Fuel Management of VVER-1000 Reactors of Kudankulam Nuclear Power Plant, India.

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Abstract

Two units of VVER-1000 reactors of Russian design are under construction at Kudankulam site in India. These reactors are expected to be commissioned in 2008. The fuel management services for these reactors shall be carried out indegeneouly using Russian Computer codes. This paper includes a brief description of the core, fuel assembly lattice and physics modeling of the lattice and core for these reactors. Presented in this paper are the salient features of the core load pattern designs and fuel performance for 8 operating cycles of these reactors. The Paper describes key improvements in the core load pattern designs to enhance the fuel utilization and its thermal behaviour.

Presented in the paper are also the on site fuel management strategies with regard to fuel inventory and nuclear material accounting. A computer code for Fuel Inventory and Nuclear Material Accounting (FINMAC) has been developed for this purpose. The code FINMAC takes care of receipt of fresh fuel, flow between various accounting sub areas (ASAs), burnup or production of nuclear isotopes in the reactor cores and discharge from the reactor core. The code generates Material Balance Reports (MBRs) and Composition of Ending Inventory Reports (COEIs) as per the IAEA standards.

1. Introduction

1.1 Kudankulam Reactors

Indian Nuclear Power Programme started with Tarapur Boiling Water Reactor (BWR). Subsequently the main thrust of our nuclear power programme has been design, construction and operation of CANDU type Pressurized Heavy Water Reactors (PHWR). Today we operate 16 nuclear power units with net installed capacity of 3900 Mwe. These include 14 PHWRs and the 2 BWRs. Total seven reactors (2 x VVER-1000 , 4 x 220 PHWRs and 1 FBR of capacity 500 Mwe) are under construction. The two units of VVER-1000 (Version V-412) reactors are being constructed at Kudankulam site in the state of Tamil Nadu, in collaboration with Russian Federation. These units are scheduled to be commissioned in 2008-09. The Kudankulam project is being implemented on a technical co-operation basis. The Russian organizations are responsible for design, supply of equipment, material, machinery, Fuel, construction supervision & training of Indian personnel(**Ref. -1**).

1.2 Fuel Management

Fuel Management activities, staring from lattice level to core simulations, for all the BWRs and PHWRs operating or under construction in India, are being done indigenously by computer codes developed by BARC, India. These codes have been extensively validated against the wealth of operation data as well as against a large number of IAEA CRP benchmarks on in-core fuel management code package validation for modern BWR,PWR,VVER and PHWRs (**Ref. – 2,3,4**).

For physics design studies of VVER type reactors computer codes package starting from lattice calculations to core simulation both at Fuel Assembly level and pin by pin level have also been developed (**Ref. -5,6**). These codes are being extended to include all physics and thermal hydraulic phenomenon to have full potential of analyzing VVER-1000 cores.

Since VVER type of reactors are new to India, it is decided to acquire Russian Codes for in-core fuel management of these reactors in addition to indigenous codes. Indian specialists have been trained on these codes to carry out the in-core Fuel Management of VVER-1000 reactors in India. Starting from first reload of these reactors, Indian specialists shall be responsible for both in-core and out of core fuel management.

1.3 Nuclear Material Accounting (NUMAC)

In India, it is obligatory on part of an NPP to submit NUMAC reports to the federal NUMAC cell under Department of Atomic Energy. Moreover the Kudankulam reactors shall be under IAEA Safeguards. As per our Safeguards Agreement with IAEA it is required to submit Nuclear Material Accounting (NUMAC) and Material Balance Reports (MBRs) to IAEA at regular intervals. A computer code for Fuel Inventory and Nuclear Material Accounting (FINMAC) has been developed to cater all the Nuclear Material Accounting / Fuel Inventory needs of Kudankulam reactors. The code FINMAC takes care of receipt of fresh fuel, flow between various accounting sub areas (ASAs), burnup or production of nuclear isotopes in the reactor cores and discharge from the reactor core. The code generates Material Balance Reports (MBRs) and Composition of Ending Inventory Reports (COEIs) as per the DAE & IAEA formats.

2. Description of Core

2.1 General Description

The core of Kudankulam reactors is designed to produce 3000 Mwt of power under normal operating conditions. The core contains 163 fuel assemblies arranged in hexagonal geometry **(Fig. 1,2 &3**). Each fuel assembly consists of 311 fuel pins, 18 guide tubes for placing burnable absorber cluster (BAR) or for movement of absorber rods of control and protection system (CPSAR), one guide tube for keeping in core instrumentation detectors (ICID) and a slotted central tube for structural support. All these fuel pins / tubes are held by a frameworks of 15 hexahedral spacer grids and a supporting tail grid. In order to reduce the parasitic capture of neutrons in the core the fuel clad, guiding tubes, BAR clad, spacing grids are made of zirconium alloy. There are 54 locations in the core where Rhodium type SPND detectors shall be installed in ICID tubes. In the first cycle 42 BAR clusters will be used for the purpose of flux flattening and ensuring negative moderator coefficient of reactivity. In further cycles 18 BAR clusters will be used. No. of CPSAR used in first cycle is 85 which will be increased to 103 from subsequent cycles.

2.2 Fuel Types, BARs & CPSAR

Five different type of enrichments viz. 1.6%, 2.4%, 3.3%, 3.7% and 4.1% will be used in forming 4 types of FAs (viz. 16, 24, 36 and 40) with average enrichment 1.6%, 2.4%, 3.62% and 4.02% respectively. The FAs of type-16 and type-24 will have all their fuel pins of the same enrichment. These are called non profiled FAs (**Fig. 4**). On the other hand the fuel type -36 will use 245 fuel pins of 3.7% enrichment in the central part and 66 pins of 3.3% enrichment in the peripheral part. Similarly the fuel type-40 will use 245 fuel pins in central part with enrichment 4.1% and 66 peripheral fuel pins with enrichment 3.7%. These are called profiled FAs (**Fig. 5**). The BAR cluster of type (0.020, 0.036 or 0.050 g/cc boron content) when inserted in these basic FA types makes a total of 11 types of fuel assemblies **namely** 16, 24, 36, 40, 24B20, 24B36, 36B20, 36B36, 40B20, 40B36 and 40B50 (**Fig.** 6). Chromium diboride (CrB2) in matrix of aluminum alloy with 3 different natural boron content (0.020, 0.036 and 0.050 g/cc) is used as burnable absorber. Absorbing material for CPSAR is B4C powder in top 320 cm length and dysprosium titanate in the bottom 30 cm of the CPSAR pin.

3. Fuel Management Computer Codes

3.1 Indegenous Codes

To carry out physics design and core simulation studies, computer codes EXCEL, TRIHEXFA and HEXPIN have been developed. The code EXCEL is a lattice assembly cell burnup code. This code uses combination of 1-D multigroup (172 group) transport and 2-D few group (5 group) diffusion method. The code generates few group (2 or 5 group) homogeneized cross sections of fission, absorption, ν-fission, diffusion coefficients, delayed neutron fractions, prompt neutron life times, and isotopic weight fractions of U,Pu and other actinides. The code EXCEL has been validated against IAEA CRP benchmarks and VVER-TIC lattice experiments. Computer code TRIHEXFA is a few group diffusion theory code to carry out 3-D core simulation at fuel assembly level. The code uses few group lattice data library generated by EXCEL for various fuel types and non fuel materials of core external regions consisting of various reflector zones. Computer code HEXPIN does the pin by pin simulation for entire core. These codes have been used to analyze Kudankulam core and cycle follow-ups up to 8 cycles in an earlier study (**Ref. - 7**).

3.2 Russian Codes

In addition to indigenous code system, NPCIL has decided to use the designers codes to carry out in-core fuel management studies of VVER reactors. These codes include TVS-M, BIPR7-A, PERMAK-A and PROROK-A (as part of code complex KASKAD). A licensing agreement to use these codes have been concluded with Russia. A team of Indian specialists have undergone training on these codes in Kurchatov Institute Moscow.

Code TVS-M is the lattice parameter code used for generating multi parameter relations for few group neutron cross sections for fuel assemblies, cells of fuel elements, absorbing elements, burnable poison rods etc as required for core simulator codes BIPR7-A and PERMAK-A.

Code BIPR7-A is used for performing calculations of criticality parameters , coefficients of reactivity, differential and integral efficiency of control rods, 3-D power distribution, calculations of burnup, refueling simulations, Xenon and Samarium transients. It is a 3-D, (2 group) coarse mesh diffusion theory code.

Code PERMAK-A is a few group (4 or 6 groups) fine mesh diffusion theory code intended to perform pin by pin burnup simulations and for obtaining linear heat generation rates during movement of control rods, xenon transients or during load following operations.

All these codes are licensed by Russian Regulatory body to carry out physics design calculations of VVER reactors.

3.3 Present Analysis

The present analysis of core pattern designs for 8 cycles of Kudankulam reactors is carried out using Russian codes. The lattice parameters have been generated by code TVS-M for all type of fuel under different states of reactor operations. The core simulations have been followed by codes BIPR7-A and PERMAK-A.The parameters chosen for the study are: FA burnup,critical boron concentration, FA relative power factor(Kq), volumetric FA relative power factor (Kv) and fuel pin relative power factor (Kr).

4. Fuel Pattern Designs of Kudankulam reactors

4.1 Initial Core Loading

Initial core load consists of 54 FAs of average enrichment 1.6%, 67 FAs of 2.40 % and 42 FAs of 3.62%. Making the core average enrichment of 2.48%. There will be 42 BAR clusters (6 x 0.020 type and 36 x 0.036 type) and 85 CPSARs in the initial core. The design cycle length is about 300 effective full power days (EFPD). In the first cycle the fuel of highest enrichment (3.62%) is loaded in the peripheral region while the lower (1.60%) and medium (2.40%) enrichment fuel is distributed (in alternating hexagonal rings) in the inner region **(Fig. 9)** . Such a distribution allows maximumu utilization of fuel and also the flattening of flux. At end of first cycle (EOC-1) 54 FAs will be discharged with average burnup of 12.0 Mwd/kg-U.

4.2 First three reloads

During first reload total 54 fresh FAs of average enrichment 3.76% (30 FAs of 3.62 % and 24 FAs of 4.02 % enrichments) shall be loaded in the core (**Fig. 10**). Design cycle duration is about 300 EFPDs. At EOC-2, 48 FAs shall be discharged with average discharge burnup of about 26.0 Mwd/kg-U. During second reload 48 fresh FAs of average enrichment 3.92 % (12 FAs of 3.62% and 36 FAs of 4.02 %) are loaded to achieve a cycle length of about 300 EFPDs. At EOC-3, 49 FAs with average burnup of 34.0 Mwd/kg-U shall be discharged.

During reload-3, 49 fresh FAs of average enrichment 3.91 % (13 FAs of 3.62% and 36 FAs of 4.02 %) are loaded to achieve the cycle length of about 300 EFPDs. At EOC-4, 48 FAs with average burnup about 41 Mwd/kg-U are discharged.

4.3 Stationary Core Loading

The stationary characteristic of the core are reached in the fifth cycle **(Fig. - 11)**. The FAs discharged in steady cycles will be 48 or 49. Under these cycles 30 or 31 FAs will be discharged after their third cycle while 18 FAs will be discharged after their 4th cycle. Thus the average life time of an FA in core would be 3.37 operating cycles. The third cycle FAs are loaded in the central region along with fresh FAs and FAs in their second cycle operation while the 4th cycle FAs are essential placed in the peripheral region to ensure low leakage fueling pattern. Such an arrangement would minimize the mismatch in the discharge burnup of the FAs. It is observed that average discharge burnup of the FAs under steady cycles would be 43 Mwd/kg-U where as the maximum FA average burnup is about 44 Mwd/kg-U. Maximum fuel pin burnup under these conditions will be 58 Mwd/kg-U. Presented in **Figure-12** are the core performance parameters for cycle-8.

The low leakage pattern would improve the neutron economy, it wil reduce the fast fluence to the RPV, increase the effectiveness of the emergency shutdown rods and improve the fuel utilization.

5. Nuclear Material Accounting & IAEA Safeguards

5.1 Accounting SubAreas (ASAs) & Key Measurement Points (KMPs)

At Kudankulam NPP, safeguards shall cover nuclear material in following ASAs

- Fresh fuel storage (common for units 1 and 2)
- Reactor cores of Unit 1 and Unit 2
- Spent fuel storage in Reactor building pool 1 and 2
- Spent fuel storage in other locations (common for units 1 and 2)
- Away From Reactors (AFR) Spent Fuel Storage Facuility (Proposed)
- Temporary Storages in Transport Casks for Fresh / Spent Fuel

Total 9 KMPs have been identified.

- KMP 1: Receipts of nuclear material
- KMP 2: Nuclear loss (burnup) and production in reactor core of Unit-1
- KMP 3: Nuclear loss (burnup) and production in reactor core of Unit-2
- KMP 4: Transport to Away from Reactor Facility from Unit-1
- KMP 5: Transport to Away from Reactor Facility from Unit-2
- KMP 6: Exemption,de-exemption,accidental loss/gain , substitution
- KMP 7: Shipment of nuclear material from facility
- KMP 8: Termination of Safeguards on nuclear material through Substitution
- KMP 9: Nuclear Loss (Pu-241 decay), upon shipment from Away from Reactor Facility

5.2 Fresh Fuel Storage & Transportation

Fresh Fuel for Kudankulam reactors shall be supplied by Russian Federation. The Fuel shall be transported in Fuel Transportation Packaging Casks (TKC). Upon arrival at the facility the fuel shall be stored in common fresh fuel storage facility. Initially the fuel will be stored in Packaging Set Groups in side transportation casks in horizontal position. After inspection, it will be stored in either Fresh Fuel Storage Racks or Inner Station Transportation Flasks (ISTPS), in vertical position.

At facility the fresh fuel shall be transferred to reactor hall by ISTPS where it can be either stored in Spent fuel racks before being loaded in core or directly go to core from ISTPS.

5.3 Spent Fuel Storage & Transportation

After discharge from reactor cores the spent fuel shall be stored in spent fuel racks in spent fuel ponds which are separate for each unit. The leaky fuel will be stored in special bottles. After getting cooled for at least 5 years, the fuel can be transferred by spent fuel transportation casks (TKC-13) to Away From Storage (AFR) facility for further storage till its transfer from facility.

5.4 Reporting System of Nuclear Material

Nuclear material at the facility is reported by submitting monthly material balance reports (MBR) (**Fig. 14**) and composition of ending inventory (COEI) (**Fig. 15**) reports for fissile and total isotopes of Uranium and Plutonium separately. In addition to these reports the general ledger for these materials is also maintained. The weights are reported upto nearest gram of that material. Fuel Assembly is the smallest physical unit for which these weights are required to be calculated, preserved and reported if required.

5.5 Computer Code FINMAC

A computer code FINMAC for Fuel Inventory and Nuclear Material Accounting of Kudankulam reactors has been developed. Major functionalities of the code are as below.

- Capability to receive FUEL, CPSAR,BAR along with transportation casks (TKC) at designated ports in India.
- Capability to transfer back the empty casks or casks with defective fresh fuel as declared after inspection in fresh fuel storage facility, to Russian Federation
- Capability to transfer TKC, ISTPS, FAs, CPSARs, BARs between different ASAs of the facility
- Automatically maintaining general ledgers for TKCs, FAs, CPSARs, BARs
- Generate working documents /procedures for transfer of fresh fuel /non fuel items between differents ASAs or within same ASA
- It can generate working documents/procedures for transfer of fuel / non fuel items between reactors core and spent fuel ponds. The code will be integrated with the core unload /reload program during refueling so that it will be automatically refreshed during refueling.
- Automatically manages the flow of nuclear material between two ASAs or between two facilities.
- It manages account of isotopic weights at various KMPs.
- It is being integrated with core simulator codes to account depletion / production of isotopic weights in the core during burnup with cycle operation. The weigth fractions of isotopes with burnup for different type of FAs are generated by TVS-M code (**Fig. – 8**). These weight fractions together with average nodal FA burnups generated by BIPR7-A shall be used by FINMAC to generate isotopic weights in each FA.
- It generates MBRs and COEIs for any given period in standard formats.
- It displays the updated maps of various ASAs and general ledger for any type of material at any instant.
- Can generate various other reports regarding fuel/non fuel items.

Code FINMAC is a WEB based system consisting of 3 layers viz. Front End which is implemented using HTML/JavaScript , Middle Ware is implemented using Common Gateway Interfacing (CGI) programs and Back End is a SQL server.

6. Results & Conclusions

This study is an attempt to reproduce the results submitted by the designers. All the lattice parameters were generated by TVS-M code and core follow-ups done by BIPR7-A and PERMAK-A. Total 8 operating cycles with regard to cycle length, critical boron concentration, FA burnup, relative power peaking factors for FA and fuel pins, have been analyzed. The design operating cycle lengths is about 300 EFPDs for all the cycles. It is observed that all the power peaking factors remain well with in the design limits. FA relative power factor peak (Kq) is around 1.3 for all the operating cycles while the FA nodal power peak factors (Kv) remains less than 1.5 for all the cycles except in the beginning of first cycle (**Fig. – 9 to 12**). Relative fuel pin power peak factor (Kr) remains less than 1.5 for all the cycles (**Fig. - 13**). Under steady state cycle operations which is achieved from fifth cycle, each reload consists of 48 or 49 FAs with an average discharge burnup of about 43.0 Mwd/kg-U. All the results are in agreement with the results submitted by the designers. Code FINMAC is being upgraded to generate isotopic weights, their production and depletion in the core during core burnup. The code shall use weight fractions generated by TVS-M and FA nodal average burnup generated by BIPR7-A, to generate these weights.

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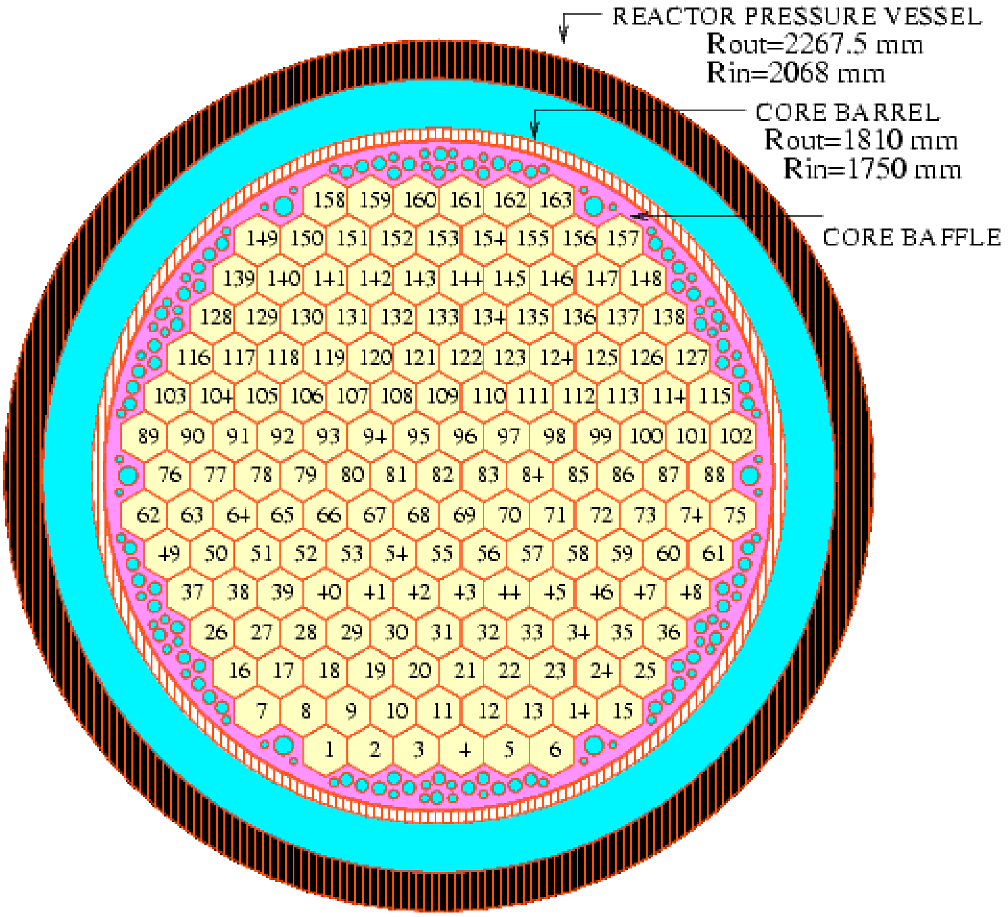


Fig. 1 - View of Kudankulam VVER-100 Reactor Internals

- Thermal Power = 3000 MWt
- No. of FAs = 163
- No. of Fuel pins/FA = 311
- Core height, dia = 3.55, 3.16 m
- Coolant I/L temp = 291°C
- Coolant O/L temp = 321 °C
- Coolant Pressure = 15.7 MPa
- Coolant Flow = 86000 m^3/h
- Pitch between FA = 23.6 cm
- Fuel pin pitch = 1.275 cm
- Avg. Specific power = 42.6 kW/kgU
- Avg. LHGR = 166.7 W/cm
  - No. of CPSARs : 85 / 103
  - No. of BARs : 42 / 18

Fig. 2 – General Core Characteristics

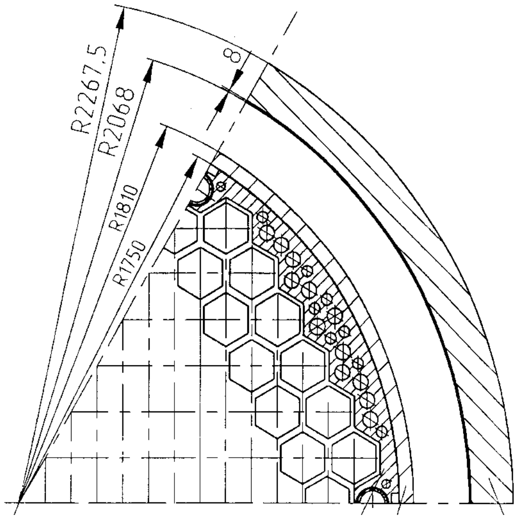


Fig. 3 – View of Core Internals & Reflector

Fig. 4 - Non Profiled Fuel Assembly

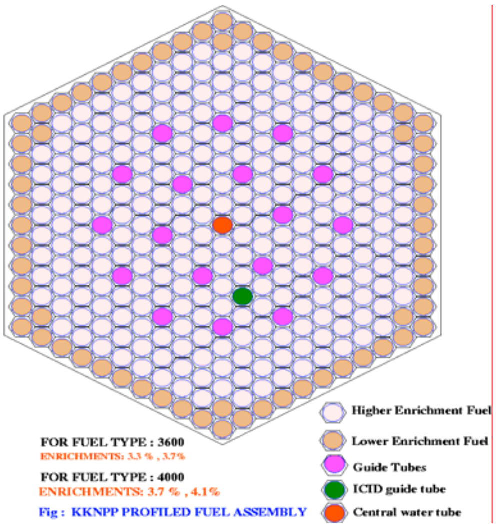
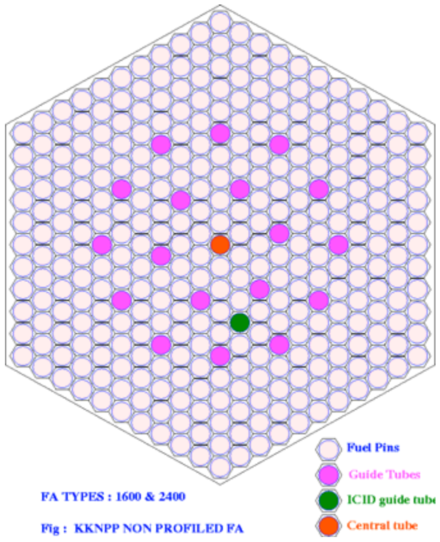
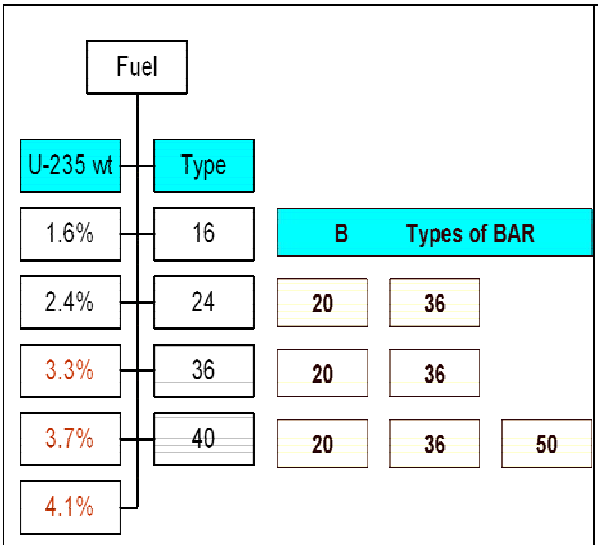


Fig. 5 - Profiled Fuel Assembly

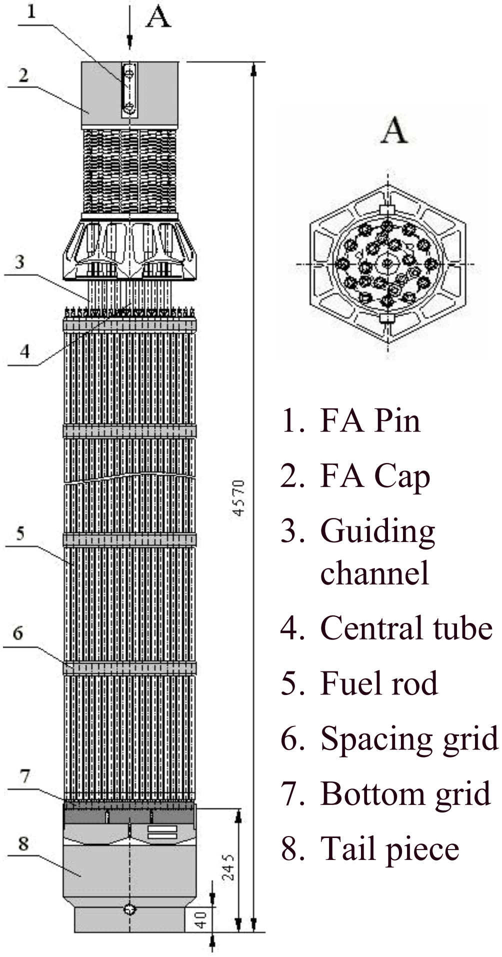




Total 11 types of FAs viz.
16
24, 24B20, 24B36
36, 36B20, 36B36
40, 40B20, 40B36, 40B50

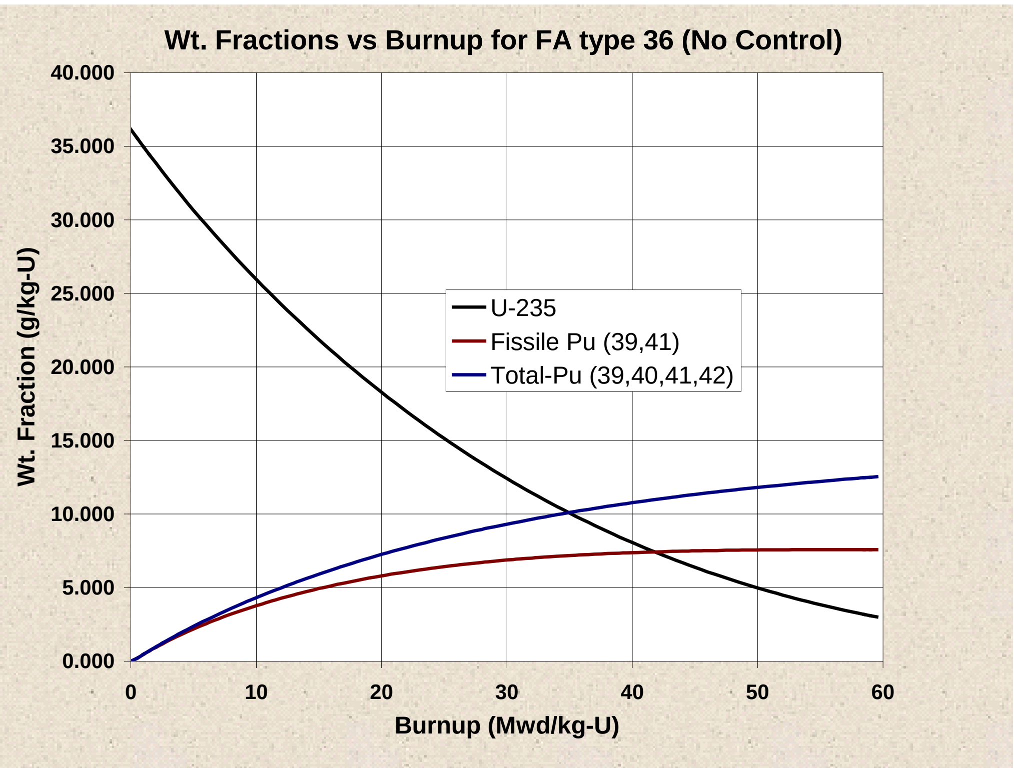
[FA TYPES 36 USES 3.3% & 3.7% U-235]
[FA TYPES 40 USES 3.7% & 4.1% U-235]

Fig. 6 – Different Types of FAs



1. FA Pin
2. FA Cap
3. Guiding channel
4. Central tube
5. Fuel rod
6. Spacing grid
7. Bottom grid
8. Tail piece

Fig. 7 – Schemetic of FA



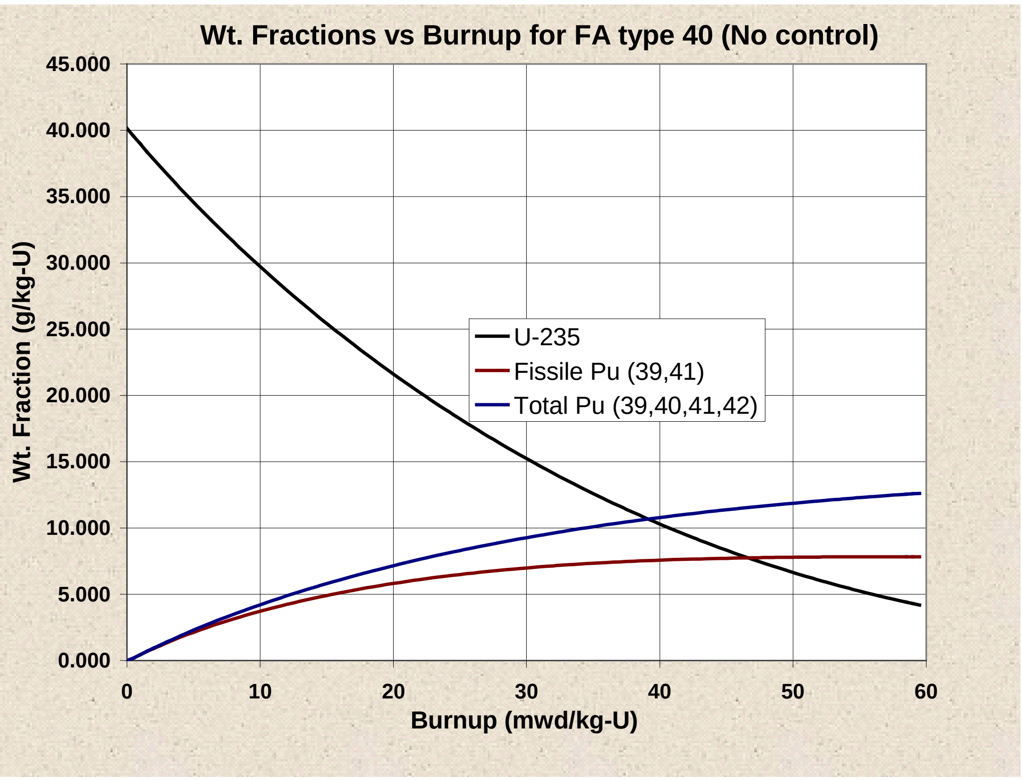
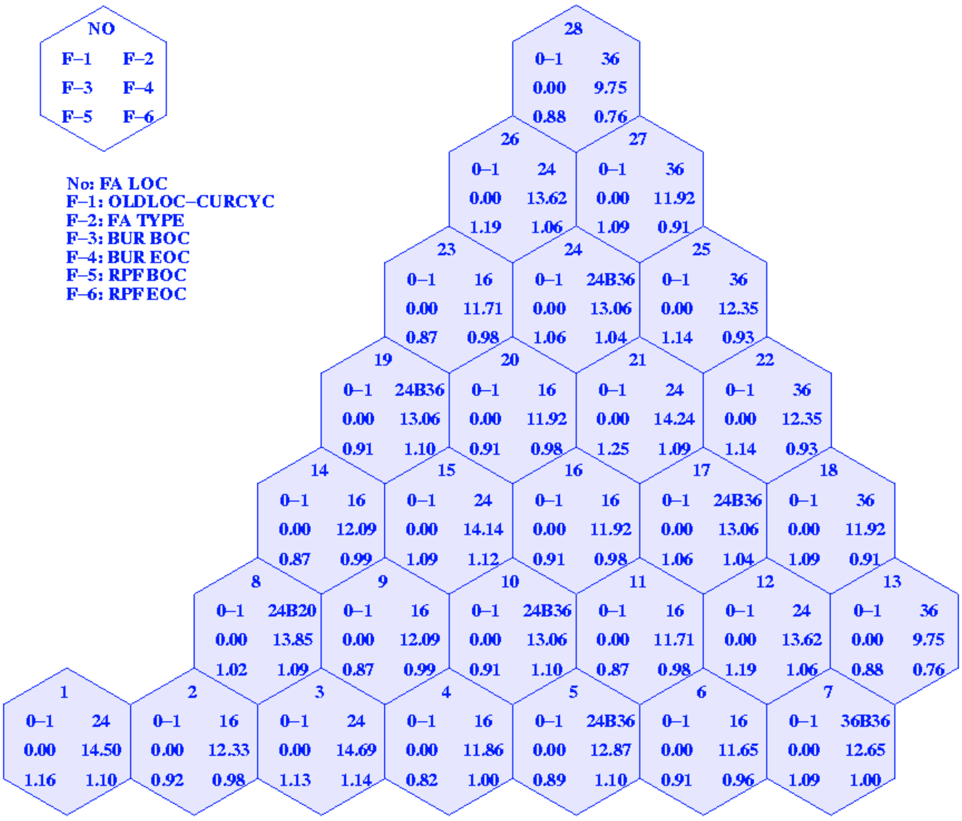


Fig. 8 - Isotopic Weight Fractions with burnup for FA types 36 & 40 (No Control)

Kudankulam – 1/6th Initial Core



[AV DISCH BURNUP AT EOC–1=12.0 Mwd/kgU]

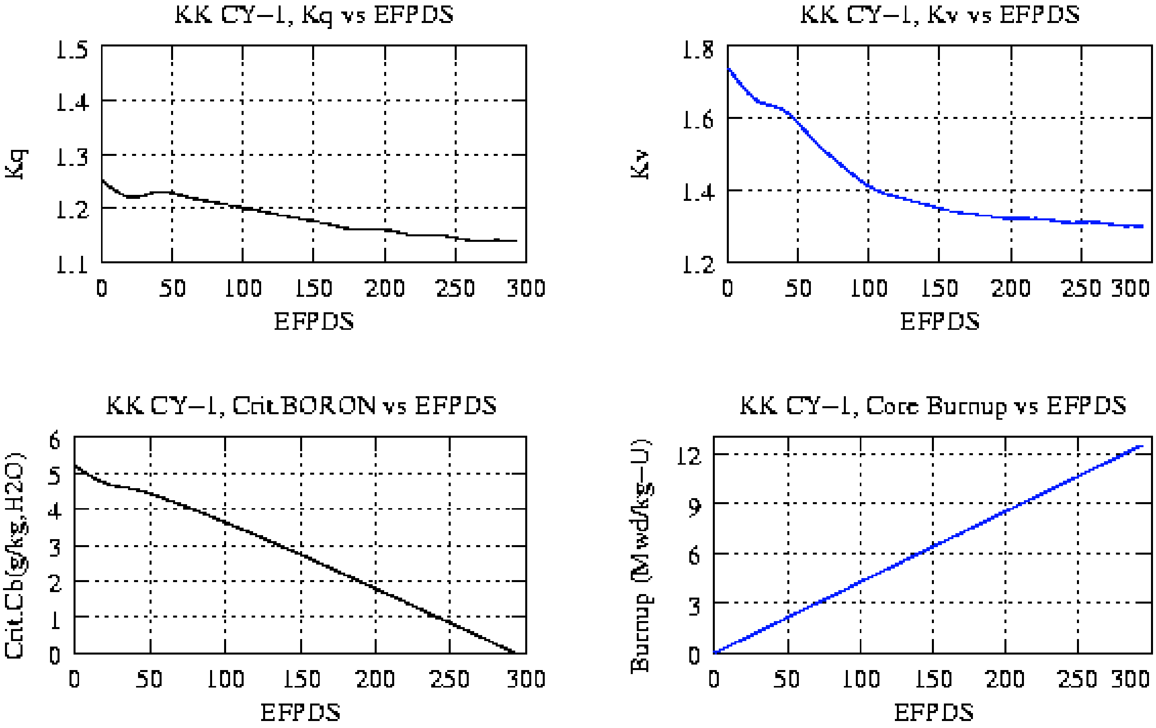
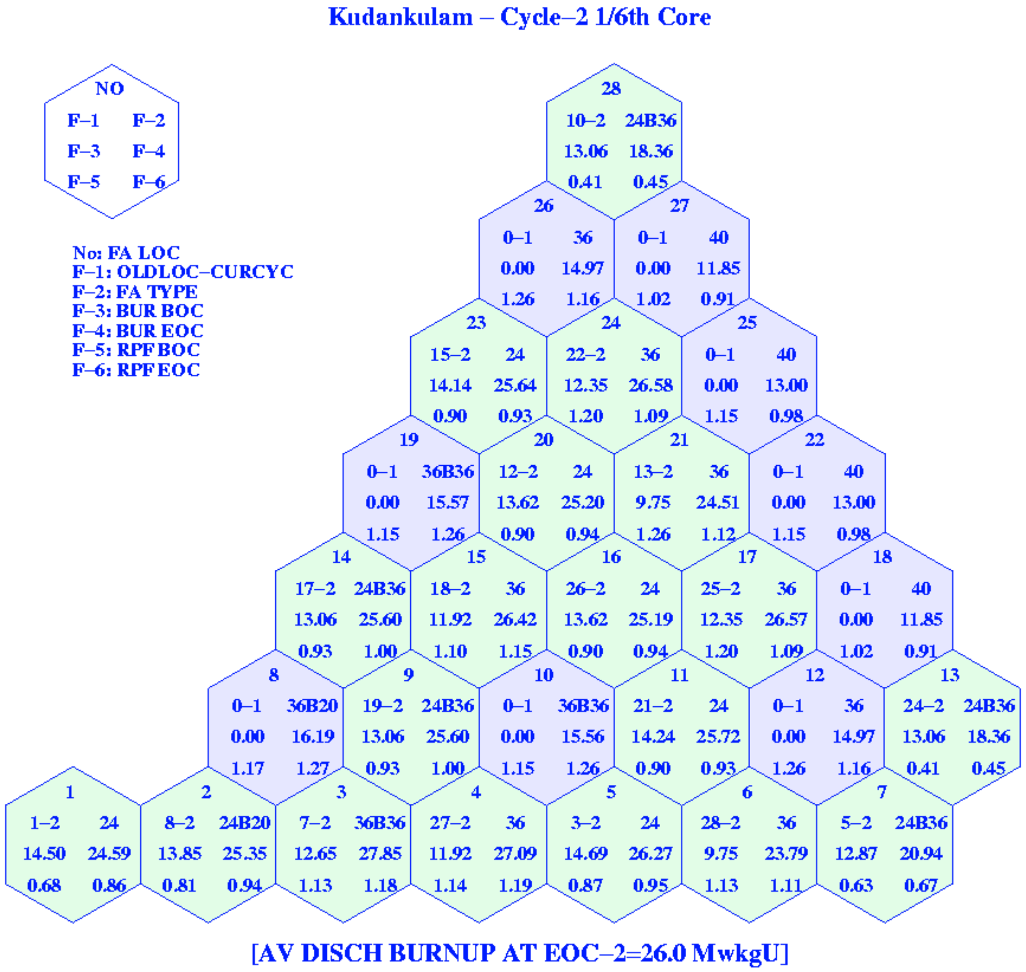


Fig. 9 – Initail Core Performance



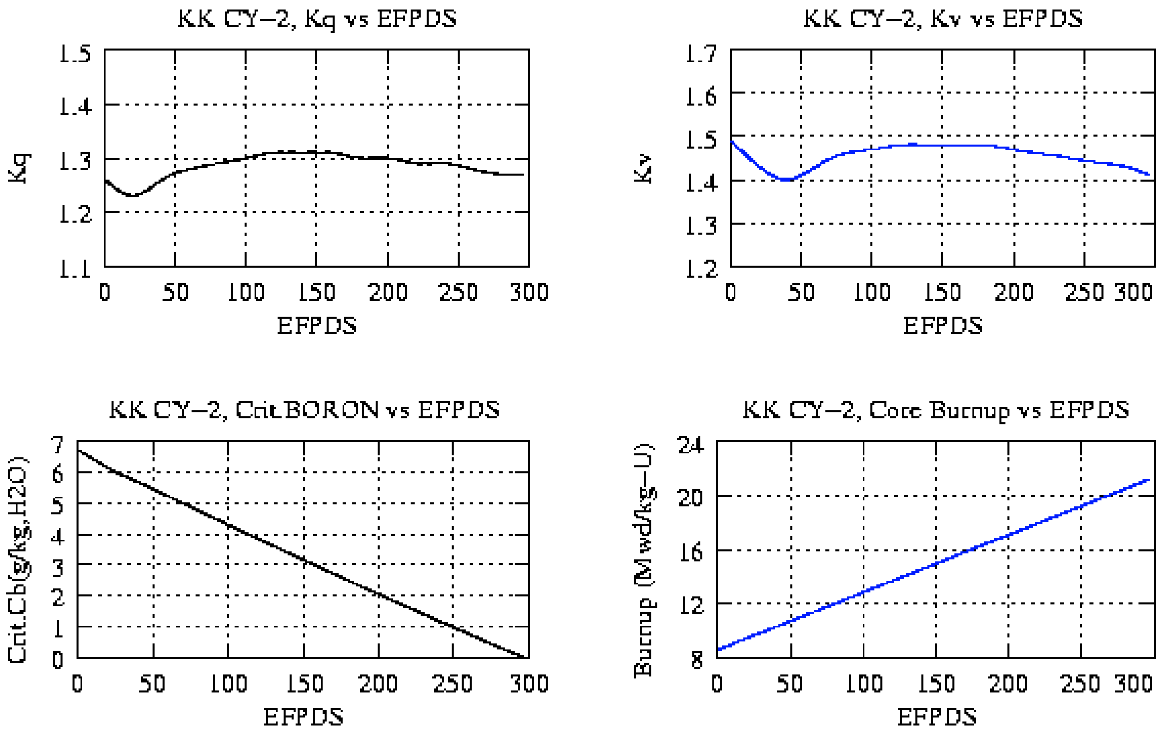
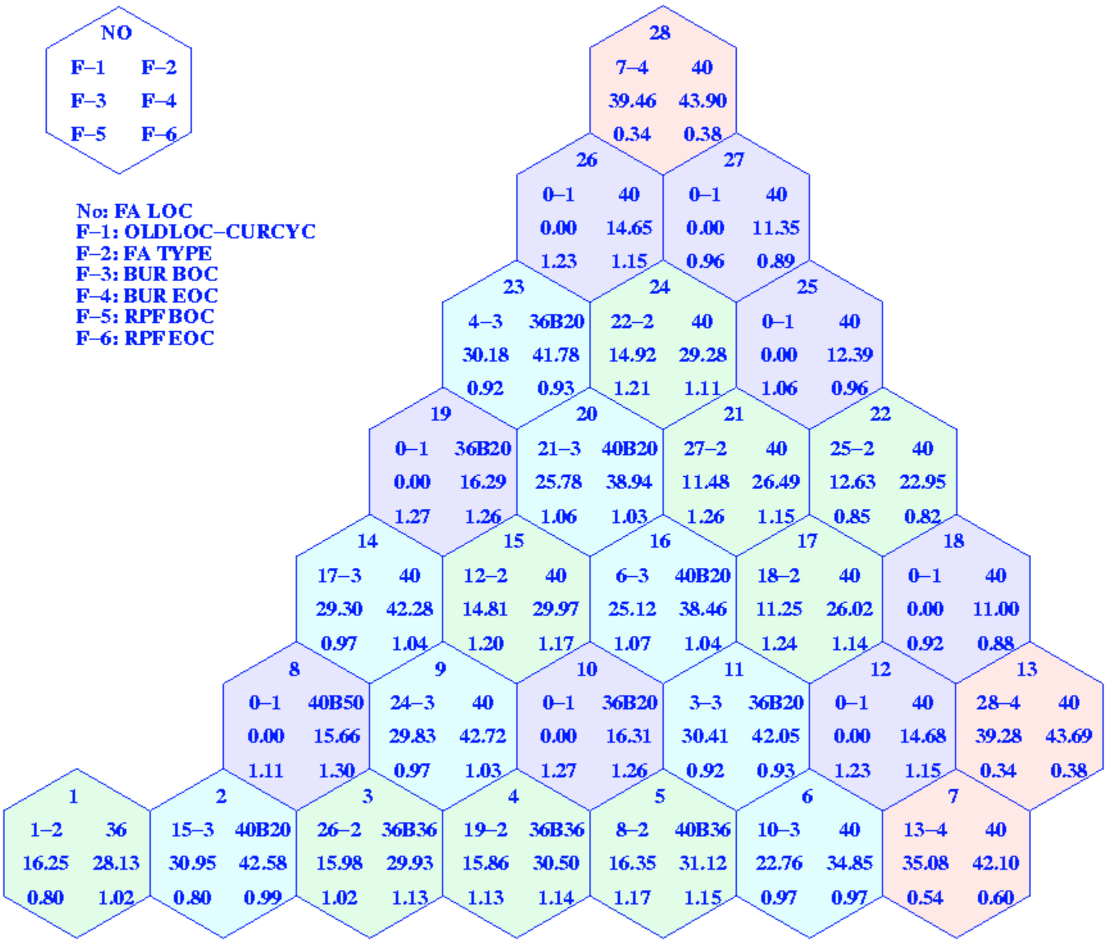


Fig. 10 – Reload-1 Core Performance

Kudankulam – Cycle–5 (Steady Cycle) 1/6th Core



NO
F–1 F–2
F–3 F–4
F–5 F–6

No: FA LOC
F–1: OLDLOC–CURCYC
F–2: FA TYPE
F–3: BUR BOC
F–4: BUR EOC
F–5: RPF BOC
F–6: RPF EOC

NO	F–1	F–2	F–3	F–4	F–5	F–6
28	7–4	40	39.46	43.90	0.34	0.38
26	0–1	40	0.00	14.65	1.23	1.15
27	0–1	40	0.00	11.35	0.96	0.89
23	4–3	36B20	30.18	41.78	0.92	0.93
24	22–2	40	14.92	29.28	1.21	1.11
25	0–1	40	0.00	12.39	1.06	0.96
19	0–1	36B20	0.00	16.29	1.27	1.26
20	21–3	40B20	25.78	38.94	1.06	1.03
21	27–2	40	11.48	26.49	1.26	1.15
22	25–2	40	12.63	22.95	0.85	0.82
14	17–3	40	29.30	42.28	0.97	1.04
15	12–2	40	14.81	29.97	1.20	1.17
16	6–3	40B20	25.12	38.46	1.07	1.04
17	18–2	40	11.25	26.02	1.24	1.14
18	0–1	40	0.00	11.00	0.92	0.88
8	0–1	40B50	0.00	15.66	1.11	1.30
9	24–3	40	29.83	42.72	0.97	1.03
10	0–1	36B20	0.00	16.31	1.27	1.26
11	3–3	36B20	30.41	42.05	0.92	0.93
12	0–1	40	0.00	14.68	1.23	1.15
13	28–4	40	39.28	43.69	0.34	0.38
1	1–2	36	16.25	28.13	0.80	1.02
2	15–3	40B20	30.95	42.58	0.80	0.99
3	26–2	36B36	15.98	29.93	1.02	1.13
4	19–2	36B36	15.86	30.50	1.13	1.14
5	8–2	40B36	16.35	31.12	1.17	1.15
6	10–3	40	22.76	34.85	0.97	0.97
7	13–4	40	35.08	42.10	0.54	0.60

[AV DISCH BURNUP AT EOC–5=43.0 Mwd/kgU]

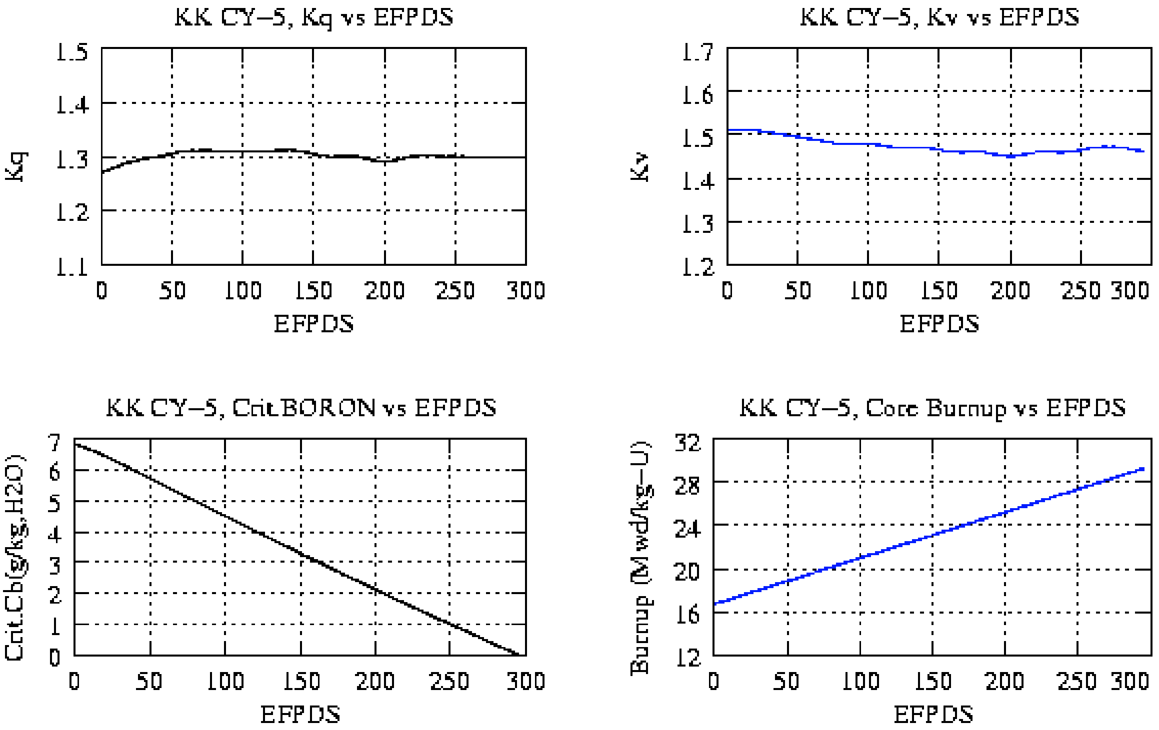
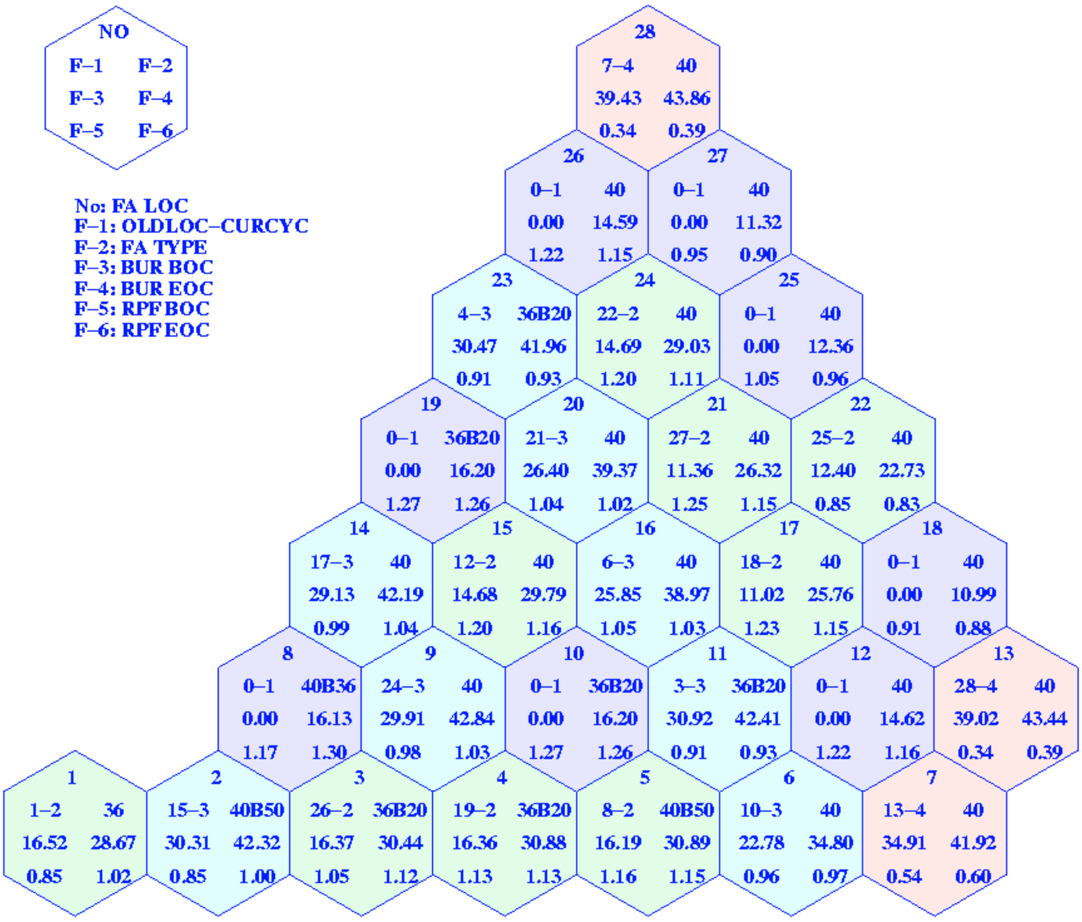


Fig. 11 – Reload-4 (Steady Stae) Core Performance

Kudankulam – Cycle–8 1/6th Core



NO	F–1	F–2	F–3	F–4	F–5	F–6
28	7–4	40	39.43	43.86	0.34	0.39
26	0–1	40	0.00	14.59	1.22	1.15
27	0–1	40	0.00	11.32	0.95	0.90
23	4–3	36B20	30.47	41.96	0.91	0.93
24	22–2	40	14.69	29.03	1.20	1.11
25	0–1	40	0.00	12.36	1.05	0.96
19	0–1	36B20	0.00	16.20	1.27	1.26
20	21–3	40	26.40	39.37	1.04	1.02
21	27–2	40	11.36	26.32	1.25	1.15
22	25–2	40	12.40	22.73	0.85	0.83
14	17–3	40	29.13	42.19	0.99	1.04
15	12–2	40	14.68	29.79	1.20	1.16
16	6–3	40	25.85	38.97	1.05	1.03
17	18–2	40	11.02	25.76	1.23	1.15
18	0–1	40	0.00	10.99	0.91	0.88
8	0–1	40B36	0.00	16.13	1.17	1.30
9	24–3	40	29.91	42.84	0.98	1.03
10	0–1	36B20	0.00	16.20	1.27	1.26
11	3–3	36B20	30.92	42.41	0.91	0.93
12	0–1	40	0.00	14.62	1.22	1.16
13	28–4	40	39.02	43.44	0.34	0.39
1	1–2	36	16.52	28.67	0.85	1.02
2	15–3	40B50	30.31	42.32	0.85	1.00
3	26–2	36B20	16.37	30.44	1.05	1.12
4	19–2	36B20	16.36	30.88	1.13	1.13
5	8–2	40B50	16.19	30.89	1.16	1.15
6	10–3	40	22.78	34.80	0.96	0.97
7	13–4	40	34.91	41.92	0.54	0.60

[AV DISCH BURNUP AT EOC–8=43.0 Mwd/kgU]

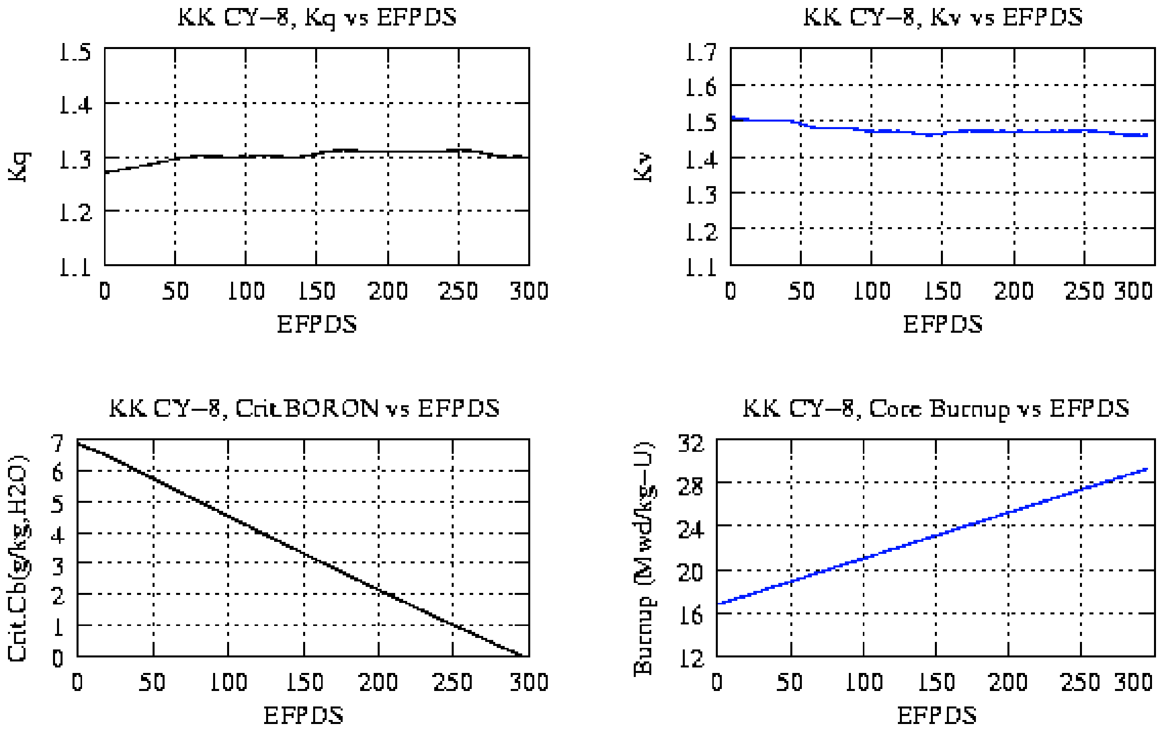


Fig. 12 – Cycle-8 Core Performance

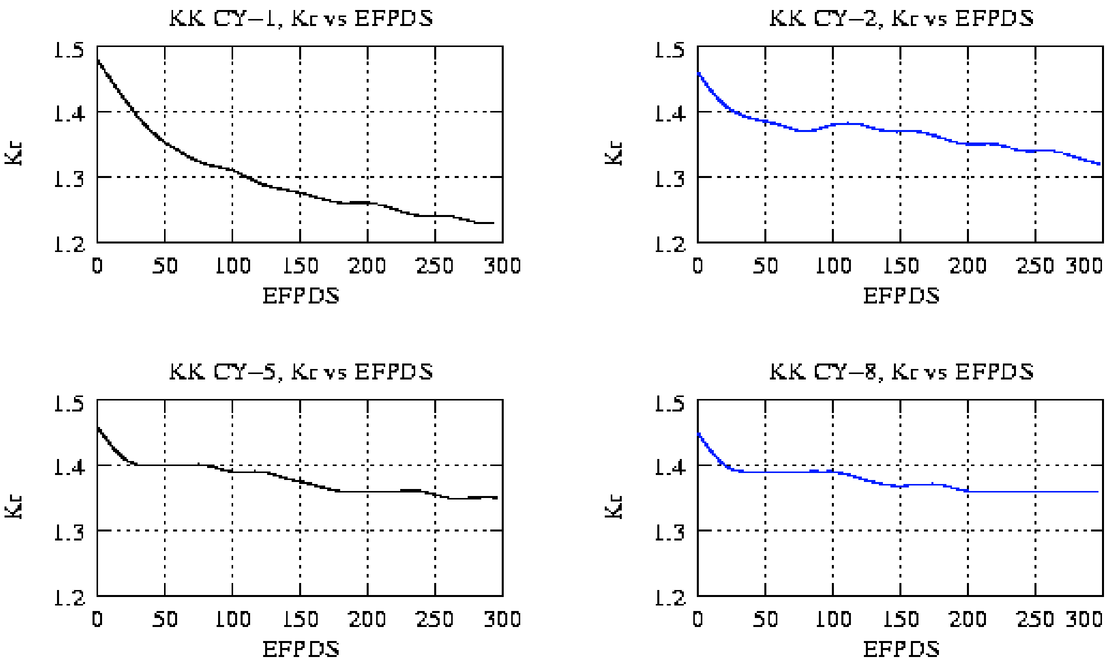


Fig. 13 – Kr vs EFPDS for 4 cycles of operations

No	Material Balance Component	Weight of Nuclear Material (grams)	
		Element Total	Fissile (for LEU)
1.	Beginning Inventory		
2.	Receipts		
3.	Nuclear Production		
4.	Total Additions (1+2+3)		
5.	Nuclear Loss (burnup)		
6.	Nuclear Loss (Pu-241 decay)		
7.	Shipments		
8.	Total deductions		
9.	Ending Book Inventory (4 – 8)		

Fig. 14 – Format of Material Balance Report

No		Locations	KMP	No. of Items	Weight of Nuclear Material (grams)	
					Total	Fissile
1		In Reactor				
	1.1	Core-1				
	1.2	Core-2				
2		Irradiated material in Storage				
	2.1	Pool-1				
	2.2	Pool-2				
	2.3	Outside Containment				
3		Fresh fuel assemblies				
4		Total Ending Inventory				

Fig. 15 – Format of Composition of Ending Inventory Report