

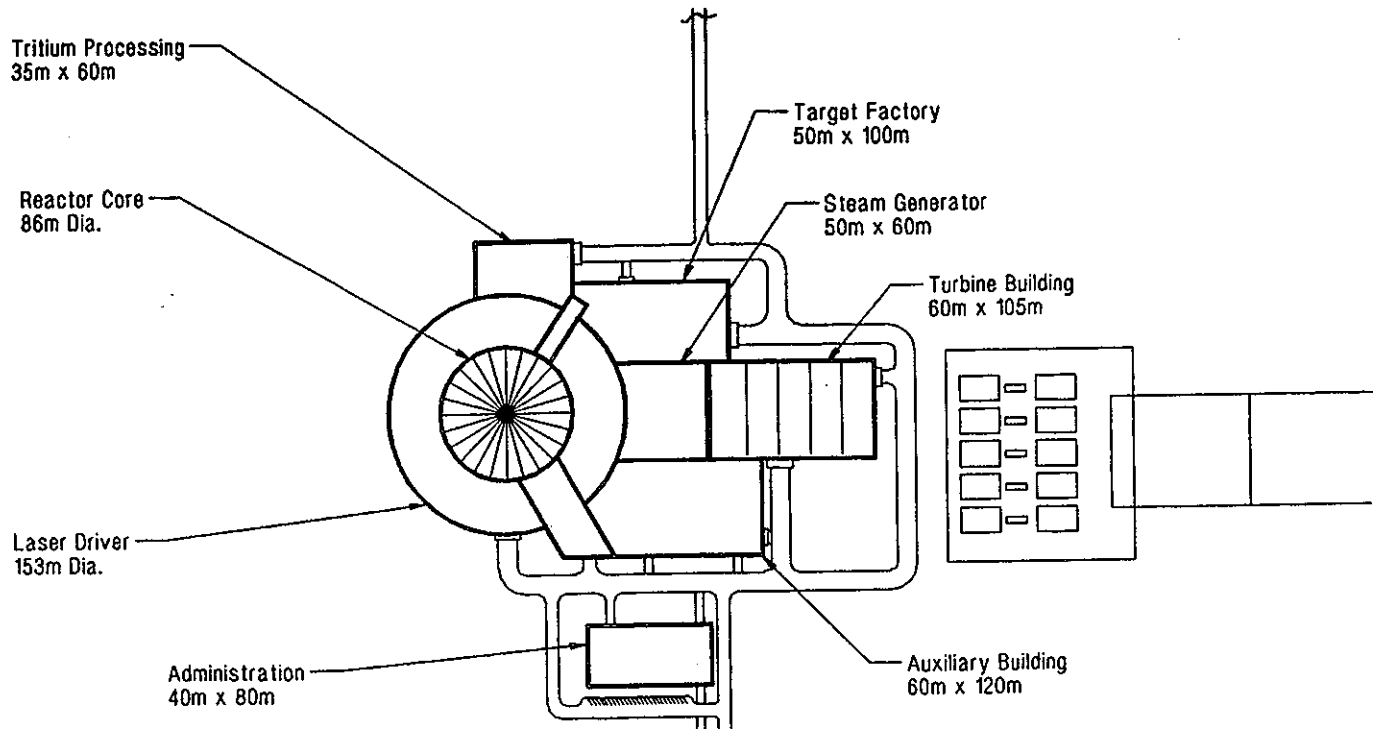
## **2.4 Prometheus-L Reactor Plant Design Overview**

The Prometheus-L power plant is a KrF excimer laser-driven commercial central station power plant. These designs are based upon an extrapolation of today's technology advanced some 20-30 years into the future. The necessary technology and engineering basis is assumed to have been developed previously. The design emphasizes safety, environmental attractiveness, economic competitiveness, soundness of physics and engineering data, and a high degree of reliability, maintainability, and availability.

The data base upon which to design the two power plants is rich in reactor concepts both from the IFE and MFE communities. Many reactor designs have preceded these design studies, each with innovative and valuable system concepts worthy of consideration. A following chapter, Chapter 4, will thoroughly discuss the rationale for choosing the key design options addressed in these studies. Additional trade study data, design rationale, and detailed definition and analyses for the reactor systems are presented in Chapter 6, Conceptual Design Selection and Description. This section is intended to provide the reader with a brief overview of the key features of the KrF laser-driven inertial fusion power plant that evolved out of the design study. Section 2.5 provides a similar review for the heavy ion beam-driven power plant.

**2.4.1 General Plant Features** - An overall site plan for the Prometheus-L reactor power plant is shown in Figure 2.4-1. The reactor building is located at the center of the complex with the fusion reactor cavity at its center. Surrounding the reactor building is an annular laser hall housing the laser driver subsystems including 60 identical sets of the final electric discharge laser amplifiers, Raman accumulators, Stimulated Brillouin pulse compression cells, and pulse shaping and delay line optics shown in Figure 2.4-2. The annular arrangement was selected to simplify beamline layout for the symmetric direct drive illumination geometry. The laser system architecture builds on reliable, moderate energy (~6 kJ), electric discharge lasers coupled with non-linear optical (NLO) systems for final beam combination and pulse compression. This is an attractive, flexible, and low-risk approach to the driver design as discussed in Section 2.4.3.

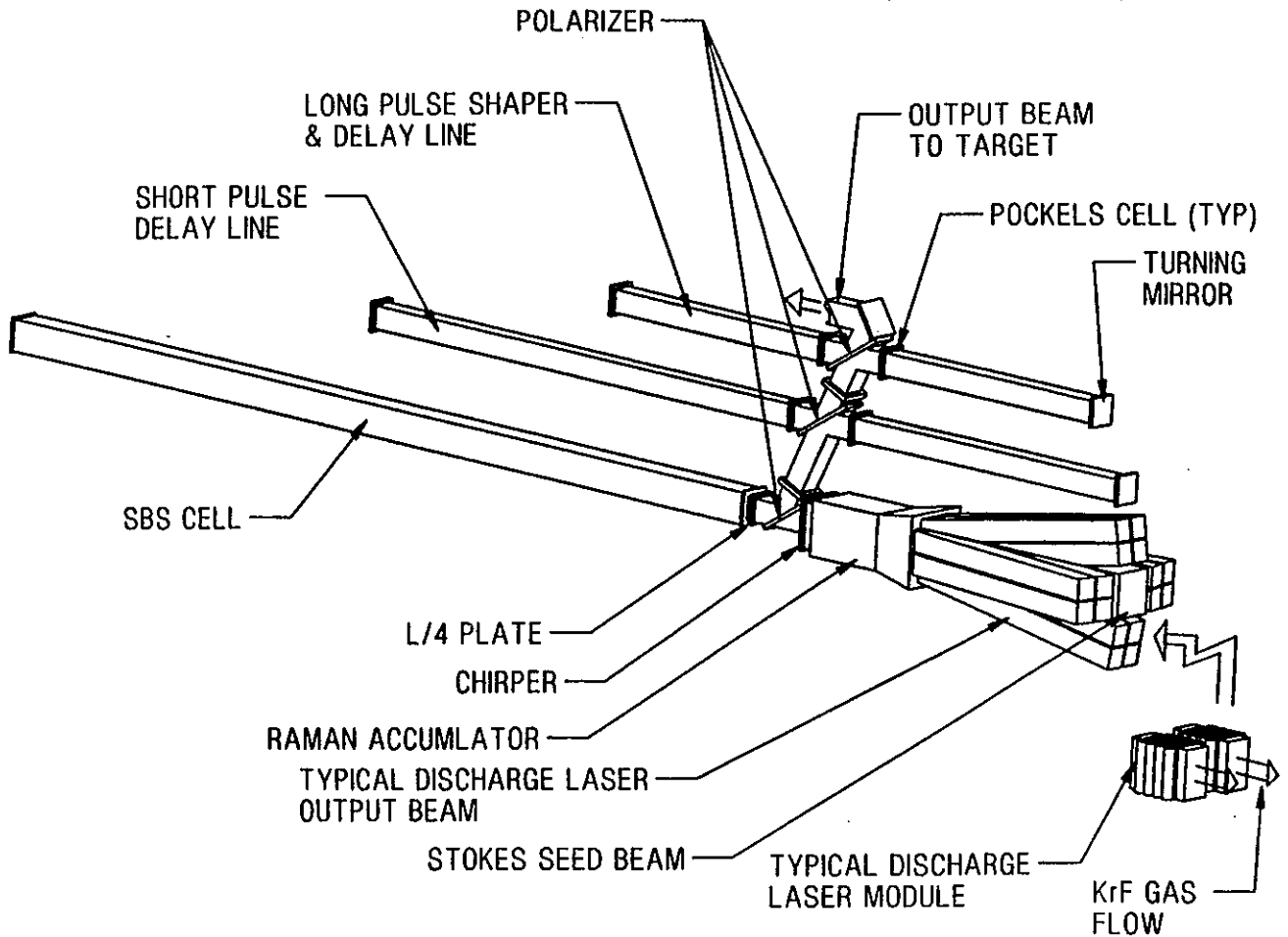
Figure 2.4-1 also indicates the other ancillary facilities necessary for an inertial fusion power plant. The steam generator building houses six sets of steam generators for both the blanket coolant loop (1.5 MPa He at 650°C outlet temperature) and the first wall protectant/coolant loop (liquid lead at 525°C outlet temperature). These systems are discussed in Section 2.4.4. A tritium processing building provides for recovery of unburned fuel and target debris (carbon and hydrogen) from the liquid lead loop and removal of fresh fuel from the blanket purge loop (1 MPa He = 0.2% H<sub>2</sub>). An auxiliary building provides for processing of spent blanket modules (ten-year lifetime) and first wall panels (five-year life). Analyses indicate that the resulting waste material will all qualify for Class C or better disposal.



**Figure 2.4-1. Prometheus-L Site Plan**

The turbine building houses the 1,400 MWe main steam turbine for the power plant. It employs an advance Rankine steam cycle to achieve 42.3% overall efficiency. The recirculating power fraction is high at 29% for the Prometheus-L system due to the low 6.5% driver efficiency. This is offset to some extent by using the laser gas waste heat for feedwater heating in the turbine plant. Finally, a target factory is also included for manufacturing the 180 million targets used annually by the power plant. This eliminates the need to ship tritium off-site for target processing and leads to a self-contained on-site fuel cycle. The targets are simple hydrocarbon (CH) shells, diffusion-filled with DT, and then cooled to cryogenic temperatures. Beta heating is used to provide for uniform layering of the fuel inside the capsule. A total tritium inventory of ~7 kg ( $7 \times 10^7$  Ci) is anticipated in the target factory. Release concerns are minimized by dividing this inventory into several separate chambers.

The major Prometheus-L design parameters are summarized in Table 2.4-1. The plant produces a net power output of 972 MWe to the electric grid from a total thermal power of 3,091 MWt, for a net system efficiency of 31%. The gross power of 1,382 MWe is derived from 3,264 MWt that is composed of 3,049 MWt from the fusion power core and 215 MWt of waste heat from the driver and lead pumping systems. Thirty percent of the gross power supports in-plant requirements for the laser driver (342 MWe), auxiliary systems (36 MWe), and liquid lead pumping (25 MWe). Helium-flow through the blanket is provided by steam-driven circulators. The fusion core



**Figure 2.4-2. Raman Accumulator/SBS Cell/Delay Line**

power results from a target yield of 497 MJ at a pulse repetition rate of 5.65 per second with an energy multiplication factor of 1.14. The liquid lead first wall loop handles 1,267 MWt of this power with the remainder going to the blanket loop. The power in the first wall loop is significantly higher than the surface heating of 780 MWt due to neutron interactions in the lead coolant channels.

The reactor cavity features a first wall (FW) system employing liquid lead that both cools the silicon carbide FW structure and bleeds through the porous inner wall to provide a protective film on the FW surface. The blanket features a SiC composite tube sheet structure sandwiched around layers of packed bed Li<sub>2</sub>O breeder. The blanket has separate helium purge and helium coolant streams.

The reactor cavity radius and height of 5.0 and 15.0 m, respectively, are determined from the need to conduct the surface heat energy through the first wall support structure into the coolant, with a surface temperature that enables the lead vapor pressure in the cavity to reach the level required for laser propagation without breakdown (~3 mtorr) before the next pulse. This is driven by the available surface

**Table 2.4-1 Prometheus-L Major Design Parameters and Features**

| <u>Parameter</u>                                       | <u>Value</u>                    |
|--|---------------------------------|
| Net Electric Power (MWe)                               | 972                             |
| Gross Electric Power (MWe)                             | 1382                            |
| Driver Power (MWe)                                     | 349                             |
| Auxiliary Power (MWe)                                  | 36                              |
| Cavity Pumping Power (MWe)                             | 25                              |
| Total Thermal Cycle Power (MWt)                        | 3264                            |
| Blanket Loop Power (MWt)                               | 1782                            |
| Wall Protection Loop Power (MWt)                       | 1267                            |
| Usable Driver Waste Heat (MWt)                         | 193                             |
| Usable Pumping Waste Heat (MWt)                        | 22                              |
| Thermal Conversion Efficiency                          | 42.3%                           |
| Recirculating Power Fraction                           | 30%                             |
| Net System Efficiency                                  | 31%                             |
| Fusion Power (MW)                                      | 2807                            |
| Neutron Power (MW)                                     | 2027                            |
| Surface Heating Power (MW)                             | 780                             |
| Fusion Thermal Power (MWt)                             | 3092                            |
| Thermal Power to Shield (MWt)                          | 43                              |
| -----  |                                 |
| Cavity Radius (m)                                      | 5.0                             |
| Cavity Height (m)                                      | 15.0                            |
| First Wall Protection/Coolant Media (In/Out Temp., °C) | Liquid Lead (375/525)           |
| Breeder Material                                       | Li <sub>2</sub> O Pebbles       |
| Structural Material, Wall and Blanket                  | SiC                             |
| Blanket Heat Transfer Media (In/Out Temp., °C)         | 1.5 MPa Helium (400/650)        |
| Cavity Pressure (mtorr, Pb)                            | 3.0                             |
| Neutron Wall Load, Peak/Ave (MW/m <sup>2</sup> )       | 6.5/4.3                         |
| Energy Multiplication Factor                           | 1.14                            |
| Tritium Breeding Ratio (TBR)                           | 1.20                            |
| -----  |                                 |
| Target Illumination Scheme                             | Direct Drive, Symmetric         |
| Number of Beams  | 60                              |
| Driver Output Energy (MJ)                              | 4.0                             |
| Overall Driver Efficiency (%)                          | 6.5                             |
| Type and Number of KrF Amplifiers                      | Electric Discharge, 960         |
| Beam Combining Technique                               | Raman Accumulators              |
| Pulse Compression Technique                            | Stimulated Brillouin Scattering |
| Final Beam Transport Efficiency (%)                    | 100                             |
| Target Gain  | 124                             |
| Target Yield   | 497                             |
| Repetition Rate (pps)                                  | 5.65                            |
| Plant Availability (%)                                 | 79.4                            |
| Cost of Electricity (mills/kWh, 1991\$)                | 72.0                            |

area so the cavity is elongated slightly by inserting a one-radius high cylindrical section between the hemispherical ends. This shortens the recondensation time without introducing a large difference between the peak and average wall loading.

Safety and environmental impact were strongly considered during the design option selection and design definition stages of the program. The design team favored the use of the low activation SiC material as the principal structural material in the first wall

and blanket region. Use of this material also extended to the primary coolant piping from the plenum regions out through the primary bulk shield. Care was taken to only include a minimum of ferritic materials within the bulk shield and then only in the vacuum vessel. Helium was chosen as the main heat transfer media to reduce the danger of fires and explosions present with liquid metals. The pressure of the helium coolant was lowered from the more conventional high pressure of 50 atmospheres to 15 atmospheres to reduce the safety consequences of a blanket tube leakage or rupture. To accomplish a viable wetted wall protection system, a liquid metal film on the surface is required. Lead provides excellent heat transfer capability, neutron multiplication, no fire hazard, and minimal decay heat. Lead has a toxicity and radioactivity concern but these have been carefully analyzed and considered to be acceptable. A composite shield composed of aluminum structure, B<sub>4</sub>C, Pb, SiC and water is used to provide a predictable, low activation shield that will reduce decommissioning costs. Electric discharge lasers were chosen over the large e-beam pumped KrF lasers to eliminate the hazard associated with the foil rupture and release of the high temperature KrF gases. More numerous (960) electric discharge lasers operated at lower output energies (~6 kJ) permit safer, more reliable reactor operation.

With the attention to selection of materials, innovative design approaches and careful design practices, Prometheus-L is rated as a Level of Safety Assurance (LSA) = 1, which means safety is assured by passive mechanisms of release limitations no matter what the accident sequence. The radioactive inventories and materials in Prometheus-L preclude a fatal release regardless of the reactor's condition. This definition is extracted from the ESECOM study<sup>1</sup>. The usage of low-activation materials, such as SiC, allows all waste material to be classed as Class C or better.

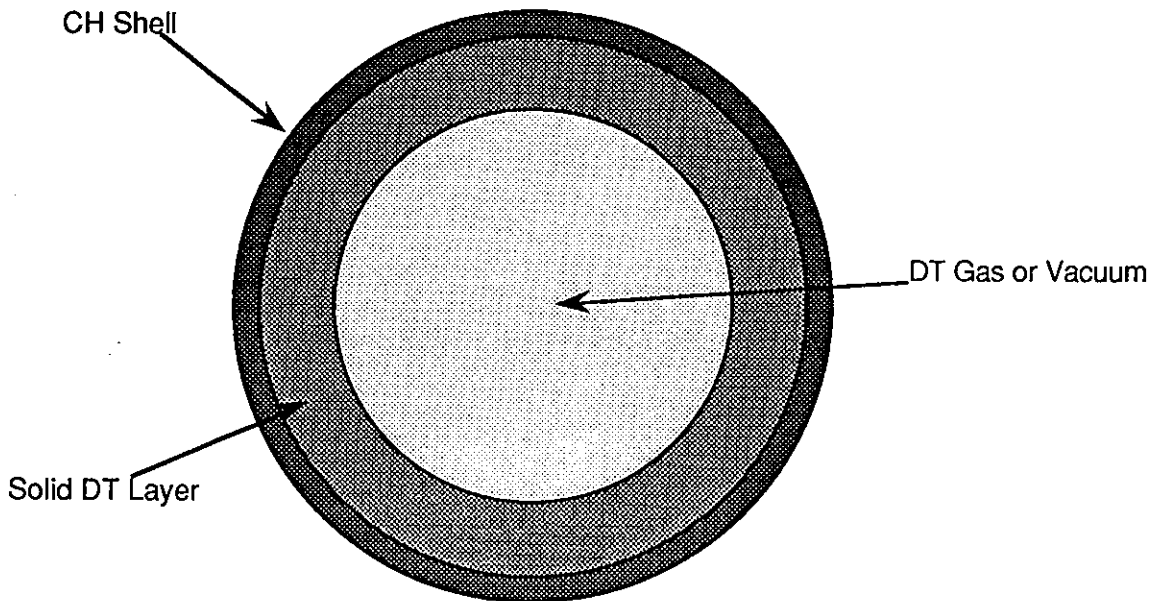
**2.4.2 Target Features** - Both the direct drive (DD) and indirect drive (ID) targets were considered for the Prometheus-L power plant. Target illumination requirements provided by the TWG were used to determine beamline geometries and pulse comparison and shaping systems. Target performance was parameterized in the form of the gain curves shown on Figure 2.3-2. An assessment of the supplied target data showed that direct drive targets were more favorable in terms of lower operational cost and better performance at the same driver energy. However, the chosen driver and reactor designs can easily accommodate either target configuration.

The unknown factor in this decision is the risk associated with the technical performance of both types of targets. Quantitative assessments of target physics feasibility are difficult. Extrapolations are required in incident energy, number of illuminating beams, power balance and pointing of the beams, gain of the target, and from stationary to moving targets. The design team heard differing opinions as to the inherent risk in each target concept, but the TWG provided assurance that supplied gain curves and associated data had been normalized to account for those risk factors. Thus the team elected to adopt the direct drive, symmetrically illuminated target for the baseline design.

A target factory or plant is located on site adjacent to the Reactor Building to provide a ready supply of targets with a minimum tritium inventory. The direct drive target will be a hydrocarbon (CH) shell approximately 6 mm in diameter, the inner shell filled with a mixture of frozen DT. Figure 2.4-3 schematically illustrates the direct drive target configuration. Droplet generators combined with micro-encapsulation processes will form the shells with the necessary surface finish. A diffusion process will fill the shell with DT within 24 to 36 hours. The DT will be frozen, forming on the inner shell walls. Beta heating will be used to achieve the necessary uniform DT layer. The targets will be inspected, mated to an injection sabot, and held in a short queue to be injected into the cavity.

The target injection system is an electromagnetic synchronous accelerator that accelerates the capsule and sabot with 100 g's to a velocity of 200 m/s. The sabot protects the capsule from abrasion in the 20 meter long accelerating tube, provides thermal protection in the holding and acceleration processes, and provides the accelerating forces via an imbedded ferromagnetic insert. The robust CH shell and inner DT layers should easily withstand the acceleration forces. Analyses have also shown that the heating during the transit time across the reactor cavity will be acceptable for the direct drive target. The target velocity and position will be determined after the exit from the injector in order to predict the target position relative to the center of the cavity. Repeatability of the positioning of the target at the center of the cavity was addressed and the resulting positional requirements are thought to be within current technology capabilities. The final mirrors and/or grazing incidence metal mirrors (GIMMs) can be adjusted in angle to account for slight variations in target position. Estimates indicate that the target will be within a millimeter of the final focus position from the time the excimer laser master oscillator initiates the 60 laser beams until beam arrival.

**2.4.3 KrF Laser Driver Features** - The laser driver architecture chosen for the Prometheus-L design is based upon a moderate energy (~6 kJ) electric discharge excimer laser amplifier module coupled with non-linear optical (NLO) systems for beam combination and pulse compression. This approach yields a safer and more reliable design with design flexibility and capabilities to meet the target demands for beam quality and illumination requirements. The Prometheus-L laser driver delivers 4.0 MJ of laser energy at ~250 nm. This energy is delivered with 60 beams symmetrically arranged to converge simultaneously on the target. The NLO system architecture incorporates special optical delay lines to tailor each arriving beam to have a long (80 ns), low energy precursor beam followed by a shorter (6 ns), high energy main pulse. Beam profiles are tailored to be flat-topped to fully illuminate the target from all 60 locations. The beams interact with the target to compress and heat the target to fusion conditions.

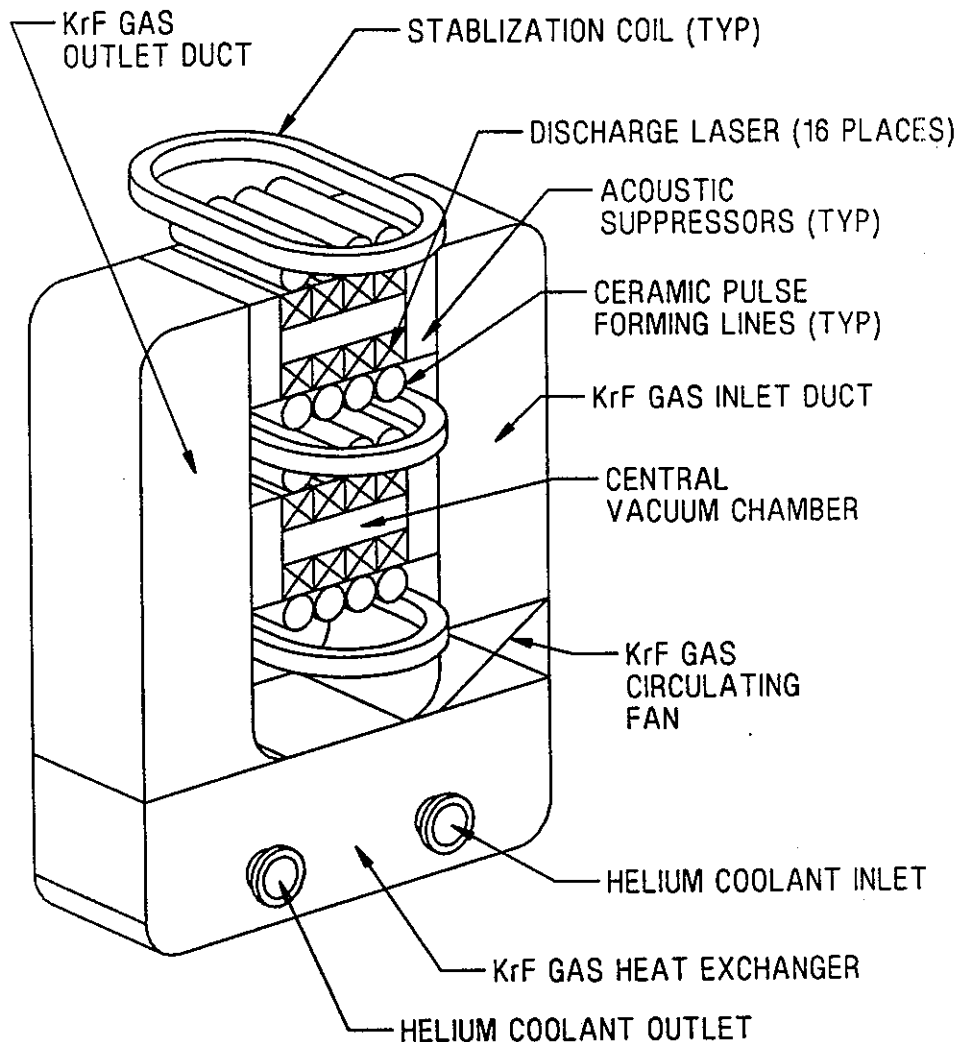


**Figure 2.4-3. Schematic of Laser Direct-Drive IFE Target Structure.**

The primary pulse of laser energy is provided by 960 electric discharge laser power amplifiers (16 for each of 60 beamlines), each producing ~6 kJ in a nominal (250 ns) pulse. These amplifiers are driven from a common master oscillator through a series of beam splitters and pre-amplifiers. Figure 2.4-4 illustrates a module of 16 power amplifiers combined in a common module for a single beamline. The KrF working gas is circulated through the lasing cavities and the waste heat is removed to maintain proper thermal conditions in the lasing cavity. This waste heat is used in the thermal conversion process to improve the effective driver efficiency.

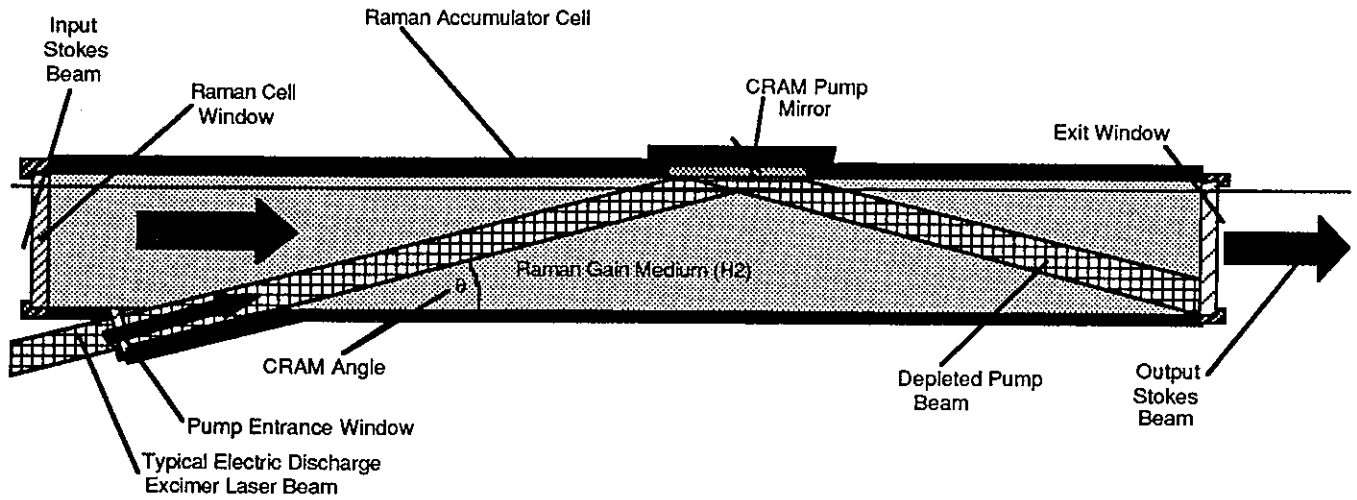
The relatively low quality beam outputs from the 960 excimer laser power amplifiers (ELPAs) are directed into 60 Raman Accumulator Cells (RAC) to combine the energy of the individual ELPAs into that required for each beamline. The Raman Accumulators are 1.8 m square aperture x 5 m long cavities filled with D<sub>2</sub>. One of the attractive features of the RAC is that it converts relative low quality, high power pump beams into a high quality, high power output beam. The output beam from each RAC is now 81 kJ and 250 ns long. This is achieved at a high conversion efficiency of 88%. The Raman accumulator process is schematically shown in Figure 2.4-5.

The next step in the Prometheus-L optical train is to compress the 250 ns beams exiting the Raman Accumulators into shorter beam pulses suitable for the primary and precursor interactions with the target (~6 ns for the main pulse and ~80 ns for the prepulse). This is accomplished with the use of a stimulated Brillouin scattering (SBS) cell. The leading edge (10 ns) of the long duration pulse from the RAC is "chirped" or frequency-shifted by an amount equal to the Brillouin shift in the SF<sub>6</sub> gas used as the SBS gain medium. The duration and modulation depth of the "chirped" signal permit

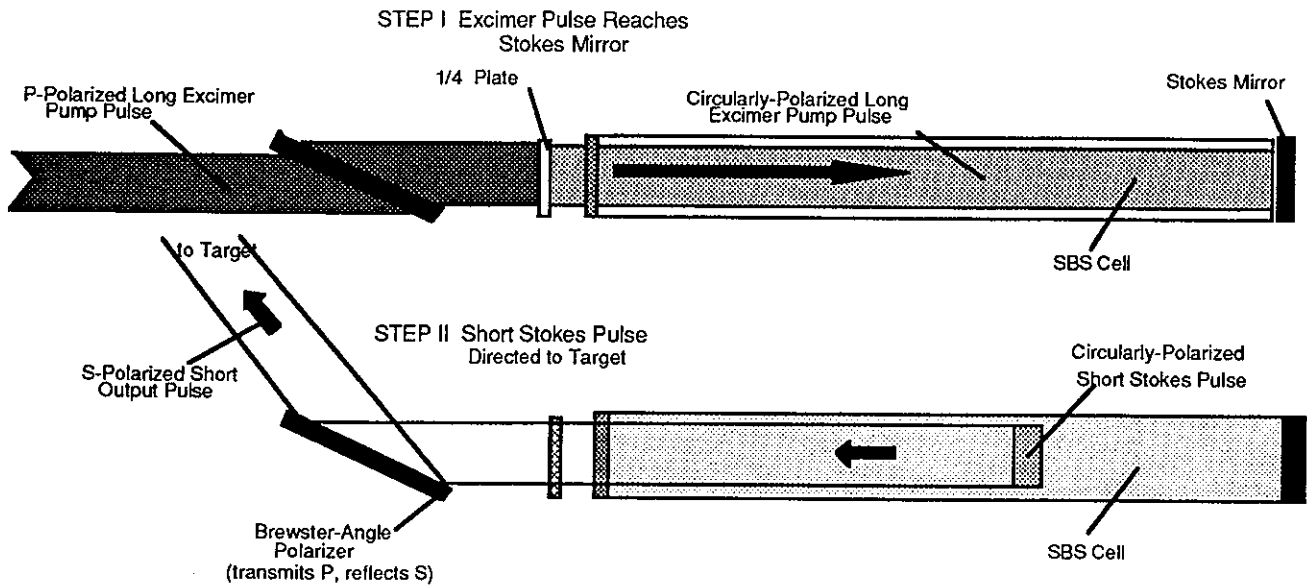


**Figure 2.4-4. Electric Discharge Laser Subsystem**

control of the shape and pulse duration of the resulting compressed pulse. The entire 250 ns beam with the "chirped" 10 ns leading edge travels the 37.5 m length of the SBS cell and reflects off an internal mirror aligned normal to the beam. As the "chirped" leading edge and the remainder of the beam reflects back onto itself, the frequency-shifted photons in the leading edge experience high optical gain from the SF<sub>6</sub> gas pumped by the incoming beam. This results in a highly compressed beam, suitable for the main pulse. The process is depicted in Figure 2.4-6.



**Figure 2.4-5** Injection of the Stokes seed into the Raman accumulator cell permits the efficient extraction of the excimer pump beams into a 81 kJ beam having an aperture of 1.2 x 1.2 m.



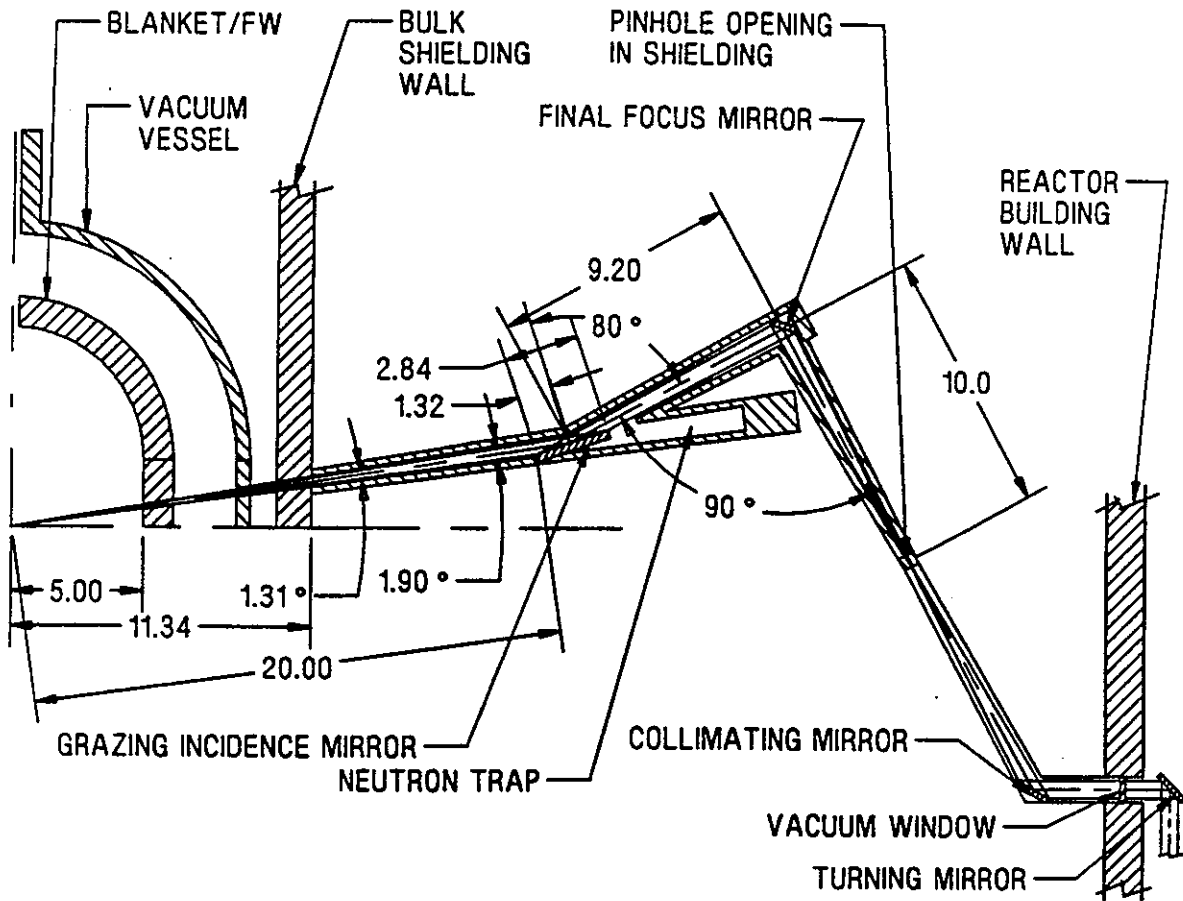
**Figure 2.4-6** By frequency-"chirping" the leading edge of the SBS pumping pulse and reflecting it back upon the incoming pulse within an SF cell, it is possible to compress the RAC output pulse from 250 ns (or 500 ns) down to short pulse durations.

Although the SBS cell has some control over the pulse shape and energy content of the emerging beams, additional temporal tailoring of the beam is required. The residual energy in the unextracted portion of the original 250 ns pulse is used to generate a prepulse beam. An optical switchyard of delay lines inverts the sequence of the leading and trailing pulses from the SBS cell to form proper prepulse and main pulse durations and energy content while achieving high energy conversion efficiency in the SBS cell. An illustration of the entire optical train from each set of 16 ELPAs through the Raman Accumulator, SBS cell, and delay lines for one of the 60 beamlines was shown previously in Figure 2.4-2.

The 60 beams are directed from the SBS cells and delay lines through the reactor building wall, down shielded beamlines to the reactor cavity as shown in Figure 2.4-7. To protect upstream optics and driver plant equipment, a neutron pinhole is provided upstream of the final turning mirror. A grazing incidence metal mirror (GIMM) is used at a distance of 20 meters from the center of the reactor cavity. This long-lived component will be located in the direct line-of-sight of the target. The final focus mirror will not be in the direct line-of-sight of the target but will still be in a high radiation zone. Neutron traps are provided to help minimize radiation down the beamlines. The GIMMs and the final focus mirrors are equipped with fast-acting actuators to align the beams on the targets. Tracking systems will provide information from the targets at the end of the injector and, if needed, within the reactor cavity.

Considerable effort was directed toward identifying the physical processes governing the transmission of the optical beams through the reactor cavity. The predominant constituent in the gas atmosphere within the reactor cavity is lead vapor. Trade studies were conducted to determine the optimum combination of wall protectant temperature, cavity radius, repetition rate, beam losses by various mechanisms, and vacuum pumping requirements. The studies showed that the lead protectant operating at its highest possible temperature (525°C) for compatibility with external stainless steel piping and a cavity radius of 5.0 meters would result in a 3 mtorr Pb vapor pressure. This vapor pressure is not anticipated to cause significant loss in beam energy content or quality during transit across the cavity.

**2.4.4 Reactor Cavity Features** - The reactor cavity for the Prometheus-L design includes the first wall system, blanket, coolant manifold, vacuum vessel, and shield. The main purpose of the cavity is to contain the radiation and blast effects from the inertial fusion reaction, transform that nuclear energy into a more useful form of energy, and to breed tritium for sustaining fuel supplies. Since the reactor cavity is exposed to a very harsh radiation environment, it is the component that would have the most impact on the safety and environmental impact associated with the plant.



Note: Dimensions are in meters.

**Figure 2.4-7. Final Optics Configuration-Reactor Building**

Safety and environmental impact played a significant role in the choices of materials and the design approaches employed. Many concepts and materials were evaluated for inclusion. Silicon carbide (SiC) composite material was chosen as the primary structural material for the first wall, blanket, and coolant piping. This material offers low level activation for both long-term and short-term activation products that minimizes the waste disposal difficulties and provides low decay heat. Lead offers excellent heat transfer properties and good neutron multiplication although it has both toxicity and radioactivity concerns. Even with these concerns, it is thought to be superior to other liquid metals in the reactor cavity. A composite shield material is employed to significantly reduce the activation in the bulk shield and the component shielding. A few applications require more traditional metals such as aluminum and steel and, in those cases, the alloys are tailored to reduce the activation properties.

A cylindrical cavity with hemispherical ends was chosen to improve the maintainability of the reactor components. A wetted wall with a layer (0.5 mm) of liquid lead on the surface was chosen as the first wall protection scheme, shown in Figure 2.4-8.

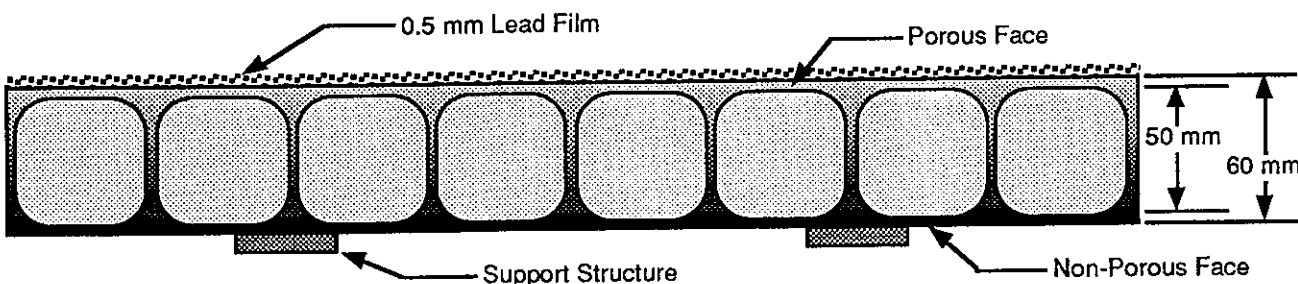


Figure 2.4-8. First Wall Panel; Cross Sectional View

Rectangular coolant channels for the liquid lead cool the surface and bulk material. The composite SiC material is also graded in density from fully dense at the back face to 10% porosity at the front face. This porosity allows the lead to migrate from the coolant channels to the surface. A portion of the lead film is vaporized by the target explosion and subsequently recondensed on the surface. A separate Pb film injector is used near the top of the cavity to establish and maintain a film in contact with the wall surface in that area. The lead coolant is introduced at the top of the cavity and it flows downward to the bottom of the cavity.

SiC occupies a minimal FW volume fraction (~10%) to ensure good neutron multiplication. The thickness of SiC behind the liquid film is 5 mm to assist heat conduction into the coolant flow. The heat deposited in the first wall system is 1,267 MWt which is over 40% of the generated thermal power. Removal of this heat requires a mass flow rate of 54,422 kg/s with an inlet bulk temperature of 375°C and an outlet bulk temperature of 525°C.

Lead recondensation on the first wall surface is the primary vacuum pumping mechanism in the cavity. The surface temperature of the lead determines the vapor pressure. With a repetition rate of 5.65 Hz, it is calculated that the base pressure of the cavity will be 3 mtorr. The non-condensable gas load created by the He, unburned D and T, and the H from the target capsule is pumped with cryogenic vacuum pumps and roots blower backing pumps.

The expected lifetime of the first wall panel is estimated at five years. This is primarily due to radiation damage in the SiC and to surface damage and fatigue caused by the pulsed operation. The first wall modules are attached to the front face of the blankets.

The blanket region is directly behind the first wall systems. The chosen design builds upon the existing blanket data and design base developed by MFE. The general blanket arrangement is shown in Figure 2.4-9. The structural material is SiC composite material, serving all the structural functions including coolant tubes, pebble bed container, outer blanket module wall, reflector region, and coolant plenum. Helium at 1.5 MPa is the coolant media extracting heat from the blanket region. The

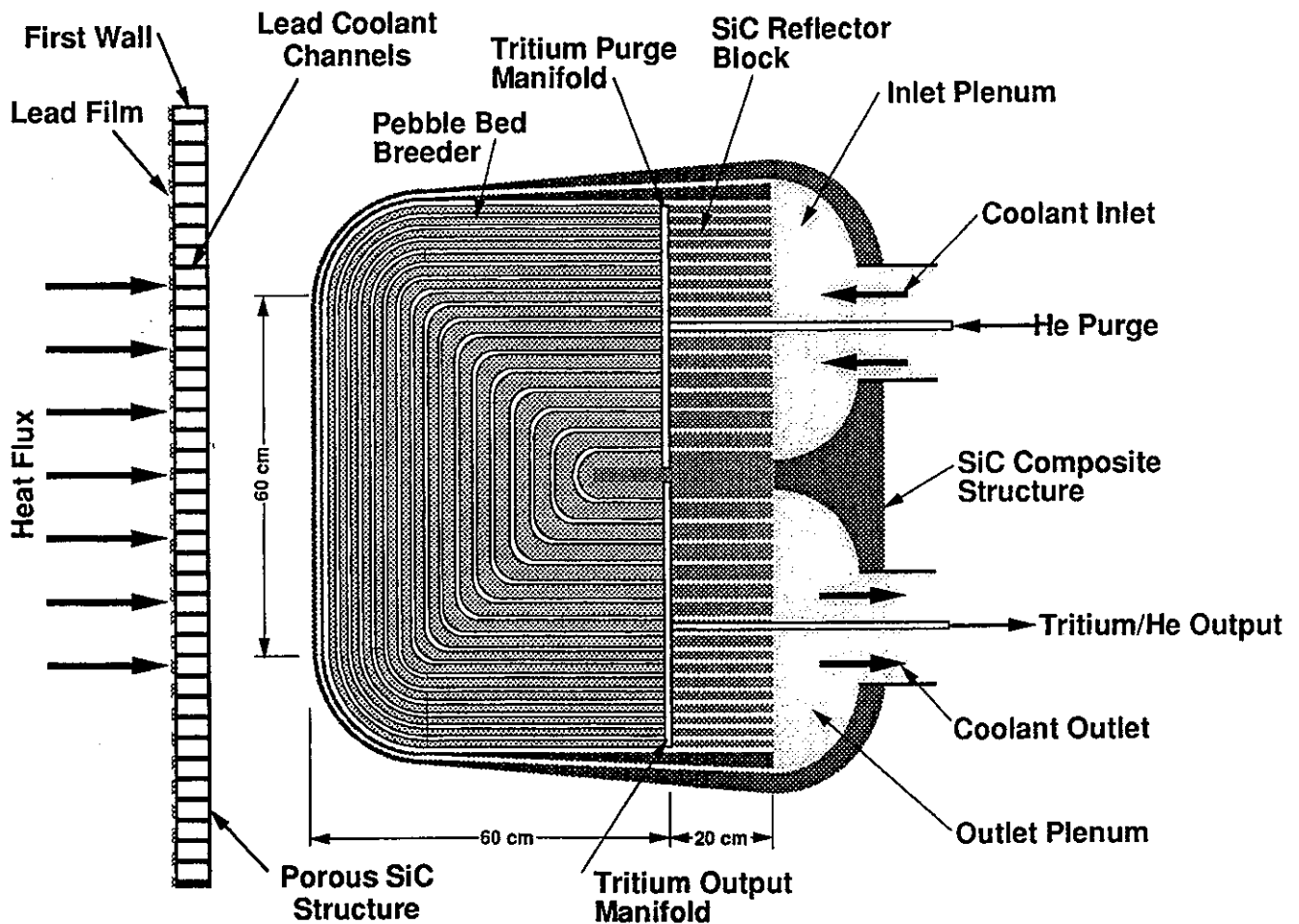


Figure 2.4-9 Schematic of a Blanket Module

tritium is bred in a  $\text{Li}_2\text{O}$  pebble bed breeding zone. A low pressure helium gas removes the tritium gas for processing.

The blanket system removes 1,782 MWt of power from the system. The inlet temperature of the helium is  $400^\circ\text{C}$  and the exit temperature is  $650^\circ\text{C}$ . There is an overall energy multiplication ratio of 1.14 within the first wall and the blanket. The blanket tritium breeding ratio is 1.2. The tritium inventory of the blanket is calculated to be 100 g. The peak and average neutron wall loads are equivalent to 6.5 and  $4.3 \text{ MW/m}^2$  respectively. The lifetime of the blanket is expected to be ten years or greater.

The blanket is constructed in longitudinal modules. Penetrations are allowed for the entrance of the laser beams and the vacuum ports. Plenums are provided in the annular space outside the blanket region. Adequate space is allowed for remote maintenance of the blanket and first wall piping.

A ferritic vacuum vessel is provided outside the blanket and plenum region to help contain the reactor vacuum conditions. This region is approximately 0.5 meters thick.

All of the previously addressed systems have been constructed in radial fashion outward from the basic first wall shape, as shown in Figure 2.4-10. The bulk shielding

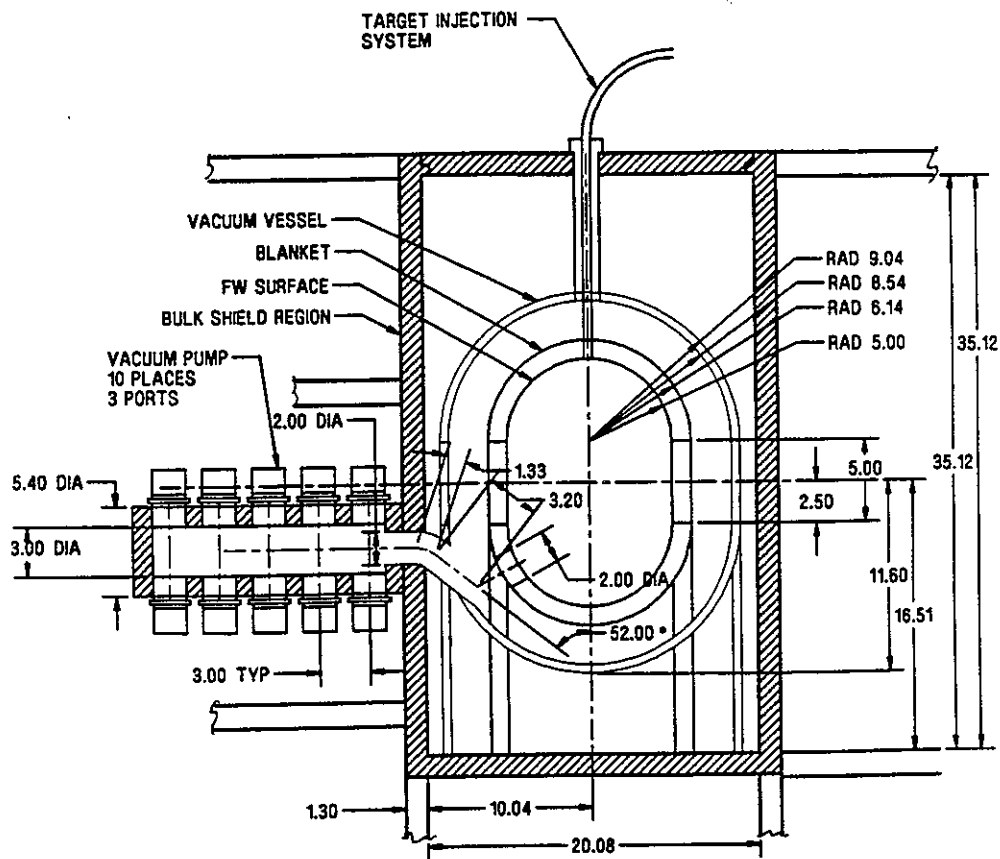
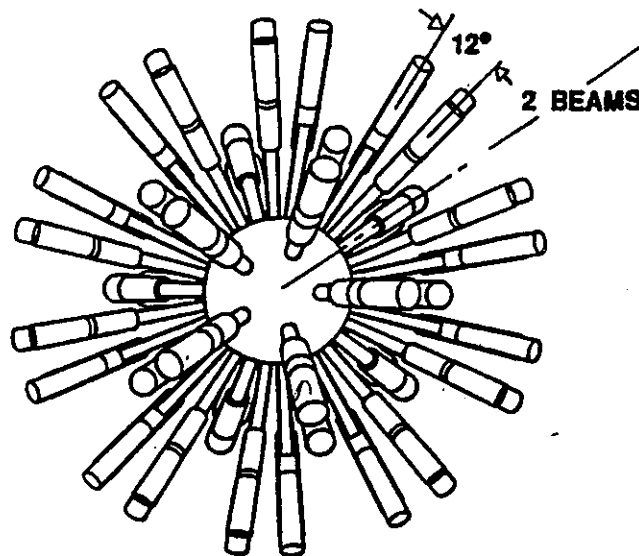


Figure 2.4-10 Elevation of Reactor Cavity Region Without Beamlines

was placed close to the vacuum vessel with a 1-m space for maintenance access, support structure, and plumbing. The basic bulk shielding shape adopted was a simple right circular cylinder 20 meters in diameter and 35 meters high (inside dimensions). The adopted composite shield composed of Al, SiC, B<sub>4</sub>C, Pb, and water is 1.3 meters thick. That figure also shows the shielding provided around the three vacuum plena. Similarly, Figure 2.4-7 illustrates the 25-cm thick shielding provided around individual beamlines. At the end of the beamline, neutron trap and thicker shielding is provided to stop neutrons with direct line-of-sight to the cavity interior.

A shielding trade study was conducted to determine if the best approach was to place the shielding as close as possible to the source or to move the shield back to the wall beyond the final mirrors. The trade study indicated it was most cost effective to place the bulk shield in as close as possible and shield each beamline out to the "pinhole" openings. This approach minimizes structural activation within the building environment and walls.

**2.4.5 Reactor Integration Features** - Reactor integration combines the major system elements of the reactor plant into a synergistic whole system. As shown in Figure 2.4-1, the reactor building is circular and contains the reactor cavity, the vacuum pumps, the lead steam generators, and the 60 beamline enclosures. The configuration of the laser beams shown in Figure 2.4-11 illustrates the difficulty in locating any components in close proximity to the reactor vessel. However, there is a symmetry exhibited every 12°. With computer-aided drawing tools, individual beam locations were defined to determine the proper locations of other components. Section 6.3 has more detail on these arrangements.



**Figure 2.4-11. 3-D Beamline/Reactor Cavity Interface - Plan View**

The general arrangement for the Driver Building was chosen to be an annular arrangement surrounding the Reactor Building. This is a more cost effective approach than a more conventional rectangular building. It also affords a common set of beamline geometries for each beamline location. The central Reactor Building will be serviced through service passageways above the Laser Building. The target injector will be located at the top of the reactor cavity and inject the targets downward into the cavity.

The energy conversion system is based on an advanced Rankine cycle. The Prometheus-L thermal conversion system uses three main sources of heat, the primary helium coolant with 1,782 MWt, the primary lead coolant with 1,267 MWt, and waste heat recovery of the driver at 193 MWt. Credit is also given for recovered lead pump work of 22 MWt. A steam-driven helium circulator is employed because it has a higher efficiency than a motor driven circulator. Power requirements for this circulator are not quoted separately, but the overall thermal efficiency is reduced to 42.3% to account for the power requirements.

**2.4.6 Summary of Prometheus-L Reactor Plant Key Features** - The reactor power plant design contained herein is indicative of what could be constructed within 20-30 years given assumed extrapolations of IFE physics and engineering technology. The plant could be constructed for a total direct capital cost of 2.2 billion dollars in 1991\$ and a total cost, including indirect costs, of 4.1 billion dollars. The estimated cost of the electricity would be approximately 72.0 mills/kWhr that is comparable to most estimates of fusion power plants and new advanced fission power plants.

The plant is inherently safe, earning the best LSA rating of one. Use of low activation materials results in waste disposal estimated to be Class C or better for the plant. An extremely safe and environmentally acceptable reactor cavity has been designed. The usage of SiC as the structural material lowers the waste disposal concern and raises the level of safety assurance. An innovative first wall approach provides a very long-lived first wall. The blanket approach builds on the MFE data base in solid breeders and adapts the concept to the unique aspects of IFE. A new concept in shielding helps lower the level of activation in the shield.

The reliability and maintainability of the plant have been stressed to assure high availability. The reactor cavity has been designed to be remotely maintained with access from the top of the vessel. This enables low maintenance times for replacement of the first wall or the combination of the first wall and blanket. The laser driver final optical elements are designed to be life-of-plant, or a major fraction thereof, with short mean-times-to-repair. The calculated inherent availability of the laser driven reactor plant is 79.4%.

The technology and physics of the direct drive targets has potential for significant improvements. The design study has contributed toward defining illumination requirements and techniques, manufacturing processes, and definition of the target factory.

A viable laser driver option has been identified and defined with innovative approaches to greatly improve the requisite beam quality, power level, beam pointing, pulse compression, and reliability.

We feel this design is a valuable contribution toward understanding IFE's needs to move toward the goal of commercial fusion energy.

#### **Reference for 2.4**

1. J. P. Holdren, Chair, et. al., "Report of the Senior Committee on Environmental, Safety, and Economic Aspects of Magnetic Fusion Energy," UCRL-53766, 25 September 1989.