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SUBMITTED FOR PRESENTATION AT THE
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DISCLAIMER

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SUMMARY

The purpose of this joint ORNL/Westinghouse Program is to develop a design concept for a tokamak reactor blanket system which satisfies engineering requirements for a utility environment. While previous blanket studies have focused primarily on performance issues (thermal, neutronic, and structural), this study has emphasized consideration of reliability, fabricability, and lifetime.

Based on the recommendation of a previous ORNL System Study[1], guidelines were established to emphasize the use of as much existing technology as possible. This approach led to restricting the design to concepts incorporating stainless steel for the structural material, liquid lithium for the breeding material, and pressurized helium as the coolant.

A preliminary reliability assessment of existing generic concepts concluded that a coolant circuit failure which could pressurize the module cannot be precluded. In addition, with the design goal for high neutron and particle heat flux (4 MW/m^2 and 1 MW/m^2, respectively), it was not possible to preclude burnout resulting from helium generated bubble formation causing thermal unbonding between the lithium and the first wall. Based on these concerns, the following additional requirements have been specified:

1. The blanket module structure must be capable of withstanding the full coolant pressure.
2. All critical blanket structure must be actively cooled.

An evaluation of previous work in the field, which included many different concepts, indicated none of these met the design requirements.

Given the above, a cylindrical module design concept was developed. The more significant design guidelines and characteristics of the module are presented in Table 1. The module consists of an outer cylinder (with a spherical nose first wall) surrounding an inner lithium-containing cylinder with pressurized helium flowing between these concentric cylinders.

To achieve added cooling of the first wall and maintain its temperature at the maximum of 450°C, it was necessary to incorporate two passes of coolant. Therefore, a double walled insulated flow baffle exists between the two cylinders. The coolant first pass is channeled between the outer cylinder and flow baffle to cool the outer cylinder and returns via the gap between the baffle and inner cylinder to cool the lithium inner cylinder (Figure 1). Inlet and outlet ports are provided for lithium and a central outlet tube is provided to remove helium generated by the reaction forming tritium. The modules are arranged in a close triangular pitch, to minimize void, in a tube sheet type support to form a subassembly containing several modules and the necessary piping and manifolds for helium and lithium. The close pitch and the large length to diameter ratio minimize concern for neutron streaming. The subassemblies are mounted into a D-shaped segment structure.

A detailed structural lifetime and performance assessment considering possible module failure and subsequent coolant leakage by fatigue crack growth or brittle fracture mode showed positive margins of safety which indicated these modes would not lead to failure for 10^5 operating cycles (approximately 3.5 years of operation). Simplified 1-D neutronics calculations indicated a > 1.1 breeding ratio. A less detailed investigation of other than normal operating conditions and incorporation of a divertor was performed. A positive margin of safety was predicted for these cases also.

Based on the effort to date, we conclude that this concept is a viable approach for further development. We also conclude that stainless steel continues to be a viable candidate for the structure of helium cooled liquid lithium blankets operating for 10^5 cycles. In addition, reasonable thermal performance and tritium breeding can be achieved. Since the effort to date focused primarily on developing a reliable basic module, additional effort is required to incorporate the module into an integrated blanket system. The impact on reliability of a blanket containing a large number of small modules needs further evaluation.

REFERENCE:

1. Steiner, D., et al., "ORNL Fusion Power Demonstration Study: Interim Report," ORNL/TM-5813, March 1977.

TABLE 1

KEY DESIGN GUIDELINES AND MODULE CHARACTERISTICS

Design Guidelines	
Structural Material	Type 316 Stainless Steel, 20% CW
Coolant	Pressurized Helium
Breeding Material	Liquid Lithium
Fusion Neutron First-Wall Loading	4 MW/m^2 (w/o Divertor)
Pumping Power, $\left(\frac{\text{Pump Work}}{\text{Thermal Output}}\right)$	$\leq$ 2 - 2.5%
Tritium Breeding Ratio	$\geq$ 1.2
Duty Cycle	20 Min Cycle, 95% Duty, 10^5 Cycles
Structural Material Temperature Limit	$\leq$ 450° (First Wall)
Design Characteristics	
Module	∿ 10 cm O.D. x 75 cm Long
Material Thickness	
Outer Cylinder	0.16 cm
Inner Cylinder	0.16 cm
Flow Baffle	Double Thickness, 0.038 cm each
Performance Characteristics	
Module Thermal Power	45.1 KW/Module
Coolant Pressure	54.4 atm
Coolant Temperature T_{in}, T_{out} (°C)	200, 435
Coolant Flow	35 g/s
Flow Channel Gaps	
Inlet Pass (Variable)	0.127 cm - 0.076 cm
Outlet Pass (Constant)	0.127 cm
Material Temperature (°C, Max)	
Outer Cylinder	452
Inner Cylinder	492
Tritium Breeding Ratio	> 1.1
Pumping Power, $\left(\frac{\text{Pump Work}}{\text{Thermal Output}}\right)$	2.2%

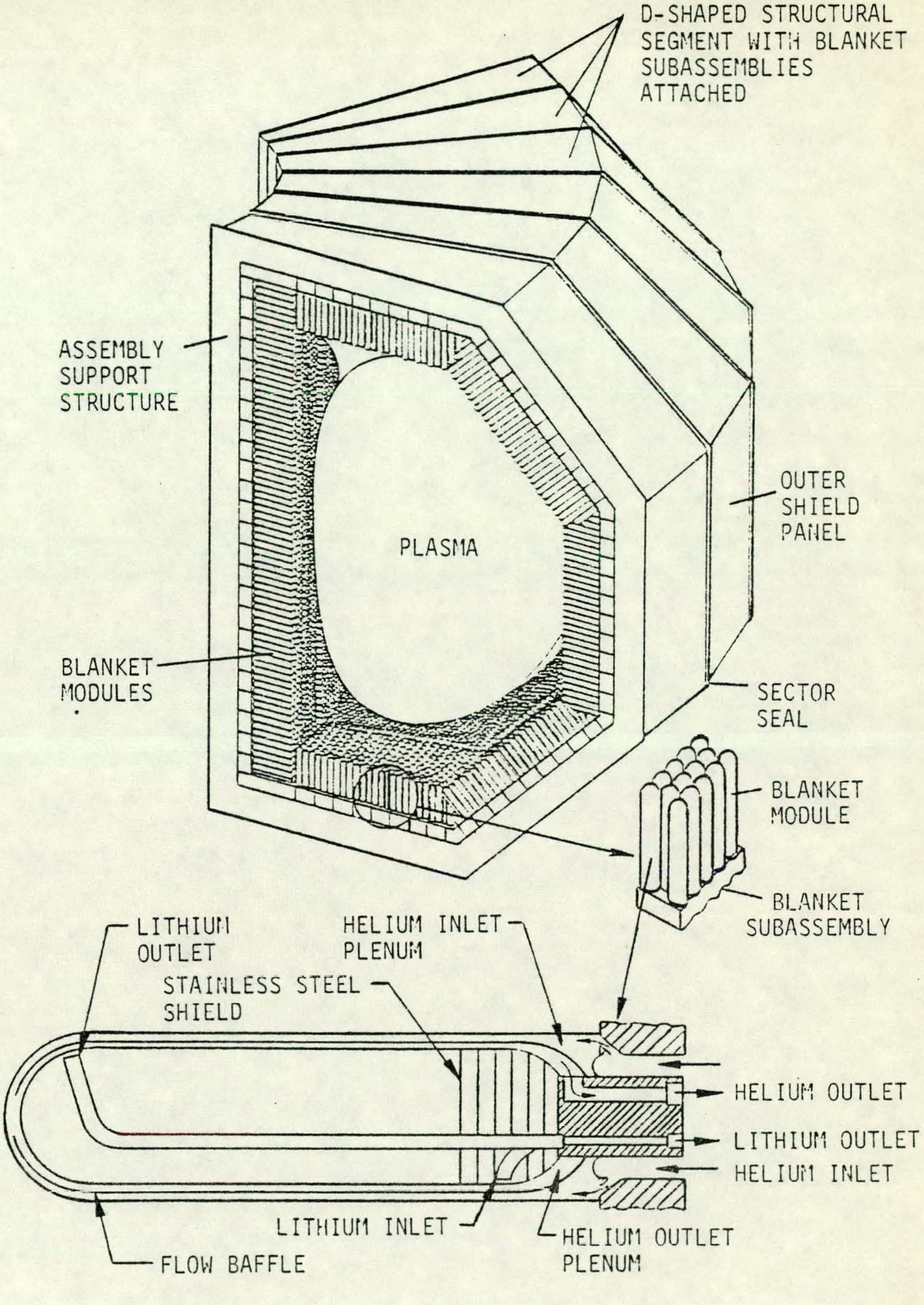

Figure 1. Blanket Sector Assembly Concept