INVESTIGATIONS ON PRODUCTION OF $^{233}$U USING FEW PIN THORIA IN EXISTING PHWRs
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INTRODUCTION
Thorium is not a fissile material and cannot be used to either start or sustain the chain reaction. Therefore, a reactor using thorium would also need either enriched uranium or plutonium to sustain the chain reaction until enough of the thorium has converted to fissile $^{233}$U. In order to retrieve and reprocess the irradiated fuel, the bundle is designed with few thorium pins and rest SEU pins. In the present study, different pin configurations of thorium in 19 and 37 element fuel clusters of Indian PHWRs have been considered as follows:

1. 19 pin fuel cluster used in 220 MWe PHWR (Figure-1):
   (a) Thorium in central pin and 1.2% SEU in remaining outer 18 pins,
   (b) Thorium in central 7 pins and 2.2% SEU in remaining outer 12 pins.

2. 37 pin fuel cluster used in 540 MWe PHWR (Figure-2):
   (a) Thorium in central pin and 1.05% SEU in remaining outer 36 pins,
   (b) Thorium in central 7 pins and 1.38% SEU in remaining outer 30 pins.

RESULTS AND DISCUSSIONS
The lattice calculations have been done using the multi-group transport theory code CLUB\textsuperscript{[1]}. The variations of $k_{\infty}$ versus burn up are shown in figures-3&4. The production of $^{233}$U (considering also the decay of $^{233}$Pa into $^{233}$U) is shown in figure-5&6. From these lattice calculations, the requirements of the fuel have been summarized in Table-1. Burn up optimization studies have been done using different bundle shift schemes. Bundle power envelopes\textsuperscript{[2]} have also been worked out and been found to be much lower than the BP envelope for NU bundles (Figures-7&8).

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Table-1: Summary of fuel requirements

<table>
<thead>
<tr>
<th>Burn up Optimization Study</th>
<th>Requirement</th>
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<tr>
<td>1 pin Thoria</td>
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<td>7 pin Thoria</td>
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<td>NU</td>
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Figure-1: 1 pin and 7 pin thorium configurations for 19 pin fuel cluster
Figure-2: 1 pin and 7 pin thorium configurations for 37 pin fuel cluster
Figure-3: Variation of $k_{\infty}$ for 19 pin fuel cluster
Figure-4: Variation of $k_{\infty}$ for 37 pin fuel cluster
CONCLUSION
Average discharge burn ups of the order 20 and 17 GWd/Te can be achieved with the use of thorium pins in 19 and 37 element fuel clusters respectively with appropriate bundle shift scheme. Derating of power is required during operation because of bundle power restrictions. It is found that 1 pin thorium configuration is preferable from the point of view of fuel requirements and power reduction consideration. Since 37 element fuel cluster used in 540 MWe PHWR fuel has large margins in bundle power, the restriction in power operation is much less than 19 element fuel cluster used in 220 MWe PHWR.

REFERENCES