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Research Reactors Performance and Safety: Computer Exercise Instructions

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<u>Purpose:</u>

Use of TRIGLAV code for practical fuel management problems in a typical TRIGA research reactor.

<u>Assumptions:</u>

You are in the position of reactor manager, responsible for economic fuel utilisation and operation within the safety limitations.

Your reactor is a TRIGA with circular fuel mesh (rings A, B, C, D, E, F and cylindrical graphite reflector), irradiation channel in central position (A-01), neutron source in outer most ring (F-07), four control rods, always withdrawn during operation (water in their place). Control rod positions in the core are fixed to C-04, C-10, D-01 and D-10.

<u>Limitations:</u>

Total reactor power **750 kW**
Maximum fuel element power **15 kW**
Excess reactivity (zero power, no Xenon conditions) 7% ($\mathbf{k_{eff} < 1.07}$)

<u>Fuel Management Assumptions:</u>

Economic fuel utilisation with maximum achievable discharge burnup.

Initially available 85 fuel elements of Standard 8%Uranium concentration type (fuel elements denoted ST8 with id numbers from 0101 to 0185). Operation with ST8 core as long as possible. When operation at full power and equilibrium xenon no longer possible, 20 fuel elements of LEU type purchased (fuel elements with id numbers from 0201 to 0220) and introduced into the core. Operation with mixed core as long as possible.

<u>Running the TRIGLAV Program:</u>

- Under **Windows** copy **Triglav** directory from your **Home** directory to **Desktop**.
- Open MS-DOS window using **`DOS triglav`** icon in **Triglav** directory on **your** Desktop.
- Copy prepared input files: `copy ictpcore.inp triglav.inp`
  `copy ictpelem.inp elem.inp`
- Run the TRIGLAV program: `triglav`
- After program completion use text editor to open `triglav.out` output file.

Exercise Procedure:

1. Consider first critical core loading configuration (fresh fuel, first criticality, and all control rods withdrawn). By definition critical core k_{eff} equals one. Find calculated k_{eff} in output file. Compare calculated k_{eff} to the experimental value ($k_{eff} = 1.0000$). Why the difference?

In our case (ictpcore.inp) k_{eff} was calculated with arbitrary axial buckling (e.g. $B^2 = 0.001\ cm^2$).

2. Adjust axial buckling in the input file (triglav.inp) until calculated k_{eff} equals approximately one. Axial buckling is defined after keyword `$* BUCKLING`. After changing buckling run the TRIGLAV again and observe the change. Repeat the procedure until calculated reactivity is approximately zero.

Expected result: $B^2 \cong 0.005$

3. Add fuel elements to the critical core for operation at full power, equilibrium Xenon conditions (`$* POWER 750.0 $* XENON 1`). For example add 6 new elements to F-ring. Find core loading pattern in triglav.inp file and replace water unit cells (`LW`) in locations from `F-19` to `F-25` with new fuel elements id numbers (from `0163` to `0168`).

After running TRIGLAV check if the `power per element` is less than 15 kW for all fuel elements. Respect limitations! Adjust the number of fuel elements or reduce maximum reactor power if necessary.

Expected result: there should be at least 80 fuel elements in the core.

4. Repeat the calculation with new core loading pattern (with added fuel) at cold zero power and Xenon free conditions to check excess reactivity (`$* POWER 0.01 $* XENON 0`).

5. Increase the power back to full power and perform a short burn up calculation (e.g. for one full power day `$* BURNUP 1.0`).

Remember that reactivity calculated and displayed in output is reactivity at the beginning of the cycle (still at zero burnup). To observe the burnup effect you must copy the new `elem.out` file over existing `elem.inp`. During burn up calculations is useful to make a backup copy of core (triglav.inp) end fuel data (elem.inp) files for each core configuration.

6. Calculate power and Xenon defects in reactivity. Power defect is defined as change in k_{eff} when going from zero power (or 10W) to 750kW conditions. And Xenon defect when going from xenon free to equilibrium Xenon conditions.

Expected results: P def. $\cong$ 2.2% Xe def. $\cong$ 1.7%

7. Operate the reactor - perform burn up calculations in several steps (increase burn up time from one day to 10 or 30 days) at normal conditions (750kW, equilibrium Xenon) as long as possible (reactivity after burn up must be positive).

8. Replace the most burned ST8 elements with fresh LEU fuel elements (in the triglav.inp file replace the selected burned ST8 id numbers with fresh LEU id numbers).

Respect the limitations, particularly the fuel element power limitation. Find optimal number and position of fresh LEU elements (hint: do not use all 20 in one loading).

9. Operate the reactor (perform burn up calculations in several steps) at normal conditions (750kW, equilibrium Xenon) as long as possible ($k_{eff} > 1$). Find the best fuel management strategy with respect to fuel utilisation (maximum burnup of the fuel elements leaving the reactor permanently)