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HYLIFE-II REACTOR CHAMBER MECHANICAL DESIGN: UPDATE

Palmer A. House

October 28, 1992

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HYLIFE-II Reactor Chamber Mechanical Design: Update

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October 27, 1992

Abstract

Mechanical design features of the reactor chamber for the HYLIFE-II inertial confinement fusion power plant are presented. A combination of oscillating and steady, molten salt streams (Li_2BeF_4) are used for shielding and blast protection of the chamber walls. The system is designed for a 6 Hz repetition rate. Beam path clearing, between shots, is accomplished with the oscillating flow. The mechanism for generating the oscillating streams is described. A design configuration of the vessel wall allows adequate cooling and provides extra shielding to reduce thermal stresses to tolerable levels. The bottom portion of the reactor chamber is designed to minimize splash back of the high velocity (17 m/s) salt streams and also recover up to half of the dynamic head. Cost estimates for a 1 GW_e and 2 GW_e reactor chamber are presented.

Introduction

HYLIFE-II is a design study of a 1 GW_e inertial confinement fusion power plant (Moir, 1992). A molten salt called Flibe (Li_2BeF_4) is used as a shield for neutrons and x rays and for heat transfer to the steam cycle. Flibe also serves to reduce blast effects on the vessel wall and as a medium for breeding tritium (used in the targets). The temperature of most of the vessel structure and the Flibe will be at 650°C. Construction material for the 6 m internal diameter vessel, Fig. 1, is 316 stainless steel.

Targets containing capsules loaded with nuclear fuel (D and T) are injected to the vessel centerline, then caused to implode by 12 heavy ion beams. The planned repetition rate for target detonations is 6 Hz. Between each shot the Flibe protective blanket must be regenerated and Flibe droplets in the path of heavy ion beams must be removed.

The subject of this updated paper is the mechanical design of the reactor chamber system. Three new sections have been added to the prior work (House, 1992): beam line shutters, cost estimation, and Flibe inventory.

Flibe Flow Circuits

Flibe shielding circuits inside the vessel vacuum chamber include oscillating flow, and steady flow. The remaining inside circuits are for spray nozzles and a shielding tray. Flibe spray inside the vessel increases the liquid surface area to aid in vapor condensation after each shot. The shielding tray provides an additional 50 cm of Flibe shielding to protect the oscillating flow deflector drive shafts from excessive heating and thermal stress. Two more circuits are contained in the vessel wall. They consist of a cooling circuit and a shielding circuit.

The vessel first structural wall (FSW) and other internal metal components require about 50 cm of Flibe shielding in order to obtain a 30 year lifetime, due to neutron damage. The shielding also provides blast protection and reduces neutron heating of the FSW. Oscillating flow is used to sweep out Flibe droplets from the previous shot and to create a pocket for the new shot. The pocket is bounded on two sides by the oscillating streams and closed at each end by steady streams. Twelve heavy ion beamline paths and the target injection path, at one end of the pocket are shielded by a series of vertical and horizontal streams as shown in Figure 2. Both the oscillating flow streams and the fixed flow streams at the other end of the pocket are made up of separate curved streams of Flibe. Line of sight shielding in any direction is assured by the stream curvature, and space between the streams allows venting of shot induced vapor. Rapid venting is necessary in order to reduce induced bulk liquid velocity toward the FSW, caused by the pressure of the unvented vapor.

Vessel Wall Configuration

The reactor vessel wall is necessarily complex in order to satisfy a number of requirements. The composite wall is a vacuum barrier and must also prevent tritium leakage to the atmosphere. In addition the wall is subjected to cyclic pressure loads and needs be cooled to carry away neutron heating thermal loads.

The FSW is made from 10 cm diameter tubes with a 1.2 mm wall thickness. The tubes are separated by 2.5 cm spacer bars, 1.2 mm thick, see Figure 3. This wall configuration lacks adequate hoop strength, so it is supported from the next shell by perforated rings spaced 30 cm apart. Shells No. 2 and 3 supply the required hoop strength.

Neutron heating of the tube metal is a maximum of 23.9 W/cm^3 (Lee, 1992). This results in wall heating of 2.9 W/cm^2 and requires turbulent flow inside the tube for cooling. A velocity of 1 m/sec results in a Reynolds No. of 28000, in the Flibe, which is well into the turbulent zone. Thermal stress in the tube is only 2.05 MPa. Spacers between the tube are cooled by conduction to the tube walls, a Flibe spray on the outside, and low velocity (0.26 m/s) Flibe on the inside.

This low velocity Flibe is 50 cm thick and provides additional shielding between the FSW and the second shell. Since the main function of this thick Flibe layer is neutron shielding, and not heat transfer, it does not require turbulent flow. Flibe pumping costs are reduced by having the shielding flow velocity lower than the cooling flow velocity. Neutron heating of shell No. 2 is reduced to 0.52 W/cm^3 by the extra shielding. This reduction in internal heating was necessary to reduce thermal stress in the relatively thick (2.5 cm) shell No. 2. With Flibe cooling on the outside surface, the maximum thermal stress is 18.1 MPa.

Shell No. 3 is 2.5 cm thick also and is separated from shell No. 2 by a 2.5 cm gap. Flibe flowing in this annular space at 1 m/s velocity will cool both shells. The internal neutron heating rate of 0.30 W/cm^3 in shell No. 3 results in a maximum thermal stress of 10.4 MPa.

A gap of 10.2 cm separates shell No. 3 and shell No. 4. This gap is filled with a permeable insulation to allow flow of a purge gas. Shell No. 4 is 1.6 mm thick and is supported from shell No. 3 by support rings spaced 46 cm apart.

Oscillating Flow

Oscillating flow in two opposed Flibe streams, subsequent to a shot, establishes a new pocket for the next shot. Pressurized Flibe is piped to two fixed nozzles inside the vessel where downward velocity of 12 m/s is established, see Figures 1 & 4. Streams from the nozzles enter an oscillating deflector system that is mechanically driven from outside the vessel. There is a small gap between the nozzle and the deflector. No seal is needed at this location as there is no change in pressure. Deflectors are 2 m in length from the shaft centerline and are rotated ± 2.5 degrees. Shaft centerlines are 1.2 m apart. Streams emerge from the opposed deflectors with sine wave motion and merge to form the pocket, Figure 1. As a new pocket is formed the previous one grows larger. Both the oscillating and fixed stream nozzles could be sectioned and supplied with lower temperature Flibe to form a lower temperature (475°C) shot cavity liner. The lower Flibe vapor pressure would provide lower density for beam propagation, if required.

Pressure from Flibe vaporization at shot time causes additional pocket expansion and breakup. The calculated envelope of Flibe particles with a 7 m/s shot induced motion of the pocket wall is shown in Figure 1. The 7 m/s Flibe velocity is at the upper range of velocities calculated (1.7 to 6.7 m/s), and the average velocity may only be 2.0 m/s (Moir, R. W. et al, 1991).

Oscillating Flow Mechanism

Flow deflectors are shaft driven from outside the reactor chamber.

A rotary seal system will need to be developed to prevent air from leaking in and tritium from leaking out, Figure 5. A Labyrinth seal inside the vessel will protect the first seal from Flibe liquid, but not Flibe vapor. Thus the first seal may need to run at a temperature above the freezing point of Flibe. Space between the first and second seals will be vacuum pumped to capture any tritium that leaks through. An inert gas at slightly above atmospheric pressure will occupy the space between the second and third seals. This will prevent oxygen from entering the differential vacuum pumping system. Rubbing surfaces for the seals are graphite and ceramic.

Each drive shaft is supported by two main bearings, one outside and one inside the vacuum chamber. Oil (or grease) lubricated radial and thrust bearings are used outside the vacuum chamber. A Flibe lubricated hydrostatic bearing is proposed for use inside the chamber. A graphite bushing could be used with a metal shaft. A layer of pressurized Flibe will prevent contact of the surfaces during operation. The large diameter (.914 m) thick (4.1cm) wall hollow drive shafts needed a total of 100 cm of Flibe shielding to reduce neutron heating to an acceptable level (0.48 W/cc). Thermal stress at this rate of heating is 43.1 MPa. The 100 cm of Flibe shielding is a total of 50 cm from the shielding streams and 50 cm from the shielding tray.

Both the deflector assembly inside the vessel and the crank outside are counter weighted for dynamic balance. The cranks are oscillated by a shaft with crank throws 180 degrees apart. Horizontally opposed connecting rods connect the crankshaft to the deflector cranks, see Figure 6.

The forces required to oscillate the flow deflectors are horizontally opposed and will consequently cancel out in the bearing block assembly. Only +/-2.5 degrees of travel of the Flibe deflectors are required. With careful balancing of the two oscillating assemblies, vibration transmitted to the vessel can be minimized. Design calculations indicate that the oscillating flow mechanism can be designed with stresses below the endurance limit.

Head Recovery System

The head recovery system has two main functions. The first one is to prevent splash and upward deflection of rapidly (> 12 m/s) falling Flibe streams. Partial recovery of the dynamic head, prior to the pump inlets, is the second goal. The design selected to accomplish both functions is shown in Figures 1 and 2. Downward moving Flibe, below the shot point elevation, will encounter a central cone, the vessel wall, or the turning vanes directly.

In all cases the flow is directed into the turning vanes where the direction is changed to near horizontal. After a small void zone, flow will join (and maintain) a rotating volume of liquid, see Fig. 4. Liquid then exits the annular volume at four locations and enters diffusers where velocity decreases and static head increases. On the average the liquid travels about a quarter of a turn before entering the diffuser. Each diffuser feeds three Flibe pumps, see Figure 7.

Efficiency of the head recovery section will need experimental evidence to determine. Following are estimates used to determine the head recovery for use in the pump power calculations.

<u>Efficiency</u>	<u>Process</u>
80 %	Losses due to adverse deflections and velocity mismatches prior to turning vanes.
86 %	Losses in non tangential exit of liquid from turning vanes.
86 %	Losses in non-tangential meshing of streams with the rotating liquid surface.
85 %	Loss in reservoir and diffuser due to friction and velocity mismatches.

Thus the overall efficiency of head recovery is:
 $(0.8)(0.86)^2(0.85) = .503$ or 50 %.

BEAMLINE SHUTTERS

The 12 heavy ion beam tubes need protection from Flibe liquid propelled by blast effects. It would also be desirable to prevent all of the shot generated Flibe vapor from entering the beam tubes but some amount is expected to get through.

The shutter design configuration is illustrated in Fig. 8 and Fig. 9. Two side by side 5.2 m diameter disks are rotated in vacuum at 360 RPM. They are driven by external electric motor drives. Rotary vacuum seals on the drive shafts prevent air from entering the reactor chamber. Twelve 0.14 m diameter holes in each disk are coincident with the beam tubes at shot time.

The large side by side disks are needed to obtain a fast (0.001 s) closing time without opening again until the next shot. Coaxial counter-rotating disks, centered on the beam lines, when rotated fast enough to obtain a 0.001 s closing time reopen several times before the next shot. The side by side disks when rotated in the same direction will block liquid particles when each disk has rotated half a hole. The 22.5 degree offset of the shaft center lines was required in order to prevent partial reopening of the beam line as the holes in the disks crossed each other and the beam line tubes. Operating clearance is needed for disk rotation, so they can impede vapor flow but not seal against it. The 0.001 s closing time will stop liquid particles from the nearest Flibe streams having velocities up to 1000 m/s.

A tube is provided at the center of the 12 beam line array for target injection. The target velocity is expected to be about 100 m/s (Petzoldt, 1992).

A slot provided in each disk will be in line with the injection tube when the target passes through.

Power Consumption

Operating the HYLIFE-II reactor vessel consumes a considerable amount of power. The main power requirement is for pumping Flibe. Another power requirement is to drive the oscillating flow deflectors. The deflectors add a time varying horizontal component to the Flibe velocity. This horizontal kinetic energy is dissipated and must therefore be supplied by a drive motor. If the motor were 90% efficient and the mechanical drive system 80% efficient then 0.38 MW of electrical power would be used for the deflectors.

Pumping power for the Flibe pumps was based on a differential head across the pumps of 17.4 meters. The outlet pump head of 25.4 m is a total of 7.4 m of velocity head at the nozzles, 10.5 m of lift and 7.5 m (Hoffman, 1991) of pipe friction and minor losses. The head recovery section of the vessel is estimated to recover 8 m of head at the pump inlet. Table I is a summary of the Flibe pumping flow rates and power. A pump efficiency of 80% (electrical to fluid) was used to calculate the drive power (31.5 MW_e total) needed. Most (81%) of the power used is for high speed (12 m/s) shielding flow inside of the vacuum chamber. The increase in Flibe flowrate and pumping power over that listed in previous work (Hoffman, 1991) is due to larger oscillating flow nozzles (to allow for beam path clearing), more wall flow and the addition of the shielding tray.

Cost Estimates

Cost estimates have been prepared for Account Number 22.1 and include the reactor, bypass ducts, pumps and motors. Results are shown in Table II for HYLIFE-II (2500 MW thermal) and in Table III for the Enhanced HYLIFE-II (5000 MW thermal). The basic method used was to calculate the weight of fabricated components and multiply by the Coal Standard of about 60 \$/kg for stainless steel piping (United Engineers & Constructors Inc., 1983). Components that would require more labor to fabricate were assigned higher cost per unit weight. Parts or sub-assemblies that would be purchased were estimated directly.

A recent decision by T. J. Dolan, et al. of INEL is that the Reactor Vessel and other components ahead of Flibe Vacuum Disengagers, in the balance of plant system, should meet Nuclear Standards, rather than the Coal Standard. This means that the totals for the Reactor and Bypass (BP) Flibe Ducts in tables II and III should be multiplied by a factor of 1.5 to reflect the INEL decision. Nuclear Standards were already incorporated in the costs for the BP Pumps and Motors.

Twelve 6.16 m³/s Flibe bypass pumps are used for HYLIFE-II and twenty bypass pumps are required for the Enhanced HYLIFE-II. For both power plants the bypass pumps and motors represent the largest cost entry. The method of pump cost estimation used in this report is probably not very accurate, and needs to be improved as more information becomes available.

Ruby Code cost equation for primary coolant pumps and motors:

$$C_{pcpm} = 1.35(P_{th}/(T_i - T_o))^{.74} \text{millions of 1988 \$'s.}$$

For 2500 MW_t and a delta T of 66 Deg. C and 4% inflation/year to 1990 \$'s,

$$C_{pcpm} = 21.5 \text{millions of 1990 \$'s.}$$

Flow rate of bypass pumps = 6.16(10.3) = 63.45 m³/s
(10.3 pumps are used for bypass flow
and 1.7 are used for flow to the
Balance of Plant (BOP) circuits)

$$\text{Flow rate of primary BOP coolant} = 3.43(3) = 10.29 \text{ m}^3/\text{s}$$

Cost estimation per pump and motor for 6.16 m³/s = C:
(The cost is determined by multiplying C_{pcpm} by
the ratio of flowrates raised to the .74 power,
then dividing by 10.3 to obtain the cost per
pump and motor)

$$C = (21.5(63.45/10.29)^{.74})/10.3 = 8.02 \text{ million dollars}$$

Flibe Inventory

The HYLIFE-II Flibe inventory for both the Reactor and the Balance of Plant (BOP) was obtained from an INEL report (Longhurst and Dolan, 1992). The reactor inventory for HYLIFE-II (452.8 m³) along with an estimated reactor inventory for the Enhanced HYLIFE-II (704.7 m³) is listed in Table IV.

Following is the method used to estimate the total Flibe inventory (2022 m³) for the Enhanced HYLIFE-II. Five complete BOP loops are used for the enhanced version of HYLIFE-II, compared to three BOP loops for HYLIFE-II.

$$\text{Total HYLIFE-II Flibe inventory (Longhurst and Dolan, 1992)} = 1243.2 \text{ m}^3$$

$$\text{HYLIFE-II Balance of Plant inventory} = 1243.2 - 452.8 = 790.4 \text{ m}^3$$

$$\text{Enhanced HYLIFE-II total Flibe inventory} = 704.3 + (5/3) * 790.4 = 2022 \text{ m}^3$$

Summary

The major design problems of the HYLIFE-II reactor chamber have been addressed. Shielding and first wall protection are provided by internal Flibe streams. These streams provide about 50 cm of Flibe thickness for FSW shielding. Debris in the beam path is cleared by oscillating flow as a new pocket is formed, prior to a shot. The oscillating flow mechanism will need a 350 kW drive motor. The total Flibe flowrate required is $72 \text{ m}^3/\text{s}$, and the pump drive motors will need to deliver 32 MW of power. The bottom section of the vessel is designed to prevent splashback and recover 50% (estimated) of the dynamic energy in the Flibe as it exits the chamber. The vessel wall is designed to handle a heat flux of 24 W/cm^2 at the first shell (made from tubes and spacers). An additional 50 cm of Flibe shielding reduces the heat flux to 0.5 W/cm^2 at the second shell (2.5 cm thick). The fourth shell is insulated from the high (650°C) temperature third shell and will serve as a tritium barrier. Beam line protection from Flibe liquid and vapor is accomplished with two rotating disks. The high temperature shaft seals for the deflector and rotating disk drive shafts will require careful engineering, fabrication and testing. Cost estimates for both the base and enhanced versions of HYLIFE-II are included.

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References

- United Engineers & Constructors Inc. (1983), "Energy Economic Data Base Program, Phase VI Update".
- Hoffman, M. A. (1991), "The Heat Transport System and Plant Design for the HYLIFE-II Fusion REactor", Fusion Technology 19, 625.
- House, P. A. (1992), "HYLIFE-II Reactor Chamber Mechanical Design", Fusion Technology 21, 1487.
- Lee, J. D. (1992), "HYLIFE-II Nucleonics Update, Revision 1", internal LLNL memorandum, Dated 7/2/92.
- Longhurst, G. R. and Dolan, T. J. (1992), "HYLIFE-II Tritium Management System", Idaho National Engineering Laboratory Report: EGG-FSP-9971.
- Moir, R. W. et al (1991), "HYLIFE-II Progress Report", UCID-21816, 4-24.

Moir, R. W. (1992), "HYLIFE-II Inertial Fusion Energy Power Plant Design", Fusion Technology 21, 1475.

Petzoldt R. W. (1992), Personal Communication, Lawrence Livermore National Laboratory, Livermore, CA 94550.

Schrock, V.E., Jin, H., and Peterson, P. F., (1992), "Spray Condensation System for HYLIFE-II", UCB-NE-4193, Sept.

Figure Captions

- Fig. 1. HYLIFE-II Reactor Vessel
- Fig. 2. Shot Point Plan View
- Fig. 3. Vessel Wall Construction
- Fig. 4. Flibe Shielding Streams
- Fig. 5. Flibe Deflector Drive Shafts
- Fig. 6. Deflector Drive System
- Fig. 7. Reactor Building - Plan View
- Fig. 8. Beam Line Shutters
- Fig. 9. Shutter Disks

Table Captions

- Table I. Flibe Pumping Parameters
- Table II. HYLIFE-II Reactor Cost Estimate
- Table III. Enhanced HYLIFE-II Reactor Cost Estimate
- Table IV. Reactor Flibe Inventory

FIGURE 1. HYLIFE II REACTOR VESSEL

FIGURE 2. SHOT POINT PLAN VIEW

FIGURE 3 VESSEL WALL CONSTRUCTION

FIGURE 4. FLIBE SHIELDING STREAMS

FIGURE 5. FLIBE DEFLECTOR DRIVE SHAFTS

FIGURE 6. DEFLECTOR DRIVE SYSTEM

FIGURE 7. REACTOR BUILDING - PLAN VIEW

Fig. 8 BEAMLINE SHUTTERS

Fig. 9 SHUTTER DISCS

Table 1. Flibe Pumping Parameters

FLOW CIRCUIT	FLOW RATE (m ³ /s)	PUMP POWER (MW)
Internal fixed nozzle	17.6	7.5
Internal oscillating flow	25.2	10.7
Beam shielding, vertical flow	9.2	3.9
Beam shielding, horizontal flow	10.8	4.6
Shell 1, tubes	1.1	0.5
Between shells 1 & 2	1.9	0.8
Between shells 2 & 3	0.4	0.2
Spray nozzles	7.1 *	3.0 *
Shielding tray	0.6	0.3
TOTAL	73.9	31.5

* Recent analysis (Schrock, Jin, and Peterson, 1992) has shown that a flowrate of only 1.2 m³/s is required for Flibe spray. Pump power at this flowrate would be 0.5 MW.

Table II. HYLIFE-II Reactor Cost Estimate

COST ESTIMATE: HYLIFE-II REACTOR, BYPASS DUCTS, PUMPS AND MOTORS

(ACCOUNT NUMBER: 22.1, COAL STANDARD, 1990 DOLLARS)

PART NAME	TYPE OF CONSTRUCTION	WEIGHT (kg)	COST:\$/kg or unit	# REQ'D -	COST (\$)
CYL.@BOT.OF CONE	ROLLED & WELDED	2244	60	1	134640
BOTTOM PLATE	WELDED	21790	60	1	1307400
HR TOP PLATE	WELDED	8720	60	1	523200
DIFF.PIPE, 2.2m	ROLLED AND WELDED	10629	85	4	3613860
DIFF. PIPE, 1.25m	ROLLED AND WELDED	1348	85	12	1374960
BOTTOM CONE	ROLLED AND WELDED	16880	60	1	1012800
TURNING VANE	ROLLED	467	60	50	1401000
TAPERED VES. WALL	WELDED TUBES&SPR'S	2280	100	1	228000
" " "	ROLLED AND WELDED	42950	85	1	3650750
STRAIGHT VES.WALL	WELDED TUBES&SPR'S	2290	100	1	229000
" " "	ROLLED AND WELDED	56230	85	1	4779550
UPPER SHELL&DOME	" " "	42220	85	1	3588700
SHIELDING TRAY	" " "	2800	60	1	168000
DEF'L. DR. SHAFT	FORGED & MACHINED	4925	100	2	985000
DEFLECTORS	FORMED AND WELDED	2320	85	2	394400
COUNTER WEIGHTS	WELDED HEAVY PLATE	1043	60	4	250320
SHAFT SEALS	SPECIAL ORDER		8000	6	48000
EXT BEARINGS	ROLLER BEARINGS		10000	4	40000
EXT.BRG. HOUSING	FORMED & MACHINED	6480	100	2	1296000
INT. BRG. HOUSING	FORMED & MACHINED	1010	100	2	202000
INT. BRG. BUSHING	MACHINED GRAPHITE	80	100	2	16000
OSC. SHAFT CRANKS	FORGED STEEL	3200	30	2	192000
CONNECTING RODS	" "	630	60	4	151200
DRIVE CRANK ASSY.	" "	2390	85	1	203150
GR. REDUCT. ASSY.	GEARS, ETC., HOUSING		160000	1	160000
DRIVE MOTOR	ELEC, 3PH, 1000 hp		80000	1	80000
INT. FLIBE DUCTS	316 ST STL	11260	60	1	675600
VACUUM PORTS	WELDED	320	85	2	54400
BLP FLIBE DUCTS	WELDED 316 ST STL	22520	85	1	1914200
REACTOR TOTAL =					28,674,130
BP PUMPS & MOTORS			8020000	10.3	82,606,000
BP FLIBE DUCTS	ROLLED & WELDED	26950	85	4	9,163,000

REACTOR, FLIBE PUMPS & MOTORS, AND DUCTS: TOTAL = 120,443,130

Table III. Enhanced HYLIFE-II Reactor Cost Estimate

COST ESTIMATE: ENHANCED HYLIFE-II REACTOR, BYPASS DUCTS,
PUMPS AND MOTORS

(ACCOUNT NUMBER: 22.1, COAL STANDARD, 1990 DOLLARS)

PART NAME	TYPE OF CONSTRUCTION	WEIGHT (kg)	COST:\$/kg or unit	# REQ'D -	COST (\$)
CYL.@BOT.OF CONE	ROLLED & WELDED	5229	60	1	313740
BOTTOM PLATE	WELDED	43580	60	1	2614800
HR TOP PLATE	WELDED	17440	60	1	1046400
DIFF.PIPE, 2.2m	ROLLED AND WELDED	17219	85	4	5854460
DIFF. PIPE, 1.25m	ROLLED AND WELDED	2184	85	12	2227680
BOTTOM CONE	ROLLED AND WELDED	39330	60	1	2359800
TURNING VANE	ROLLED	663	60	50	1989000
TAPERED VES. WALL	WELDED TUBES&SPR'S	3762	100	1	376200
" " "	ROLLED AND WELDED	100074	85	1	8506290
STRAIGHT VES.WALL	WELDED TUBES&SPR'S	3778	100	1	377800
" " "	ROLLED AND WELDED	131016	85	1	11136360
UPPER SHELL&DOME	" " "	84440	85	1	7177400
SHIELDING TRAY	" " "	5600	60	1	336000
DEF'L. DR. SHAFT	FORGED & MACHINED	6698	100	2	1339600
DEFLECTORS	FORMED AND WELDED	2320	85	2	394400
COUNTER WEIGHTS	WELDED HEAVY PLATE	1043	60	4	250320
SHAFT SEALS	SPECIAL ORDER		8000	6	48000
EXT BEARINGS	ROLLER BEARINGS		10000	4	40000
EXT.BRG. HOUSING	FORMED & MACHINED	6480	100	2	1296000
INT. BRG. HOUSING	FORMED & MACHINED	1010	100	2	202000
INT. BRG. BUSHING	MACHINED GRAPHITE	80	100	2	16000
OSC. SHAFT CRANKS	FORGED STEEL	4352	30	2	261120
CONNECTING RODS	" "	857	60	4	205680
DRIVE CRANK ASSY.	" "	3250	85	1	276250
GR. REDUCT. ASSY.	GEARS,ETC.,HOUSING		160000	1	160000
DRIVE MOTOR	ELEC, 3PH, 1000 hp		108900	1	108900
INT. FLIBE DUCTS	316 ST STL	15990	60	1	959400
VACUUM PORTS	WELDED	640	85	2	108800
BLP FLIBE DUCTS	WELDED 316 ST STL	22520	85	1	1914200
REACTOR TOTAL =					51,896,600
BP PUMPS & MOTORS			8020000	16.5	132,330,000
BP FLIBE DUCTS	ROLLED & WELDED	43659	85	4	14,844,060

REACTOR, FLIBE PUMPS & MOTORS, AND DUCTS: TOTAL = 199,070,660

Table IV. Reactor Flibe Inventory

<u>HYLIFE-II</u>	<u>Enhanced HYLIFE-II</u>	<u>Location</u>
(m ³)	(m ³)	-
75.0	87.5	Flibe below spray
8.0	16.0	Flibe Spray & header
45.0	74.4	Chamber walls
94.2	152.6	Bottom ducts
212.1	343.6	Bypass ducts
<u>18.5</u>	<u>30.6</u>	First wall ducts
Total = 452.8	704.7	

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