Experimental Evaluation of a Water Shield for a Surface Power Reactor

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INTRODUCTION

As part of the Vision for Space Exploration the end of the next decade will bring man back to the surface of the moon. One of the most critical issues for the establishment of human presence on the moon will be the availability of compact power sources. The establishment of man on the moon will require power from greater than 10's of kWt's in follow on years. Nuclear reactors are extremely well suited to meet the needs for power generation on the lunar or Martian surface.

Shielding is a key component of any surface power reactor system. Several competing concepts exist for lightweight, safe, robust shielding systems such as a water shield, lithium hydride (LiH), Boron Carbide, and others. Water offers several potential advantages, including reduced cost, reduced technical risk, and reduced mass. Water has not typically been considered for space reactor applications because of the need for gravity to remove the potential for radiation streaming paths. The water shield concept relies on predictions of passive circulation of the shield water by natural convection to adequately cool the shield. This prediction needs to be experimentally evaluated, especially for shields with complex geometries. MSFC has developed the experience and facilities necessary to do this evaluation in the Early Flight Fission - Test Facility (EFF-TF).

EXPERIMENT DESCRIPTION

The testbed is comprised of a core simulator that simulates the reactor vessel and everything inside (core, reflector, control drums, coolant manifolds, etc.), and the outer tank that forms the outer boundary of the water shield. The testbed is unpressurized, and has a simple 2.5" thick foam lid. Both the core and lid can be moved vertically to accomodate different shield configurations (Figure 1).

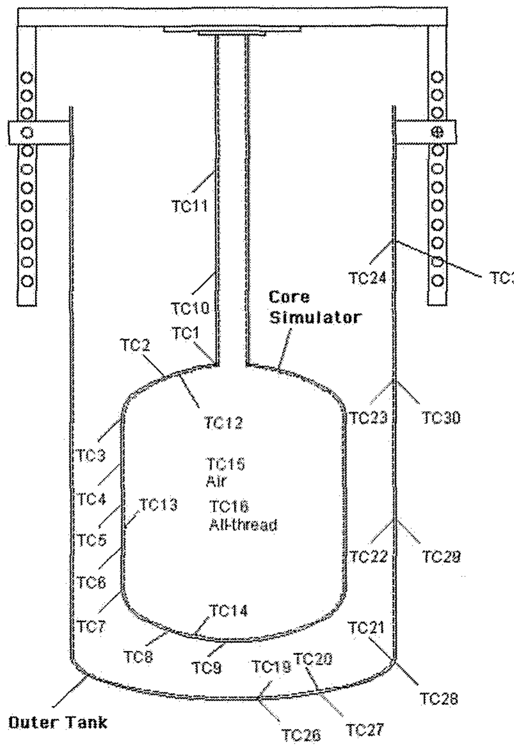

Fig. 1. Schematic of the Testbed with thermocouple placement and numbering.

The thermal load on the water shield is supplied by heaters on the inner surface of the core simulator in three 'zones' with a maximum total power of 18.8 kW. This thermal load represents thermal heat from the reactor vessel, and neutron heating in the water. It is assumed that the majority of the neutron heating in the water occurs close enough to the reactor vessel to make the simulator relevant. This assumption is conservative, since one of the major questions to be answered is whether the natural convection is strong enough to handle the thermal load.

Heat removal from the outer tank is accomplished with natural convection in still air at room temperature. This is sufficient for the initial run of tests, that used a total heat load of 2 kW. Future tests will incorporate forced convection and/or heat pipes for larger heat loads and better control of the boundary.

RESULTS

Three test cases have been run and evaluated using the testbed. The nominal case is based on a SNAP derivative reactor, with a predicted thermal load in the water shield of 2 kW. One case was run at ½ nominal power, and the third was run with 0.33 kW to match the Rayleigh number for the nominal thermal load in lunar gravity. The results are presented in Figure 2.

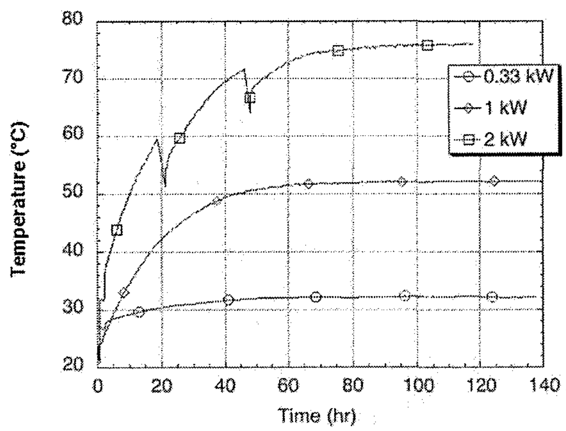

Fig. 2. Representative data from three cases (TC4).

Note the two temporary power failures in the nominal case. In all cases the time to reach steady state is approximately 80 hours. These results demonstrate the effectiveness of natural convection in removing heat from the core. Higher fidelity tests are being planned, with more prototypic heat removal from the shield. Further work is also being done to detrmine other relevant similarity parameters that will allow the testbed data to be extrapolated to lunar conditions.