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UCRL-15376
S/C 5817009

CONF-811103--40

OPTIONS; THE JADE REACTOR AND HEAT
TRANSFER BY HEAT PIPES

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American Nuclear Society
San Francisco, CA
November 29, 1981

August 10, 1981

Lawrence
Livermore
Laboratory

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Liquid metal walls (LMW) were introduced in inertial confinement fusion (ICF) reactor design in order to protect the first wall from surface damage due to soft x-rays and ionic debris and from internal damage due to hard x-rays and neutrons. If the concept is successful it will allow longer, perhaps permanent, wall life with the consequence of less maintenance, some relaxed design criteria, reduced occupational exposure to radioactivity and reduced activated waste. Presently available materials may be able to be used for the first wall. Difficulties with the LMW include the ubiquity of liquid in the reactor after its firing with the subsequent problem of effecting a rapid recovery of cavity initial conditions before the next shot. Accomplishing such a recovery entails large pumping requirements. Other problems faced are high gas pressures due to the vaporized fluid and impact stresses on and erosion of the wall due to fluid momentum.

The JADE reactor is a new Lawrence Livermore National Laboratory (LLNL) concept¹ which maintains advantages of LMWs and addresses some of their problems. The concept envisions a porous medium, called the jade, of specific geometry lining the reactor cavity. Its purpose, among others, is to increase the residence time (above the HYLIFE free fall time)² during which the liquid lithium (Li) shield and coolant is in the chamber, thus reducing the pumping power

and cost requirements on the primary heat transfer system. Furthermore, a porous wall will, in principle, quickly and simultaneously replenish all exposed surfaces with liquid Li before the next shot, a necessity if low target gains require high repetition rates in ICF reactors. Also, the jade is designed to convert the kinetic energy of the fluid to thermal energy before it reaches the first wall. Finally, its particular geometric shape is used to minimize reaction forces on the first wall due to blow-off caused by soft x-rays and debris, to provide empty spaces for fluid expansion after neutron energy deposition where droplets collide with droplets cancelling their kinetic energies, and to provide large surface areas for rapid condensation of vapor.

LLNL also suggested that heat pipes might be used to eliminate portions of the primary or secondary coolant loops, thereby reducing pumping requirements found in current reactor designs.

The Bechtel Group, Inc. was directed by LLNL to make an initial evaluation of these reactor options.

Initially an annular jade composed of consolidated fibers was assumed to line the inside of a cylindrical reactor. Darcy's linear and Ergun's nonlinear flow laws indicated that when used in a medium of high permeability (~90%) a fiber size from 0.01 to 1 mm might allow a jade to operate under only moderate pressurization. The interior of an ICF reactor is far from static, so the above steady state laws must not be relied on too heavily even during the quiescent time between shots. Furthermore, the fluid is not homogenous, and the development of gas in the liquid Li can not be neglected (although one can

attempt to treat the phases of a heterogeneous fluid separately as being homogeneous).

The actual shape of the jade structure in a cylindrical chamber will resemble a set of vertical fins making an angle ϕ with the radius vector in the horizontal plane. Horizontal rib planes will support the fins. The surface area exposed to soft x-rays and debris may be 5 to 10 times that of the cylinder. Between the fins and the cylinder wall will be an annular cellular section whose porous walls are, as the fins, laden with Li. This section will provide adequate fluid for neutron energy deposition and empty cells into which the fluid can expand, dissipating its mechanical energy into thermal energy by fluid-fluid collisions.

The difficulty of adequately modeling the complex geometry and the dynamic, nonlinear nature of the problem must be met before final conclusions on the JADE reactor can be reached. But the promise of solutions to major LMW problems that this concept offers is incentive to carry the idea forward.

Typically the maximum flux that heat pipes carry is $\sim 10 \text{ MW/m}^2$. For a 3.8 GW_t reactor a rectangular array of pipes measuring 10 m by 76 m would be needed. Therefore, pipes carrying much higher fluxes must be used. Only the use of Hg as the working fluid in heat pipes can offer the possibility of managing the power of a reactor. This high flux requirement and other issues such as materials compatibility, maintenance requirements, and pipe lifetime makes the application of pipes unattractive.

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Part of this work was performed for University of California, Lawrence Livermore National Laboratory under the auspices of the U.S. Department of Energy, contract No. W-7405-Eng-4B