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March 8, 1991
WRM-SF91-024

MEMORANDUM

To: Reactor Studies Team
From: Wayne Meier
Subject: Rating Reactor Concepts

As you know, it is time to make a decision and proceed with the design phase of the study. We would like input on how you rate the various reactor concepts. We will use the same procedure that we used at the review meeting in Berkeley.

Evaluation Criteria

Recall that we reduced the number of evaluation criteria to three:

• Technical Issues (includes Technical Credibility and Technology Development)	50%
• Environmental and Safety	30%
• Economics (Operability effects economics)	20%

Rating Scale

We will us a simple rating based on the following scale:

• Very good	5
• Good	4
• OK	3
• Poor	2
• Very Poor	1

Reactor Concepts for KrF Driver - Uniform Illumination Target

1) Onion with Flibe breeder/coolant and a gas protected first wall (CVI SiC)

2) SBMB with a Li_2O breeder/coolant and a gas protected first wall (C/C composite)

3) Higher pressure SBMB

We completed preliminary evaluations of the first two concepts for the KrF driver at the LBL meeting. Based on the input of 7 individuals at the LBL meeting, the two concepts were rated nearly equal, with Onion slightly favored (26.4 to 25). However, we still need one more evaluation from UW. I have enclosed a copy of the rating you did at LBL in case you want to change your mind.

Most of the concern with the SBMB concept seemed to focus on the pressure isolators. Therefore, please rate option 3 listed above which is a higher pressure version of SBMB. In this case the chamber would run at a pressure closer to the pressure of the gas stream used to lift the breeder to the top of the chamber (~3-4 atm, which is about the same as Onion's hydrostatic head). This would reduce or maybe illuminate the need for the pressure isolators. A higher pressure design could also incorporate an onion-type cooling scheme. Cold Li_2O could be injected and fluidized up along the first wall to remove first wall heating. The material would then flow down and out of the reactor in a slower moving outer region that absorbs the bulk of the neutron heating.

Reactor Concepts for HIB Driver - Indirect Drive Target

1) Cascade with Be coated $LiAlO_2$ breeder/coolant

2) LIFE reactor with PbLi coolant/breeder

3) Onion with PbLi breeder/coolant and a PbLi wetted first wall (V or ferritic steel)

4) Osiris with PbLi breeder/coolant filling SiC fabric blinds and neutron blanket modules

5) SBMB same as above, but at a larger radius

Note that the Flibe versus PbLi choice is still open for all concepts. Reviewers seemed to prefer Flibe, but the pressure-propagation limit is not yet firm.

Please fill out a rating sheet for each of the seven concepts. If any criteria is given a very poor or poor rating (1 or 2), please add a brief comment explaining your concern. I would like input from two people at each institution.

Your input is due on Thursday, March 14.

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March 29, 1991
MJM-SF91-035

MEMORANDUM

To: ICF Reactor Studies Team
From: M. Monsler and W. Meier
Subject: Chamber Concept Selection

Introduction: Well, the votes are in, we are back in town, and it's time to announce the Oscar winners. Before we begin, I want to tell you that we briefed Bob Price at DOE/Germantown on March 21, 1991 on the progress of our study. Our 2-hour briefing, attended by about 8 people (not including Ann Davies, Bob Dowling, or Dave Bixler, unfortunately), was well received. DOE has not been briefed by the other team. Now on to the results—

As you recall, individual scores ranging from 1 (very poor) to 5 (very good) were assigned to three aspects of each concept [technical credibility (50%), environment and safety (30%), and economics (20%)] and weighted appropriately. Combined scores were calculated for each concept for each driver. These are the scores given in the following figures. Each institution was allowed two votes; University of Wisconsin chose to combine the views of four people into one rating sheet, which counted twice.

Chamber Selection for KrF Driver: The scores for the KrF chamber concept are given in Fig. 1. As you recall, the Solid Breeder Moving Bed concept has two embodiments: a low-pressure version requiring pressure isolators and a high-pressure version not needing isolators. The Onion concept uses a Flibe breeder/coolant and a carbon first wall. All KrF driver concepts use gas protection and uniform illumination.

Fig. 1 Scores for Chamber Concepts with KrF Driver

	Onion	SBMB	HP - SBMB
Bechtel	3.70	3.60	3.60
Bechtel	3.54	3.50	3.60
GA	4.00	2.80	3.30
GA	4.10	3.10	3.60
WJSA	3.55	4.10	4.20
WJSA	3.90	3.85	3.95
UW	2.50	4.30	4.30
UW	2.50	4.30	4.30
Average score	3.47	3.69	3.86
Avg w/o Hi and Low	3.53	3.74	3.88

Our team apparently has a preference for the higher pressure SBMB over the other concepts. If you take the average of all scores, or if you drop the high and low scores and average the remaining six, the result is the same. The relative ranking also holds if you consider the rankings shown in Fig. 2, rather than the scores. Notice that HP-SBMB took 5 firsts and 8 firsts or seconds, compared to Onion's 3 firsts and 5 firsts or seconds. If you look at Wayne's scoresheet, you will see that he was consistent in his method of handling ties for rankings, so that if there were two ties for first place, the next ranking was a third place.

Fig. 2 Ranking of Chamber Concepts with KrF Driver

	Onion	SBMB	HP - SBMB
Bechtel	1	2	2
Bechtel	2	3	1
GA	1	3	2
GA	1	3	2
WJSA	3	2	1
WJSA	2	3	1
UW	3	1	1
UW	3	1	1

I interpret the slight preference of the higher pressure version of SBMB over the original as dissatisfaction with current concepts for pressure isolation, not with a desire to operate blankets at higher pressure. Note that the average scores for all three concepts spanned the range from good to very good. From the sparse comments that were offered, Onion did not lose because of any fatal flaws; in fact, it is certainly more conventional in appearance and operation. The concerns mentioned were the effects of isochoric heating from neutron deposition, the use of CVI carbon as unnecessarily exotic, concern over Be, and heat transfer. Instead, I read into the results the desire to look at something different from MFE that may have advantages.

We shall now begin to work on the SBMB concept for a KrF driver, attempting to solve the pressure isolation issue by clever fluidized engineering. I would like suggestions for a brilliant name for this concept. More careful heat transfer calculations must be done to understand the operational trade-off between trying ot operate the carbon first wall as hot as possible while limiting the maximum temperature of Li_2O. Finally, there is plenty of concern over the heat exchanger design. Can this concept also avoid an intermediate loop?

Chamber Selection for HIB Driver: The chamber selection for the HIB driver is more complicated. The average scores fell into two groupings. From Fig. 3, we see that Onion and OSIRIS are clustered together at the top, with the SBMB and rotating chambers ranked lower.

Fig. 3 Scores for Chamber Concepts with HIB Driver

	Cascade	LIFE	Onion	Osiris	SBMB
Bechtel	3.40	3.30	3.70	3.50	3.60
Bechtel	3.10	3.55	3.45	3.75	3.64
GA	2.50	2.90	3.90	2.70	2.80
GA	5.00	3.60	3.60	2.50	3.60
WJSA	2.20	2.45	3.40	4.25	2.70
WJSA	3.00	2.75	3.25	3.85	2.60
UW	2.80	3.00	3.40	3.45	3.10
UW	2.80	3.00	3.40	3.45	3.10
Average	3.10	3.07	3.51	3.43	3.14
Avg w/o Hi and Low	2.93	3.08	3.49	3.45	3.15

In our view, and from the comments given, it seems there are solid reasons for not selecting the bottom three. The HIB-SBMB, having a wall radius over 10 meters, was a great concern for HIB propagation. The Cascade and LIFE concepts have a rotation problem, and I don't think it is just a superficial image problem. The amount of stored mechanical energy is enormous. Monsler calculated that for LIFE spinning at 36 RPM, the energy of rotation is 300 MJ. While this is not a high thermal energy (we handle it at 10 Hz in normal operation), it is enough mechanical energy to throw a two-ton automobile 15 kilometers vertically into the air. This is a seismic and accident safety issue, which I believe was intuitively avoided by many on the team.

Of the two remaining concepts, Onion slightly outscores OSIRIS both on average and when the high/low scores are eliminated. (If only Monsler's and Bourque's scores are eliminated, the scores are equal.) OSIRIS has a much higher standard deviation (not shown) than Onion; apparently, team members either love it or hate it. The picture changes, however, if we look at the rankings shown in Fig. 4.

Fig. 4 Ranking of Chamber Concepts with HIB Driver

	Cascade	LIFE	Onion	Osiris	SBMB
Bechtel	4	5	1	3	2
Bechtel	5	3	4	1	2
GA	5	2	1	4	3
GA	1	2	2	5	2
WJSA	5	4	2	1	3
WJSA	3	4	2	1	5
UW	5	4	2	1	3
UW	5	4	2	1	3

We see that OSIRIS scores 5 firsts compared to 2 for Onion, with Onion the dominant second choice. From the comments, our team liked the more conventional appearance of Onion and potentially higher efficiency, but disliked the metal structure with welds exposed to neutron flux and the need to change out the entire chamber every few years. Our team likes the robust and compact nature of OSIRIS, but was concerned about surface heat transfer. Some ranked OSIRIS very high on chamber clearing, while others were concerned about recondensation times and HIB propagation. All are concerned with the Be and F problems with Flibe and the Po problem with LiPb.

We could live with either of these two reactor concepts for HIB reactor; either has the potential for being engineered into a credible design. As the project manager, I (Monsler) chose the OSIRIS concept, not only because it was selected first by 5 of the 8 votes, but because it shows how the unique features of ICF allow a radically different solution to the engineering problems of fusion than those used in MFE.

My view of ICF reactor design is that, first, the ideal concept has no solid materials: the fusion pellet is simply surrounded by a reestablishable breeding/heat transfer liquid. Given that this is insufficient, one should reluctantly introduce the minimum amount of low-activation solid materials necessary to guide the fluid flow and establish a configuration to accommodate gravity. Second, the configuration should be designed to solve the problems encountered (e.g., HYLIFE jets or HIBALL tubes) rather than living with a simple sphere and trying only to select materials. Third, from the point of view of neutron or mechanical damage and/or lifetime, eliminating the first wall always beats struggling with first wall design. For an HIB reactor, we can follow this philosophy very closely to get the absolute minimum material exposed to neutrons. The only reason we turn to a more conventional first wall/blanket structure for the KrF driver is the dominant geometrical constraint of uniform illumination.

Conclusion:

We now have selected two terrific concepts:

a) A gas protected chamber with a solid-breeder moving-bed blanket, driven by a uniform-illumination KrF laser.

b) A thick liquid wall chamber driven by a heavy ion beam and radiation-driven targets.

This is a great combination to show how we can design for two distinct drivers, two types of targets, two types of reactors, and still have ICF reach its potential and compete favorably with MFE.