CONVERSION AND START UP OF TEHRAN RESEARCH REACTOR WITH LEU FUEL

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ABSTRACT

The 5 MW Tehran Research Reactor, Highly Enriched Uranium (HEU) fuel has been converted to Low Enriched Uranium (LEU) fuel using U308-Al with less than 20% enriched uranium. Measured value of excess reactivity, control rod worth and other parameters indicate good agreement with computational predictions.

INTRODUCTION

The Tehran Research Reactor (TRR) is an open pool, light water moderated with a thermal power of 5 MW. The reactor belongs to the Nuclear Research Centre of Atomic Energy Organization of Iran (AEOI).

Initial criticality was achieved in November 1967. The TRR was originally fulled with uranium aluminium alloy, high enriched Uranium (HEU), utilizing curve type plate. The HEU Standard Fuel Element (SFE) had 16 active plates and two external dummy plates. The general view of this fuel element is shown in Fig(1).

The TRR has been converted LEU fuel and since November 1993 the reactor is operated with LEU fuel.

The LEU fuel is U308-Al containing 19.7% enriched uranium, fabricated in Argentina. The LEU fuel element has 19 active plates without any dummy plate. The general picture of LEU fuel is given in Fig(2).

A joint study program between Nuclear Research Centre of AEOI and INVAP in Argentina was carried out in order to study different aspects of TRR core conversion. Since the main concern of this report related to the neutronic, therefore a brief description of calculational models which applied for neutronic calculations are as follows.

CALCULATIONAL MODELS

The core calculation were performed with the CITATION-CITVAP/1/ code in XY or XYZ geometry using the following three energy group structures.

Group 1 10.0 Mev 0.821 Kev
Group 2 0.821 Kev 0.625 Ev
Group 3 0.625 Ev 0.0

Three different models were selected for the core calculations.

a: Three dimensional XYZ with explicit frames model for the SFE. In this model SFE was divided to the active and non active zones.
The non active zone consists of a mixture of aluminum and water. This model was used for detailed flux distribution calculations.

b: Three dimensional XYZ with homogenous model for SFE. This model was used for reactivity calculations.

c: Two dimensional with homogenous model for SFE. This model was used for reactivity calculations with no partial insertion of control rods. Also this model was used for fuel burn up and fuel management. The geometrical axial buckling was used with a reflector saving of 8 Cm.
For the Control Fuel Element (CFE) explicit frame model was used for all core calculations. This model consists of fuel zone Guide plate and absorber zone with two state of control rod in and control rod out.

For the calculations of cell constant the WIMS code in the slab geometry was used. The five group energy structure was used for SFE and twelve groups for control fuel element.

CORE CONFIGURATION

Due to the variety of possible core configuration which may be operated, it was necessary to define some core configuration for different analysis purpose. Detailed calculations and analysis were made for the following core configurations.

a: First Operating Core
This core configuration is shown in Fig(3). It refers to the first configuration which allows reactor operation at maximum power level of 5 MW.

b: Equilibrium Core
This core configuration is shown in Fig(4). This core is the main core configuration in which fuel management systematically applied.

c: Operating Core
It refers to the core configuration which is possible to operate reactor at 5 MW. There are some transitory core between first operating core and equilibrium core.

CORE LOADING AND APPROACH TO CRITICALITY

According to the TRR fuel loading procedures the CFE loaded first. They placed in the core positions C8, D7, C6, E6, and D5 core NO (A). After loading CFE the shim safety rods were installed. The regulating rod was installed in the position C8.

All necessary tests were made in order to assure that the control system operate according to the technical specification limits. The test include rod withdrawal, insertion, drop time, magnet test etc.

Approach to the criticality was performed based on predetermined loading scheme and calculations. According to the calculations the criticality is attained with 9 SFE and 5 CFE. in reality the criticality was attained with 10 SFE and 5 CFE while three safety rods and regulating rod were completely out and one safety rod was 61% out of the core.

Steps loading was performed and in the all steps inverse count rate against fuel element loading was plotted in order to see feasibility of next loading and critical mass assessment.

The count rate were taken from two fission counter which located in different position of the core.

When the criticality was almost reached, another graph showing the relation ship between inverse count rate against safety rod D5 position was plotted. This was made in order to see in what position of the safety rod the criticality could be expected. The loading scheme is summarized in the following steps.

1. Loading 5 CFE in positions D7, C6, E6, D5, and C8.
   Installation shim safety and regulating rods. Core NO (A).
2. Loading 6 SFE in positions D8, C7, E7, D6, C5, and E5.
3. Loading 1 SFE in position B6 .
   Loading 6 Graphite Reflector Box. Core NO (B).
4. Adding 1 SFE in position F6. Core NO (C).
5. Loading 1 SFE in Position D4. Core NO (D).
6. Loading 1 SFE in position E8. Core NO (E).
   This core became critical.

Excess reactivity loading .

7. Adding 1 SFE in position B7. Core NO (F).
8. Adding 1 SFE in position F7. Core NO (G).
9. Adding 1 SFE in position C4. Core NO (H).

Replacing Graphite Reflectors with Empty Boxes
10. Adding 1 SFE in position B5. First operating core. Fig(3).

Several core parameters of first operating core were measured and compared against their computed values. Results of measured are given in Table (1) and Table (2).

- Control rods worth were measured using doubling time method.
- Calorimetry technique was used for power calibration.
- Stringers were used in order to measure flux distribution of the core.

CONCLUSION

The TRR has been successfully converted from HEU to U308-Al LEU fuel and since november 1993 the reactor is operated without any difficulty. According to the fuel management program several transitory cores will be created in order to reach to the equilibrium core. All transitory cores should fulfil operational conditions as well as equilibrium core.

ACKNOWLEDGMENT

I would like to express my appreciation from TRR Reactor Operation Group for their hard work during the different steps of core conversion and from Neutron Physics group for the core flux mapping.

REFERENCES

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2. TRR core conversion from HEU to LEU fuel, 1987
3. Neutronic calculations for the First Operating LEU core, 1990
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5. Equilibrium core and fuel management of TRR, 1990
6. Amendment to the TRR, SAR, 1992
7. TRR LEU start up safety report, 1991

Table (1)- TRR Core Loading Scheme

No	LOADING SFE, CFE, GR	U-235 Mass Grams
1	5 CFE	1065.5
2	6 SFE	2799.1
3	1 SFE + 5 GR	3089
4	1 SFE	3379
5 6	1 SFE Critical Mass	3668.9 3843.8
	1 SFE	3959.2
7	1 SFE	4248.5
8	1 SFE	4538.4
9	1 SFE	4827.9
10 FOC	1 SFE - 5 GR	5117.5

Table (2)- Measured and Predicted Excess Reactivity
and Control Rod Worth of First Operating Core

PARAMETER	MEASURED % ΔK/K, pcm		PREDICTED % ΔK/K, pcm	
EXCESS REACTIVITY	7.461	7461	6.549	6549
SHUT DOWN MARGIN	13.50	13500	12.99	12991
SR1 WORTH	5.67	5670	5.29	5290
SR2 WORTH	5.471	5471	5.29	5290
SR3 WORTH	4.633	4633	4.25	4250
SR4 WORTH	4.716	4711	4.25	4250
RR WORTH	0.476	476	0.45	450

GR Graphite Reflector
FOC First Operating Core
SR Safety ROd
RR Regulating Rod

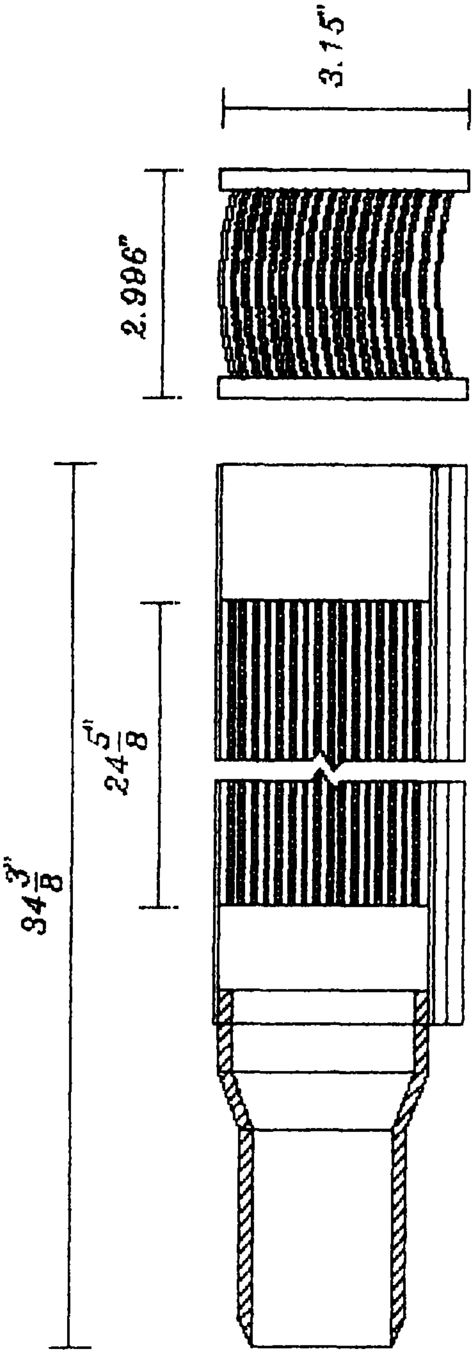
Table (3)- Calculated and Measured Average Thermal Flux
Per Box of First Operating Core

POSITION	MEASURED	CALCULATED
E8	2.30*10 E13	2.87*10 E13
F7	1.89*10 E13	2.71*10 E13
B7	2.55*10 E13	3.08*10 E13
B5	2.21*10 E13	2.93*10 E13
C4	2.28*10 E13	2.60*10 E13
C7	2.91*10 E13	3.49*10 E13
D8	2.50*10 E13	3.03*10 E13
E4	5.10*10 E13	5.94*10 E13
D3	3.35*10 E13	3.99*10 E13

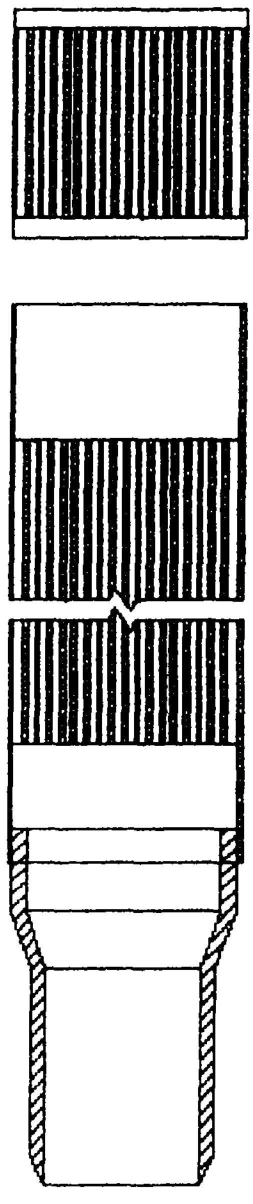
Table (4)- Some calculated parameters of first operating core

PARAMETER	CALCULATED
COLD CORE	6916 pcm
HOT CORE 0 MW	6529 pcm
HOT CORE 5 MW	3319 pcm
GR REFLECTOR	230 pcm
P.N. LIFE TIME	45.28 MSEC
E.D. NEUTRON	813 pcm
REFLECTOR SAVING	8 CM
SHUT DOWN MARGIN WITH STUCK ROD	6000 pcm
TOTAL PEAKING FACTOR	2.1 - 2.7
Xe REACTIVITY	3200 pcm

GR Graphite Reflector
P.N Prompt Neutron
E.D Effective Delayed

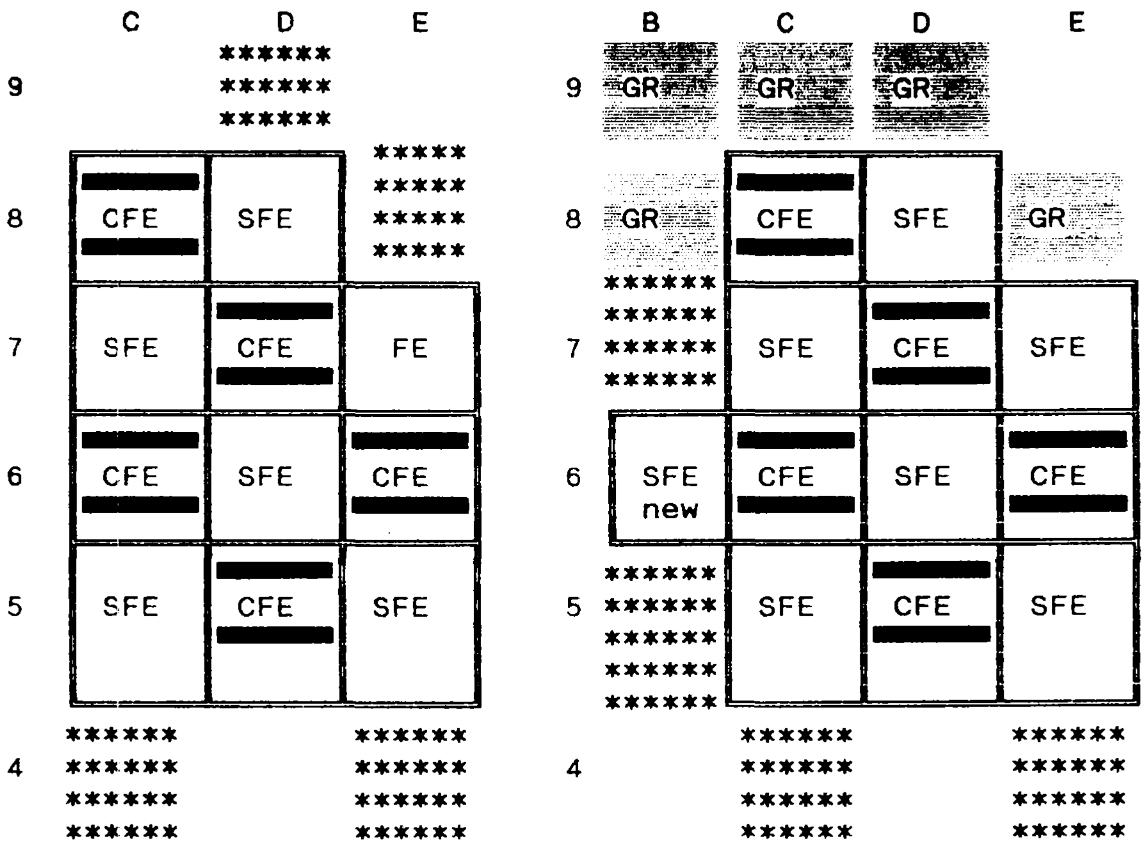


Fig(1) HEU Fuel



Fig(2) LEU Fuel

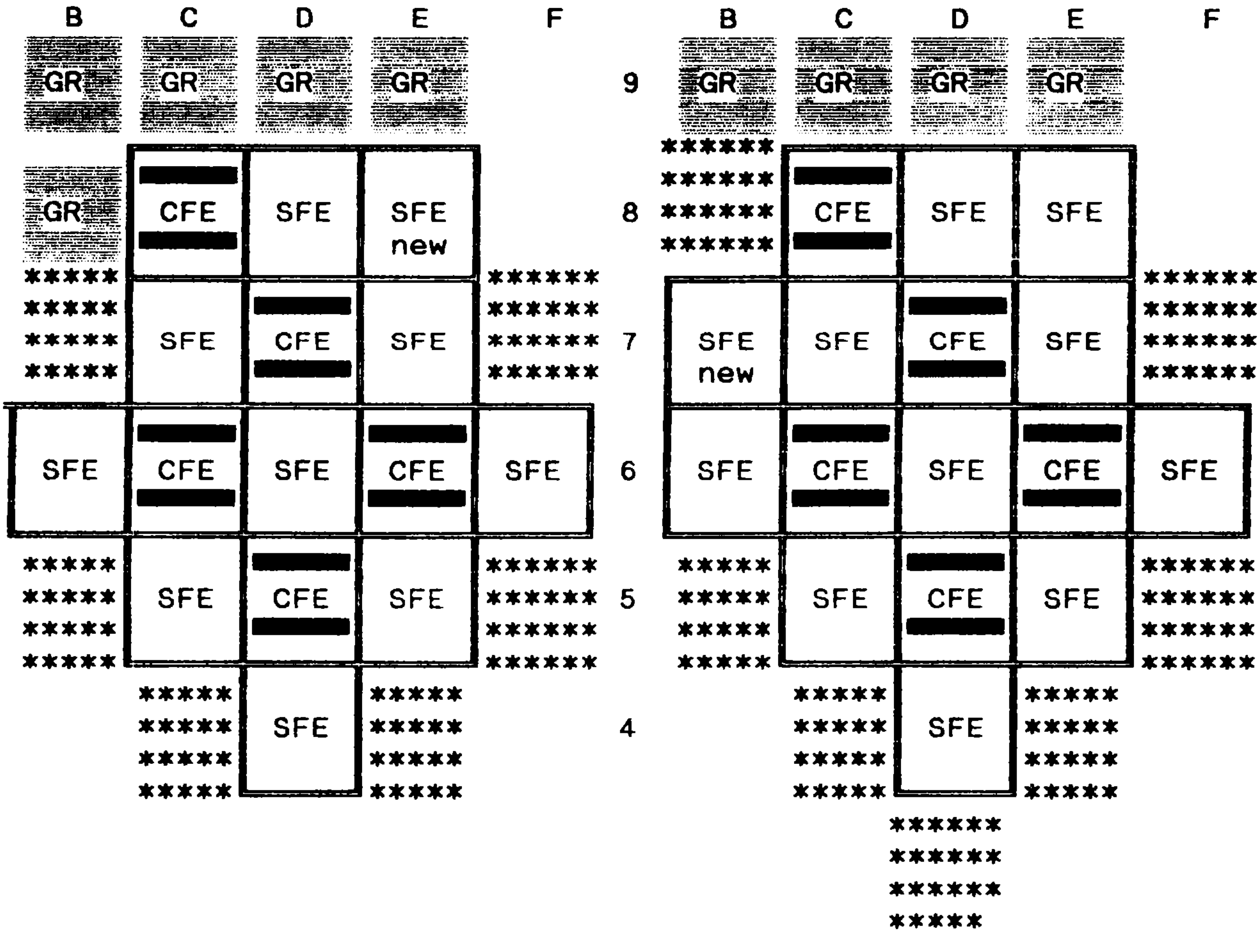
Unit : Inch



CORE NO (A)

CORE NO (B)

SFE = STANDARD FUEL ELEMENT
CFE CONTROL FUEL ELEMENT
GR GRAPHITE REFLECTOR
** EMPTY BOX, FILLED WITH WATER
GUIDE PLATE



CORE NO (E)

CORE NO (F)

SFE STANDARD FUEL ELEMENT
CFE CONTROL FUEL ELEMENT
GR GRAPHITE REFLECTOR
** EMPTY BOX, FILLED WITH WATER
▬ GUIDE PLATE

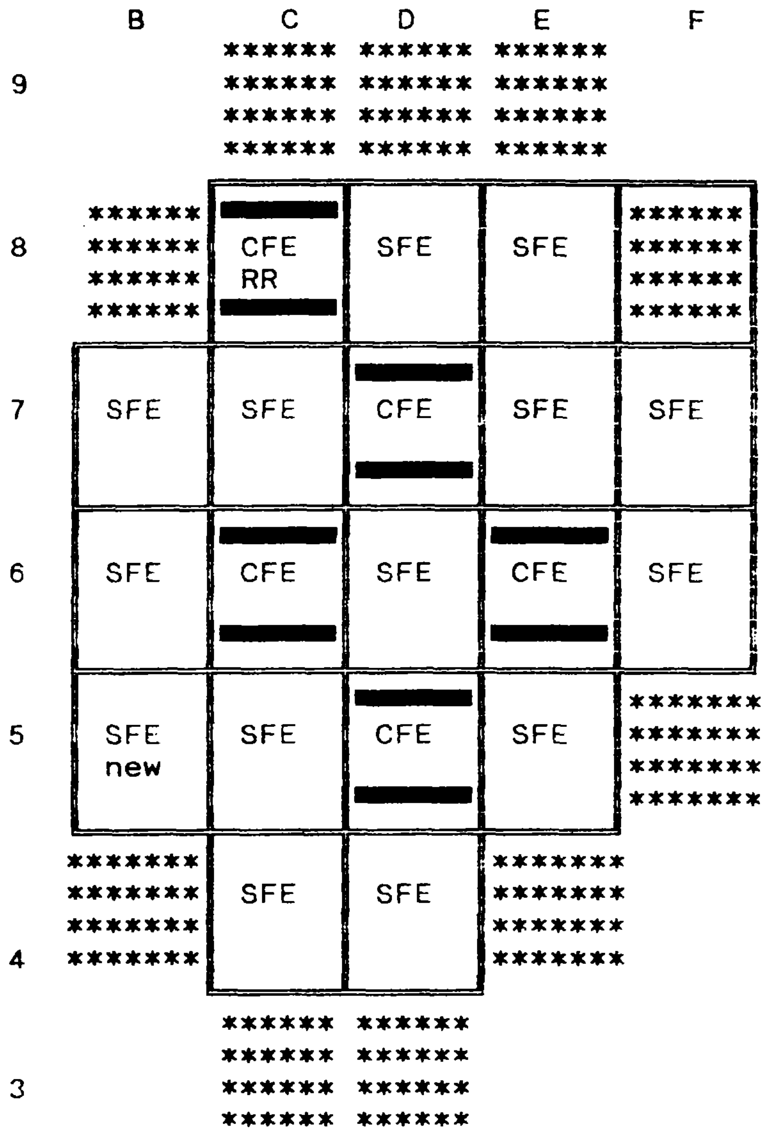


FIG (3)

FIRST OPERATING CORE

SFE STANDARD FUEL ELEMENT
CFE CONTROL FUEL ELEMENT
RR RGULATING ROD
GR GRAPHITE REFLECTOR
** EMPTY BOX, FILLED WITH WATER
GUIDE PLATE

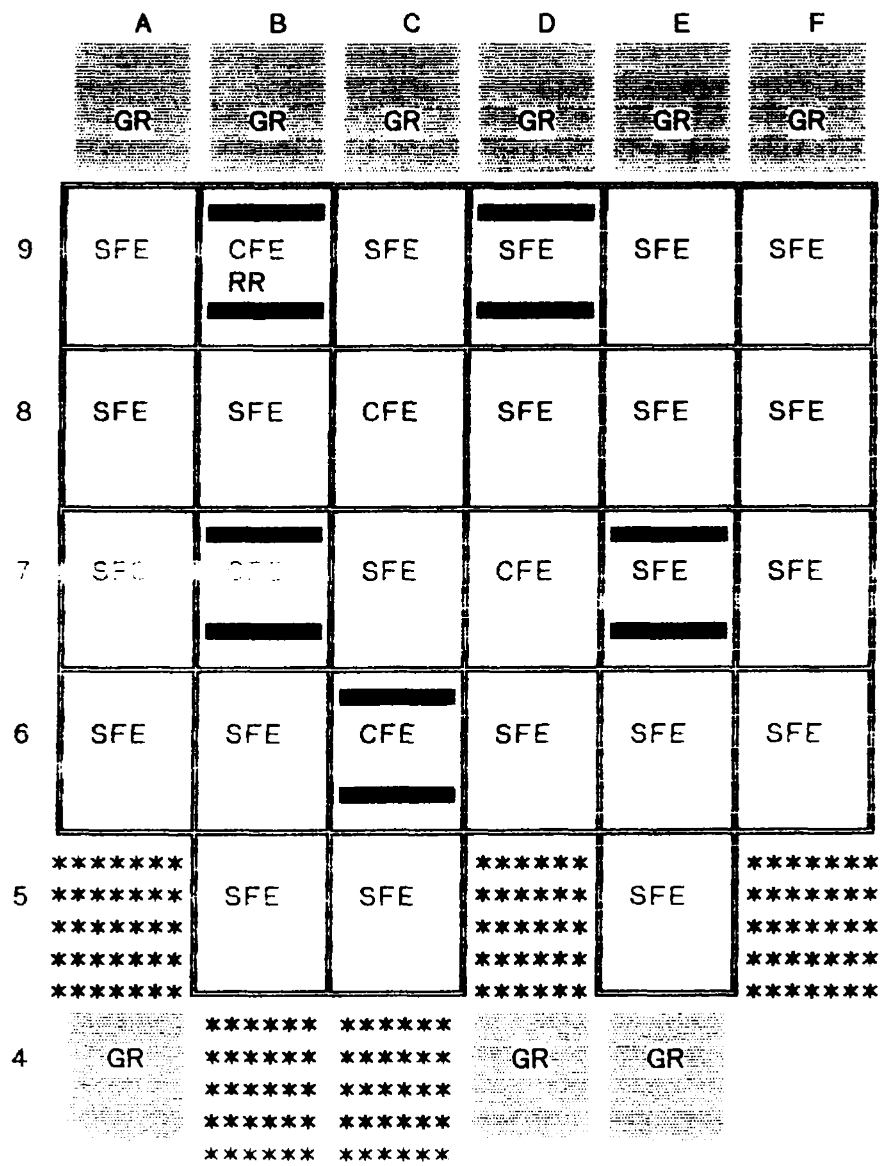


FIG (4)

EQUILIBRIUM CORE CONFIGURATION

SFE	STANDARD FUEL ELEMENT
CFE	CONTROL FUEL ELEMENT
RR	RGULATING ROD
GR	GRAPHITE REFLECTOR
**	EMPTY BOX, FILLED WITH WATER
▬	GUIDE PLATE