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MARS HIGH-TEMPERATURE BLANKET

TRW, INC.

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Lawrence Livermore Laboratory

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The MARS high temperature blanket is designed for the dual applications of either high efficiency electricity production or process heat for synthetic fuel production. Other blanket des n goals are tritium self-sufficiency, low tritium inventory, mo than 40% of the blanket energy extracted at high energy, long lifetime in the neutron environment, no use of reactive liquid metals, minimization of long term activation and use of characterized mat ials and fabrication techniques. This challenging set of goals has been met with a novel blanket design that uses radial zoning and the unique properties of the lead-lithium eutectic, $Pb_{83}Li_{17}$, as a coolant/neutron multiplier/breeder. During the first year of MARS, the blanket design was optimized for electricity production. A reoptimization for the synthetic fuel application is in progress.

Twenty-four blanket modules, each 6.32 meters long, make up t tandem mirror central cell. An isometric of the module is sho n in the figure. The modular design allows rapid changeout of all central cell components. The blanket is radially zoned to maintain the metallic structure at moderate temperature. The front zone of the blanket has an HT-9 ferritic steel structure cooled by $Pb_{83}Li_{17}$. HT-9 was chosen because of its excellent mechanical properties, low swelling, compatibility with $Pb_{83}Li_{17}$ and relatively low long term activation. The $Pb_{83}Li_{17}$ cools the structure to a maximum temperature of 520°C while also serving as a neutron multiplier and supplemental tritium breeder. About 52% of the energy incident on the blanket is deposited in the front radial zone. A small heat leak from the high temperature zone, causes 54% of the energy to be extracted in the $Pb_{83}Li_{17}$ coolant. The $Pb_{83}Li_{17}$ enters the blanket at 372°C and exits at 482°C. The upper temperature was chosen for HT-9/$Pb_{83}Li_{17}$ compatibility and for thermal creep reasons. The lower temperature was chosen to minimize radiation embrittlement of the steel. The key radiation effects problem is shift of DBTT or radiation embrittlement; this problem is amelioriated by sixty hours of annealing at a uniform temperature of 450°C performed during an annual maintenance period.

The high temperature blanket zone is composed of 12 circumferential HT-9 pods that are thermally insulated from the energy absorbing material. A porous silicon carbide (80% TD) pebble bed impregnated with 2 atomic % enriched $LiAlO_2$ is used for energy absorption. Placing the tritium breeding material in the high temperature zone increases the fraction of high temperature heat. Enriching the breeding material to 90% in ^6Li allows it to be present in low concentration and eliminate sintering of the breeder. The zone is cooled by 80 atmosphere helium with an outlet temperature of 900°C. The maximum pebble temperature is about 980°C. This high temperature increases the speed of tritium diffusion and allows moderate $LiAlO_2$ grain sizes of 50 µm. The preclusion of thermal sintering and the insolubility of tritium in SiC along with fast thermal diffusion results in an estimated tritium inventory in the blanket of 25 g for 3500 MW of fusion power. This new concept of enriched $LiAlO_2$ in a SiC matrix has significantly improved the performance of high temperature blankets.

The MARS blanket is designed for a neutron wall loading of 5 MW/m^2 accompanied by a surface heat flux of 6 W/cm^2. Neutronics analyses show that the tritium breeding ratio at beginning of life is 1.13; the TBR decreases to 1.06 after 4 years. Energy multiplication is 1.15. About 90% of the tritium breeding occurs in the $LiAlO_2$ with the rest occuring in $Pb_{83}Li_{17}$. Radiation damage to the first wall is at 70 dpa/full power year. However, the radiation resistance of HT-9 combined with a swelling-tolerant design should allow a lifetime in excess of 200 dpa or 4 calendar years.

The blanket has been integrated with a combined Brayton and Rankine energy conversion cycle to produce electricity with a thermal efficiency greater than 45% including helium compression and pumping and lead-lithium pumping. The combination of high thermal efficiency and reasonable blanket costs result in a relatively low cost of electricity. Blanket costs are dominated by the cost of silicon carbide. Blanket producibility studies have shown that the design is fabricable with standard techniques that are in current practice.

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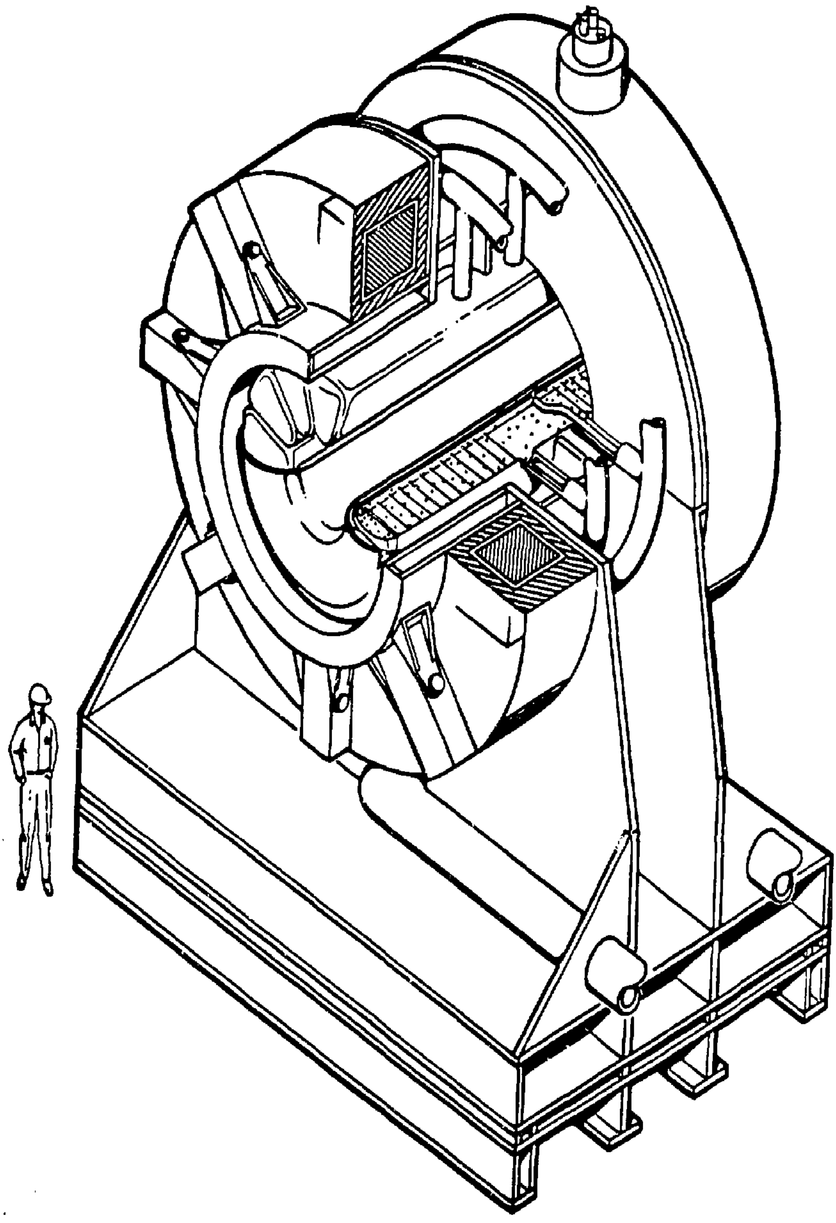

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We prefer oral presentation

Topic: Blanket and First-Wall Engineering