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CHAPTER 3
OBJECTIVES, REQUIREMENTS, AND ASSUMPTIONS

3.1 Introduction

The primary objective of the Prometheus study is to develop two conceptual designs of a commercial fusion electrical power plant based on inertial confinement, one with KrF Laser Driver (Prometheus-L) and the other with Heavy Ion Beam Driver (Prometheus-H). In addition, the study emphasized the following goals.

- State-of-the-art advancement of Inertial Fusion Energy (IFE) power plant design
- Assessment of inertial power production including technical feasibility, economics, safety, and environmental aspects
- Identification and characterization of key technical issues including R&D requirements to resolve each issue
- Comparison of the two IFE reactor design concepts
- Development of information necessary to compare the IFE designs to other concepts based on Magnetic Fusion Energy (MFE).

In order to meet the above objectives and goals, it was necessary to develop a set of requirements and guidelines based on (1) recommendations by an Oversight Committee[1] commissioned by DOE, and (2) study management effort. The Oversight Committee, chaired by Ronald Davidson (PPPL), had two working groups, one chaired by Robert Krakowski (LANL) responsible for guidelines as to the study approach and content, and the other chaired by Roger Bangerter (LBL/LLNL) responsible for developing unclassified guidelines[2] for the target information. These guidelines were developed for the Prometheus team and a parallel study team led by W. J. Schafer Associates. The study management refined and augmented the Oversight Committee guidelines based on the project specific needs.

This chapter discusses the important requirements and guidelines adopted in the course of the study. The current data base for IFE is not sufficient to fully develop a complete conceptual reactor design and accurately predict its performance; therefore, assumptions were made where knowledge gaps exist. These assumptions were carefully made after consultation with experts and are summarized in this chapter.

3.2 General Guidelines

- The IFE reactor plant is to serve as a commercial central station electric power plant. The only product is electricity.

- The reactor is operated on the deuterium-tritium fuel cycle and must satisfy tritium self-sufficiency conditions assuming a mature fusion power economy.

- The design is for tenth-of-a-kind commercial power plant. Thus, the machine performance will be highly predictable and it will have resulted from an extensive R&D program and utility operating experience from earlier plants. This also implies that the development costs have been amortized over prior plants.

- The net electric power output of the plant is 1000 MW. The power level of the plant affects the economics and is important to the utility's ability to finance. The smaller size (e.g., 500 MWe and below) is easier to finance, construct, and incorporate into existing grids but the cost of electricity will be higher. The economy of scale is important for both magnetic and inertial fusion reactors, albeit for different reasons. For example, tokamaks have a minimum size dictated by plasma burn and ignition considerations. In IFE reactors, a larger size is typically more economical because drivers represent a significant fraction of the Cost of Electricity (COE) and the strong dependence of gain on driver energy. The study adopted 1000 MW net electric power as a nominal size for comparison purposes with previous and ongoing MFE and IFE reactor design studies.[3-9] Assessments of the advantages of the larger and smaller sizes will be made.

- The design will have a single generating unit at the site. The target factory will be included in the power plant description.

- The data base used in the design will need to be extrapolated in many areas of physics, technology, and economics. For the purpose of this extrapolation, the plant is assumed to start operation in the year 2040-2050 time frame; thus, the data base should be that available in the period 2030-2040. It is difficult to extrapolate to such a distant future and such extrapolations will necessarily involve judgment that varies among experts. The designers are asked to: (a) strive for a balance between credibility and attractiveness; (b) be consistent with assumptions made for MFE where similar conditions prevail (for example, the development of a particular structural material such as SiC has to assume the same probability of success in MFE and IFE subsystems experiencing the same environment. In contrast, if different conditions can lead to different probabilities of success for MFE and IFE, such conditions will have to be delineated); and (c) assumptions on extrapolation and probable outcome of R&D should be clearly documented. The study should identify the key feasibility issues and assess, for each major reactor system, the development program that is needed to advance the physics and technology from its present status to the status that is required for the performance of that system as specified in the design. This assessment should attempt to quantify the magnitude of the extrapolations involved relative to prior advances. An evaluation of the role of the IFE Defense Program and the ongoing MFE Program in resolving these issues is needed.

- The plant lifetime is 40 years for engineering design and 30 years for economic analysis.

- The construction time is assumed to be six years.

- The power plant availability is very difficult to predict because of the lack of a data base for both IFE and MFE designs. At present, the logical approach is to define "goal" availability consistent with current experience from other types of existing power plants and to make an effort to quantify the requirements on component lifetimes and maintenance as well as the R&D to achieve such a goal. The following goals are suggested. Assume an overall plant availability goal of 75% as a "base case." This is consistent with availability factors attained on the average in the nuclear industry. A commonly used goal for PWR designs is 80%. Current practice in many power plants calls for an annual shutdown for about 30 days to perform maintenance and inspection. This 30-day period can be used for scheduled maintenance simultaneously on both the reactor and balance of plant. Furthermore, present data indicate that 20 days downtime per year is caused by failures in balance of plant. Given a 75% overall plant availability implies a total downtime of 91 days per year. The 91 days can be allocated as 30 days for annual scheduled maintenance on both the reactor and balance of plant, 20 days for unscheduled maintenance on balance of plant, and 41 days for unscheduled maintenance on the reactor.

  The following is a summary of recommendations on "base case" availability.

Downtime Allocations for an Overall Plant Availability Goal of 75%			
Reactor		Balance of Plant	
Scheduled	Unscheduled	Scheduled	Unscheduled
30	41	30	20

- Differences in the achievable availability between Laser- and Heavy Ion-Driven reactors are expected. Also, one would anticipate differences between IFE and MFE reactors. These differences will be identified and their impact on the achievable availability and/or the required R&D program will be quantified. This impact will be assessed at least comparatively relative to the "base case."

- The study will perform and document tradeoff studies for key design choices, for example, direct versus indirect drive targets. The study will also analyze and document the impact of key design assumptions and extrapolations in physics, technology, and economics; for example, target gain and target cost.

- Studies to evaluate the sensitivity of power plant figures of merit (e.g. COE, safety features, attractiveness, cost of R&D) to variations in key design assumptions are encouraged.

- The limitations on the resources for the study dictate a focused approach that will emphasize key IFE reactor components such as target, driver, cavity, and fuel cycle. The effort on the balance-of-plant and other areas that are similar in many respects to MFE should be limited. The study will also devote some special effort to those technical areas that affect the comparative evaluations where previous effort was limited; for example, fuel cycle modeling analysis, evacuation of the reactor chamber, tritium and debris recovery, material recycling, and final optics design.

- Generating data sufficient to compare IFE designs with different drivers and to compare IFE to MFE is an important part of the study. Designers of each subsystem must provide the information specified in the Evaluation Methodology.

3.3 Target and Driver Guidelines

The requirements and the design of all systems, except perhaps the BOP, are strongly influenced by target physics and design. Most target designs and performance data are classified. The charter to do classified target physics and design resides at Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL), Sandia National Laboratories (SNL), and KMS Fusion. This study is to accomplish its objectives based on unclassified information. The Target Working Group[2] (TWG) has provided the study team with unclassified information and requirements on capsule designs, target gain, and driver performance and coupling to the target. The target designs encompass both direct and indirect drive targets for a range of physics assumptions from conservative to optimistic, consistent with extrapolations to the 2030-2040 time frame.

3.3.1 Target Factory - Targets are currently hand-crafted for a few shots per day. For economical power production, the cost of targets must drop many orders of magnitude and the production rate must be increased to about 10^5-10^6 targets per day. Therefore, mass production techniques must be introduced. These extrapolations in cost and production rates are sufficiently large that, despite some excellent previous studies, large uncertainties remain. It is important to reduce the uncertainties since target production costs appear to contribute significantly to total COE. Therefore, the studies must continue to address this issue, with prototype development of actual target fabrication facilities.

The most recent and complete DOE-supported study of target costs was performed for the Heavy-Ion Fusion Systems Assessment.[6,9] Since the completion of this study, there has been some evolution in target design and substantial progress in hand-crafted target fabrication techniques. Furthermore, some of the newer target fabrication techniques appear suitable for mass production; therefore, continuing studies are needed. The studies must include conceptual techniques for fabricating the targets and must be performed by a group that includes individuals with industrial experience and demonstrated expertise in the mass production of small, high precision components. These individuals must be familiar with advanced manufacturing R&D. Also, target inventory and shelf life and tritium inventory, handling, and control must be addressed. Target factory development needs must be detailed.

The target factory must be on site and financially possible. The maximum allowable cost per target for an IFE plant to be economically competitive can be derived from simple arguments. The presently projected COE from an IFE plant may exceed that from conventional and nuclear power plants because of the presence of large expensive reactor components such as the driver. Therefore, the cost of the targets should be no more than about 10% of the busbar COE for an IFE plant. At present, a reasonable goal for the busbar COE is 5¢/kWh. For a power plant with a net electric power output of 1000 MW, the cost of energy per day is $1.2 million. With the 10% assumption, the maximum allowable cost for the targets is $0.12 million per day. For a pulse repetition rate of about 6 per second, the number of targets required is about 0.52 million targets per day; therefore, the total cost per target should not exceed about 23 cents per target. This is the suggested maximum cost per target including materials, fabrication, and delivery.

3.3.2 Direct-Drive KrF Laser Target and Driver - Direct-drive KrF target designs are relatively mature as they have undergone a number of iterations with respect to issues associated with hydrodynamic stability, effect of long-wavelength drive nonuniformities, and laser energy coupling. However, these direct-drive (DD) targets have not been tested at anything resembling IFE reactor-level laser energies. Current DD target experiments are being conducted at laser energies three orders of magnitude below the ~4 MJ Prometheus-L design. The gain curves for directly driven laser targets are given by the TWG in Figures 3.3-1 and 3.3-2. The direct-drive target described in this report is similar to the target used in determining the gain curves.

The gain curves for the direct-drive target were based on an unclassified code (University of Rochester). The curves in Figure 3.3-1 assume that the laser focal spot radius is constant in time and equal to the target radius. Also assumed is a spatial intensity profile described by $\sin^2 x/x^2$. Because detailed target designs are not

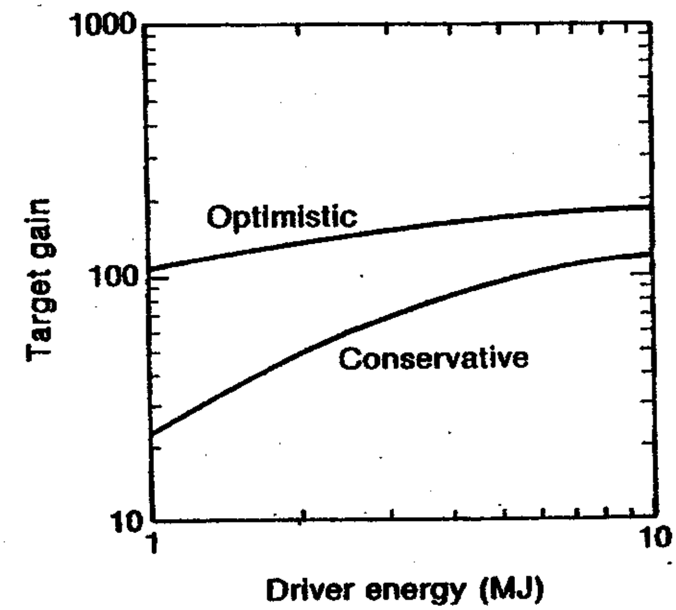

Figure 3.3-1. Gain as a Function of Energy for Directly-Driven Laser Targets[2]

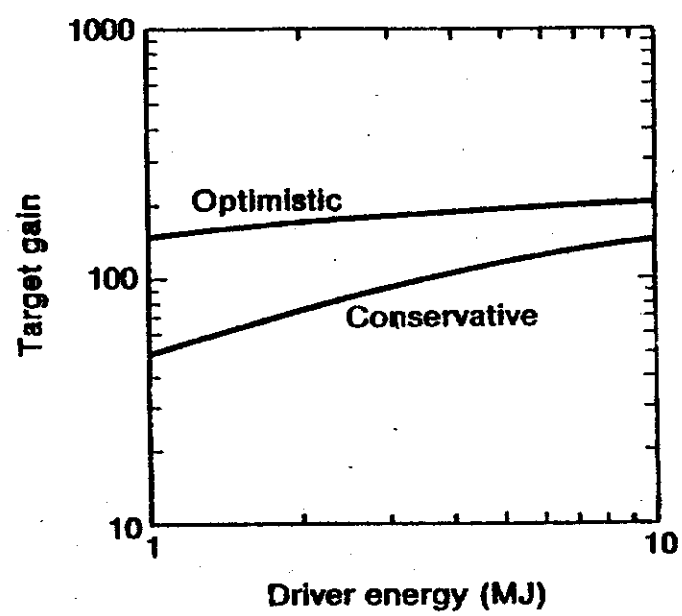

Figure 3.3-2. Gain as a Function of Energy for Directly Driven Laser Targets. These Curves Assume Zooming.[2]

available to this study, we have assumed the well-known hydrodynamic scaling laws to obtain the focal spot radius, (i.e., assume the radius scales as $E_L^{1/3}$ (where E_L is laser energy)). Using a radius of 2.8 mm at 4 MJ has allowed us to compute the coefficient of the gain curves. Similarly, we assumed the peak power scales as $E_L^{2/3}$. We then used a peak power of 500 TW at 4 MJ to get the value for gain curve coefficient. The curves in Figure 3.3-2 assume that the focal spot radius is "zoomed" so that it remains equal to the critical surface throughout the implosion. Detailed guidelines are provided below for the cases in Figure 3.3-1; i.e., for a laser focal spot radius that is constant in time. In Figures 3.3-1 and 3.3-2 the gain curves are shown as a band to represent the current "level of risk" understanding associated with hydrodynamic stability issues. The upper curve represents the optimistic case while the lower curve represents the conservative case. For the purpose of this study, the base line gain should be taken to be the arithmetic mean of the optimistic and conservative curves.

Illumination uniformity requirements were provided by the TWG for the designs represented in Figure 3.3-1. The requirements are summarized as follows:

(a) A minimum of 60 beams is required and the initial focal spot radius should equal the radius of the capsule.

(b) Power balance must be better than about 5% rms for 1% rms illumination uniformity.

(c) Random beam mispointing must be less than 0.1 of the capsule radius to obtain better than about 1.2% rms illumination uniformity.

(d) Capsule mispositioning with respect to the center of the chamber must be less than 0.1 of the capsule radius in order to maintain the nonuniformity below 1% rms.

(e) The required level of individual beam uniformity is difficult to specify accurately at present. Some form of beam smoothing technique is required (asymptotic level of illumination nonuniformity will have to be less than about 1% rms), and smoothing (or averaging) times will have to be as short as possible (less than about 10-20 picoseconds).

Details of the illumination uniformity requirements are provided below.

Illumination Uniformity Requirements for Direct-Drive KrF - The near-field laser beam irradiation pattern on the capsule can be represented as the product of two factors: (1) a single-beam factor that depends on the focusing geometry, the f-number of the lens, the capsule conditions, and the individual beam profiles; and (2) an interbeam interaction factor that is determined by the number, orientation, synchronization, polarization, and bandwidth of the individual beams about the capsule and the energy or power imbalance between the beams. (The balance-of-time, integrated, individual beam energies do not preclude the occurrences of instantaneous differences in intensity between beams at different times in the pulse.)

Number of Beams and Focal Spot Radius - Figure 3.3-3 illustrates the predicted rms irradiation nonuniformity on the capsule for 24-, 32-, 60-, and 96-beam irradiation configurations. The individual beam radial-beam profiles in all cases are assumed to be $\sin^2x/x^2$ characteristic of the intensity envelope produced by distributed phase plates. This intensity distribution function is, however, characteristic of far field diffraction from a rectangular aperture and is inconsistent with the near-field laser illumination scenario. All of the beam configurations provide adequate uniformity at a focal ratio (beam radius at the 5% intensity point divided by the capsule radius) of ~1 (tangential focus). However, as the capsule implodes, this ratio increases due to the inward motion of the critical surface. By the time the laser pulse has finally turned off,

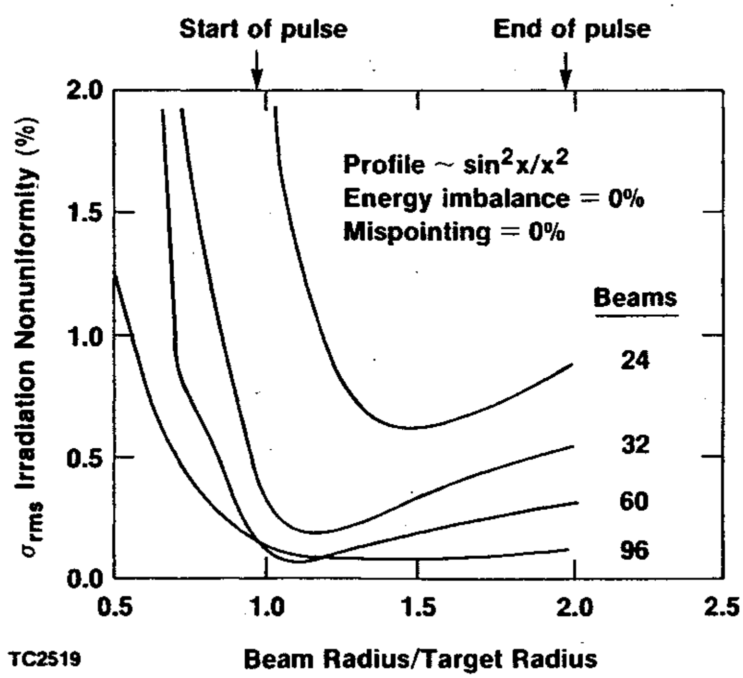

Figure 3.3-3. Irradiation Non uniformity (σ rms) as a Function of Focus Ratio for 24-, 32-, 60-, and 96-Beam Geometries, assuming a Smooth $\sin^2x/x^2$ Radial Beam Profiles.[1]

the focal ratio typically doubles. From Figure 3.3-3, clearly a minimum of 32 beams is required to obtain a high level of uniformity over the duration of the laser pulse. However, when issues associated with other contributions to illumination nonuniformity are included, it is found that a 32-beam system requires much more control over power balance and beam mispointing than a system with more beams. Therefore, in terms of stating a requirement on the number of beams and their focal spot radii, a minimum of 60 beams is required and the initial focal spot radius should equal the radius of the capsule. As to the beam placement, assuming that the 60 beams are symmetrically disposed about the capsule is a good first approximation.

Power Balance and Beam Alignment - The effects of beam (power) imbalance and beam alignment on capsule performance result in temporally varying illumination nonuniformities with spectral magnitudes that vary with time. Analysis has shown that these illumination nonuniformities produce mainly low-order modes ($l < 6$). Two-dimensional simulations of designs representing the upper gain curve have shown that the $l \leq 6$ modes must have amplitudes less that 1-2% (rms). Using this requirement, an estimate of the power imbalance and beam alignment (mispointing) can be obtained. Figure 3.3-4 shows that a 60-beam system requires power balance

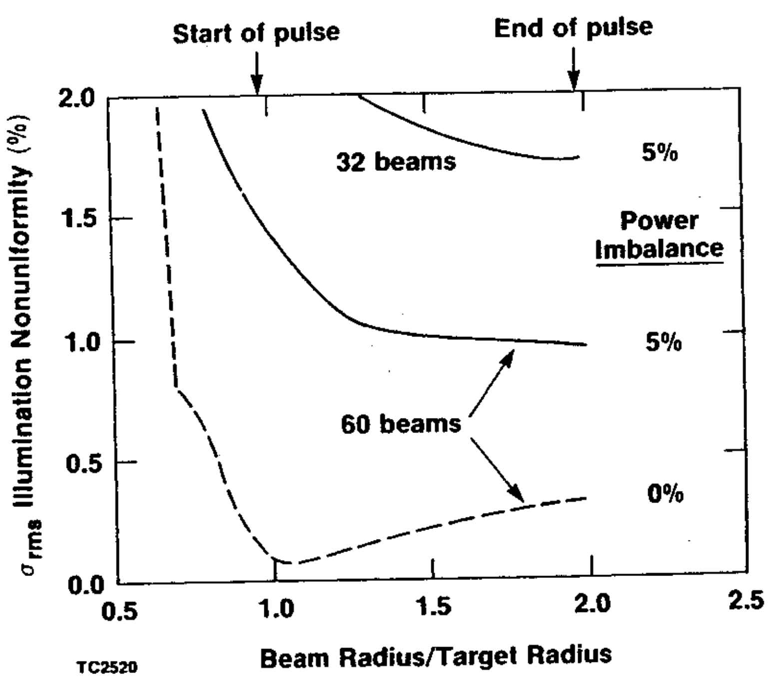

Figure 3.3-4. Irradiation Non uniformity (σ rms) as a Function of Focus Ratio for 32 and 60 Beams, assuming a 5% Power Imbalance and Smooth $\sin^2 x/x^2$ Radial Beam Profiles. The dashed line is the reference σ rms for 5% rms power imbalance for the 60-beam system.[1]

which must be better than ~5 rms for 1% rms illumination nonuniformity for $1 \leq l \leq 6$. The amount of beam mispointing that can be tolerated is shown in Figure 3.3-5. The rms nonuniformity is plotted as a function of the maximum beam mispointing, measured in terms of the target radius. The mispointing is chosen to be random in magnitude (up to the maximum indicated) and random in direction; the error bar indicates the spread in values that is obtained for different sets of pointing errors at a given maximum. For a 60-beam system, a random mispointing of 0.1 of the capsule radius will result in ~1.2% rms illumination nonuniformity. The calculations in Figure 3.3-5 assume perfect power balance. The combined results of power imbalance and beam mispointing add in quadrature.

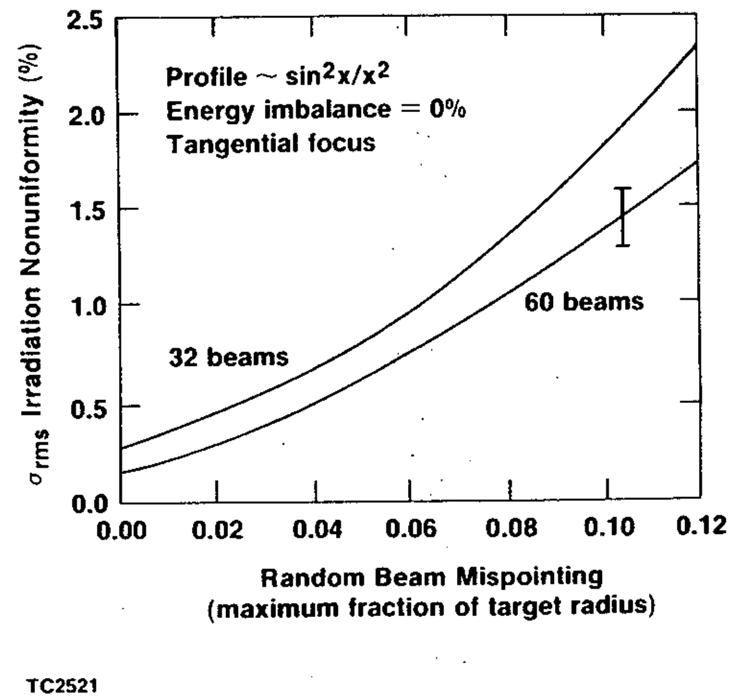

Figure 3.3-5. Effect of Beam Pointing Error on Irradiation Non uniformity for 32- and 60-Beam System. A smooth $\sin^2 x/x^2$ radial beam profile is assumed.[1]

Capsule Positioning - Uniformity calculations indicate that the capsule mispositioning with respect to the center of the chamber must be less than 0.1 of the capsule radius in order to maintain the nonuniformity below 1% rms. These calculations did not take into account the time dependent effects on the capsule drive of the energy that misses the capsule due to its miscentering. This would depend on the particular capsule design and the pulse shape under consideration.

Individual Beam Uniformity - The required level of individual beam uniformity is still an area of active research. It is difficult to give a precise answer as to the uniformity requirements because capsule performance is affected by both the magnitude of the nonuniformity as well as the modal content of the resulting beam overlap pattern. Some form of beam smoothing technique will be required, and smoothing (or averaging) times will have to be as short as possible (tens of picoseconds). Therefore, since this study is limited to a KrF laser system, some form of induced spatial incoherence (ISI) beam smoothing may have to be employed. As an estimate of the level of illumination uniformity required, initial calculations indicate that the asymptotic level of illumination nonuniformity will have to be <1% rms and that the averaging times must be less than 10-20 ps.

3.3.3 Indirect-Drive KrF Laser Target and Driver - Target gain, using indirectly driven capsules for inertial fusion energy production, will be a function of a large number of variables, including laser geometry, focusability, pointing accuracy, wavelength, and possibly beam smoothness and bandwidth, as well as target performance determined by such effects as hydrodynamic instabilities and plasma physics effects in hohlraums. Most of these effects are coupled and a system optimization must be carried out to determine the best set of operating conditions. Since most of the target physics is classified, many of the choices that go into any particular set of gain curves must remain classified. Figure 3.3-6 shows two gain curves that we believe span the range of target gains likely to be achievable using standard capsule and hohlraum designs. The lower curve is based on detailed target design studies carried out for the Department of Energy Defense Programs LMF (Laboratory Microfusion Facility). This gain curve is consistent with an extrapolation to the megajoule scale of all current data. This curve represents the present best estimate of the gain that would be achieved in a first-of-a-kind experimental high gain facility. The higher gain of the upper curve results from an increased coupling efficiency that we believe can be achieved after optimization of both the laser-plasma interaction effects and the target geometry. Advanced target designs could have gains of about a factor of two higher than the upper curve. These designs have increased physics uncertainties and have been less thoroughly analyzed than our baseline designs; however, for these studies the enhanced performance curve should be used as the base case. The LMF baseline curve is the conservative case. The enhanced performance curve should be multiplied by 2 to give the more optimistic case called for in the Guidelines; however, the optimistic case should not be used for laser energies less than 2.5 MJ. Figure 3.3-7 shows the peak power requirements for the two gain curves in Figure 3.3-6. The power curve for enhanced hohlraum performance may be used for the optimistic case. About 70% of the total energy is delivered during the peak power part of the pulse. The rest is delivered in a precursor pulse that is 4-5 times the duration of the peak power pulse.

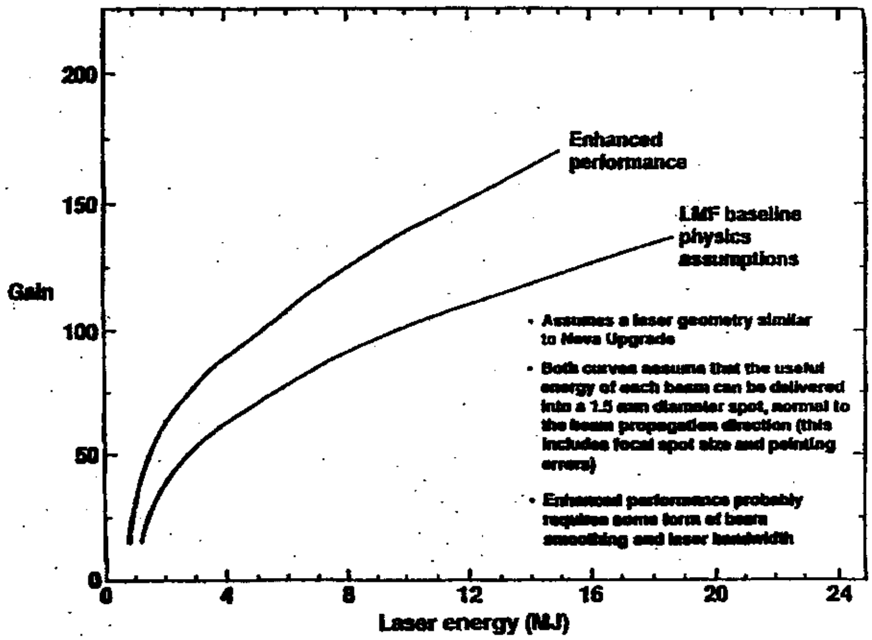

Figure 3.3-6. Gain as a Function of Laser Energy for Indirectly-Driven Targets[2]

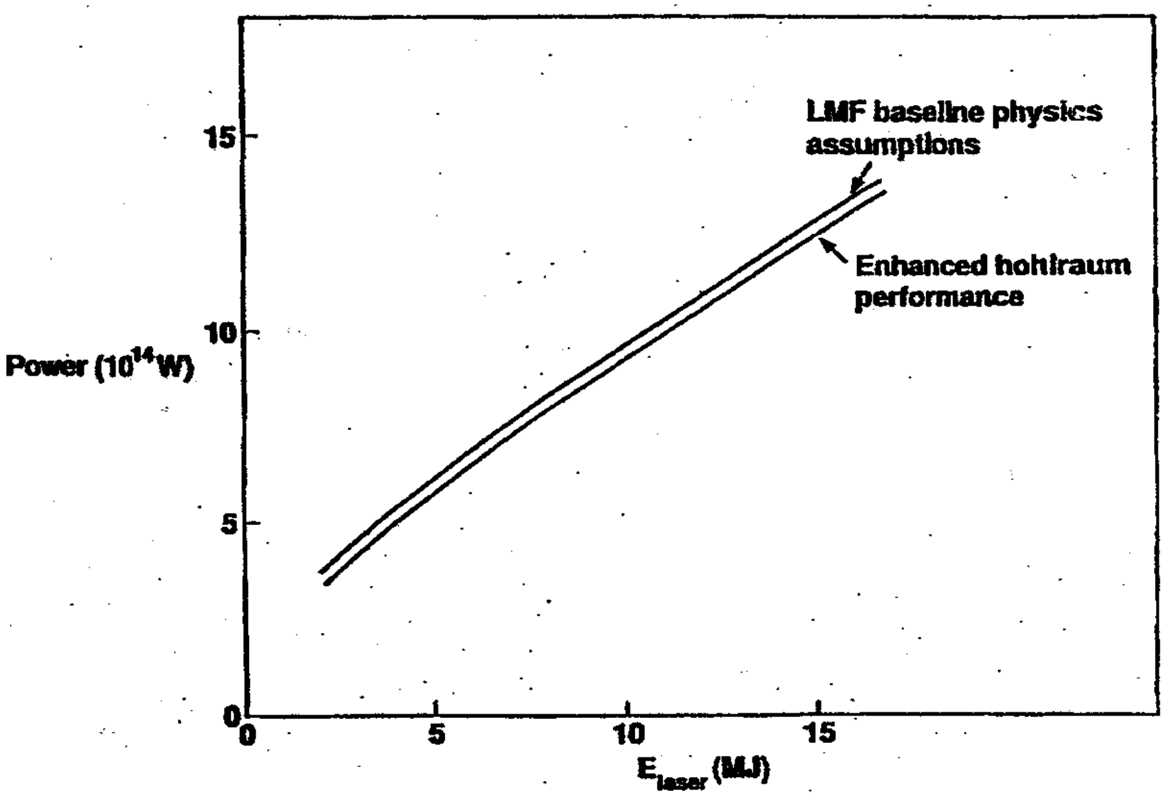

Figure 3.3-7. Power as a Function of Laser Energy for Indirectly-Driven Targets[2]

In order for the laser energy to be efficiently utilized, it is necessary that the laser beam be capable of achieving a spot size that is nearly diffraction limited. It is also important that the pointing errors be limited to a few microradians. A convenient way of stating these requirements is to specify a focal spot within which the laser energy can be delivered. Both gain curves in Figure 3.3-6 assume that all of the useful energy of each beam can be delivered into a 1.5-mm diameter spot. This spot size includes both the size of the focal spot and any pointing errors. All energy outside this spot will not be useful in driving an implosion. However, this divergent energy could adversely affect an implosion if it exceeds even 0.1% of the total energy. Plasma closure phenomena can significantly affect the time-dependent delivery of laser energy to the secondary targets within the hohlraum. In addition, both curves assume a laser geometry similar to that being planned for the Nova Upgrade. The Nova Upgrade laser plan calls for 288 independently pointed beams. The beams are distributed in three or four rings of beams on each side of the target at angles between approximately 30 and 60 degrees from the target axis. The large number of beams allows great flexibility for achieving irradiation uniformity at the capsule while complicating the beams' alignment problems. It also relaxes the instantaneous power and energy balance requirements and allows an rms variation of 10% or more. It may ultimately be possible to reduce the number of beams to a total ranging between 20 and 50. With a smaller number of beams, the power balance must be better than about 5% and the gain may be lower. For these studies we recommend a minimum of 50 beams.

3.3.4 Indirect-Drive Heavy Ion Beam Target and Driver

Target Performance - Figure 3.3-8 gives target gain as a function of driver energy, ion range, and focal spot size for targets driven by two diametrically opposed beams or beam clusters. The peak power requirements for these targets are given in Figure 3.3-9.

The curves in Figures 3.3-8 and 3.3-9 should be considered the "base case." Concepts exist that should give gains about a factor of two higher. Thus the gain can be multiplied by a factor of two (only for cases with driver energies above the ~200 MJ "knee" in the base case curves) to give a more speculative case. The power curves remain unchanged for this case. For a lower limit, the gain should be multiplied by 0.7; the power curves again remain unchanged.

Ion range as a function of ion mass and kinetic energy is given in Figure 3.3-10.

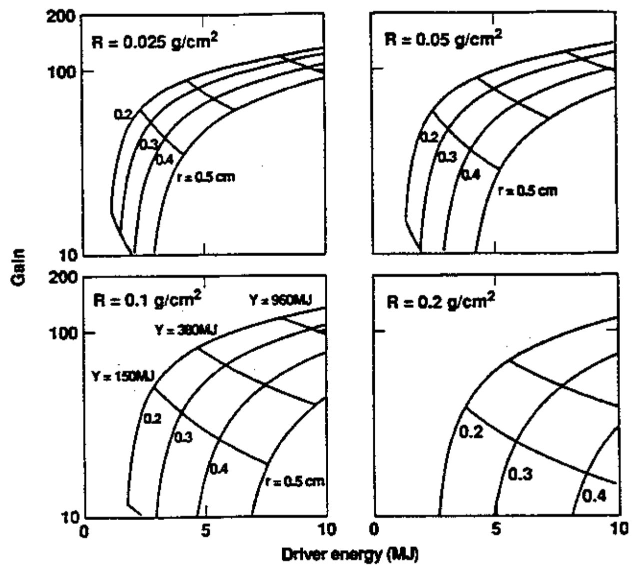

Figure 3.3-8. Target Gain for Indirect-Drive Heavy ions as a Function of Driver Energy,Ion Range, and Focal Spot Size for Targets Driven by Two Diametrically Opposed Beams[1]

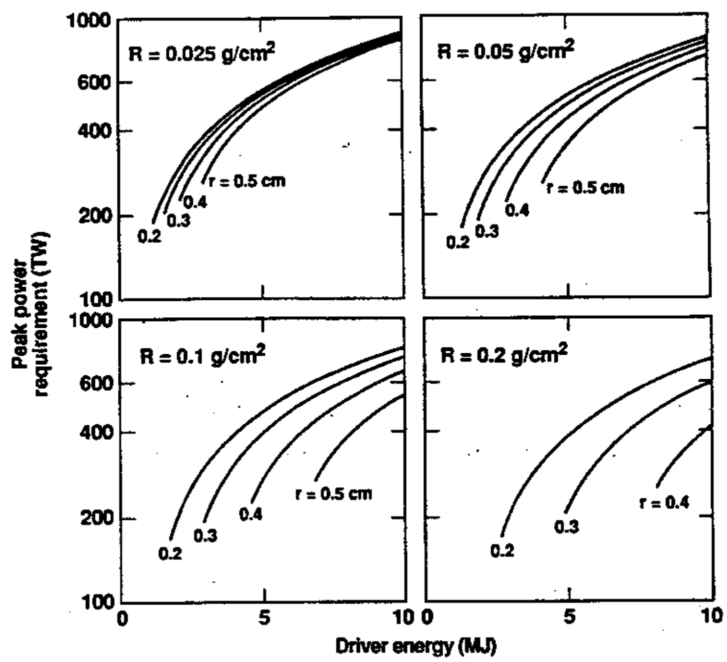

Figure 3.3-9. Peak Power Requirements for Indirect-Drive Heavy ions as a Function of Driver Energy, Ion Range, and Focal Spot Size for Targets Driven by Two Diametrically Opposed Beams[1]

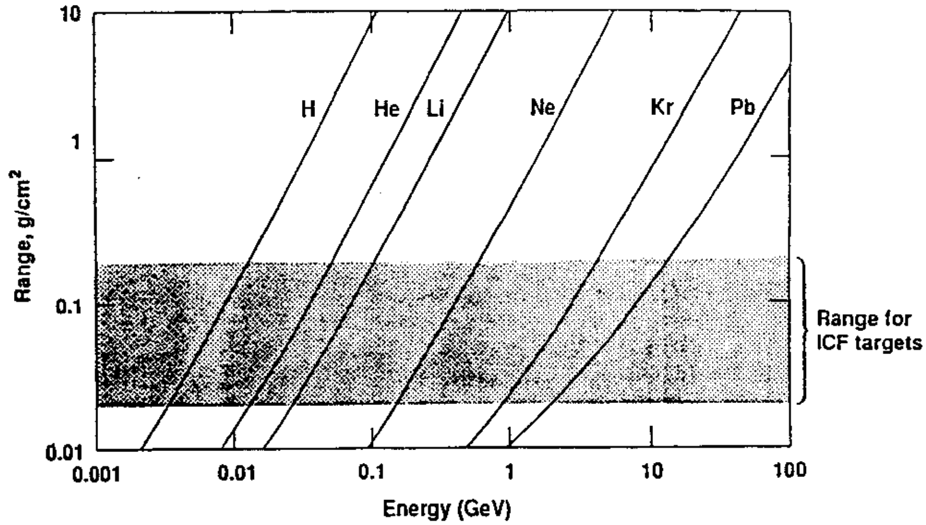

Figure 3.3-10. Ion Range as a Function of Ion Mass and Kinetic Energy[1]

Pulse-Shape Precision, Power Balance, and Beam Alignment - As noted in the previous section, there is considerable flexibility in pulse shape; however, once a pulse shape is chosen, the power at any time during the pulse must be within 3% of its nominal value. This requirement must be met for both beam clusters.

The center of each beam or beam cluster must be aligned within 10% of the focal spot radius. If beam clusters are used and if the beam errors are statistically independent, each beam can clearly have looser tolerances than the tolerance on the entire cluster.

Misalignment and imperfections in the beams and lenses may lead to some fuzziness in the beam radius. If the conditions on power balance and centroid alignment are satisfied, the effect of beam fuzziness can be estimated by using only that fraction of the beam energy that falls in the focal spot radius when using Figures 3.3-8 and 3.3-9. Thus, within limits, there is a trade-off between target gain and beam alignment and radius.

3.4 Reactor Systems

The two drivers to be considered are the KrF excimer laser and the Heavy Ion (HI) beam. A design will be developed for each driver. Most of the key requirements on the driver were specified earlier in discussing the requirements on target design information.

The study should evaluate the technical issues and perform trade-off studies to select among the options and design variables and to determine the performance for each driver design. Key considerations include physics and engineering feasibility, cost, efficiency, reliability, lifetime, safety, and environmental impact. Some of the selection decisions that have to be made for the designs include: (1) direct versus indirect drive, (2) pulse shape and number of beams for the KrF laser, (3) double- or single-sided HI illumination, and (4) configuration and radiation protection schemes for the driver systems (e.g., optics for laser).

In addition to the target and driver system discussed earlier, other reactor systems included are the reactor chamber evacuation system, first wall and its protection system, blanket, radiation shield, tritium system, and primary heat transport system. The evacuation system provides for vacuum pumping of the reactor chamber between pulses down to the pressure required for efficient transmittal of the driver beams to the target. The function of the wall protection system is to absorb the x-rays, charged particles, and target debris generated from the fusion reactions, target disintegration, and interactions with the background gases in the reactor chamber. Depending on the specific design, the amount of nuclear heating generated by neutrons and gamma rays in the wall protection system can be a significant fraction of the energy of the fusion neutrons. The function of the blanket is to breed tritium at the rate required by tritium self-sufficiency condition and to convert the kinetic energy of neutrons and associated gamma rays into sensible heat. The function of the tritium system is to process tritium from the wall protection system, blanket, reactor chamber exhaust and from other reactor components and to supply tritium to the target factory and to a storage system. The function of the primary heat transport system is to transport the recoverable heat from the blanket, wall protection, driver system, and from other reactor components to the secondary energy conversion system.

These reactor systems have important technical feasibility issues and they greatly influence the potential attractiveness of fusion reactors. The study should develop viable engineering solutions that enhance the potential attractiveness of IFE reactor power plant designs with respect to cost of energy, safety, and environmental impact. Selection of the design for various components and the overall reactor configuration should emphasize simplicity, reliability, and maintainability. Tradeoff studies and the rationale for selection of materials and engineering design features should be documented. Key technical issues and the R&D programs required to resolve these issues must be identified.

These reactor systems in the IFE reactors will have similarities to, as well as differences from, corresponding systems in MFE reactor designs. Applicable experience and data base from MFE designs and R&D programs should be fully utilized. Extrapolations required for materials and technology R&D to meet the feasibility and attractiveness goals should be consistent with those assumed for MFE.

3.5 Economic Guidelines

Many of the previous requirements and criteria have profound effects on the economics of the power plant. These would include such items as the net power output, the tenth-of-a-kind assumption, and technology assumptions. The Oversight Committee also recommended some specific economic groundrules in concert with the NECDB methodology[10] and the latest ARIES costing methodology.[11,12,13] The economic requirements and guidelines shown in Table 3.5-1 have been worked out with the Economics Working Group, headed by Robert Krakowski of LANL and Ron Miller for ARIES.

Table 3.5-1 Prometheus Economic Guidelines

Plant Operating Lifetime, yrs		30				
Plant Construction Lead Time, yrs		6				
Contingency Factor, Project and Process		See below, may add risk factor				
Spare Parts Multiplier		1.0 (no spares)				
Constant Year Dollars		1991				
Nominal Year Dollars		1997				
Inflation Rate		.05				
Escalation Rate		.05				
		Average	Tax-Adjusted			
Effective Cost of Money, Nominal Dollars		.1135	.0957			
Effective Cost of Money, Constant Dollars		.0605	.0435			
Fixed Charge Rate, Nominal Dollars		.1638				
Fixed Charge Rate, Constant Dollars		.0966				
Indirect Cost Factors	LSA	1	2	3	4	
91 Constr Serv & Equipment	(x TDC)	.113	.120	.128	.151	
92 Home Office Engr & Services	(x TDC)	.052	.052	.052	.052	
93 Field Office Engr & Services	(x TDC)	.052	.060	.064	.087	
94 Owners Cost	(x TDC+91+92+93)	.150	.150	.150	.150	
95 Process Contingency	(x TDC+91+92+93+94)	.000	.000	.000	.000	
96 Project Contingency	(x TDC+91+92+93+94)	.1465	.173	.184	.195	
		Constant $	Nominal $			
97 IDC Factor		.1652	.3178			
98 EDC Factor		-0	.2436			
Operations and Maintenance Cost [$91]		$78.9x(L^*)\ (P_E/1200)^{0.5}$				
LSA Factor, L*		0.7[1]; 0.85[2]; 0.952[3]; 1.0[4]				
Decommissioning Allowance, mill/kWeh		0-1 (LSA-dependent)				
Deuterium Fuel Cost, mill/kWeh		-0.05				
Learning Curve		85-90% on fusion systems, 75-100% on non-fusion systems				
Quantity Assumption		10th of kind commercial plant + Prototype and Demo if applicable				
Other Factors Influencing the Economics						
Plant Availability/Capacity		Value derived from design approach Will use typical MCF values (.75) as a starting value				
Cost Adjustment Factor up to 1991$		Use Gross National Product Implicit Price Level Deflators [1982 Basis]				

References for 3

1. R. C. Davidson, et. al, "Inertial Confinement Fusion Reactor Studies Recommended Guidelines," September 1990.

2. R. Bangerter, "Revised Target Information for ICF Reactor Studies," memo from R. Bangerter, February 1991.

3. W. J. Hogan, G. L. Kulcinski, Fusion Technology 8, 17 (1985).

4. The HIBALL studies are good examples. "HIBALL: A Conceptual Heavy Ion Beam Driven Fusion Reactor Study," UWFDM-450, University of Wisconsin Fusion Technology Institute (1981); see also KfK-3202, Kernforschungszentrum Karlsruhe (1981) and "HIBALL II: An Improved Heavy Ion Beam Driven Fusion Reactor Study," UWFDM-625, University of Wisconsin Fusion Technology Institute (1984); see also KfK-3480, Kernforschungszentrum Karlsruhe (1984) and FPA-84-4, Fusion Power Associates (1984).

5. The HYLIFE study is a good example. J. A. Blink, W. J. Hogan, J. Hovingh, W. R. Meier, and J. H. Pitts, Lawrence Livermore National Laboratory Report UCRL-53559, (1985).

6. The Heavy-Ion Fusion Systems Assessment (HIFSA) is a good example. Fusion Technology, 13, No. 2 (1988).

7. F. Najmabadi, "The ARIES-I Tokamak Reactor," 9th Topical Meeting on Technology of Fusion Energy, Oakbrook, Illinois, 7-11 October 1990)

8. R. O. Bangerter, J.W.-K. Mark, and G. Magelssen, "Simple Target Models for Ion Beam Fusion Systems Studies," LLNL Report UCID-20578 (1985).

9. J. H. Pendergrass, D. B. Harris, and D. J. Dudziak, Fusion Technology 13, 375 (1988).

10. "Nuclear Energy Cost Data Base: A Reference Data Base for Nuclear and Coal-Fired Powerplant Power Generation Cost Analysis," US Department of Energy Report DOE/NE-0095, September 1988.

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

12. J. G. Delene, "Updated Comparisons of Economics of Fusion Reactors with Advanced Fission Reactors," 9th Topical Meeting on Technology of Fusion Energy, Oakbrook, Illinois, 7-11 October 1990.

13. R. L. Miller, "Options and Optimizations for Tokamak Reactors: ARIES," 9th Topical Meeting on Technology of Fusion Energy, Oakbrook, Illinois, 7-11 October 1990.