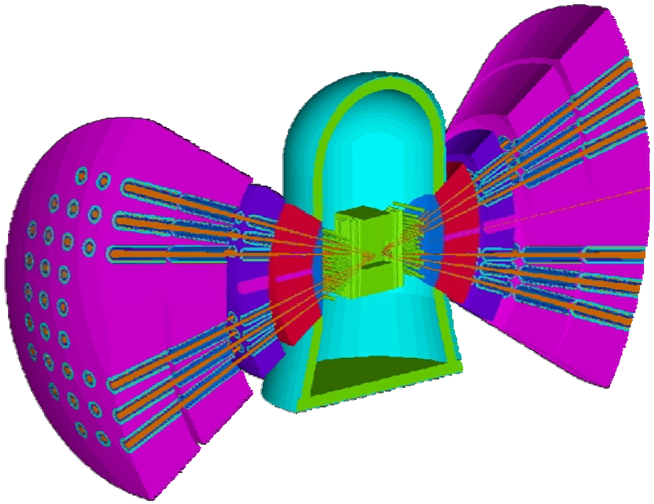
Final focus magnet shielding designs were improved

Magnet waste disposal ratings are low enough to meet Class C requirements

- Last set of magnets would have average WDR of 0.18 → should qualify as Class C even with increased beam-to-structure stand-off distance (present results all assume 1 mm clearance; move to 5 mm clearance gives ~2x increase in activation & doses)
- Even coil regions of 2nd-to-last and 3rd-to-last magnets have WDR<1
- Variability between magnets is relatively small – certainly not 5× about average → **no individual magnets should exceed WDR=1**
- Have not included impurities in shielding materials from R/X, Inc.:
  - Impurities are unlikely to be bad enough to change classification
  - Will perform study to determine impurity limits in W-poly and Ti-poly
- As designs progress, should continue to monitor magnet lifetime, waste disposal rating, etc.

JFL—ARIES 5/7/03



Latkowski
May 2003 Project Meeting

ARIES IFE work should continue

- Promotes interactions within broad IFE community
- Brings new faces, new ideas into play
- Increases opportunity for synergy with other OFES funded work
- Continuation is supported by VLT Program Advisory Committee
- Needs: sufficient Advance Design Studies budget to support two studies (MFE and IFE)