2.0 OSIRIS HIB-DRIVEN POWER PLANT

2.1 OVERVIEW OF OSIRIS POWER PLANT DESIGN

2.1.1 Chamber Design

The reactor chamber for the heavy ion beam-driven power plant employs low activation ceramic materials and a drainable liquid coolant/breeder. The ceramics are used as woven cloth panels stitched together. This avoids many of the problems caused by flexing and stress concentration in large solid ceramic structures, which are still in the developmental stages of production. The cloth supports a liquid lithium-bearing coolant, and coolant bleeding through the cloth provides a sacrificial protective film on the first wall. A pool of coolant and coolant sprays at the bottom condenses blowoff vapor. The pool also provides hot storage of the coolant during changeouts.

Figure 2.1 shows the final Osiris configuration. (Section 2.2.1.1 reviews the evolution of the final design.) A three-layer carbon cloth blanket is suspended from the cover of the vacuum chamber, which is made of carbon composite. Flibe flows from the top of the reactor, makes a quick pass along the backside of the first wall, and returns more slowly through the wider channels between the second and third cloth layers. It then cascades down the outside of the blanket, releasing some of the bred tritium and other gases. It then falls into the annular cascade flow blanket and dumps into the pool at the bottom. In a second inlet flow path, Flibe at high pressure enters an annular manifold at the bottom of the blanket and sprays into the pool. Blowoff vapor from the first wall is condensed by this spray. The entire blanket/manifold assembly is replaced periodically by lifting it from the reactor along with the reactor cover.

2.1.2 Heavy Ion Beam Driver

We used conservative driver design assumptions and created an optimized design for a 5 MJ driver that has a total direct capital cost of only $120/J and produces a target gain of 86. The base driver design has lower cost and better performance than was anticipated at the beginning of this study, primarily because the driver parameters were determined from an extensive examination of the large parameter space available for heavy-ion accelerators. These parameters are the number of beams, type of superconductor used in the quadrupole focusing

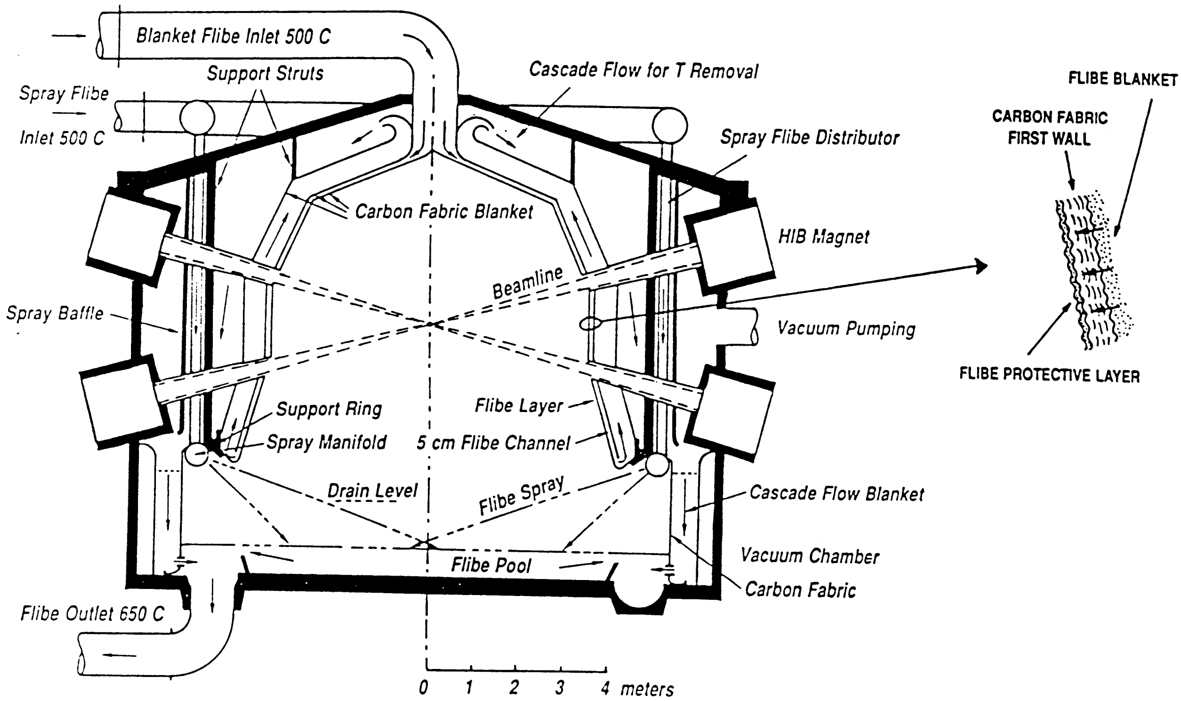

Fig. 2.1. **Osiris heavy-ion-beam reactor chamber concept showing carbon fabric blanket structure with Flibe spray and pool.**

magnets, maximum magnetic field allowed at the superconducting windings, the axial packing fraction occupied by the focusing fields, the ion mass, and the ion charge state.

We used conservative design choices to create a credible driver design. We chose not to use beam combination, beam separation, or recirculation. All of these options have the potential to reduce the cost of the driver, but they do it at the expense of added complexity and uncertainty and (with the possible exception of beam separation) at the expense of beam quality and anticipated driver performance. Driver designs using these design options will require results from future experiments or development programs before they can be certain of their performance scaling.

The only aggressive design feature is the use of compact Nb_3Sn quadrupole arrays. The high current densities of Nb_3Sn allow for smaller quadrupole windings and smaller quadrupole arrays. Reducing the size of the arrays also reduces the required bore radius for the induction cells. Because Nb_3Sn quadrupoles have been built and operated at fields approaching 10 T, their use in our designs at 10 T relies on minimal extrapolation from present technology.

Although we found small cost savings from the use of ions with charge states greater than 1, our base design uses singly-charged ions. The cost saving with higher charge states were achievable only by using designs with more beams and larger spot sizes. These designs introduce more complicated final focusing and beam combination requirements and give slightly lower anticipated gain even if the effects of beam combination on spot size are ignored. Higher charge states may be less prone to additional electron stripping, but they require much more complicated sources and may require higher vacuums to prevent electron capture from residual gas in the accelerator.

2.1.3 Final Focusing and Beam Transport

Target gain was improved by using an autoneutralized final focusing scheme. In this scheme, electrons are injected with the converging heavy-ion beams after they leave the final focusing magnets. The co-injected electrons provide charge neutralization to the beams by forming an autoneutralized plasma with the heavy-ions. Models for the autoneutralized beams differ from those based on a fraction of charge neutralization, but provide similar reductions in the achievable spot size.

2.1.4 Balance of Plant

The Osiris reactor building provides biological shielding. A sliding shield block separates the reactor building from the maintenance building. The latter building is used to build up and tear down replacement blankets. Intermediate heat exchangers are used with liquid lead as the intermediate coolant. A double reheat supercritical steam cycle is used giving 45% gross conversion efficiency. After subtracting the recirculating power to the driver, net plant efficiency is 40%. This cycle is chosen over advanced cycles in order to meet the requirements of moderate Flibe vapor temperature in the chamber. Flibe, lead, and steam peak temperatures are 650°C, 600°C, and 538°C, respectively. The lead temperature is compatible with type 347 stainless steel. Table 2.1 shows the basic parameters of the power plant. All plant parameters seem quite reasonable, and none of the power systems require great modifications to existing systems.

Table 2.1. Major Osiris Plant Parameters

Target Yield	432 MJ
Rep-Rate	4.6 Hz
Fusion Power	1987 MW
Surface Power	596 MW
Blanket Power	1908 MW
Total Thermal Power	2504 MW
Power Conversion Efficiency	45%
Gross Electrical Power	1127 MWe
Net Electric Power	1000 MWe
Flibe Inlet Temperature	500°C
Flibe Outlet Temperature	650°C
Spray Flow Rate	2265 kg/s
Blanket Flow Rate	4598 kg/s
Max First Wall Channel Velocity	5 m/s
Flibe Upflow Average Velocity	0.2 m/s
Spray Velocity	46 m/s
Spray Manifold Pressure	2.1 MPa
Spray Ideal Pumping Power	3 MW
Total Flibe Mass in Chamber	456,000 kg
Total Supported Mass	274,000 kg
Main Support Hangers Diameter	10 - 24 cm
Hanger Tensile Stress	14 MPa
Total Flibe Inventory	940,000 kg
Flibe Vaporized per Shot	4.3 kg
Peak Vaporization Pressure on First Wall	36.9 GPa
Impulse on First Wall	89.5 Pa-s
Surface Heat Load per Pulse at Target Plane	0.84 MJ/m^2
Neutron Wall Loading at Target Plane	9.0 mW/m^2