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For The Atomic Energy Commission

H. F. Canale
Chief, Declassification Branch

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COMMENTS ON BOILING SLURRY
BLANKETS FOR HOMOGENEOUS REACTORS

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Comments on Boiling Slurry Blankets for Homogeneous Reactors

SUMMARY

The advantages and problems associated with employing boiling as a method of power removal from the ThO_2 slurry blanket of large two region homogeneous reactors is examined in the light of existing information. It is concluded that boiling is the most promising of the systems of energy removal principally because of the simplicity attained in keeping the slurry within the blanket vessel and elimination of mechanical pumping of the slurry.

It does not appear desirable to adapt a boiling blanket as a modification of the present HRT design. A large fraction of the experience and information required for design of a boiling blanket will be obtained from operation of the presently planned circulating slurry blanket.

GENERAL FEATURES OF THE BOILING BLANKET

Physically, the arrangement of core vessel assembly is similar to that for a circulating system. The differences are the inclusion of a draft tube to guide the natural circulation and possibly separators at the free surface to aid in disengagement of the vapor from the circulating slurry. The blanket thickness would be greater to compensate for the vapor fraction (estimated to be in the range of 10 to 20 per cent at design power for a system such as the TBR) and the decreased density due to increased operating temperature. The separated vapor would be sent to a condenser and the resulting condensate returned to the blanket.

The apparent advantages of this system are:

1. No circulating pump handling slurry would be required.

2. Circulation velocities in the blanket in the range of 2 to 10

fps. These appears sufficiently great to keep the slurry suspended in critical regions, such as the turn at the bottom and still sufficiently low so that erosion is not a difficulty.

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3. The high activity material remains in the blanket vessel; the heat exchanger receives only D_2O vapor and any fission product gases that might be carried along.

4. About 3 points improvement in thermodynamic efficiency of the power plant cycle if the blanket is operated at core pressure and the blanket power is employed for superheating the secondary steam (see CF-55-3-57).

5. Possible use of the blanket system as a core pressurizer.

MAJOR PROBLEMS AND UNCERTAINTIES

For steady state operation at design power, there seem to be no major uncertainties. The relationship between the power removal rate and the mean density of the boiling slurry mixture can be calculated with sufficient accuracy for preliminary design particularly since there is some latitude in the choice of blanket thickness and ThO_2 concentration. In this direction some small scale mockup experiments might be of help. Little is known about the circulation properties of a boiling slurry in the temperature range of 300 to $335^{\circ}C$ but a boiling ThO_2 slurry has been circulated in a small glass boiling loop at $100^{\circ}C$ for about 3 months without caking or redispersal difficulties upon shut down. Some foaming was in evidence but it would appear that, if necessary, washing with condensate would keep it under control.

Recombination of radiolytic gas does not appear to present difficulty. If high pressure recombination is employed, the main condenser could be followed by an after condenser with, say, a catalytic recombiner between the two condensers. The catalyst bed would be cooled by steam. The after condenser would provide the pressure drop required to force the vapor-gas mixture through the bed. If low pressure recombination is employed, a bleed flow from the top of a single condenser could be used to feed the recombiner and maintain a non-explosive mixture at the top of the condenser.

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The major problem seems to be associated with keeping the slurry suspended during the start-up operation. Assuming a non-settling slurry is not developed, the following appear to be possible solutions to the problem:

1. Bubbling a gas through the riser under start-up and low power operation (a gas lift). A relatively small throughput of gas is required to maintain sufficient slurry circulation. In this system the gas leaving the top of the blanket passes through the condenser where water vapor it has picked up is condensed and then into a compressor which returns it to the riser inlet. As operating temperature is approached, the gas flow required to maintain circulation gradually decreases since vapor evaporating into the gas bubbles increases their volume and hence the buoyant force required for circulation. Incidentally, this arrangement permits the blanket to be operated over a range of temperatures up to saturation, although only at part power.

2. Provide an auxiliary heat source to bring the blanket to boiling temperature at a low pressure and then bring the entire system to operating conditions. Besides requiring what appears to be a considerable amount of auxiliary heat, this system would require particularly careful programming of reactor start up.

3. Circulation of the slurry by means of a pump during start up. While this system would not require pumping the slurry through the heat exchanger and the pump would be used only during start up, a certain measure of simplicity inherent in the boiling system would be sacrificed. In addition, for at least a fraction of the time, the pump would be required to operate at a condition near saturation, which is an unfavorable one.

Of the various arrangements the first, gas bubbling, appears most satisfactory.

As a whole, the boiling slurry blanket gives promise of dependable and economic operation. A schematic diagram of a possible arrangement is shown in

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Fig. 1. Of course, to obtain a quantitative measure of desirability of a boiling blanket, a study should be made in which it is adapted to a specific reactor such as the TBR.

BOILING BLANKET FOR HRT

In a preliminary way, Si Jaye looked at the problem of adapting a boiling blanket to the HRT. He found that at a pressure of 2000 psia and a power of 660 kw, the blanket would operate at about 5% vapor. Under these conditions, there is some question as to whether the circulation velocity is sufficiently high to re-suspend slurry that has settled near the bottom of the blanket. In any event, some scheme to augment circulation such as discussed above would be required since it would be expected that a substantial fraction of the time the blanket power would be below the postulated design power.

As a whole, it appears that a boiling blanket could be satisfactorily employed on the HRT. However, a review of the overall objectives in employing a ThO_2 slurry blanket on the HRT and the current status of the program indicate that it would be undesirable to use a boiling system on the HRT in any of its subsequent modifications. The argument runs as follows:

1. Most of the uncertainties in handling a slurry are common to both the non-boiling and the boiling blanket systems. For an experimental system in which a large fraction of operating time will be under off design conditions, the forced circulation non-boiling system possesses greater flexibility. In any case some experience with a boiling slurry will be obtained since it is expected that circulation in the dump tank will be maintained by natural circulation boiling.

2. One objective of the HRT is to determine the breeding ratio and compare it as nearly as possible with results obtained from available methods of calculation. The density decrease resulting from both the vapor and the

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Fig. 1 Schematic Diagram of a Possible Boiling Blanket System

increased operating temperature (280°C to 335°C) in addition to the need for a draft tube in the boiling system would additionally complicate the interpretation of results.

It appears, then, from the standpoint of demonstrating the feasibility and desirability of a boiling blanket, little would be gained from adapting one to the HRT and complication in interpreting some of the experimental data would result. The only development which would appreciably alter this conclusion would be if unusual difficulties were encountered in circulating slurry with pumps or through a heat exchanger. In any case, it would seem desirable to obtain experience in pumping active slurry through the heat exchanger and associates equipment under actual reactor conditions.

CONCLUSIONS

Preliminary investigation indicates that boiling as a method of power removal from the blanket of large two region homogeneous reactors promises greater operating reliability under at least as favorable and possibly more favorable power cost conditions when compared with equivalent circulating blanket reactors. It is desirable to study the application of a boiling blanket to a particular full scale system such as the TBR to establish a quantitative comparison of the boiling vs. the single phase circulating system.

It appears a large fraction of the information and experience required to design a boiling slurry blanket for a large system can be obtained from operation of the HRT with a circulating non-boiling blanket. It does not presently appear economical of effort to plan operation of a modification of the HRT with a boiling blanket.

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