Briefing on ALPS Activity

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Outline

- Guidelines for Study
- ALPS Team
- Performance Goals
- Issues and Data Needs
- Design Options
- ALPS Organization
- Schedule
- Comments

Guidelines for Liquid Free Surface Study

- The program will be carried out in 3 sequential phases
  - A planning phase lasting for about 3 months
  - An evaluation phase, beginning in FY 1998 and lasting for about 3 years
  - An R&D phase, beginning after the evaluation phase.

- The group should have representation from U.S. fusion community institutions with capabilities and interests toward addressing feasibility issues of liquid plasma-facing surfaces.

Guidelines for Liquid Free Surface Study (cont.)

- The activities in the evaluation phase effort include the following:
  - Specification of requirements and evaluation criteria for liquid plasma-facing surface concepts in divertor applications
  - Conceptual design and analysis of candidate concepts; selection of most promising concepts
  - Identification of generic experimental research that could be conducted in parallel with design activities
  - Detailed design and evaluation of the most promising concepts; identification of feasibility issues and assessment of overall attractiveness
  - Description of R&D required to resolve feasibility issues of the most promising concepts
- Opportunities for international collaborations should be explored.

ALPS Planning Group

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Potential Advantages of Free Surface Liquid Systems

- Unlimited erosion lifetime
- No neutron damage in liquids
- High power density capability
- Active pumping of liquid surface
- High temperature operation
- High power conversion efficiency
- Compatibility with advanced plasma physics concepts
- Low pressure operation

Questions to be Addressed

1. What are the quantitative performance goals and selection criteria that should be used in comparing options?

2. What data and modeling tools are needed in order to make a valid comparison?

3. What design options and design parameters should be selected for the comparison?

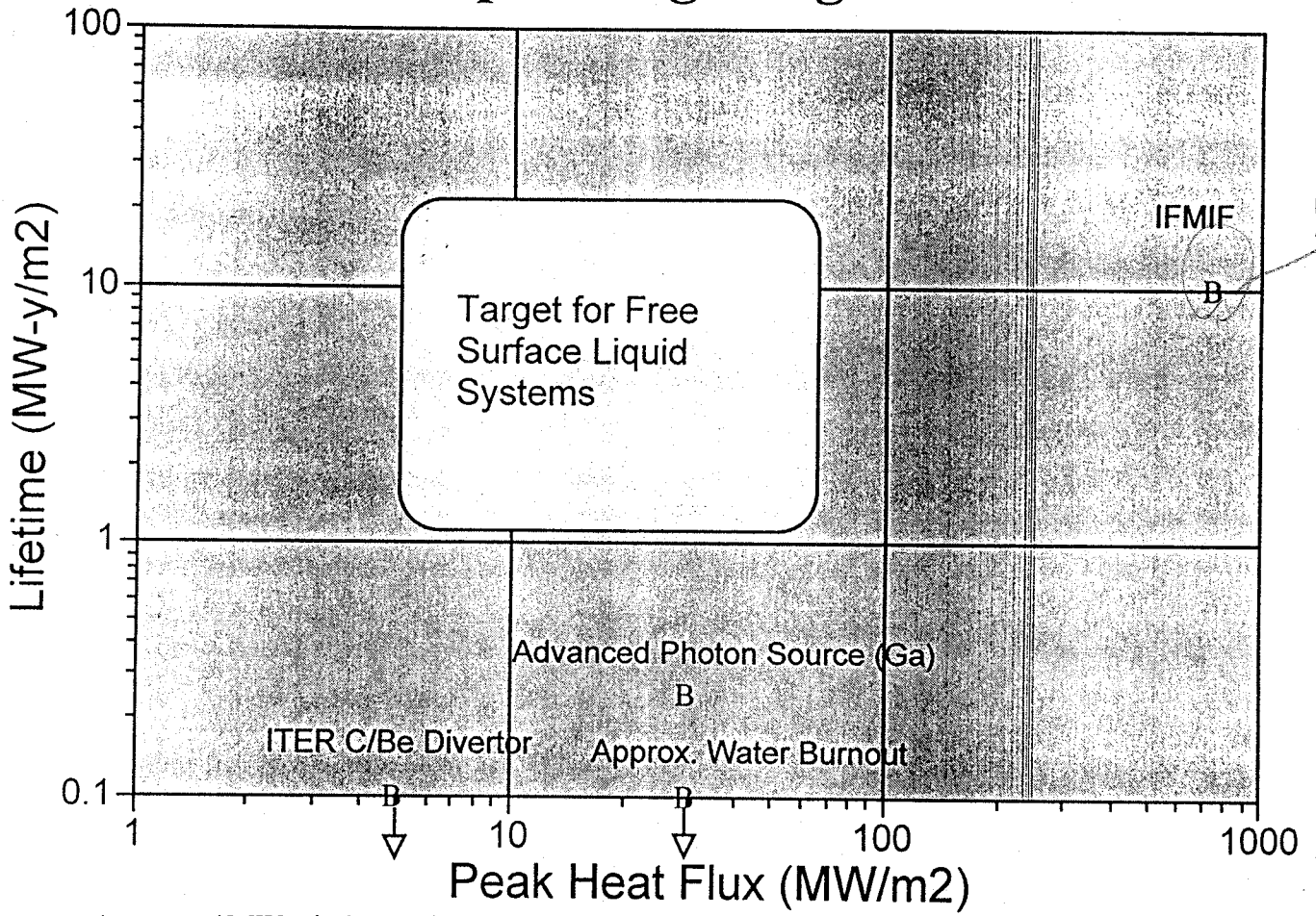
   What are the detailed magnetic confinement parameters?
   What are the free surface design options?

4. How should the ALPS team be organized to most effectively compare options

Performance Goals for Attractive Fusion Energy Systems

Attribute	Minimum Goal	Grand Challenge
Coolant Inlet/Outlet Temperature (°C) (goal of 45% conversion efficiency)	300/500	300/1000
Peak / Average Neutron Wall Load (MW/m^2)	6 / 3	10-20 / 5-10
Peak / Average Heat Flux (MW/m^2)	5 / 2	50 / 20
First Wall Fluence Lifetime ($MW\text{-}y/m^2$)	10	20
First Wall Erosion Lifetime (y)	2	∞
Time to Repair/Replace	< 1 month	< 1 week
Average Cost of Core Materials ($/kg)	100	<50
Waste Disposal Limit	Class C Major Components	Class C All Components
Worst-Case Accident Dose at Site Boundary	1 rem	0.1 rem

Operating Target



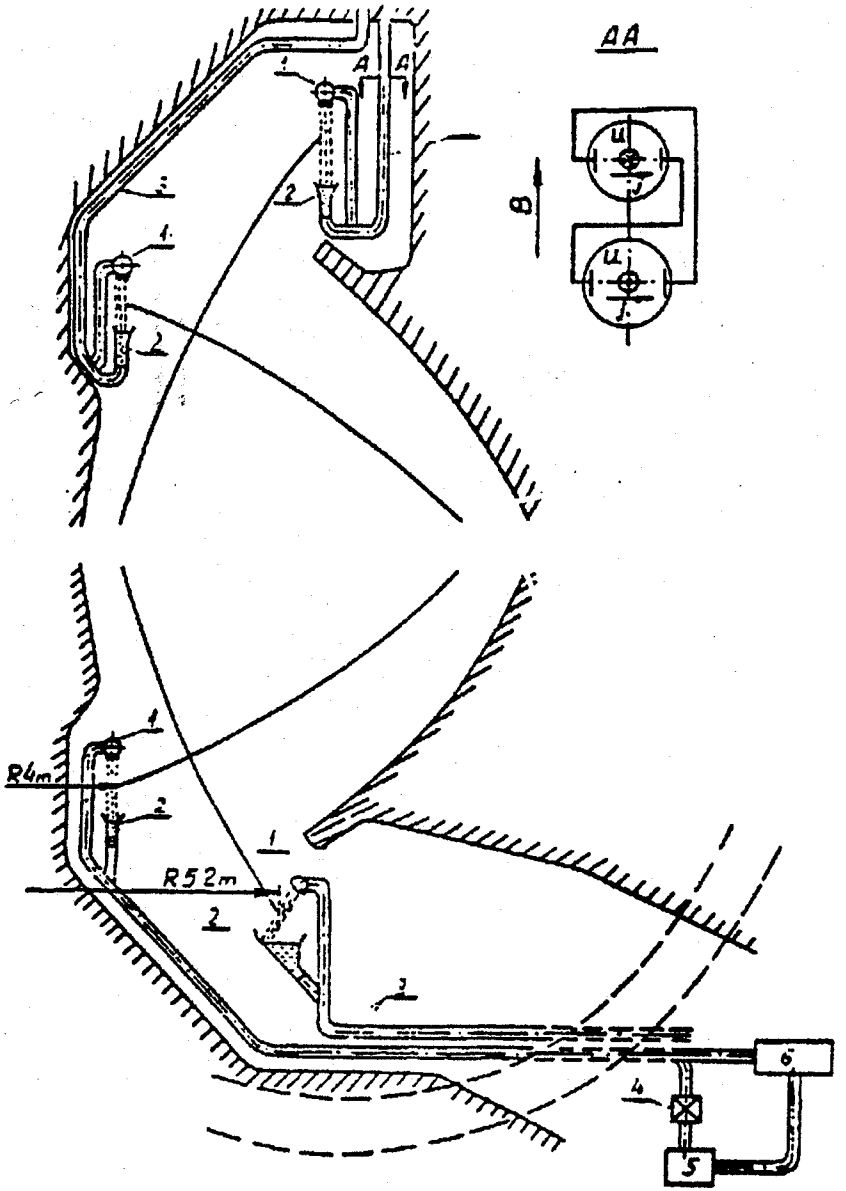
Assumes 1MW-y/m2 = 10dpa

Issues and R&D for Liquid Plasma-Facing Components

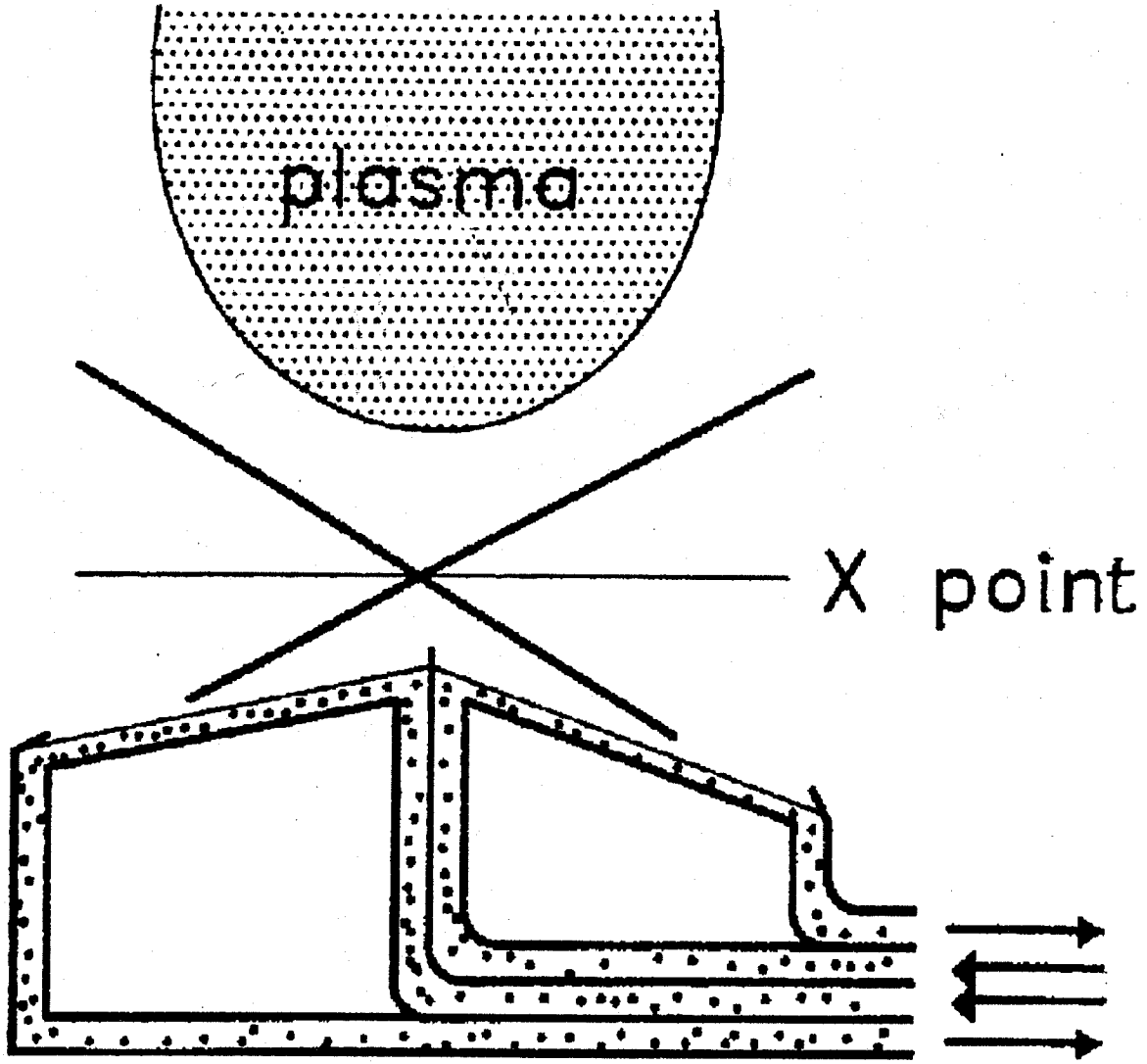
Issue	R&D Needs
Sputtering and redeposition	Assess sputtering yields at liquid surfaces by hydrogen, helium, and self-sputtering. Validate models with plasma experiments.
Species transport to plasma	Measure H, He and self-sputtering rate vs. energy for Li, Ga, Pb and Flibe. Model/measure edge plasma transport from surface.
Plasma-liquid interface stability	Modeling and data on plasma momentum flux effects. Modeling and data on electric field and current effects.
Tritium (and He) removal	Measure tritium uptake in TPE for candidate liquids. Determine basic thermophysical properties. Benchmark DIFFUSE with TPE data. Define tritium extraction system, estimate size and cost. Determine tritium inventory using DIFFUSE
Integrated plasma tests	PISCES, DiMES, DIIID tests
Power density limits and heat removal	Calculate MHD external pressure drop. Define maximum allowable temperature. Evaluate thermal response to establish maximum q. Produce benchmark heat transfer data
MHD Behavior of Liquid Metal Free Surfaces	Develop model of internal flows at free surface. Provide benchmark data for internal flows.
Insulator Coating Development	Develop insulator coatings and test in-situ resistivity. Determine irradiation effects on coating resistivity.
Radioactivity	Define existing and goal impurity levels. Identify chemical processes needed for impurity removal. Identify missing cross section data.
Tritium Fuel Cycle	Develop models for overall fuel cycle
Material transport to vacuum pump	Plasma tests with liquid at high temperature

Possible Materials, Configuration, and Confinement Options

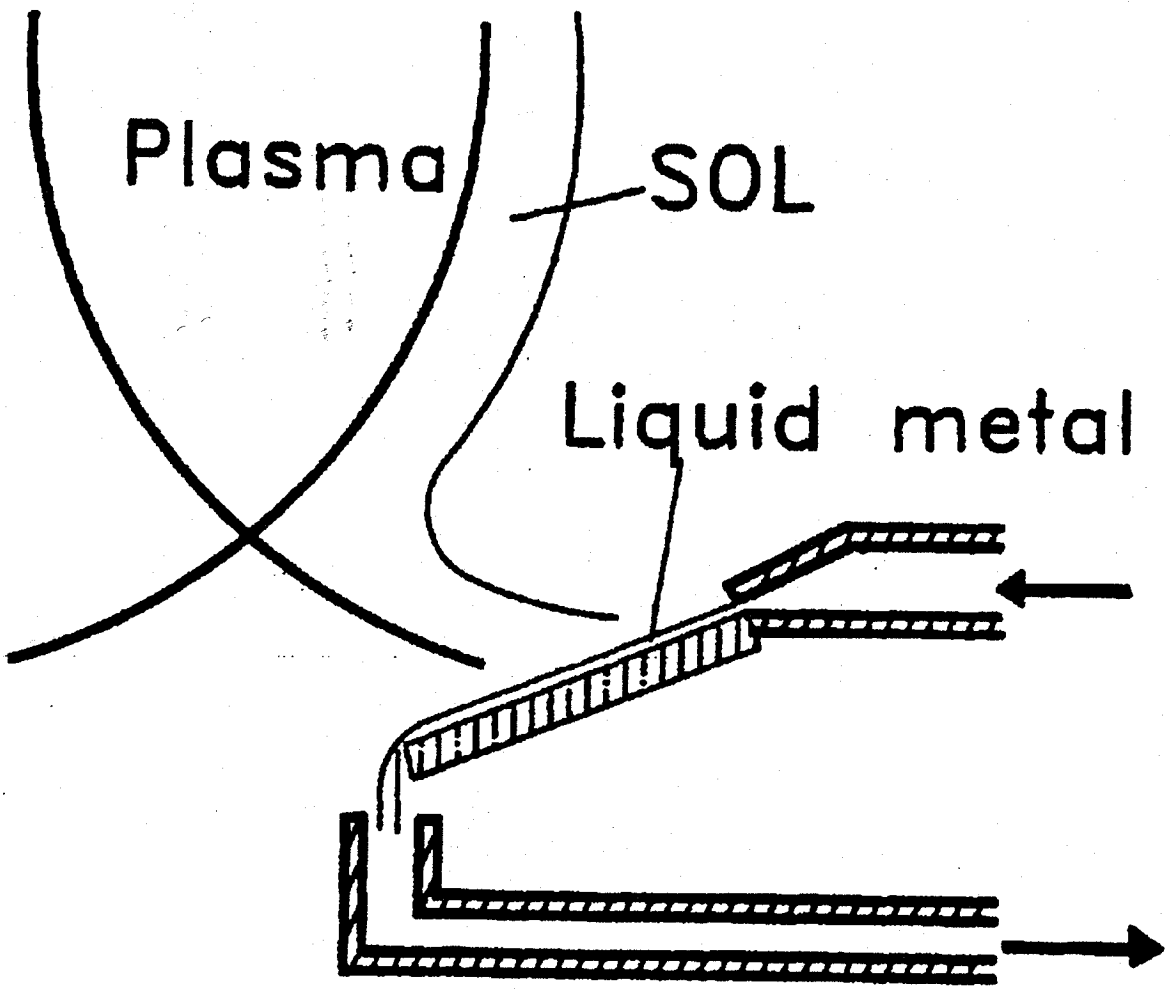
Liquid species	Li, $Li_{17}Pb_{83}$, Ga, Flibe, Sn
Surface configuration	Fast film, droplets, water fall, stagnant film, pool, backside impinging jet
Confinement	Tokamak, Advanced Tokamak, Spherical Torus, Field Reversed Configuration, Stellerator



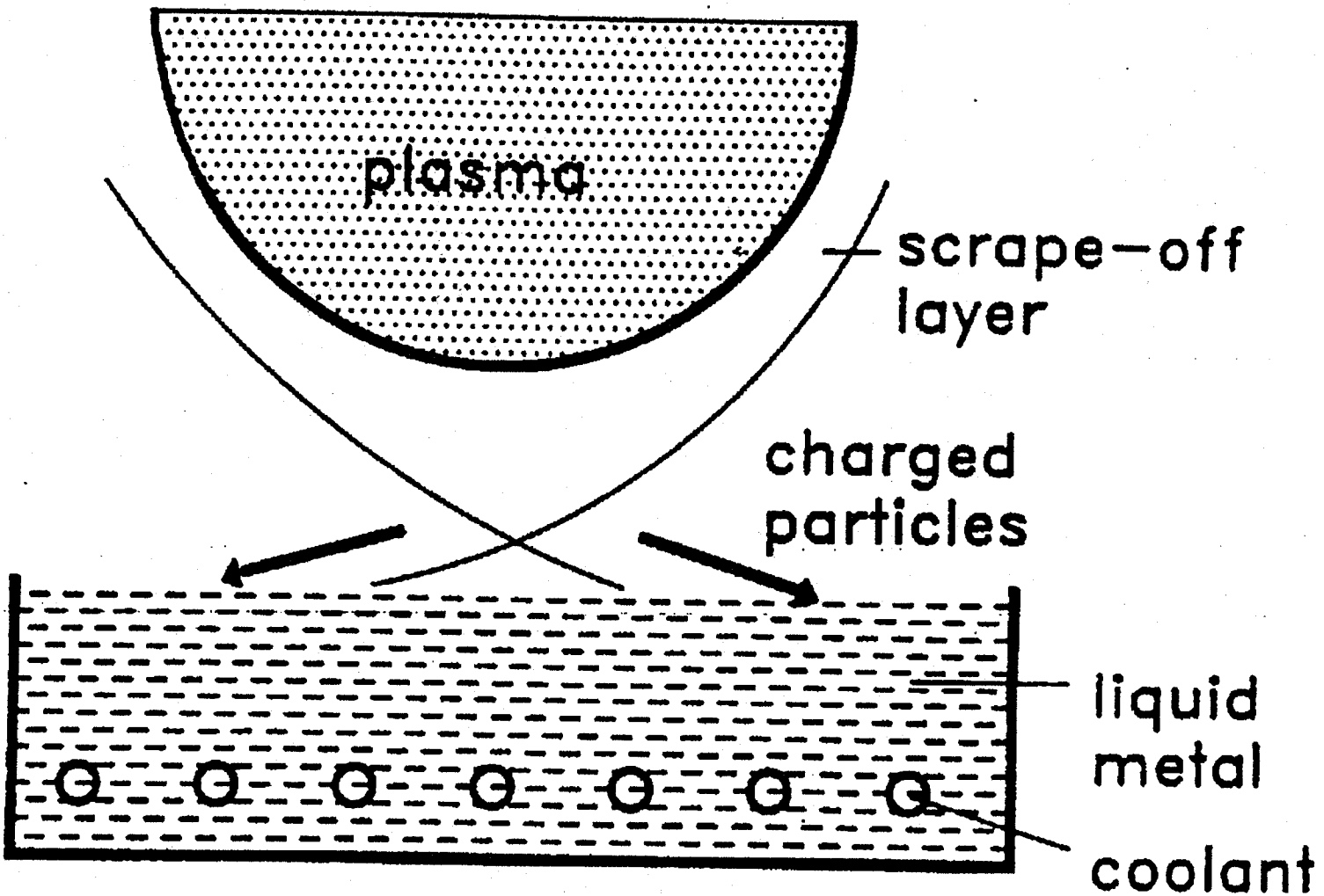
Liquid GA droplet curtain divertors in ITER tokamak [Murav'ev 1989]



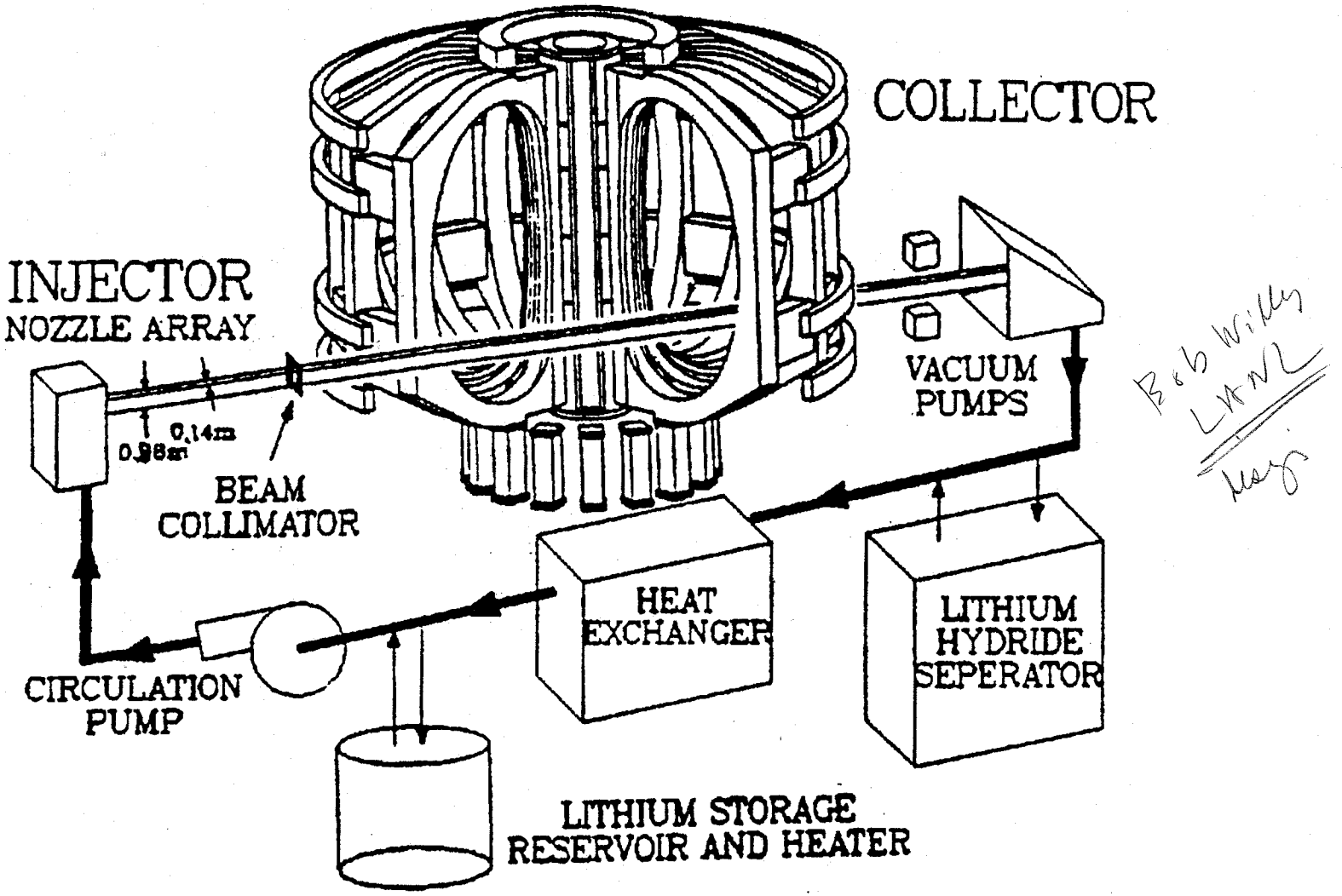
Injection type film divertor



Liquid metal film flowing down an inclined chute



Pool type liquid metal divertor



Lithium jet droplet beam divertor [Werley, 1989]

ALPS Organization

- There are alternatives to performing the concept comparison and selection.

- Assemble a single team with representatives of all fields of interest that work jointly on all concepts.
  - Each concept will likely receive an equal level of attention and review.

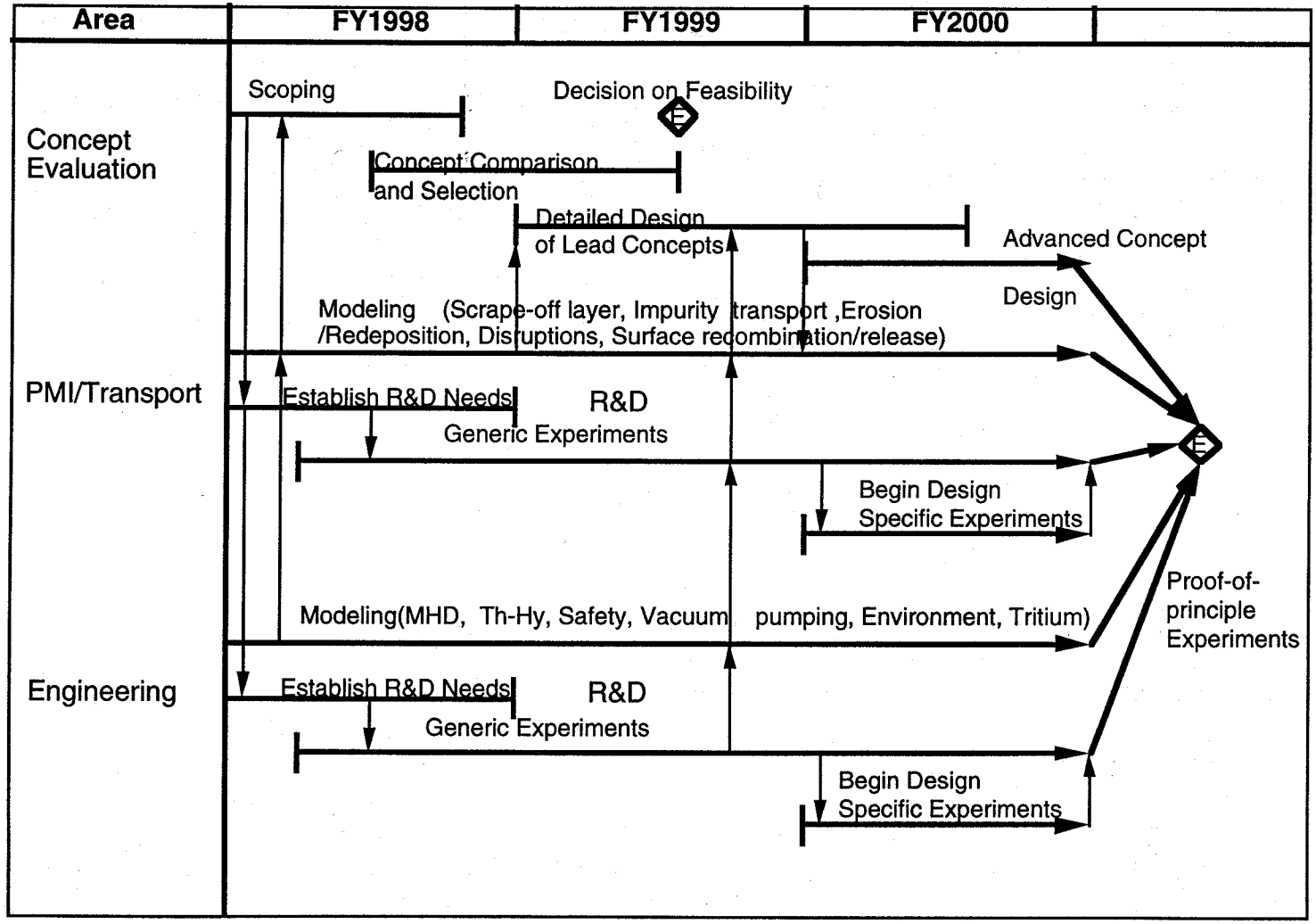
- Assemble advocate teams for each concept in the comparison and selection phase.
  - Advocates will likely be more enthusiastic about promoting their concept which provides for a more dynamic program.
  - Requires a greater number of people and also has higher funding requirements.

- There may be a hybrid alternative
  - A member of the ALPS team is the advocate of a particular concept, and the rest of the team to provides the required design and analysis.

Evaluation Phase Schedule

- There are three major parts of the program.
- Concept Evaluation
  - Main activity in first year
  - Scoping study followed by detailed design of leading concepts
- Plasma Physics/PMI
  - Modeling and R&D activities interface with concept evaluation
  - Begin R&D with generic experiments that address feasibility issues
- Engineering
  - Modeling and R&D activities interface with concept evaluation
  - Begin R&D with generic experiments that address feasibility issues
- Larger, proof-of-principle testing to follow Evaluation Phase

Fig. 2-1 Evaluation Phase Schedule
Free Surface Liquid Plasma Facing Systems



Miscellaneous Comments

- Decide early on the performance goals and selection criteria.

- Consider comparison to "best" conventional system to quantify advantages.

- Performance is determined by the "weakest link" in the system. Emphasize elimination or improvement of "weakest link."

- Improvements in one area may only come about with losses in another. What constraints could be relaxed to get improved performance?

- The Devil is in the details. The new approach that we don't know much about always looks better than the one we know well. All concepts should be examined to an equal level of detail.

- Emphasize close ties to advanced plasma physics concepts.

- Establish a bibliography.