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PROPOSED DESIGN AND MASS PRODUCTION OF WIRE ARRAYS AND TARGETS FOR A Z-PINCH IFE POWER PLANT

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Proposed Design and Mass Production of Wire Arrays and Targets for a Z-Pinch IFE Power Plant

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Abstract. This paper summarizes the results of a detailed study reported in Ref. [1]. A concept for a 1000 MW(e) Z-Pinch IFE power plant has ten reactor chambers. A Load, consisting of a wire array surrounding a cryogenic dynamic hohlraum target with a 3-GJ yield, must be produced, inserted into a Replaceable Transmission Lines (RTL), transported to one of the chambers, and shot every second. The conceptual design of the load facilitates automatic mass manufacturing and insertion at 1 Hz at minimum cost. A sequence of operations necessary to (1) fabricate each wire array on a holding and insertion tool, (2) manufacture, evacuate, fill with DT, freeze, layer, and assemble each target with helium gas and liquid hydrogen, (3) insert a wire array and a target under vacuum into an RTL, and (4) remove their debris, is described. Detailed cost estimates derived for the complete load production and solid debris removal cycle in a commercial-scale facility are summarized.

1. INTRODUCTON

As explained in Refs. [1] and [2], the power plant has 12 reactors, 10 of which are operating continuously (Fig. 1). Assuming 30% efficiency, a new cartridge, composed of a Replaceable Transmission Line (RTL) containing a Z-Pinch load with a 3 GJ yield, must be placed into each reactor (Fig. 2) and shot every 10 seconds to produce 1000 MW of electricity. Therefore, a load, made up of a wire array and a cryogenic target, must be produced and inserted into an RTL every second.

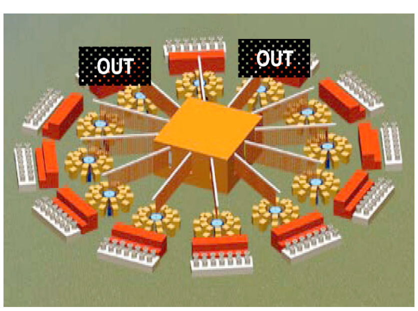

Figure 1. Plant Layout, from Ref. [2].

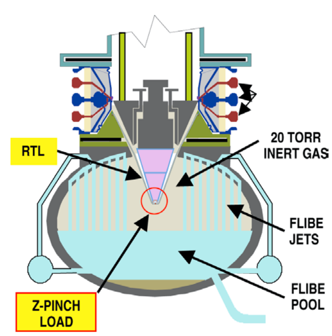

Figure 2. Reactor (cross section), from Ref. [2].

2. LOAD DESIGN

2.1. Wire Array

A wire array is composed of 300 tungsten wires with a 10-µm diameter that form a 100-mm diameter x 30-mm high cylindrical cage around the target assembly, shown schematically in Fig. 3(a). The wires, stretched at room temperature between two steel ring-plates, are inserted under vacuum into the open tip of the RTL and clipped to the RTL electrodes. During a shot, each wire array will convert stored electrical energy carried by the RTL into a burst of x-rays that ignites the target located at the center of the cage.

2.2. Cryogenic Target

The target is of the dynamic hohlraum type. Its DT fuel is frozen at ~18 K into a thin, very uniform ice layer on the inside surface of a 10-mm diameter x 0.3-mm-thick spherical beryllium capsule. The "layered" capsule is placed at the center of a 60-mm diameter x 30-mm high cylinder of open-cell, low-density, foam. To keep the fuel properly "layered" during load assembly and insertion, its temperature must not exceed ~19.7 K. Helium gas at 18 K is sealed at 3 Torr inside the foam cylinder by a polyimide film to conduct away the heat released by the beta-decay of the DT fuel to small steel reservoirs of LH_2 placed above and below. The thin tungsten layer surrounding the foam cylinder provides a "first strike liner" and contains the x-rays during the shot. Its low emissivity minimizes the radiation heat load absorbed by the cryogenic target from the RTL until the shot. The sealed cryogenic target assembly, placed on a pedestal of thermally insulating foam mounted on the steel RTL sealing plate, is inserted into the tip of the RTL under vacuum at the center of the wire array, as shown in Fig. 3(b).

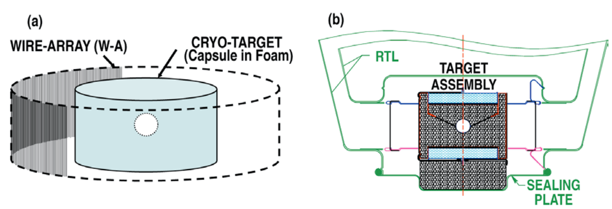

Figure 3. Z-Pinch load (cryogenic target assembly and wire array): (a) schematic, (b) in the tip of an RTL (cross section).

3. LOAD PRODUCTION AND INSERTION PROCESS

Figure 4 summarizes the main steps needed to produce and insert the 32 million Loads/year burn by the plant. The wire arrays are made by placing two ring-plates on a holder, mechanically winding a tungsten wire around them into a cage, cinching the wires onto the plates, and cutting off the excess lengths. For the targets, the carbonized resorcinol formaldehyde (CRF) foam parts are mass produced by pumping liquid foam mix into multi-cavity molds and curing; the fuel capsules are made by producing thin, hollow poly-alpha-methyl-styrene (PAMS) shells by wet micro-encapsulation and curing, coating them first with a thin film of glow discharge polymer (GDP) to obtain a very smooth and accurate surface, then with a layer of beryllium by sputtering.

Large batches of Be/GDP/PAMS shells are placed between dimpled platens, 5-µm diameter holes are laser drilled through the top wall of the shells through holes in the top platen, and the PAMS and GDP are removed through the holes, in an oven. The now empty beryllium shells are filled with DT by cryocondensation through their holes, then sealed by laser welding. Next, the fuel capsules are cooled and "layered" in helium gas fluidized beds, then assembled under vacuum at 18 K with the other target assembly components. Every 10 seconds, one of 10 robotic LIS receives a wire array and a cryogenic target assembly via loop conveyors, and insert them under vacuum into the tip of an evacuated RTL [Fig. 3(b)] to make a cartridge that is then sent to a reactor and shot.

The 104 tonnes per year of tungsten debris deposited as tungsten carbide by the Loads into the FLiBe liquid salt coolant are removed by adding 14 tonnes of 0.5-μm diameter tungsten carbide seed particles and filtering them out when they have doubled in size. The steel debris is removed together with the much larger quantities of RTL debris.

We modeled in detail the entire load production process shown in Fig. 4 by using recognized chemical engineering analysis methods. Our detailed cost analysis yielded a total load cost of 90 M$/year, or $2.90 per load, for production and tungsten debris removal. This cost must still be reduced by a factor 2 or 3 for economic feasibility.

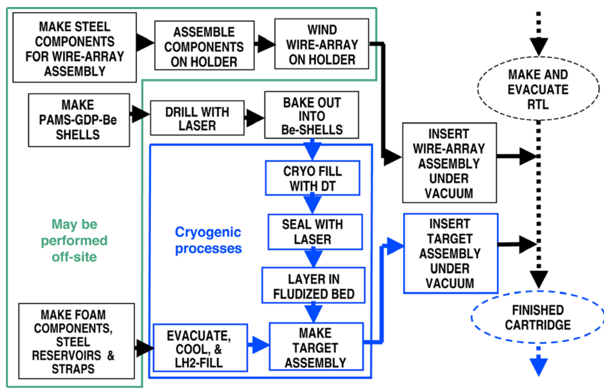

Figure 4. Load production and insertion process.

4. CONCLUSION

This short paper summarizes the results of the first comprehensive and detailed engineering study of load production for a Z-Pinch IFE power plant [1]. This study can serve as a basis to further develop and optimize the Z-Pinch load design and its mass production and insertion process.

ACKNOWLEDGMENT

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[1] R. Gallix, et al., "Z-Pinch IFE Task 2 - IFE Power Plant Technology - Load Production and Debris Removal, Final Report," General Atomics Report GA-A25247 (2005) http://web.gat.com/pubs-ext/AnnSemiannETC/A25247.pdf].
[2] C. Olson, et al., Fusion Sci. and Technol. **47**, 633 (2005).