CHAPTER 3

REACTOR CALCULATION MODEL

3.1 Computer Models

Figures 1.2 and 3.2 show horizontal and vertical cross sections of the core and the computer models that were used in this study. Labeled in Fig. 1.2 and 3.2 are the locations of the central thimble, the four in-core irradiation tubes, the three neutron detectors, and the five control rods (transient, regulating, 2 shim, and safety). The region labeled S contains the startup source. All other grid positions can be used for fuel elements(Fig.3.3). A typical core contains about 110 elements.

Inside the core, radioisotopes are produced in the Central Thimble and in the four irradiation tubes in the G ring. Surrounding part of the reactor tank is a rotary specimen rack or"Lazy Susan"that is used as a sample holder for isotope production. The Lazy Susan can be raised above the core when it is not needed or lowered into position when samples are to be irradiated, and it can also be rotated around the core for uniform irradiation activities.

The EPRI-CELL/RERTR(9) code was used to generate microscopic cross sections with 11 broad energy groups for subsequent use in diffusion theory calculations. Separate cross sections were prepared for:

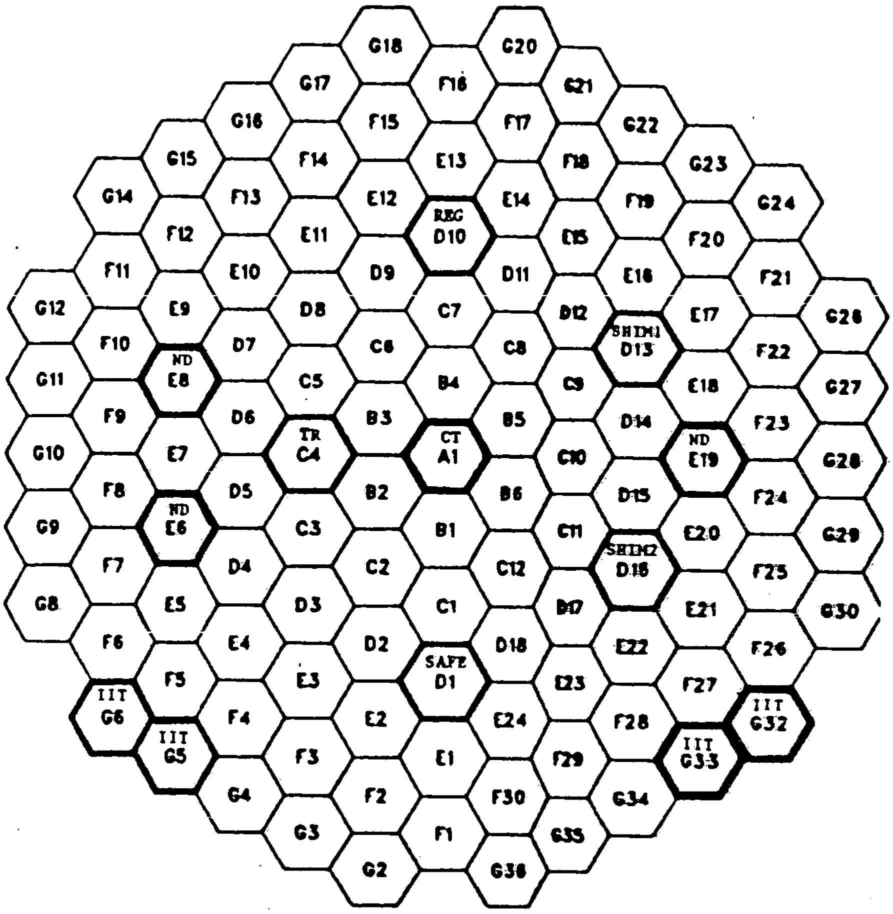

Fig. 3.1 Horizontal Cross Sections of TRR-1/M1 Reactor Core Computer Model

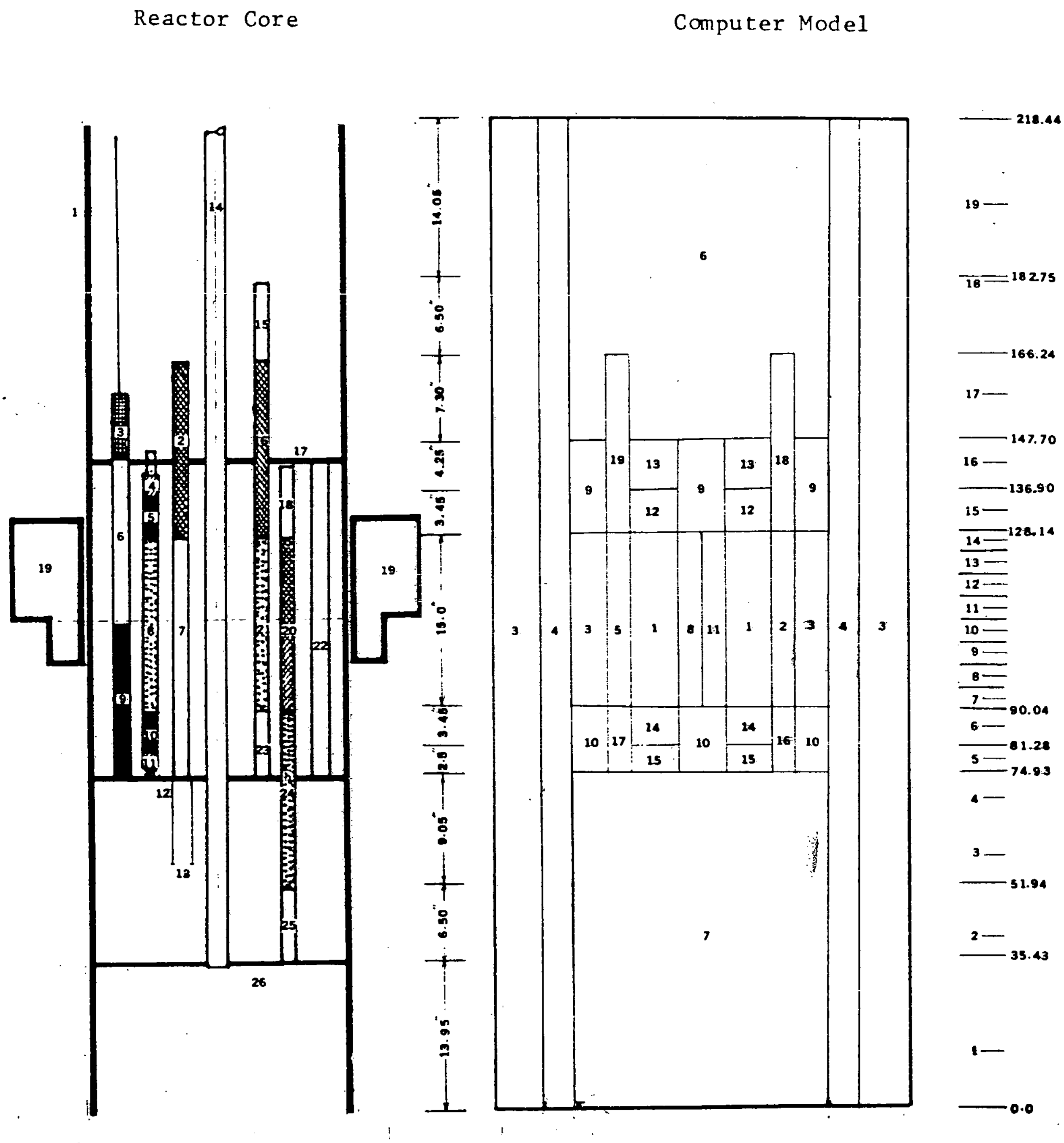

Fig. 3.2 Vertical Cross Section of TRR-1/M1 Reactor Core and Computer Model. Region Labels and Material Volume Fractions are Provided in Appendix B.

Nomenclature (Fig 3.2 left)

1. Reactor tank
2. Boron carbide absorber (Upper portion of transient control rod)
3. Neutron dectector
4. S.S 304 (Top end fitting of fuel-moderator element)
5. Graphite reflector (Upper portion of fuel-moderator element)
6. Air filled tube(Void; Lower portion of Neutron Detector)
7. Void (Lower portion of Transient rod)
8. Fuel meat (UZrH)
9. Graphite reflector (Bottom-end of Neutron Detector)
10. Graphite reflector (Lower part of fuel-moderator element)
11. S.S.304 (Bottom-end fitting of fuel-moderator element)
12. Lower grid plate
13. Transient rod guide tube
14. Central Thimble
15. Void (Top -end of FFCR; Fuel Follower control Rod)
16. Boron carbide absorber (Upper portion of FFCR)
17. Upper grid plate
18. Void (Top -end of fuel-moderator element)
19. Rotary Specimen rack (lazy susan)
20. Boron carbide absorber (Upper portion of fuel-moderator element)
21. Fuel meat (Lower portion of FFCR)
22. In-core Irradiation Tube.
23. Void (Bottom -end of FFCR)
24. Fuel meat (Lower portion of FFCR)
25. Void (Bottom - end of FFCR)
26. Safety plate

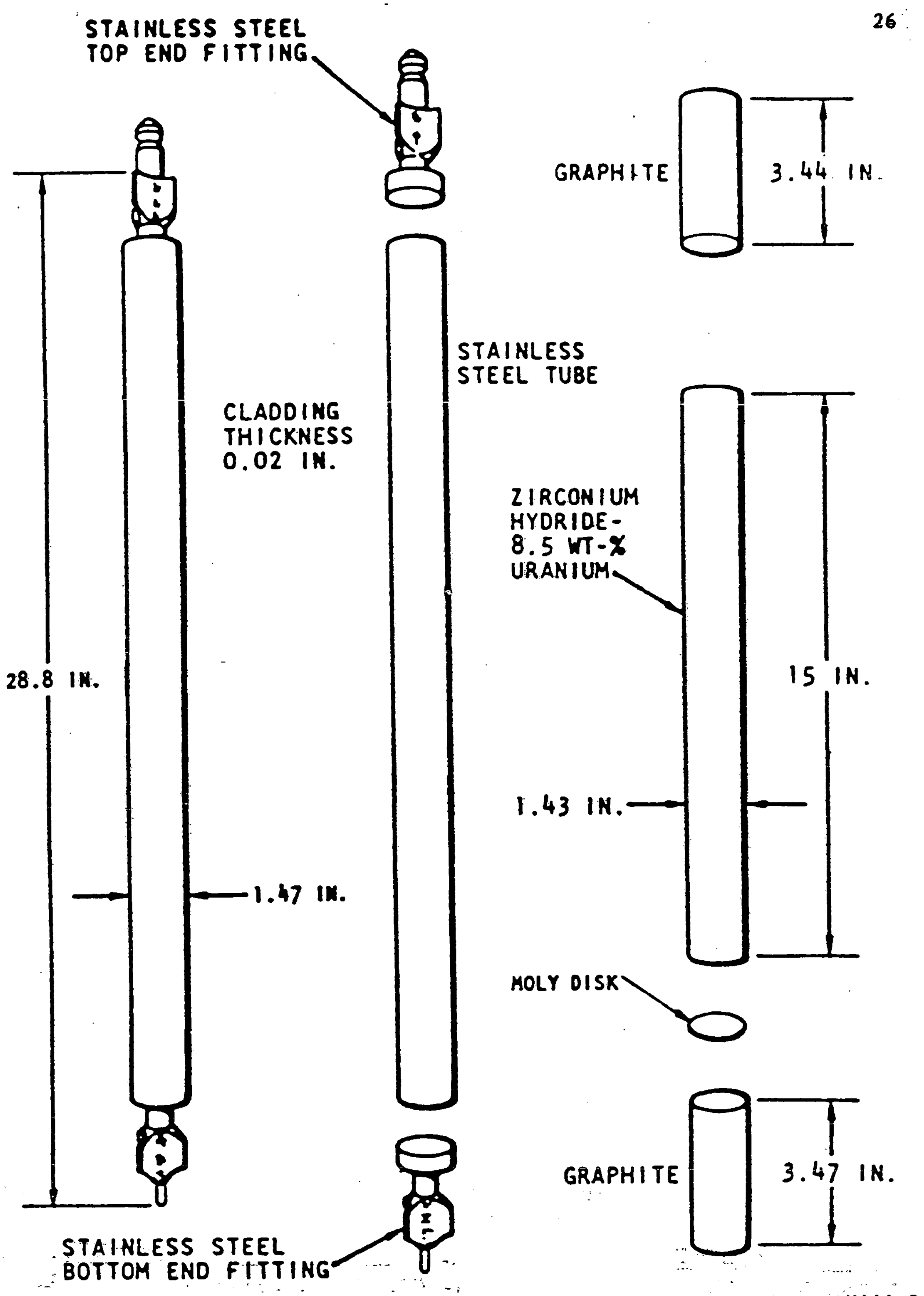

Fig. 3.3 TRIGA stainless-steel-clad fuel element with triflute end fittings. Graphite top and bottom reflector heights of 3.45 in. were used in the calculations. (Figure was reproduced from Ref.10).

(1) UZrH fuel rods with 8.5 wt% U (no burnable poison) and 20 wt.% U (including erbium burnable poison)

(2) fuel follower rods with 8.5 wt % U, and

(3) various structural and reflector regions.

A description of the methods and models that were used is shown in Appendix A. The core was modeled in extensive detail in 3 D hexagonal geometry (see Figs. 3.1 and 3.2). A detailed description of the axial model and their calculated volume fractions are provided in Appendix B. These volume fractions are essential for critical calculation in chapter 4. Static diffusion theory calculations were performed using the DIF 3 D code(11), and burnup calculations were performed using the REBUS-3 code(12). Careful attention to details in the computer model was necessary to obtain good comparisons with measured data.

3.2 The Calculation Method and Procedures

The calculation method uses basic technique as summarized below :

- Compare calculated and measured excess reactivity data for the initial fresh critical core with 8.5 wt % UZrH LEU fuel in order to verify the reactor model and computational methods.

- Calculate the burnup histories of Core No.'s 1-4 (November 1977 to March 1985) using the actual fuel shuffling pattern and MWd's of operation.

- Calculate the current Core No.5 which began operation in March 1985 and estimate the number of MWd it can be operated without refueling.

- Develop a fuel management strategy for future fuel replacements and estimate the number of MWd's each core can be operated.

The constraints for establishing the core and fuel management schemes for the TRR-1/M1 was based on the excess reactivity required, the type of fuel, the core configuration and the history of operations.

To establish the schemes the following procedures were performed:-

(a) Generate microscopic cross sections for the TRIGA fuel for subsequent use in diffusion theory calculation both 8.5 wt. % and 20 wt.% Uranium, Fuel Follower Control Rod (FFCR) including S.S. 304 cladding, Aluminum, graphite reflector, water reflector. The EPRI-CELL/RERTR Code was used to generate cross-sections in this calculation. For more details see appendix A

(b) Set up a computer model of the TRR-1/M1 core to be used in the computer code for critical calculations and burnup calculations in each core cycle.

(c) Calculate the fresh critical core for the TRR-1/M1 followed by burnup calculations as the actual loading configurations and megawatt-days of operation in each core cycle starting from core No.1 to core No. 4. The DIF3D and REBUS-3, three dimensional diffusion theory and burnup calculation codes, were used in these calculations.

(d) Calculate burnup for core No.5 (Current core) in order to predict its core excess in term of MWd.

(e) Rearrange the fuel loading for core No.6 followed by a series of burnup calculations. The calculations were subsequently carried out for cores No.'s 7-12.

3.3 Assumptions used in the Calculations

Six constraints were used in studying the TRR-1/M1 core management as follows.

(a) to maintain the flux intensities at various core locations.

(b) to keep core reactivity within limitation at the End of Cycle (EOC).

(c) to utilize only 8.5 wt. % and 20 wt. % U TRIGA fuel, and refuel only 20 wt. % U fuel.

(d) The core was free of control rods (All control rods were assumed fully withdrawn)

(e) Rotary Specimen Rack (Lazy Susan) was not taken into account in this study

(f) No Xenon poison at the Beginning of Cycle (BOC)