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A. M. Pavlovitchev
A. A. Gorokhov
V. K. Ivanov
Y. A. Styrin

Fissile Materials Disposition Program

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A. M. Pavlovitchev
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Report

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Project Manager

A.M.Pavlovitchev

Executed by

A.A.Gorokhov
V.K.Ivanov
Y.A.Styrin

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ACRONYMS

Russian		American Equivalent
AZ	emergency (accident) protection	AP
AZ-1	state with all the control rods fully inserted except of one the most effective stuck in upper position	AP-1
AKNP	Source Range Channel	
APN	Safety Injection Pump	
ARM	Automated Power Regulator	
ASP	Emergency Diesel Generators (Loading Program)	
ATWS	Anticipated Transient Without Scram	ATWS
BOC	Beginning Of fuel Cycle	BOC
BPR	Burnable Poison Rod	BPR
BZOK	Rapid Cut-off Isolating Valve	
BRU-A	Atmospheric Steam Dump (PG Relief Valves)	
BRU-K	Condenser Steam Dump (PG Relief Valves)	
BShU	Control Room Of the Unit	
	Critical Heat Flux	CHF
	all the control rods in upper position	CRU
	all the control rods inserted	CRD
	Control Rod Drive Mechanism	CRDM
VKS	Reactor Upper Mixing Chamber	
VPEN	Auxiliary Feedwater Electrically Driven Pump	
VRK	Reactor Internal Control System	
DNBR	Departure from Nucleate Boiling Ratio	DNBR
DTC	Doppler Temperature Coefficient	DTC
EFPD	Effective Full Power Day	EFPD
EOC	End Of fuel Cycle	EOC
FGR	Fission Gas Release	FGR
FP	Fission Products	FP
GE (YT)	Hydro-tank of SAOZ system (passive part of SAOZ)	AC
GO	Containment	
GPZ	Main Steam Valve	
GZK	Primary Cooling Circuit	
GZN	Primary Cooling Pump	RCP
GZT	Main Circulation Pipeline	
IPU	Impulse protection unit	
ISA	Initial Event of an Accident	
KD	Pressurizer	
KI	Kurchatov Institute	KI
LOCA	Loss Of Coolant Accident	LOCA

LTA	Lead Test Assembly	LTA
LWR	Light Water Reactor	LWR
MCL	Minimum Controllable reactor power Level	MCL
MDC	Moderator Density Coefficient	MDC
MOX	Mixed OXide	MOX
MTC	Moderator Temperature Coefficient	MTC
NKS	Reactor Bottom Mixing Chamber	
NPP	Nuclear Power Plant	NPP
OR	Regulatory Body (Control Rod)	CR
PVD	Intermediate High Pressure Heater	
PG	Steam Generator	SG
PK	Relief Valve or Safety Valve	
PZ-1	1st-level Preventive Protection	
PZ-2	2nd-level Preventive Protection	
PND	Intermediate Low Pressure Heater	
PWR	Pressurized-Water Reactor	PWR
P_{prim}	pressure in primary circuit (in pressurizer)	P_{prim}
P_{sec}	pressure in secondary circuit	P_{sec}
RIA	Reactivity Initiated Accident	RIA
RCT	Repeat Criticality Temperature	RCT
ROM	Power Limitation Regulator	
RU	Reactor Unit	
SAOZ	Emergency Core Cooling System	ECCS
SB	Safety System	
SLA	Accident Localisation System	
SUZ	Reactor Control and Protection System	RPS
SVO	Chemical Water Purification System	
TQ12	High Pressure emergency injection of boron (active part of SAOZ)	
TQ14	Low Pressure System of core planned and emergency cooling (active part of SAOZ)	
TVS, FA	Fuel Assembly	FA
TVEL	Fuel Element	
TG	Turbine Generator	
TPN	Feedwater Turbine Driven Pump	
UOX	Uranium Oxide Fuel	UOX
VVER	Russian water-water reactor	VVER
EGSR	Electric - Hydraulic Regulatory System	

EXECUTIVE SUMMARY

In this document the kinetics parameters intended for use in transient analysis of VVER-1000 core with 3 MOX LTAs are presented. The neutronics parameters of MOX fuelled core have been calculated by the Russian 3D code BIPR-7A and 2D code PERMAK-A using cell spectrum code TVS-M.

CONTENTS

INTRODUCTION

The present work is a part of Joint U.S. / Russian Project with Weapons-Grade Plutonium Disposition in VVER Reactor and presents the neutronics calculations of kinetics parameters of VVER-1000 core with 3 introduced MOX LTAs.

MOX LTA design has been studied in [1] for two options of MOX LTA: 100% plutonium and of “island” type. As a result, zoning i.e. fissile plutonium enrichments in different plutonium zones, has been defined. VVER-1000 core with 3 introduced MOX LTAs of chosen design has been calculated in [2].

In present work, the neutronics data for transient analysis codes (RELAP [3]) has been obtained using the codes chain of RRC “Kurchatov Institute” [5] that is to be used for exploitation neutronics calculations of VVER. Nowadays the 3D assembly-by-assembly code BIPR-7A and 2D pin-by-pin code PERMAK-A, both with the neutronics constants prepared by the cell code TVS-M, are the base elements of this chain.

It should be reminded that in [6] TVS-M was used only for the constants calculations of MOX FAs. In current calculations the code TVS-M has been used both for UOX and MOX fuel constants. Besides, the volume of presented information has been increased and additional explications have been included.

The results for the reference uranium core [4] are presented in Chapter 2.

The results for the core with 3 MOX LTAs are presented in Chapter 3.

The conservatism that is connected with neutronics parameters and that must be taken into account during transient analysis calculations, is discussed in Chapter 4. The conservative parameters values are considered to be used in 1-point core kinetics models of accident analysis codes.

1. DEFINITIONS

Table 1. Definitions

Parameter	Abbreviation	Units	Remarks
Calculational system	CS		Multi-Assembly or core
CS symmetry sector	Sim		30 for 30°, 60 for 60°, 120 for 120°, 360 for full CS.
Reactivity of CS	RO	pcm	RO = (Keff-1)/Keff*1.E5
Calculational volume	Vij		Axial fraction j of assembly number i. In VVER-1000 calculations, 10-30 axial fractions of equal volume are usually used.
Effective multiplication factor of CS	Keff		
Multiplication factor of CS	Ko		Relation of neutron generation to neutron absorption. For core calculations Ko values are attributed to Vij
3-D power distribution in core	q_{ij}		Power in Vij normalised by average Vij power
Volume power peaking factor	Kv		Maximum in q_{ij} values
Radial position of volume power peaking factor	N (Kv) or N_K		Number of assembly in calculational core sector where Kv is realised
Axial position of volume power peaking factor	M (Kv) or N_Z		Number of axial level where Kv is realised
3-D burnup distribution in core	BUij	MWd/kg	Burnup in Vij.
2-D power distribution in core	q_i		Assembly powers normalised by average assembly power in core.

Radial power peaking factor	Kq		Maximum in qi values
Radial position of radial power peaking factor	N (Kq) or N_K		Number of assembly in calculational core sector where Kq is realised
Pin linear power	Ql	W/cm	Pin power for 1 cm of an axial calculational fraction
Moment during fuel irradiation	T	EFPD	
2-D burnup distribution in core	BUi	MWd/kg	Average-assembly burnup distribution in core.
Average burnup in Uranium assemblies	$\bar{B}_U$	MWd/kg	
Average burnup in MOX assemblies	$\bar{B}_{MOX}$	MWd/kg	
Average Boron acid (H_3BO_3) concentration* in coolant	Cb or C_{H3BO3}	ppm or g/kg	H_3BO_3 fraction in coolant (unit "ppm" means mg of boron acid in 1 Kg of H_2O)
Critical boron acid concentration in coolant	Cb^{crit}	ppm or g/kg	Cb (C_{H3BO3}) value ensuring Keff=1
2-D power distribution in CS	q_k-CS		Power of fuel pins normalised by average fuel pin power in CS.
Peaking factor of 2-D power distribution in CS	K_{FA}–CS		Maximum in q_k-CS values
2-D power distribution in assembly	q_k		Power of fuel pins normalised by average fuel pin power in assembly (in some axial fraction).
3-D power distribution in axial volumes of fuel pins in core	q_{ijk}		Power of axial volumes of fuel pins normalised by average power in such volumes over a whole core

* Boron acid concentration divided by the coefficient 5.72 means natural boron (nat B) concentration. In VVER-1000 calculations the term of boron acid concentration is widely used. Below, Cb means boron acid concentration if there is no special indication.

Pin power peaking factor in assembly	Kki		Among q_k values for an assembly number i for a fraction number j where maximum q_{ij} for this assembly is realised.
Radial pin power peaking factor	Kr		max (qi * Kki)
Radial position of radial pin power peaking factor	N (Kr) or N_K		Number of assembly in calculational core sector where Kr is realised
2-D power peaking factor in assembly	K_{FA} (in Russian exploitation calculations the notation Kk or Kk_{max} is also used)		Maximum relative power of fuel pins (maximum in q_k values)
Axial power peaking factor in assembly or in fuel pin	Kz		Maximum relative power of axial volume in assembly or in fuel pin normalised by average power in such volumes (in assembly or in fuel pin)
Total power peaking factor	Ko or $K_{o\text{-}total}$		$\max_{ij} (q_{ij} * Kki) = Kr*Kz$
Radial position of total power peaking factor	N ($K_{o\text{-}total}$) or N_K		Number of assembly in calculational core sector where $K_{o\text{-}total}$ is realised
Axial position of total power peaking factor	M ($K_{o\text{-}total}$) or N_Z		Number of axial level where $K_{o\text{-}total}$ is realised
Engineering factor	K_{eng}		Coefficient taking account of uncertainty of a hot point (maximum fuel pin local power) calculations
2-D burnup distribution in assembly	BUk	MWd/kg	Average-pin burnup distribution in CS.
1-D burnup distribution in fuel pin	BUpin		Burnup distribution in concentric zones of equal volume in fuel pin, normalised by average
			zone burnup.

1-D power distribution in fuel pin	q_{pin}		Power distribution in concentric zones of equal volume in fuel pin, normalised by average zone power.
Regulation bank position	H_{reg}	cm	Distance from core bottom till rods lower edge
Control rods worth (in core)	$(RO)_{AP-1}$	pcm	Effect of control rods insertion in core supposing the most effective single CR stuck in upper position. It is defined as a reactivity difference in two states: $(RO)_{AP-1}$= RO1-RO2. The second state differs from the first one only by additional CRs inserted in core. All the other parameters correspond to the first state: Cb (that is equal to Cb crit for the first state), temperature and FP distribution in core.
Repeat Criticality Temperature	RCT	°C	Temperature that ensures a secondary critical state during core cooling in EOC in such conditions: all control rods inserted in core except one the most effective, zero boron concentration, equilibrium xenon concentration corresponding to reactor power before its shut-down.
Moderator temperature coefficient (in core)	MTC	pcm/°C	
Moderator density coefficient (in core)	MDC	pcm/g/cc	
Doppler temperature coefficient (in core)	DTC	pcm/°C	Calculated supposing average fuel temperature changing of 1°C
Doppler isotermic temperature coefficient (in core)	DTC*	pcm/°C	Calculated supposing local fuel temperature changing of 1°C

Doppler power coefficient (in core)	DPC	pcm/MW	
Boron reactivity coefficient (in core)[a]	DRO/DCB	pcm/ppm	
Effective fraction of delayed neutrons	βeff or $\beta_{ef.}$	pcm	General characteristic of infinite grid or core
Lifetime of prompt neutrons	λ_m or λ_{im} or l_{im}	s	General characteristic of infinite grid or core
Reactor thermal power	W	MW	
Specific reactor thermal power in CS	Wv	KW/litre	Reactor thermal power in CS volume unit
Nominal reactor thermal power	Wnom	MW	Equal to 3000 MW for VVER-1000
Minimum controllable level of reactor power	MCL	MW	In calculations corresponds to Zero Power and uniform temperature 280°C in core.
Core coolant flow rate	G	m^3/h	
Average entry core temperature	t_{entry}	°C or K	
Average outer core temperature	t_{out}	°C or K	
Average coolant-moderator temperature in CS	t_{mod}	°C or K	
Average Coolant-moderator density in CS	γ_{mod}	g/cm^3	
Fuel temperature	t_{fuel}	K	
Average temperature of other CS components	t_{con}	°C or K	
Fuel pin cladding temperature	t_{clad}	°C or K	
Xenon-135 concentration distribution in core	Xe	10^{24} /cc	For 1 cc in fuel. In brief description of states the following notations may be used: Xe = 0 – xenon is absent; Xe = 1 – Xe=Xe eq (W).

[a] This coefficient may be calculated either through boron acid concentration (as usual in this report) or through natural boron concentration. In the last case the special indication "(nat B)" is used. The relation is: DRO/DCB (nat.B) = DRO/DCB * 5.72.

Equilibrium Xenon-135 concentration distribution in core	Xe eq (W)	10^{24} /cc	Concentration formed during long working with W power, regulating bank in nominal position[b]
Sm-149 concentration distribution in core	Sm	10^{24} /cc	For 1 cc in fuel. In brief description of states the following notations may be used: Sm = 0 – samarium is absent, Sm = 1 – Sm=Sm eq, Sm = 3 – in BOC full decay of Pm-149 into Sm-149 is simulated.
Equilibrium Sm-149 concentration distribution in core	Sm eq	10^{24} /cc	Concentration formed during long working, regulating bank in nominal position
Samarium-149 concentration distribution, all Prometium-149 decayed in Sm	Smh	10^{24} /cc	
Core reactivity while reactor shut-down	RO_{STOP}	pcm	Under conditions: W=0, Xe=0,Sm=Smh, t_{mod}= t_{fuel}= t_{con}=20°C, Cb= 16000 ppm

[b] In VVER-1000 calculations Hreg in nominal position is equal to 80% if there is no special indication

2. KINETICS PARAMETERS IN REFERENCE URANIUM CORE

Uranium core with boron BPRs (Fig.1) has been defined in [4] as a reference core for 3 MOX LTAs introduction. The assemblies marked by the same symbol indicate positioning of some assembly during irradiation in the first, second, third and, probably, forth fuel cycle.

The Figures 2-12 and Table 3 show the results of kinetics parameters calculations for the equilibrium fuel cycle in this core.

Fig.2 and Table 3 show βeff evolution during core cycle.

Fig.3 and 3a, Table13 show core reactivity evolution in the process of control rods simultaneous movement (when AP is actuated) from top to the bottom of core. BOC and EOC moments are considered including the situations when the most effective single control rod is stuck in upper position. Stuck rods location corresponds to Fig.13. In the left column the time while scram actuating is indicated. The whole time of drop is conservatively adopted as equal to 4s (in reality its about 2.3 s).

It is seen that $(RO)_{AP-1}$ is 8330 pcm in BOC and 8570 pcm in EOC in the case of the most effective rod stuck in the core top.

Core reactivity versus regulating group (Fig.13 – bank 10) position is demonstrated in Fig.4 and 4a, Table 14 for BOC and EOC.

Fig.5 and Table 15 show core reactivity evolution while coolant density changing. Density values from 0.2 g/cc till 0.766 g/cc are considered in zero power states without Xenon. The density of 0.766 g/cc corresponds to the state of MCL.

Table 16 shows core reactivity versus core power under the condition that only fuel parameters vary (Doppler effect). For 1-point kinetics model a conventional fuel temperature, indicated also in the Table, can be related to core power levels. Fig. 6 and 6a give Doppler effect versus this conventional temperature.

Axial power distribution in BOC and EOC is shown in Fig.7 and in Table 17 for several fuel assemblies of different irradiation.

Fig.8 shows assembly average powers, burnup and temperature drop (heatings)[a] distributions in BOC and EOC calculated by 3-D code BIPR-7A with 10 levels in axial direction.

Figures 9 and 10 show correspondingly assembly-by-assembly maximum linear pin power distributions in BOC and EOC. The axial levels in Fig.9 and subsequent figures correspond to those in Table 18 (level 4 = 124.25 cm, level 2 = 53.25 cm, etc.). Figures 11 and 12 show correspondingly pin-by-pin power distribution in BOC and EOC for the most powered assembly. 2D pin-by-pin calculations by PERMAK-A have been performed for level 4[b]. It is seen from combination of BIPR-7A and PERMAK-A calculations (Figures 9-10 and further 18-19, 27-28, 37-38, 46-47, 56-57, 65-66) that maximum linear pin power in BOC is attained on level 4, in EOC – on level 2.

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[a] Temperature drop is the difference between output and input coolant temperatures for an assembly considered as a channel.
[b] Numeration begins from core bottom.

3. KINETICS PARAMETERS IN URANIUM CORE WITH 3 MOX LTAs

World experience shows that partially MOX loaded cores (widely used about 30% MOX loaded core) significantly change the following core neutronics characteristics:

- $(RO)_{AP-1}$ that is lower in MOX loaded cores (compared with uranium ones);
- βeff that is lower in MOX loaded cores[a];
- Doppler coefficient that increases (in absolute values) in MOX loaded cores.

In core loading patterns (Figures 14, 33, 52), chosen in [2], 3 MOX LTAs are placed:

- in the positions without CRs (see Fig.13);
- in core periphery (in two first cycles).

It this case MOX LTAs, even being significantly more absorbent than UOX, influence weakly upon control rods worth $(RO)_{AP-1}$. Besides, in case of 3 MOX LTAs in core, $(RO)_{AP-1}$ depends mainly on core loading pattern and may be both lower and greater than in uranium core.

Two types of MOX LTA has been considered in [1-2]:

- 100% Plutonium,
- of “Island” type.

Table 12 shows the values of $(RO)_{AP-1}$ in the case of full CRs insertion (from full power state) for different cycles in uranium reference core and in MOX loaded cores. It is seen that $(RO)_{AP-1}$ changes weakly while passing from uranium to 3 MOX LTAs loaded cores and no clear tendency is marked. Evolution of reactivity during AP insertion into core is presented in Table 13.

In Tables 4-9 and in Figures 15-17, 24-26, 34-36, 43-45, 53-55, 62-64 the average assembly parameters distributions are presented for 3 cycles with 3 introduced MOX LTAs 100% Plutonium and of “Island” type. Parameters values evolution is very close in both cases. It is seen from Figures 20-23, 29-32, 39-42, 48-51, 58-61, 67-70 that only pin-by-pin distributions are significantly different in 100% Plutonium and of “Island” type MOX assemblies. So if there is no special indication the presented data for MOX fuelled core concerns the case of 100% Plutonium MOX LTAs.

It is seen from the Tables 3-9 that βeff and DTC evolution during fuel cycles is practically the same in Uranium and MOX loaded cores.

Core reactivity versus regulating group position is demonstrated in Table 14 for BOC and EOC.

Table 15 shows core reactivity evolution while coolant density changing.

Doppler effect (core reactivity versus core power and conventional core fuel temperature) is presented in Table 16 and Figures 6 and 6a.

Axial power distribution in MOX assemblies for BOC and EOC is shown in Table 18 and Fig.7a.

[a] βeff is 0.0064 in U-235 and 0.0021 in Pu-239.

4. CONSERVATISM ADOPTED FOR TRANSIENT ANALYSIS CALCULATIONS

The following factors must be taken into account while using of presented neutronics parameters in transient analysis codes:

1.Calculation precision;
2. Uncertainty of reactor design parameters used in neutronics parameters calculation;
3. Possible modification of loading pattern in real conditions that will be different with the calcuIated case.

In VVER-1000 Uranium core calculations the following precision of neutronics parameters is adopted:

- RO – 3%;
- q_i – 5%;
- q_{ij} – 10%;
- Kk – 3%;
- $(RO)_{AP-1}$ - 10%.

Being based particularly on these predictions the limiting values were developed for VVER-1000 Uranium cores to be used in accident analysis on the base of corresponding engineering margin coefficients K_{eng}. The mentioned limiting values are considered to be used in 1-point core kinetics model of accident analysis codes particularly in RELAP-like calculations.

The mentioned limiting values actually used in VVER-1000 safety calculations are presented in the second column of Table 2. The limitations for • r and • $_{o\text{-}total}$ are aimed to respect maximum allowable pin linear powers presented in Table 23 including the cases with axial power distributions of cosinus type and of type “maximum in core upper part” (the last is the most dangerous for DNBR). These special axial power distributions are presented in Table 21.

• onservative curves presented in Tables 19-23 are proposed to adopt also for cores with 3 MOX LTAs if the best estimate values for the above-mentioned base Uranium core with boron BPRs and for 3 MOX LTAs cores are found within these limiting values.

In the third and in the forth column the calculated values are presented for the base Uranium core with boron BPRs and for the core with 3 MOX LTAs. As a rule, the parameters values for the 1-th, 2-nd and 3-d fuel cycles of MOX cores are close and in this case they are presented by averaged values. The last column contains the values recommended for VVER-1000 with 3 MOX LTAs.

In Table 20 the standard “Conservative curve” for VVER-1000 Uranium cores is compared with the calculations of control rods worth from Table 13. The curves for the base Uranium core and MOX cores have been obtained for the minimum $(RO)_{AP\text{-}1}$ values that is for BOC – “Uranium core” and (BOC, MOX-2) – “MOX cores”. It is seen that “Conservative curve” gives the slower reactivity evolution during CRs insertion ensuring “conservatism” of accident calculations.

The same conclusion can be applied to Table 19 with “Conservative curve” for Minimum effectiveness of Regulating group.

The curve from the Table 22 leads to more rapid arrival to critical state than the curves cumulated in Table 15 and so can be used as the conservative one.

Table 11 describes the scheme of conservative evaluation of core subcriticality (scram margin) after scram actuation and reactor state transformation from nominal power to MCL. The effects and uncertainties involved in this scheme (vapor effect, absorbent irradiation, uncertainty of CRs worth calculation etc.) correspond to ones adopted in the West, particularly, in the US and France.

In Table 24 delayed neutrons parameters are presented.

In accordance with a type of accident to be calculated in VVER-1000 with 3 MOX LTAs, the corresponding conservative values must be taken from Table 2 (the last column). The details concerning utilisation of these values in different transient calculations is the case of future documents.

Table 2. Neutronics Data for Transients Analysis

Parameter	Values for standard accident analysis of VVER-1000	Base Uranium core	Core with 3 MOX LTAs	Recommended values for accident analysis of VVER-1000 with 3 MOX LTAs
Radial pin power peaking factor **Kr**	1.60	1.51 (Table 10)	1.52 (Table 10)	1.60
Total power peaking factor **Ko-total**	2.24	1.86 (Table 10)	1.85 (Table 10)	2.24
Axial power distribution in assembly	Table 21	Table17	Table18	Table 21
Maximum fuel linear power, W/cm	448	309.5 (Figures 9-10)	307.8 (Figures 18-19, 27-28, 37-38, 46-47, 56-57, 65-66)	448
DTC, pcm/°C BOC, MCL BOC, full power EOC, MCL EOC, full power	 -2.0 -1.6 -3.0 -2.5	 -2.13 -2.46 -3.31 -2.80	 -2.96 -2.47 -3.31 -2.79	 -2.0 -1.6 -3.0 - 2.5
MTC, pcm/°C BOC, MCL BOC, full power EOC, MCL EOC, full power	 0 -10 -65 -60	 -1.23 -25.94 -27.52 -60.05	 -0.94 -24.63 -27.59 -59.82	 0 -10 -65 -60
MDC, pcm/g/cc	0 - 34000	12293-28260	11833 - 28338	0 - 34000
Core reactivity versus coolant density	Table 22	Table 15	Table 15	Table 22
Boron reactivity coefficient	From - 6	From – 8.87	From – 8.87	From - 6

DRO/DCB (nat. B), pcm/ppm	till - 12	Till - 9.84	Till - 8.90	till - 12
Regulation group effectiveness, pcm Minimum Maximum	 620 1000	 910 940	 750 950	 620 1000
Minimum effectiveness of Regulation group versus insertion depth	Conservative curve from Table 19	Table 19	Table 19	Conservative curve from Table 19
Control rods worth **(RO)$_{\mathbf{AP-1}}$**, Minimum over cycle, pcm Full power	5500	8330	8180	5500
Relative Core reactivity evolution in the process of control rods movement	Conservative core from Table 20	Table 20	Table 20	Conservative core from Table 20
Repeat Criticality Temperature **RCT,** °C	210	124	129 (1-st Cycle) 130 (2-nd Cycle) 117 (3-d Cycle)	210
βeff, pcm BOC EOC	 600 520	 650 551	 648 548	 600 520
Lifetime of Prompt neutrons, micro-s BOC EOC	 22.0 25.3	 22.4 25.5	 22.3 25.7	 22.0 25.3

CONCLUSION

The report is aimed to obtain data necessary for transient analysis codes while safety studying of VVER-1000 core with 3 MOX LTAs.

The set of kinetics parameters is presented both for Uranium reference core and for 3 MOX LTAs loaded cores. On this base the conservative values of neutronics parameters to be used in transient calculations are proposed.

Details about applying the presented information to different types of accidents is the case of future documents.

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Table 3. Evolution of main neutronics parameters in Uranium reference core . Equilibrium cycle

Sim = 60 , Xe = 1 , Sm = 3

№	T EFPD	$H_{reg.}$ cm	t_{entry} °C	W MW	$Cb^{crit.}$ ppm	G m^3/h	Kq	Nk	Kq^{MOX}	Nk	Kv	Nk	Nz	$\bar{B}_U$ MW• d/kg	$\bar{B}_{MOX}$ MW• d/kg	MDC pcm• $(g/cm^3)^{-1}$	MTC pcm• $°C^{-1}$	DTC pcm• $°C^{-1}$	DTC* pcm• $°C^{-1}$	DPC pcm• MW^{-1}	DRo/DCb pcm• ppm^{-1}	$\beta_{ef.}$ pcm	l_{im} •10^5 sec
1	0.0	283.2	287.0	3000	5657	84000	1.31	19	0.00	0	1.61	19	4	14.14	0.00	12293	−25.94	−2.96	−2.46	−0.29	−1.55	650	2.24
2	20.0	283.2	287.0	3000	5318	84000	1.31	19	0.00	0	1.58	19	4	15.00	0.00	12894	−26.94	−2.96	−2.47	−0.29	−1.55	639	2.24
3	40.0	283.2	287.0	3000	4899	84000	1.31	19	0.00	0	1.56	19	4	15.85	0.00	14000	−29.20	−2.94	−2.48	−0.29	−1.56	630	2.25
4	60.0	283.2	287.0	3000	4473	84000	1.31	19	0.00	0	1.53	19	3	16.70	0.00	15191	−31.69	−2.93	−2.50	−0.29	−1.57	622	2.27
5	80.0	283.2	287.0	3000	4047	84000	1.31	19	0.00	0	1.52	19	3	17.55	0.00	16400	−34.24	−2.93	−2.52	−0.29	−1.58	613	2.29
6	100.0	283.2	287.0	3000	3631	84000	1.31	19	0.00	0	1.51	19	3	18.41	0.00	17590	−36.77	−2.94	−2.55	−0.29	−1.59	606	2.31
7	120.0	283.2	287.0	3000	3215	84000	1.30	19	0.00	0	1.50	19	3	19.26	0.00	18775	−39.30	−2.96	−2.58	−0.29	−1.60	598	2.33
8	140.0	283.2	287.0	3000	2813	84000	1.30	19	0.00	0	1.49	19	3	20.11	0.00	19928	−41.77	−2.97	−2.60	−0.29	−1.62	591	2.35
9	160.0	283.2	287.0	3000	2411	84000	1.30	19	0.00	0	1.48	19	3	20.96	0.00	21077	−44.25	−2.99	−2.63	−0.29	−1.63	585	2.37
10	180.0	283.2	287.0	3000	2023	84000	1.30	19	0.00	0	1.47	19	2	21.82	0.00	22203	−46.69	−3.02	−2.66	−0.29	−1.64	578	2.40
11	200.0	283.2	287.0	3000	1634	84000	1.30	19	0.00	0	1.47	19	2	22.67	0.00	23333	−49.16	−3.04	−2.69	−0.29	−1.66	573	2.42
12	220.0	283.2	287.0	3000	1254	84000	1.29	19	0.00	0	1.47	19	2	23.52	0.00	24457	−51.62	−3.06	−2.71	−0.29	−1.67	567	2.45
13	240.0	283.2	287.0	3000	874	84000	1.29	19	0.00	0	1.47	19	2	24.37	0.00	25592	−54.13	−3.08	−2.74	−0.30	−1.68	562	2.48
14	260.0	283.2	287.0	3000	500	84000	1.29	19	0.00	0	1.46	19	2	25.23	0.00	26727	−56.64	−3.09	−2.76	−0.30	−1.70	557	2.51
15	280.0	283.2	287.0	3000	127	84000	1.28	19	0.00	0	1.46	19	2	26.08	0.00	27869	−59.18	−3.11	−2.79	−0.30	−1.71	552	2.54
16	286.9	283.2	287.0	3000	0	84000	1.28	19	0.00	0	1.45	19	2	26.37	0.00	28260	−60.05	−3.12	−2.80	−0.30	−1.72	551	2.55

Table 4. Evolution of main neutronics parameters. First cycle with 3 MOX LTAs 100%Pu(4.2-3.0-2.0)

Sim =360 , Xe = 1 , Sm = 3

№	T EFPD	$H_{reg.}$ cm	t_{entry} °C	W MW	$Cb^{crit.}$ ppm	G m^3/h	Kq	Nk	Kq^{MOX}	Nk	Kv	Nk	Nz	$\bar{B}_U$ MW•d/kg	$\bar{B}_{MOX}$ MW•d/kg	MDC pcm•$(g/cm^3)^{-1}$	MTC pcm•$°C^{-1}$	DTC pcm•$°C^{-1}$	DTC* pcm•$°C^{-1}$	DPC pcm•MW^{-1}	DRo/DCb pcm•ppm^{-1}	$\beta_{ef.}$ pcm	l_{im} •10^5 sec
1	0.0	283.2	287.0	3000	5784	84000	1.32	38	1.03	8	1.61	38	4	14.26	0.00	12029	−25.00	−2.88	−2.49	−0.28	−1.55	642	2.23
2	20.0	283.2	287.0	3000	5439	84000	1.27	38	0.98	8	1.52	38	4	15.12	0.88	12614	−25.94	−2.89	−2.51	−0.28	−1.56	632	2.24
3	40.0	283.2	287.0	3000	5012	84000	1.27	38	0.95	8	1.49	11	4	15.97	1.71	13743	−28.28	−2.88	−2.52	−0.28	−1.57	624	2.26
4	60.0	283.2	287.0	3000	4585	84000	1.26	117	0.93	8	1.47	117	3	16.82	2.52	14944	−30.82	−2.88	−2.54	−0.28	−1.58	616	2.27
5	80.0	283.2	287.0	3000	4152	84000	1.26	92	0.92	150	1.45	92	3	17.68	3.32	16173	−33.43	−2.89	−2.56	−0.28	−1.59	608	2.29
6	100.0	283.2	287.0	3000	3725	84000	1.26	92	0.91	150	1.45	92	3	18.53	4.10	17390	−36.04	−2.90	−2.58	−0.28	−1.60	601	2.31
7	120.0	283.2	287.0	3000	3298	84000	1.27	92	0.91	88	1.45	92	3	19.38	4.88	18604	−38.65	−2.91	−2.61	−0.28	−1.61	594	2.33
8	140.0	283.2	287.0	3000	2887	84000	1.27	92	0.90	88	1.44	92	3	20.24	5.66	19785	−41.20	−2.93	−2.63	−0.28	−1.62	587	2.35
9	160.0	283.2	287.0	3000	2476	84000	1.27	92	0.90	88	1.44	124	3	21.09	6.42	20964	−43.75	−2.95	−2.65	−0.29	−1.64	581	2.38
10	180.0	283.2	287.0	3000	2072	84000	1.27	92	0.89	88	1.44	124	2	21.95	7.19	22131	−46.29	−2.97	−2.68	−0.29	−1.65	575	2.40
11	200.0	283.2	287.0	3000	1669	84000	1.27	124	0.89	88	1.45	124	2	22.80	7.95	23302	−48.86	−2.99	−2.70	−0.29	−1.66	569	2.43
12	220.0	283.2	287.0	3000	1276	84000	1.27	124	0.88	88	1.45	124	2	23.65	8.70	24460	−51.40	−3.01	−2.72	−0.29	−1.68	564	2.46
13	240.0	283.2	287.0	3000	883	84000	1.28	124	0.88	88	1.46	124	2	24.51	9.46	25627	−53.97	−3.03	−2.75	−0.29	−1.69	559	2.49
14	260.0	283.2	287.0	3000	491	84000	1.28	124	0.88	88	1.46	124	2	25.36	10.21	26802	−56.58	−3.04	−2.77	−0.29	−1.71	554	2.52
15	280.0	283.2	287.0	3000	111	84000	1.27	124	0.88	88	1.46	124	2	26.22	10.96	27960	−59.14	−3.06	−2.79	−0.29	−1.72	549	2.55
16	285.8	283.2	287.0	3000	0	84000	1.27	124	0.88	88	1.45	124	2	26.47	11.18	28297	−59.90	−3.07	−2.79	−0.29	−1.73	548	2.56

Table 5. Evolution of main neutronics parameters. First cycle with 3 MOX LTAs of “Island” type: { Pu(3.8-2.8) – U3.7%}

Sim =360 , Xe = 1 , Sm = 3

№	T EFPD	$H_{reg.}$ cm	t_{entry} °C	W MW	$Cb^{crit.}$ ppm	G m^3/h	Kq	Nk	Kq^{MOX}	Nk	Kv	Nk	Nz	$\bar{B}_U$ MW•d/kg	$\bar{B}_{MOX}$ MW•d/kg	MDC pcm•$(g/cm^3)^{-1}$	MTC pcm•$°C^{-1}$	DTC pcm•$°C^{-1}$	DTC* pcm•$°C^{-1}$	DPC pcm•MW^{-1}	DRo/DCb pcm•ppm^{-1}	$\beta_{ef.}$ pcm	l_{im} •10^5 sec
1	0.0	283.2	287.0	3000	5773	84000	1.32	38	1.01	8	1.61	38	4	14.26	0.00	11944	−24.84	−2.88	−2.49	−0.28	−1.57	647	2.25
2	20.0	283.2	287.0	3000	5435	84000	1.27	38	0.97	8	1.52	38	4	15.12	0.86	12535	−25.79	−2.88	−2.50	−0.28	−1.57	636	2.25
3	40.0	283.2	287.0	3000	5014	84000	1.26	38	0.97	8	1.49	38	4	15.97	1.69	13669	−28.14	−2.87	−2.51	−0.28	−1.57	628	2.27
4	60.0	283.2	287.0	3000	4586	84000	1.26	117	0.97	8	1.47	47	3	16.82	2.52	14879	−30.69	−2.87	−2.53	−0.28	−1.59	620	2.28
5	80.0	283.2	287.0	3000	4158	84000	1.26	72	0.96	150	1.45	72	3	17.67	3.34	16104	−33.29	−2.88	−2.55	−0.28	−1.60	612	2.30
6	100.0	283.2	287.0	3000	3737	84000	1.26	72	0.96	150	1.44	132	3	18.53	4.16	17315	−35.88	−2.89	−2.58	−0.28	−1.61	604	2.32
7	120.0	283.2	287.0	3000	3316	84000	1.26	132	0.96	88	1.44	132	3	19.38	4.98	18523	−38.47	−2.90	−2.60	−0.28	−1.62	597	2.34
8	140.0	283.2	287.0	3000	2905	84000	1.26	132	0.96	88	1.44	132	3	20.23	5.80	19708	−41.02	−2.92	−2.62	−0.28	−1.63	590	2.36
9	160.0	283.2	287.0	3000	2493	84000	1.26	132	0.96	88	1.43	124	3	21.09	6.62	20889	−43.58	−2.94	−2.65	−0.28	−1.64	584	2.39
10	180.0	283.2	287.0	3000	2093	84000	1.27	132	0.96	88	1.44	124	2	21.94	7.44	22050	−46.11	−2.96	−2.67	−0.29	−1.66	578	2.41
11	200.0	283.2	287.0	3000	1694	84000	1.27	124	0.96	88	1.44	124	2	22.79	8.25	23214	−48.66	−2.98	−2.70	−0.29	−1.67	572	2.44
12	220.0	283.2	287.0	3000	1301	84000	1.27	124	0.96	88	1.45	124	2	23.65	9.07	24372	−51.19	−3.00	−2.72	−0.29	−1.68	566	2.47
13	240.0	283.2	287.0	3000	909	84000	1.27	124	0.96	88	1.45	124	2	24.50	9.88	25537	−53.76	−3.02	−2.74	−0.29	−1.70	561	2.49
14	260.0	283.2	287.0	3000	524	84000	1.27	124	0.96	88	1.45	124	2	25.35	10.70	26697	−56.33	−3.04	−2.76	−0.29	−1.71	556	2.52
15	280.0	283.2	287.0	3000	139	84000	1.27	124	0.96	88	1.45	124	2	26.21	11.51	27861	−58.91	−3.05	−2.79	−0.29	−1.73	552	2.55
16	287.4	283.2	287.0	3000	0	84000	1.27	124	0.96	88	1.45	124	2	26.52	11.81	28287	−59.87	−3.06	−2.79	−0.29	−1.73	550	2.57

Table 6. Evolution of main neutronics parameters. 2-nd cycle with 3 MOX LTAs 100%Pu(4.2-3.0-2.0)

Sim =360 , Xe = 1 , Sm = 3

№	T EFPD	$H_{reg.}$ cm	t_{entry} °C	W MW	$Cb^{crit.}$ ppm	G m^3/h	Kq	Nk	Kq^{MOX}	Nk	Kv	Nk	Nz	$\bar{B}_U$ MW•d/kg	$\bar{B}_{MOX}$ MW•d/kg	MDC pcm•$(g/cm^3)^{-1}$	MTC pcm•$°C^{-1}$	DTC pcm•$°C^{-1}$	DTC* pcm•$°C^{-1}$	DPC pcm•MW^{-1}	DRo/DCb pcm•ppm^{-1}	$\beta_{ef.}$ pcm	l_{im} •10^5 sec
1	0.0	283.2	287.0	3000	5666	84000	1.34	153	1.21	141	1.66	153	4	13.82	11.18	12450	−26.03	−2.89	−2.49	−0.28	−1.55	642	2.23
2	20.0	283.2	287.0	3000	5325	84000	1.28	153	1.20	141	1.56	153	4	14.67	12.21	13070	−27.06	−2.89	−2.50	−0.28	−1.55	632	2.24
3	40.0	283.2	287.0	3000	4904	84000	1.28	153	1.18	141	1.53	153	4	15.52	13.23	14186	−29.37	−2.88	−2.52	−0.28	−1.56	624	2.25
4	60.0	283.2	287.0	3000	4484	84000	1.28	153	1.17	141	1.50	153	3	16.37	14.23	15365	−31.85	−2.88	−2.53	−0.28	−1.57	616	2.27
5	80.0	283.2	287.0	3000	4055	84000	1.27	153	1.16	141	1.47	153	3	17.22	15.23	16573	−34.41	−2.88	−2.56	−0.28	−1.58	608	2.28
6	100.0	283.2	287.0	3000	3633	84000	1.26	153	1.16	18	1.45	47	3	18.07	16.22	17770	−36.96	−2.89	−2.58	−0.28	−1.60	601	2.30
7	120.0	283.2	287.0	3000	3212	84000	1.25	153	1.15	18	1.43	47	3	18.92	17.21	18964	−39.52	−2.90	−2.60	−0.28	−1.61	594	2.33
8	140.0	283.2	287.0	3000	2805	84000	1.25	110	1.14	18	1.41	47	3	19.77	18.19	20126	−42.02	−2.92	−2.62	−0.28	−1.62	587	2.35
9	160.0	283.2	287.0	3000	2398	84000	1.25	110	1.14	18	1.41	110	3	20.62	19.16	21284	−44.52	−2.93	−2.65	−0.28	−1.63	581	2.37
10	180.0	283.2	287.0	3000	2000	84000	1.25	110	1.13	18	1.41	110	2	21.47	20.13	22429	−47.00	−2.95	−2.67	−0.29	−1.65	575	2.40
11	200.0	283.2	287.0	3000	1602	84000	1.25	110	1.12	18	1.42	110	2	22.32	21.09	23578	−49.50	−2.97	−2.69	−0.29	−1.66	569	2.42
12	220.0	283.2	287.0	3000	1215	84000	1.26	110	1.12	18	1.42	110	2	23.17	22.05	24712	−51.98	−2.99	−2.72	−0.29	−1.67	564	2.45
13	240.0	283.2	287.0	3000	827	84000	1.26	110	1.12	18	1.43	110	2	24.02	23.00	25855	−54.49	−3.01	−2.74	−0.29	−1.69	559	2.48
14	260.0	283.2	287.0	3000	446	84000	1.26	110	1.11	18	1.43	110	2	24.87	23.96	26995	−57.00	−3.03	−2.76	−0.29	−1.70	554	2.51
15	280.0	283.2	287.0	3000	65	84000	1.26	110	1.11	18	1.43	56	2	25.72	24.90	28140	−59.54	−3.04	−2.78	−0.29	−1.71	550	2.54
16	283.5	283.2	287.0	3000	0	84000	1.26	110	1.11	18	1.43	56	2	25.87	25.07	28338	−59.98	−3.05	−2.79	−0.29	−1.72	549	2.54

Table 7. Evolution of main neutronics parameters. Second cycle with 3 MOX LTAs of “Island-2” type { Pu(3.8-2.8) – U3.7%}

Sim =360 , Xe = 1 , Sm = 3

№	T EFPD	$H_{reg.}$ cm	t_{entry} °C	W MW	$Cb^{crit.}$ ppm	G m^3/h	Kq	Nk	Kq^{MOX}	Nk	Kv	Nk	Nz	$\bar{B}_U$ MW•d/kg	$\bar{B}_{MOX}$ MW•d/kg	MDC pcm•$(g/cm^3)^{-1}$	MTC pcm•$°C^{-1}$	DTC pcm•$°C^{-1}$	DTC* pcm•$°C^{-1}$	DPC pcm•MW^{-1}	DRo/DCb pcm•ppm^{-1}	$\beta_{ef.}$ pcm	l_{im} •10^5 sec
1	0.0	283.2	287.0	3000	5658	84000	1.34	153	1.23	141	1.66	153	4	13.86	11.81	12366	−25.86	−2.87	−2.47	−0.28	−1.57	647	2.25
2	20.0	283.2	287.0	3000	5322	84000	1.28	153	1.23	141	1.55	153	4	14.70	12.86	12989	−26.89	−2.88	−2.49	−0.28	−1.57	636	2.25
3	40.0	283.2	287.0	3000	4905	84000	1.28	153	1.22	141	1.52	153	4	15.55	13.91	14105	−29.20	−2.87	−2.51	−0.28	−1.57	628	2.27
4	60.0	283.2	287.0	3000	4487	84000	1.27	153	1.21	141	1.49	153	3	16.40	14.95	15283	−31.67	−2.87	−2.53	−0.28	−1.58	619	2.28
5	80.0	283.2	287.0	3000	4061	84000	1.27	153	1.20	141	1.47	153	3	17.25	15.98	16492	−34.24	−2.87	−2.55	−0.28	−1.59	612	2.30
6	100.0	283.2	287.0	3000	3641	84000	1.26	153	1.20	18	1.45	47	3	18.10	17.00	17687	−36.78	−2.88	−2.57	−0.28	−1.61	604	2.32
7	120.0	283.2	287.0	3000	3221	84000	1.25	153	1.19	18	1.43	47	3	18.95	18.03	18878	−39.34	−2.90	−2.60	−0.28	−1.62	597	2.34
8	140.0	283.2	287.0	3000	2817	84000	1.24	47	1.19	18	1.41	47	3	19.80	19.04	20037	−41.83	−2.91	−2.62	−0.28	−1.63	590	2.36
9	160.0	283.2	287.0	3000	2413	84000	1.24	110	1.18	18	1.40	110	3	20.65	20.05	21192	−44.32	−2.93	−2.65	−0.28	−1.64	584	2.38
10	180.0	283.2	287.0	3000	2016	84000	1.24	110	1.18	18	1.40	110	2	21.50	21.06	22334	−46.80	−2.95	−2.67	−0.29	−1.65	578	2.41
11	200.0	283.2	287.0	3000	1620	84000	1.25	110	1.17	18	1.41	110	2	22.35	22.07	23479	−49.29	−2.97	−2.70	−0.29	−1.67	572	2.44
12	220.0	283.2	287.0	3000	1234	84000	1.25	110	1.17	18	1.42	110	2	23.20	23.06	24610	−51.76	−2.99	−2.72	−0.29	−1.68	566	2.46
13	240.0	283.2	287.0	3000	849	84000	1.25	110	1.17	18	1.42	110	2	24.05	24.06	25749	−54.26	−3.01	−2.74	−0.29	−1.69	561	2.49
14	260.0	283.2	287.0	3000	469	84000	1.25	110	1.16	18	1.42	110	2	24.90	25.05	26885	−56.76	−3.03	−2.76	−0.29	−1.71	556	2.52
15	280.0	283.2	287.0	3000	90	84000	1.25	110	1.16	18	1.42	110	2	25.75	26.05	28028	−59.29	−3.04	−2.79	−0.29	−1.72	552	2.55
16	284.8	283.2	287.0	3000	0	84000	1.25	110	1.16	18	1.42	56	2	25.95	26.28	28301	−59.90	−3.05	−2.79	−0.29	−1.73	551	2.56

Table 8. Evolution of main neutronics parameters. 3-d cycle with 3 MOX LTAs 100%Pu(4.2-3.0-2.0)

Sim =360 , Xe = 1 , Sm = 3

№	T EFPD	$H_{reg.}$ cm	t_{entry} °C	W MW	$Cb^{crit.}$ ppm	G m^3/h	Kq	Nk	Kq^{MOX}	Nk	Kv	Nk	Nz	$\bar{B}_U$ MW•d/kg	$\bar{B}_{MOX}$ MW•d/kg	MDC pcm•$(g/cm^3)^{-1}$	MTC pcm•$°C^{-1}$	DTC pcm•$°C^{-1}$	DTC* pcm•$°C^{-1}$	DPC pcm•MW^{-1}	DRo/DCb pcm•ppm^{-1}	$\beta_{ef.}$ pcm	l_{im} •10^5 sec
1	0.0	283.2	287.0	3000	5810	84000	1.33	126	1.04	111	1.64	126	4	13.36	25.07	11897	−24.77	−2.89	−2.48	−0.28	−1.55	647	2.23
2	20.0	283.2	287.0	3000	5472	84000	1.28	11	1.06	111	1.54	126	4	14.21	25.96	12560	−25.89	−2.88	−2.49	−0.28	−1.55	636	2.24
3	40.0	283.2	287.0	3000	5054	84000	1.28	11	1.05	111	1.51	11	4	15.06	26.86	13685	−28.21	−2.88	−2.51	−0.28	−1.56	628	2.25
4	60.0	283.2	287.0	3000	4629	84000	1.27	11	1.05	111	1.48	126	3	15.91	27.75	14883	−30.74	−2.87	−2.53	−0.28	−1.57	620	2.27
5	80.0	283.2	287.0	3000	4204	84000	1.26	11	1.04	111	1.46	126	3	16.76	28.64	16095	−33.31	−2.88	−2.55	−0.28	−1.58	612	2.28
6	100.0	283.2	287.0	3000	3779	84000	1.25	124	1.04	111	1.44	124	3	17.62	29.53	17306	−35.90	−2.89	−2.57	−0.28	−1.59	604	2.30
7	120.0	283.2	287.0	3000	3368	84000	1.25	124	1.04	111	1.44	124	3	18.47	30.42	18486	−38.42	−2.90	−2.60	−0.28	−1.61	597	2.32
8	140.0	283.2	287.0	3000	2958	84000	1.25	124	1.04	111	1.43	124	3	19.32	31.30	19661	−40.95	−2.91	−2.62	−0.28	−1.62	591	2.34
9	160.0	283.2	287.0	3000	2547	84000	1.25	124	1.04	111	1.42	124	3	20.17	32.18	20833	−43.48	−2.93	−2.64	−0.28	−1.63	584	2.37
10	180.0	283.2	287.0	3000	2150	84000	1.25	124	1.04	111	1.42	124	2	21.02	33.07	21979	−45.97	−2.95	−2.67	−0.29	−1.64	578	2.39
11	200.0	283.2	287.0	3000	1754	84000	1.25	134	1.04	111	1.42	124	2	21.88	33.95	23129	−48.47	−2.97	−2.69	−0.29	−1.66	572	2.42
12	220.0	283.2	287.0	3000	1357	84000	1.25	134	1.04	111	1.42	124	2	22.73	34.83	24284	−51.00	−2.99	−2.72	−0.29	−1.67	567	2.45
13	240.0	283.2	287.0	3000	974	84000	1.25	134	1.04	111	1.42	124	2	23.58	35.72	25422	−53.50	−3.01	−2.74	−0.29	−1.69	561	2.47
14	260.0	283.2	287.0	3000	591	84000	1.25	134	1.04	111	1.42	134	2	24.43	36.60	26568	−56.03	−3.02	−2.76	−0.29	−1.70	557	2.50
15	280.0	283.2	287.0	3000	208	84000	1.25	134	1.04	111	1.42	134	2	25.28	37.49	27720	−58.58	−3.04	−2.78	−0.29	−1.71	552	2.53
16	291.0	283.2	287.0	3000	0	84000	1.25	134	1.04	111	1.42	134	2	25.75	37.97	28351	−59.99	−3.05	−2.79	−0.29	−1.72	550	2.55

Table 9. Evolution of main neutronics parameters. 3-d cycle with 3 MOX LTAs of "Island-2" type { Pu(3.8-2.8) – U3.7%}

Sim =360 , Xe = 1 , Sm = 3

№	T EFPD	$H_{reg.}$ cm	t_{entry} °C	W MW	$Cb^{crit.}$ ppm	G m^3/h	Kq	Nk	Kq^{MOX}	Nk	Kv	Nk	Nz	$\bar{B}_U$ MW•d/kg	$\bar{B}_{MOX}$ MW•d/kg	MDC pcm•$(g/cm^3)^{-1}$	MTC pcm•°C^{-1}	DTC pcm•°C^{-1}	DTC* pcm•°C^{-1}	DPC pcm•MW^{-1}	DRo/DCb pcm•ppm^{-1}	$\beta_{ef.}$ pcm	l_{im} •10^5 sec
1	0.0	283.2	287.0	3000	5790	84000	1.33	126	1.03	111	1.64	126	4	13.41	26.28	11833	−24.63	−2.89	−2.49	−0.28	−1.56	648	2.24
2	20.0	283.2	287.0	3000	5455	84000	1.28	126	1.06	111	1.54	126	4	14.26	27.16	12483	−25.71	−2.89	−2.50	−0.28	−1.56	638	2.25
3	40.0	283.2	287.0	3000	5039	84000	1.27	11	1.05	111	1.51	126	4	15.11	28.06	13606	−28.04	−2.89	−2.52	−0.28	−1.57	629	2.26
4	60.0	283.2	287.0	3000	4616	84000	1.27	124	1.05	111	1.48	124	4	15.97	28.96	14802	−30.56	−2.88	−2.54	−0.28	−1.58	621	2.28
5	80.0	283.2	287.0	3000	4193	84000	1.27	124	1.05	111	1.47	124	3	16.82	29.85	16012	−33.13	−2.89	−2.56	−0.28	−1.59	613	2.29
6	100.0	283.2	287.0	3000	3770	84000	1.27	124	1.04	111	1.46	124	3	17.67	30.74	17220	−35.70	−2.89	−2.58	−0.28	−1.60	606	2.31
7	120.0	283.2	287.0	3000	3361	84000	1.27	124	1.04	111	1.45	124	3	18.52	31.63	18399	−38.23	−2.90	−2.60	−0.28	−1.61	599	2.33
8	140.0	283.2	287.0	3000	2952	84000	1.27	124	1.04	111	1.44	124	3	19.37	32.52	19573	−40.75	−2.92	−2.63	−0.28	−1.63	592	2.36
9	160.0	283.2	287.0	3000	2543	84000	1.26	124	1.05	111	1.44	124	3	20.23	33.41	20743	−43.28	−2.94	−2.65	−0.28	−1.64	585	2.38
10	180.0	283.2	287.0	3000	2147	84000	1.26	124	1.05	111	1.43	124	2	21.08	34.30	21889	−45.77	−2.95	−2.67	−0.29	−1.65	579	2.40
11	200.0	283.2	287.0	3000	1752	84000	1.26	124	1.05	111	1.44	124	2	21.93	35.19	23039	−48.27	−2.97	−2.69	−0.29	−1.66	573	2.43
12	220.0	283.2	287.0	3000	1357	84000	1.26	124	1.05	111	1.44	124	2	22.78	36.09	24194	−50.80	−2.99	−2.72	−0.29	−1.68	568	2.46
13	240.0	283.2	287.0	3000	974	84000	1.26	124	1.05	111	1.44	124	2	23.63	36.98	25334	−53.30	−3.01	−2.74	−0.29	−1.69	563	2.49
14	260.0	283.2	287.0	3000	592	84000	1.26	124	1.05	111	1.44	124	2	24.48	37.88	26482	−55.84	−3.03	−2.76	−0.29	−1.71	558	2.51
15	280.0	283.2	287.0	3000	210	84000	1.26	124	1.06	111	1.44	124	2	25.34	38.78	27637	−58.39	−3.04	−2.78	−0.29	−1.72	553	2.54
16	291.2	283.2	287.0	3000	0	84000	1.26	124	1.06	111	1.43	124	2	25.81	39.28	28277	−59.82	−3.05	−2.79	−0.29	−1.73	551	2.56

Table 10. Power Peaking Factors Attained During Fuel Cycle

		Uranium	MOX-1		MOX-2		MOX-3	
			100%Pu	Island	100%Pu	Island	100%Pu	Island
$K_{o\text{-total}}$	BOC	1.86	1.79	1.79	1.85	1.84	1.83	1.82
	EOC	1.52	1.52	1.51	1.49	1.48	1.46	1.47
	max	1.86	1.79	1.79	1.85	1.84	1.83	1.82
N ($K_{o\text{-total}}$)	BOC	19	38	38	153	141	126	126
	EOC	19	124	124	56	56	134	124
	max	19	38	38	153	141	126	126
M ($K_{o\text{-total}}$)	BOC	4	4	4	4	4	4	4
	EOC	2	2	2	2	2	2	2
	max	4	4	4	4	4	4	4
Kr	BOC	1.51	1.47	1.47	1.49	1.52	1.48	1.48
	EOC	1.34	1.33	1.32	1.31	1.31	1.29	1.30
	max	1.51	1.47	1.47	1.49	1.52	1.48	1.48
N (Kr)	BOC	19	38	38	153	141	126	126
	EOC	6	124	124	110	18	152	124
	max	19	38	38	153	141	126	126

- Power Peaking Factor is attained in MOX LTA

Table 11. Core Subcriticality (Scram Margin) in different states in the process of Scram actuation

State parameters						RO, pcm							
State Number	W, MW	t_{entry}, °•	Hreg , %	Positions of banks 1-9, %	Positions of the most eff. CR, %	UOX		MOX 1er cycle		MOX 2nd cycle		MOX 3d cycle	
						BOC	EOC	BOC	EOC	BOC	EOC	BOC	EOC
1	3000	Nominal.	100	100	100	+522	+605	+483	+600	+434	+563	+449	+569
	Regulation margin of reactivity												
2	3000	Nominal.	50	100	100	0.	0.	0.	0.	0.	0.	0.	0.
	Scram actuation without sticking of the most effective CR												
3	3000	Nominal.	0	0	0	-8833	-9136	-8772	-9043	-8806	-9064	-8994	-9150
	Scram actuation with sticking of the most effective CR												
4	3000	Nominal.	0	0	100	-7970	-8262	-7964	-8178	-7889	-8153	-8671	-8282
	Doppler effect												
5	0	Nominal.	0	0	100	-6391	-6807	-6989	-7296	-6865	-7244	-7628	-7379
	Moderator temperature effect												
6	0	287	0	0	100	-5550	-5088	-5718	-5001	-5609	-5000	-6488	-5192
	Moderator temperature effect												
7	0	280	0	0	100	-5358	-4711	-5530	-4624	-5417	-4624	-6294	-4817
	Vapor effect ($\Delta\rho$ = 50 pcm)												
8	0	280	0	0	100	-5308	-4661	-5480	-4574	-5367	-4574	-6244	-4767
	Uncertainty of $(RO)_{AP}$ calculation (10% of p. 4)												
9	0	280	0	0	100	-4511	-3835	-4684	-3756	-4578	-3759	-5377	-3939
	Uncertainty of temperature effect calculation ($\Delta\rho$ = 180 pcm)												
10	0	280	0	0	100	-4331	-3655	-4504	-3576	-4398	-3579	-5197	-3759
	Absorbent irradiation effect ($\Delta\rho$ = 100 pcm)												
11	0	280	0	0	100	**-4231**	**-3555**	**-4404**	**-3476**	**-4298**	**-3479**	**-5097**	**-3659**

Table 12. Control Rods Worth (RO_{AP-1}) for Uranium core and MOX cores

	Uranium Core	First cycle with 3 MOX LTAs	2-nd cycle with 3 MOX LTAs	3-d cycle with 3 MOX LTAs
BOC	8330	8300	8180	8930
EOC	8570	8480	8430	8560

Table 13. Core reactivity in the process of control rods movement

T, s	AP Position,% (Hreg=80%)	BOC									
		Uranium		MOX-1				MOX-2		MOX-3	
		No stuck	Stuck N 55	No stuck 100%	No stuck Island	Stuck N 67 100%	Stuck N 67 Island	No stuck	Stuck N 109	No stuck	Stuck N 112
0	100	0	0	0	0	0	0	0	0	0	0
0,4	90	-120	-120	-120	-120	-120	-120	-110	-110	-120	-120
0,8	80	-210	-210	-210	-210	-210	-210	-200	-200	-200	-200
1,2	70	-310	-310	-310	-310	-310	-310	-290	-290	-300	-300
1,6	60	-460	-460	-450	-450	-450	-450	-430	-430	-440	-440
2,0	50	-700	-700	-680	-690	-680	-680	-660	-660	-680	-670
2,4	40	-1150	-1140	-1110	-1110	-1100	-1110	-1070	-1070	-1090	-1090
2,8	30	-2000	-1990	-1920	-1920	-1910	-1920	-1860	-1850	-1900	-1890
3,2	20	-3620	-3590	-3490	-3500	-3470	-3480	-3430	-3400	-3480	-3460
3,6	10	-7050	-6810	-6930	-6950	-6730	-6740	-6900	-6660	-7010	-6880
4,0	0	-9150	-8330	-9060	-9070	-8300	-8300	-9060	-8180	-9250	-8930

T, s	AP Position,% (Hreg=80%)	EOC									
		Uranium		MOX-1				MOX-2		MOX-3	
		No stuck	Stuck N 55	No stuck 100%	No stuck Island	Stuck N 97 100%	Stuck N 97 Island	No stuck	Stuck N 97	No stuck	Stuck N 97
0	100	0	0	0	0	0	0	0	0	0	0
0,4	90	-140	-140	-140	-140	-140	-140	-130	-130	-140	-140
0,8	80	-190	-190	-190	-190	-190	-190	-190	-190	-190	-190
1,2	70	-260	-260	-260	-260	-260	-250	-250	-250	-260	-260
1,6	60	-360	-360	-360	-350	-360	-350	-350	-350	-350	-350
2,0	50	-530	-530	-530	-530	-530	-530	-520	-520	-530	-530
2,4	40	-880	-870	-870	-870	-870	-860	-850	-850	-860	-860
2,8	30	-1590	-1580	-1570	-1570	-1570	-1560	-1540	-1530	-1540	-1540
3,2	20	-3000	-2980	-2960	-2950	-2940	-2930	-2910	-2890	-2910	-2890
3,6	10	-6300	-6160	-6200	-6190	-6060	-6050	-6180	-6020	-6190	-6060
4,0	0	-9410	-8570	-9310	-9310	-8480	-8480	-9310	-8430	-9400	-8560

Table 14. Core reactivity versus regulation group position

Hreg, %	BOC				EOC			
	U	MOX1	MOX2	MOX3	U	MOX1	MOX2	MOX3
100	210	200	180	180	350	350	330	330
90	130	130	120	120	200	200	190	190
80	10	10	10	10	0	0	0	0
70	-120	-110	-100	-100	-140	-140	-130	-130
60	-240	-220	-190	-200	-250	-250	-230	-240
50	-350	-310	-280	-290	-330	-330	-310	-320
40	-450	-400	-360	-380	-410	-400	-380	-390
30	-540	-490	-440	-460	-470	-470	-440	-440
20	-620	-560	-500	-520	-520	-520	-490	-500
10	-680	-610	-550	-580	-570	-570	-540	-550
0	-700	-630	-570	-600	-590	-600	-560	-570

Table 15. Core Reactivity Versus Coolant Density

	UOX		MOX –1st cycle		MOX –2nd cycle		MOX –3d cycle	
	BOC	EOC						
	CB=8730 ppm, Hreg=100%	CB=3530 ppm, Hreg=100%	CB=8870 ppm, Hreg=100%	CB=3580 ppm, Hreg=100%	CB=8730 ppm, Hreg=100%	CB=3540 ppm, Hreg=100%	CB=8860 ppm, Hreg=100%	CB=3550 ppm, Hreg=100%
Density, G/cm3	RO, pcm							
0.2	-26696	-41633	-26699	-41431	-27067	-41477	-26883	-41552
0.4	-7353	-14144	-7358	-14067	-7555	-14112	-7446	-14148
0.6	-1449	-3978	-1467	-3961	-1548	-3986	-1490	-3994
0.766	0	0	0	0	0	0	0	0

Table 16. Core Reactivity versus Core Power and Average Core Fuel Temperature (Doppler Effect), pcm

Power, MW	t_{fuel}, K	BOC, Xe eq, Hreg=80%				EOC, Xe eq, Hreg=80%				EOC, Xe=0 , Hreg=80%			
		UOX	MOX 1 cycle	MOX 2 cycle	MOX 3 cycle	UOX	MOX 1 cycle	MOX 2 cycle	MOX 3 cycle	UOX	MOX 1 cycle	MOX 2 cycle	MOX 3 cycle
6000	1207	-709	-701	-701	-702	-703	-698	-696	-700	2316	2317	2315	2313
5400	1146	-592	-584	-583	-585	-585	-580	-578	-581	2428	2428	2427	2425
4800	1085	-463	-456	-456	-457	-455	-451	-449	-452	2549	2549	2548	2546
4500	1055	-394	-387	-387	-388	-386	-382	-380	-384	2614	2614	2612	2611
3900	994	-245	-240	-240	-240	-239	-236	-234	-237	2753	2752	2750	2748
3600	963	-165	-161	-161	-161	-161	-159	-157	-160	2827	2825	2823	2821
3300	933	-81	-78	-78	-78	-79	-78	-77	-79	2903	2901	2898	2897
3000	902	0	0	0	0	0	0	0	0	2983	2973	2971	2972
2700	871	99	98	98	98	92	91	93	90	3065	3055	3052	3053
2400	839	194	191	192	192	183	180	182	179	3150	3139	3136	3137
1800	775	398	389	390	390	372	367	368	364	3329	3316	3312	3312
1200	711	617	601	602	603	573	565	565	561	3519	3503	3498	3498
600	645	854	829	831	831	786	775	773	770	3720	3702	3695	3695
300	612	979	949	952	952	897	886	883	879	3826	3806	3799	3799
0	579	1112	1076	1079	1080	1013	1000	996	992	3936	3915	3907	3906

Table 17. Assembly Axial Relative Power Distribution for Uranium Reference Core. Equilibrium Cycle

Axial position, cm	BOC			EOC		
	1st year (N17)	2nd year (N15)	3d year (N16)	1st year (N17)	2nd year (N15)	3d year (N16)
337.250	0.472	0.520	0.530	0.688	0.756	0.777
301.750	0.837	0.858	0.866	1.010	1.028	1.041
266.250	1.012	1.026	1.020	1.043	1.045	1.041
230.750	1.114	1.119	1.111	1.036	1.028	1.023
195.250	1.182	1.170	1.166	1.038	1.020	1.014
159.750	1.223	1.194	1.192	1.050	1.023	1.017
124.250	1.234	1.189	1.190	1.072	1.034	1.029
88.750	1.202	1.153	1.155	1.107	1.064	1.059
53.250	1.072	1.061	1.059	1.124	1.107	1.102
17.750	0.653	0.709	0.715	0.832	0.895	0.897

Table 18. Axial Relative Power Distribution in MOX Assemblies

Axial position, cm	BOC			EOC		
	1 Cycle	2 Cycle	3 Cycle	1 Cycle	2 Cycle	3 Cycle
337.250	0.499	0.510	0.528	0.725	0.737	0.724
301.750	0.877	0.859	0.848	1.043	1.027	0.979
266.250	1.032	1.012	1.040	1.052	1.041	1.040
230.750	1.117	1.104	1.134	1.036	1.029	1.037
195.250	1.172	1.166	1.178	1.033	1.028	1.033
159.750	1.206	1.203	1.192	1.039	1.033	1.037
124.250	1.214	1.211	1.178	1.055	1.049	1.050
88.750	1.182	1.179	1.136	1.085	1.080	1.079
53.250	1.057	1.071	1.046	1.108	1.111	1.116
17.750	0.641	0.687	0.718	0.823	0.863	0.904

Table 19. Minimum effectiveness of Regulation group versus its positioning, pcm

Hreg, %	**90**	**80**	**70**	**60**	**50**	**40**	**30**	**20**	**10**	**0**
Standard "Conservative curve" for VVER-1000 uranium core	40	100	170	240	320	390	460	520	580	620
Base Uranium core	80	200	330	450	560	660	750	830	890	910
Cores with 3 MOX LTAs	60	170	280	370	460	540	620	680	730	750

Table 20. Relative Core Reactivity Evolution in the Process of Control Rods Movement

Insertion in core, %	10	20	30	40	50	60	70	80	90	100
Standard "Conservative curve" for VVER-1000 uranium core	0.01	0.02	0.03	0.05	0.07	0.11	0.19	0.36	0.74	1.00
Base Uranium Core	0.02	0.03	0.04	0.06	0.09	0.14	0.24	0.43	0.82	1.00
Core with 3 MOX LTAs	0.01	0.03	0.04	0.05	0.08	0.13	0.23	0.42	0.81	1.00

Table 21. Conservative Curves for Assembly Axial Power Distribution

Axial Position, %	5	15	25	35	45	55	65	75	85	95
Relative power, BOC	0.36	0.82	1.12	1.31	1.39	1.39	1.31	1.12	0.82	0.36
Relative power EOC	0.74	1.00	1.01	1.00	1.01	1.03	1.08	1.13	1.10	0.90

Table 22. Conservative Curve for Core Reactivity Versus Coolant Density

Density, g/cc	0.2	0.3	0.4	0.5	0.6	0.7	0.8
Reactivity, pcm	-20000	-8600	-4200	-1800	-600	-200	0

Table 23. Conservative Curve for Linear Fuel Pin Power

Axial layer	1	2	3	4	5	6	7	8	9	10
Linear Fuel Pin Power, W/cm	448	448	448	448	448	428	392	360	338	316

Table 24. Decay rates of delayed neutrons

Group	1	2	3	4	5	6
Decay rate, 1/s	0.0124	0.0305	0.111	0.301	1.13	3

Fig.1. Equilibrium Loading Pattern for Uranium Reference Core with Boron BPRs. Core 60 ° Sector

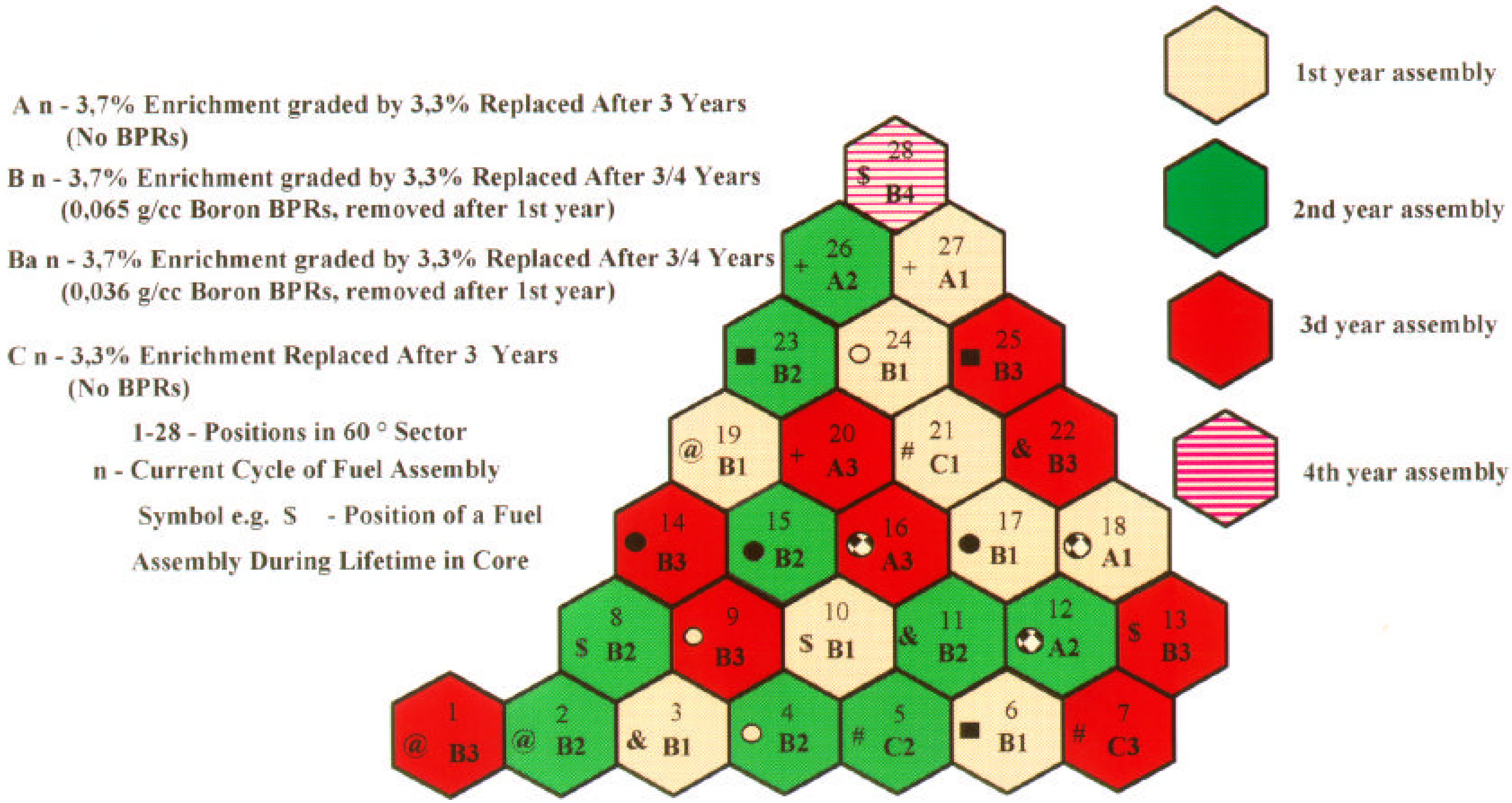


Fig.2. beff Evolution During Core Fuel Cycle for Uranium and MOX Cores

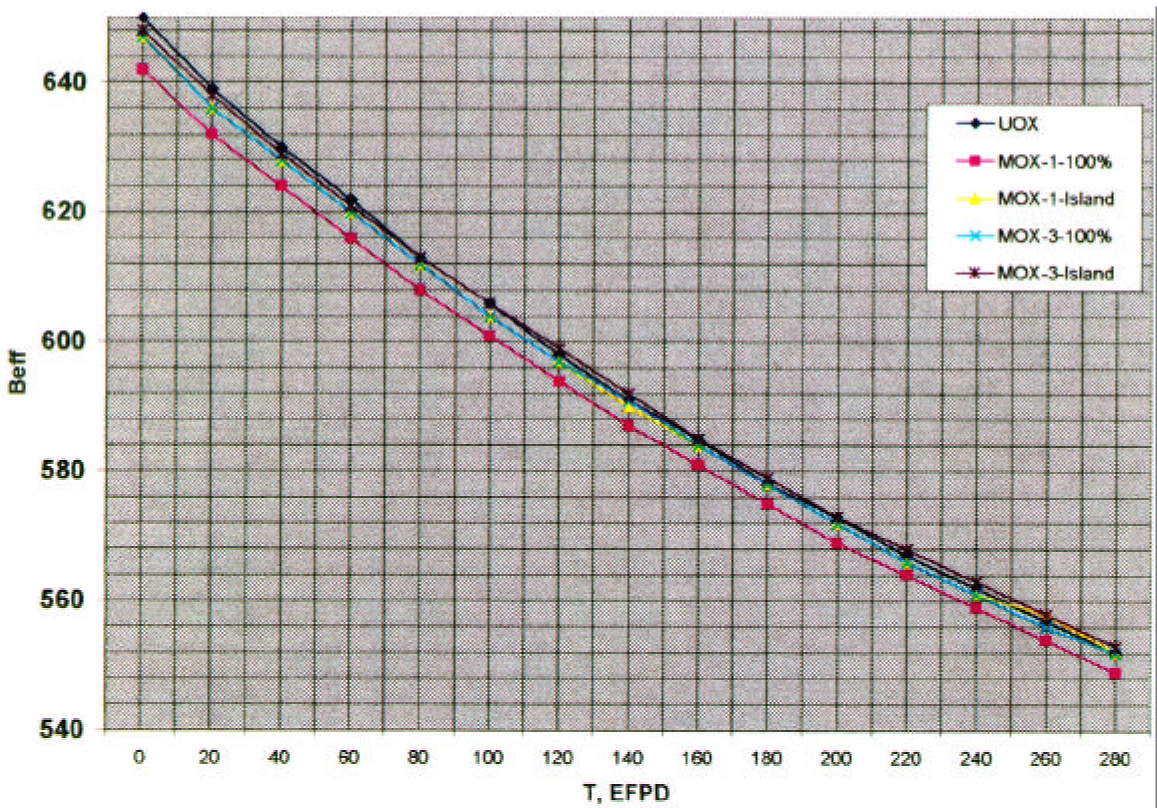


Fig.3. Core Reactivity Evolution in the Process Of Control Rods Movement for Uranium and MOX cores in BOC

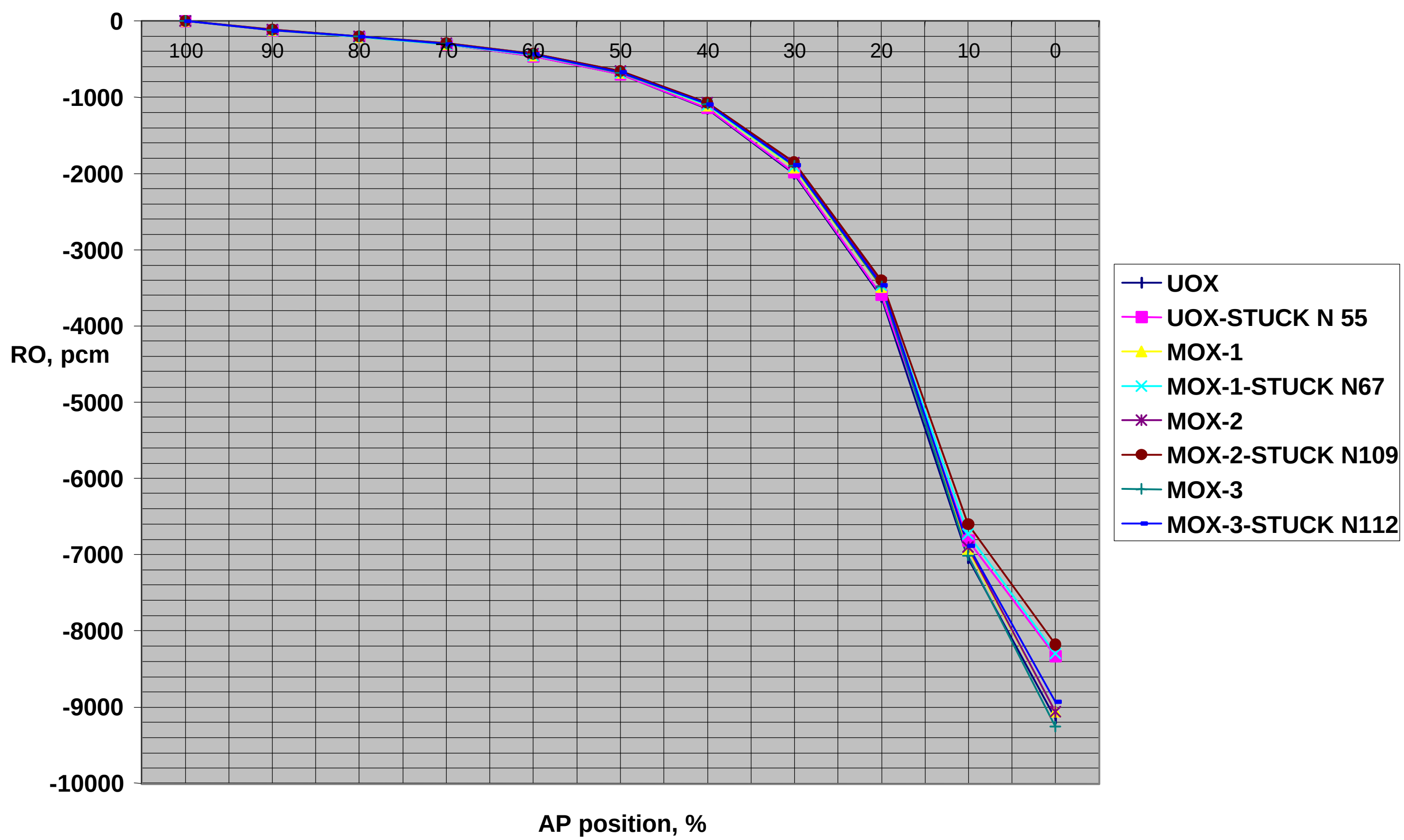


Fig.3a. Core Reactivity Evolution in the Process Of Control Rods Movement for Uranium and MOX cores in EOC

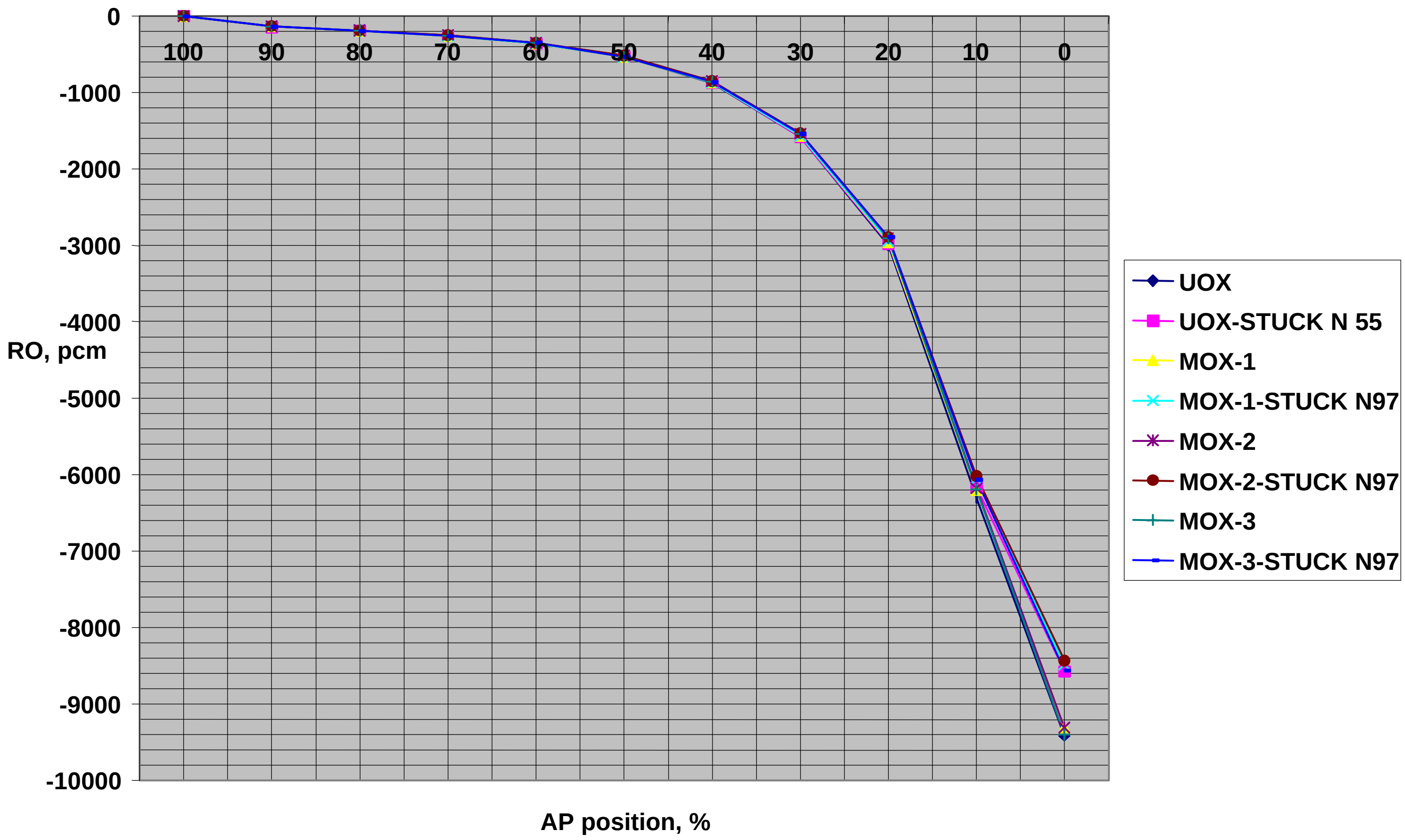


Figure 4. Core Reactivity Versus Regulating Group Position in BOC

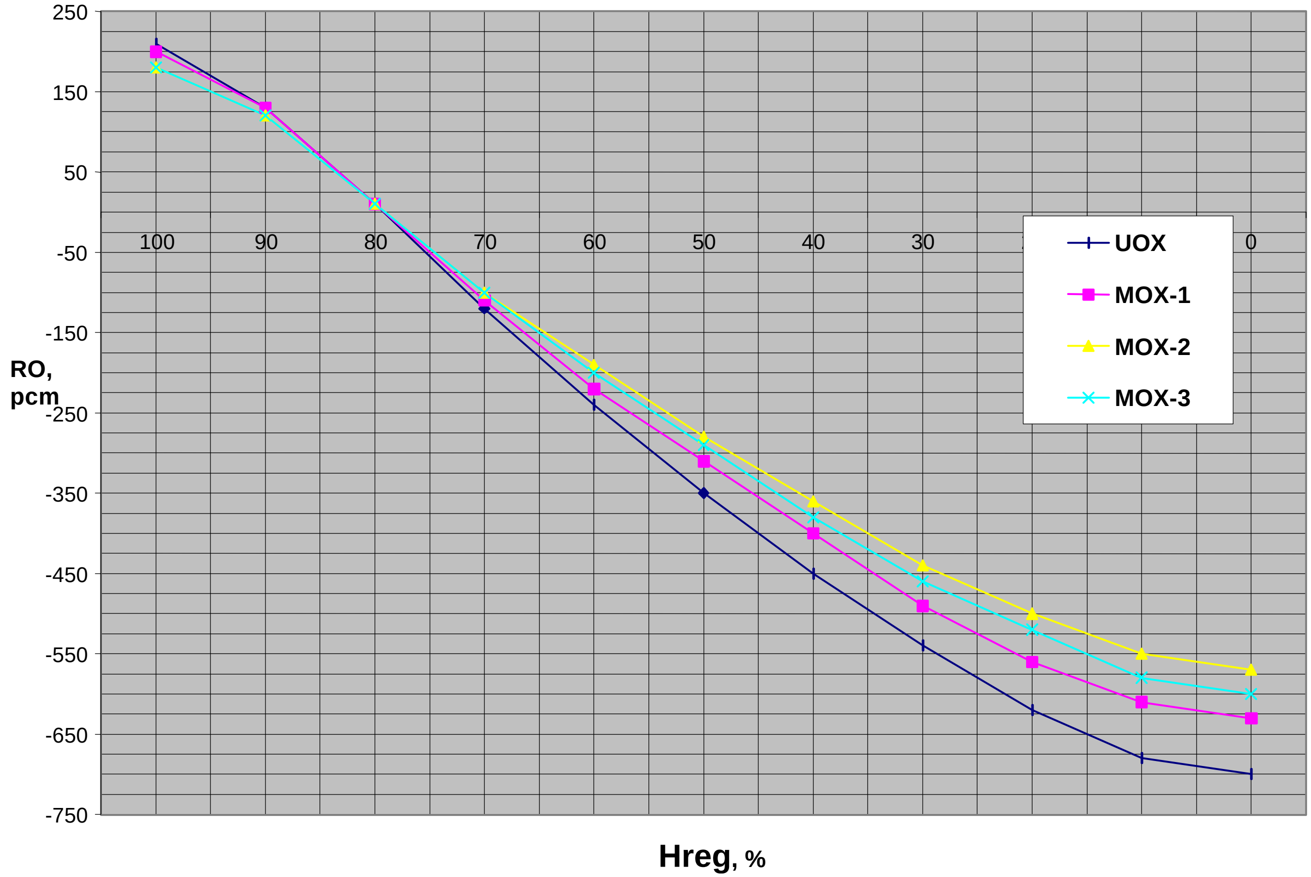


Figure 4a. Core Reactivity Versus Regulating Group Position in EOC

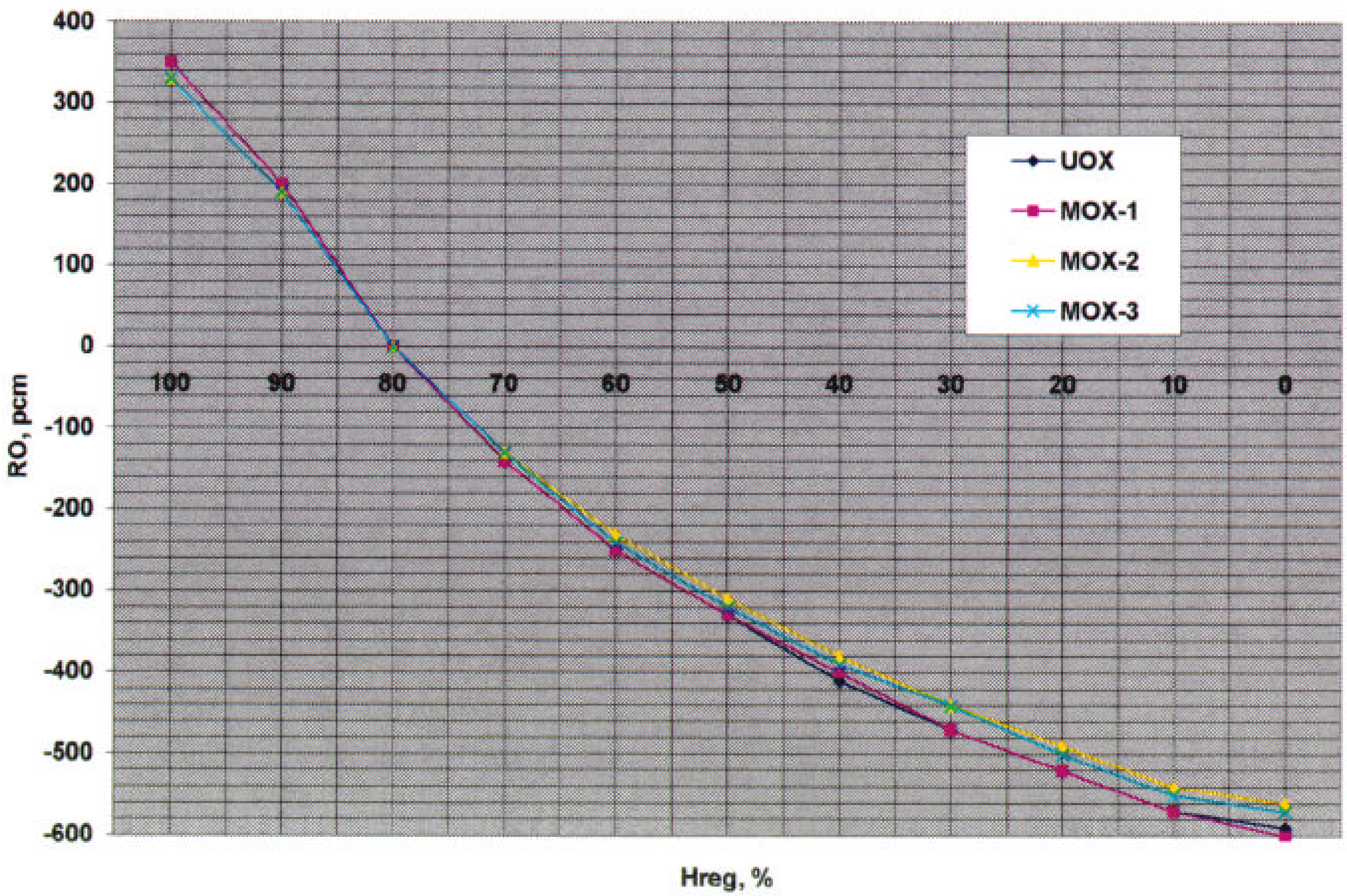


Fig.5. Core Reactivity Versus Coolant Density

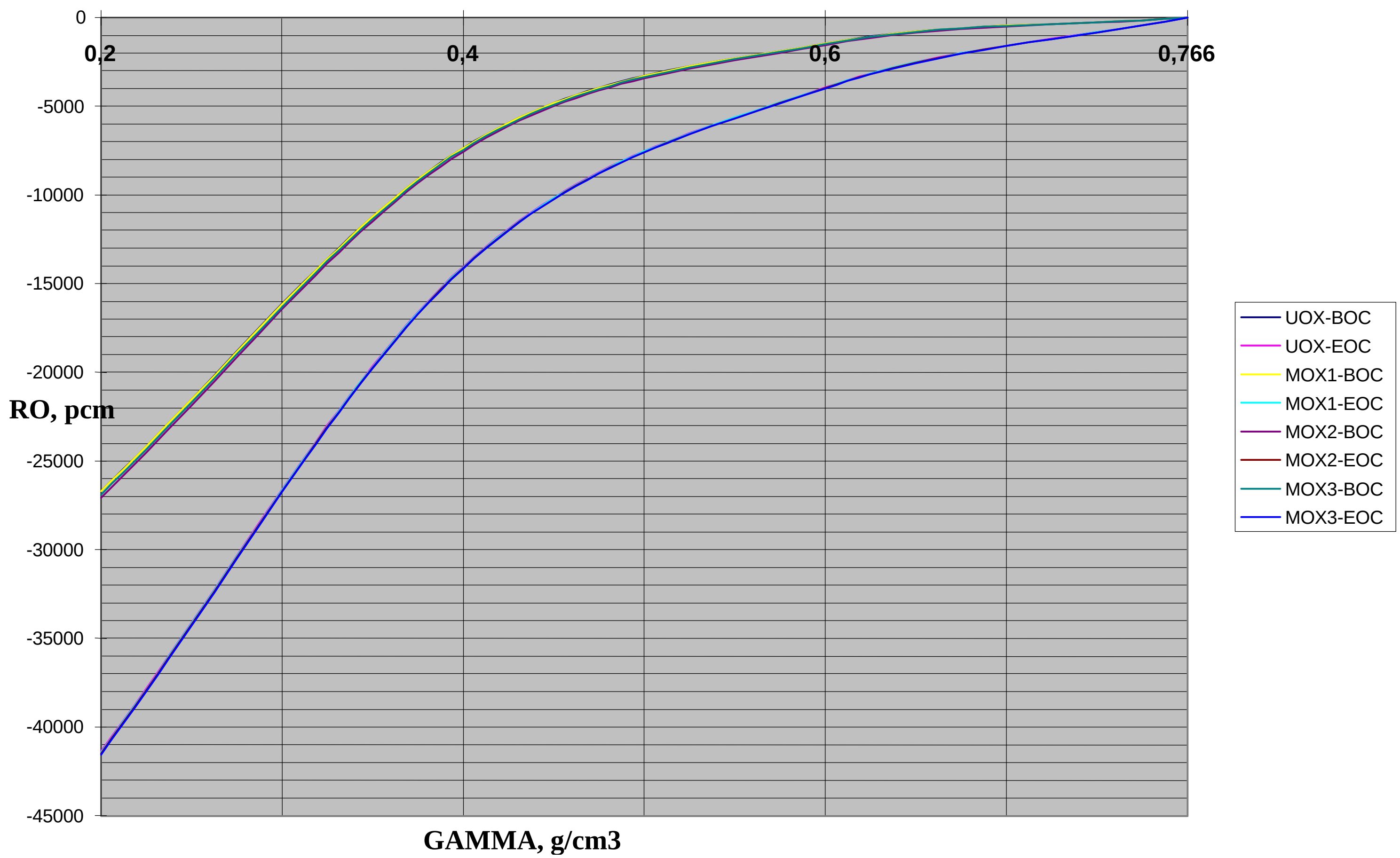


Fig.6. Core Reactivity Versus Fuel Temperature in BOC

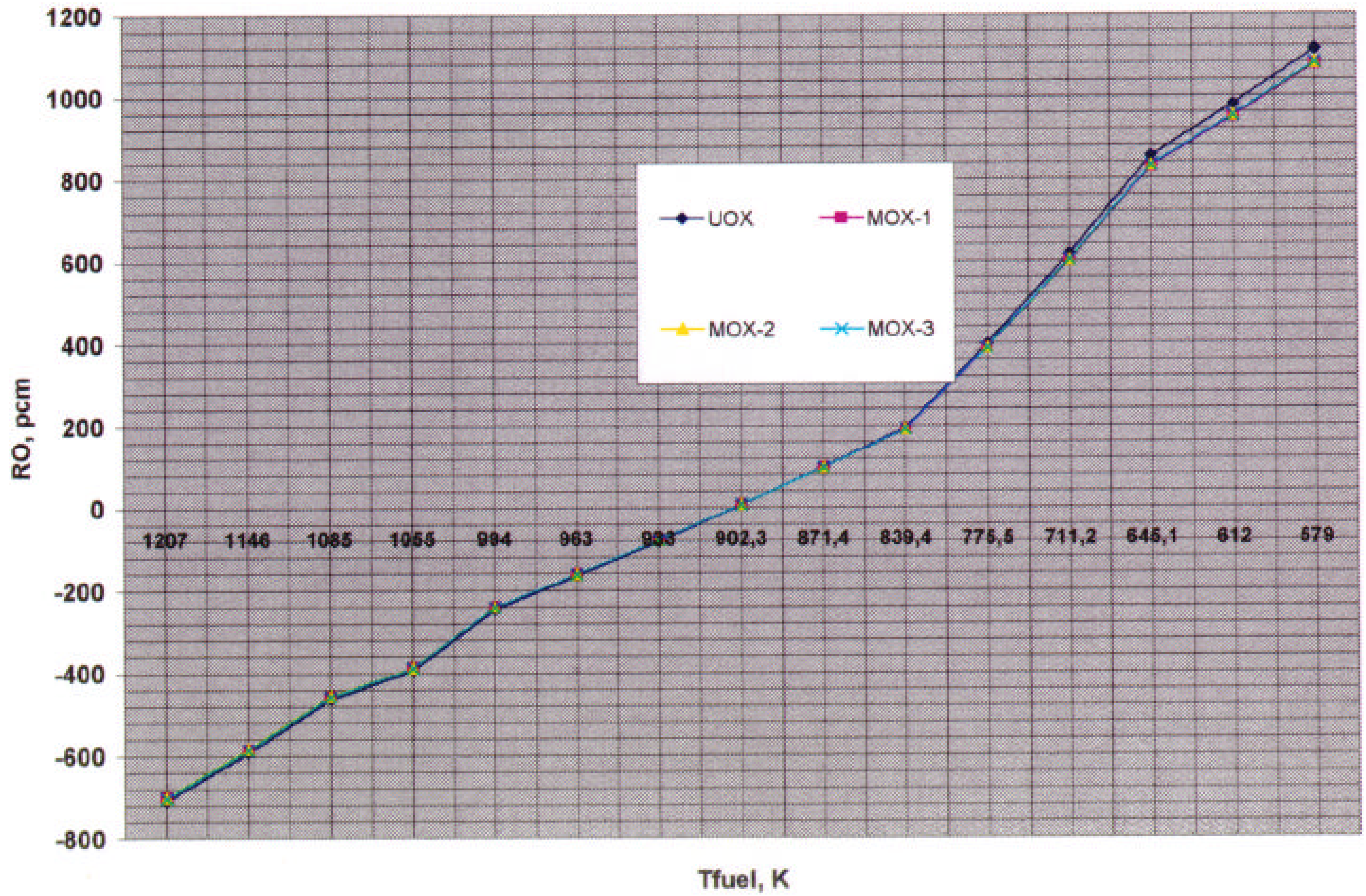


Fig.6a. Core Reactivity Versus Fuel Temperature in EOC

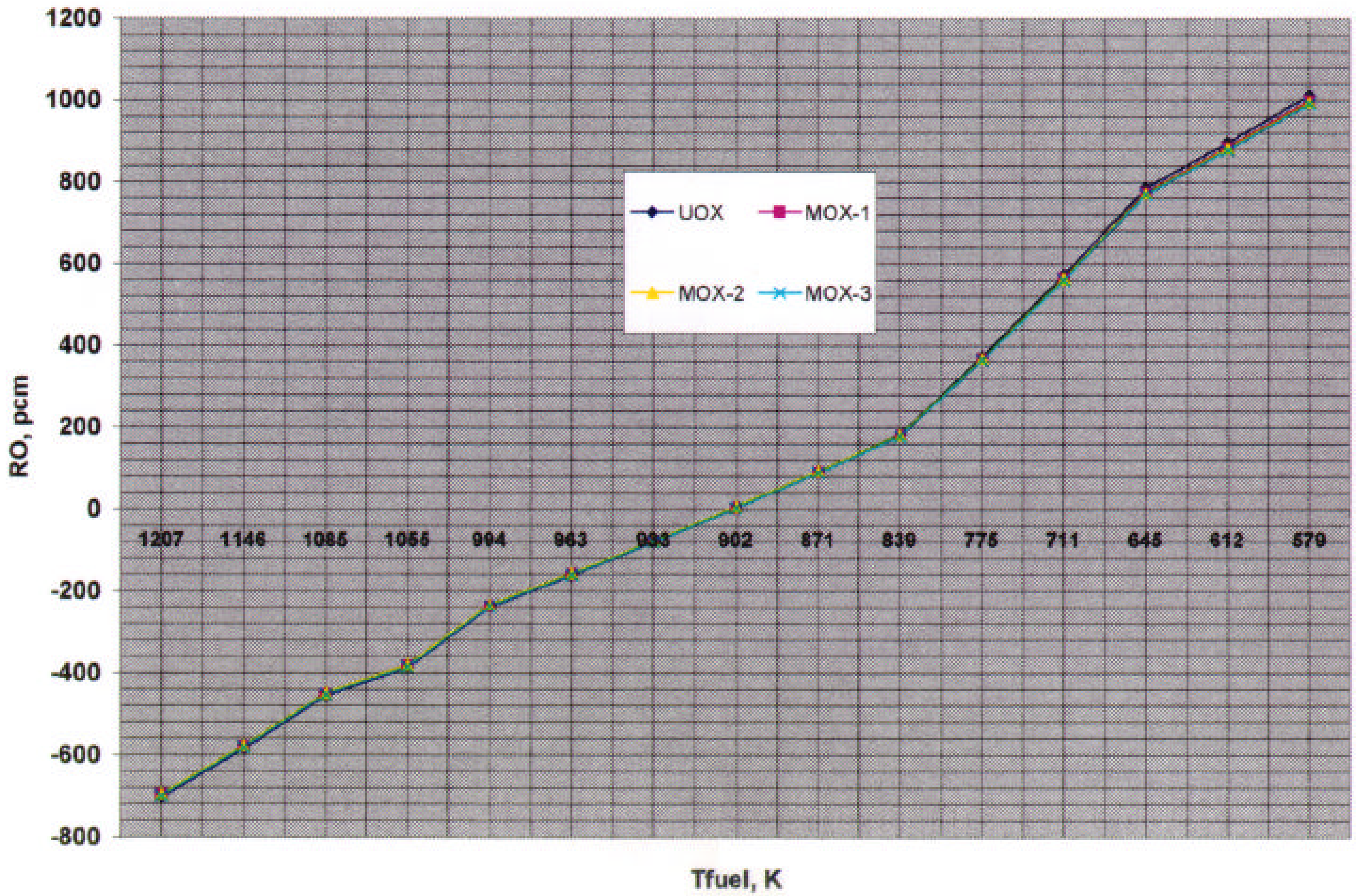


Fig.7. Assembly Axial Power Distribution for Uranium Reference Core. Equilibrium Cycle

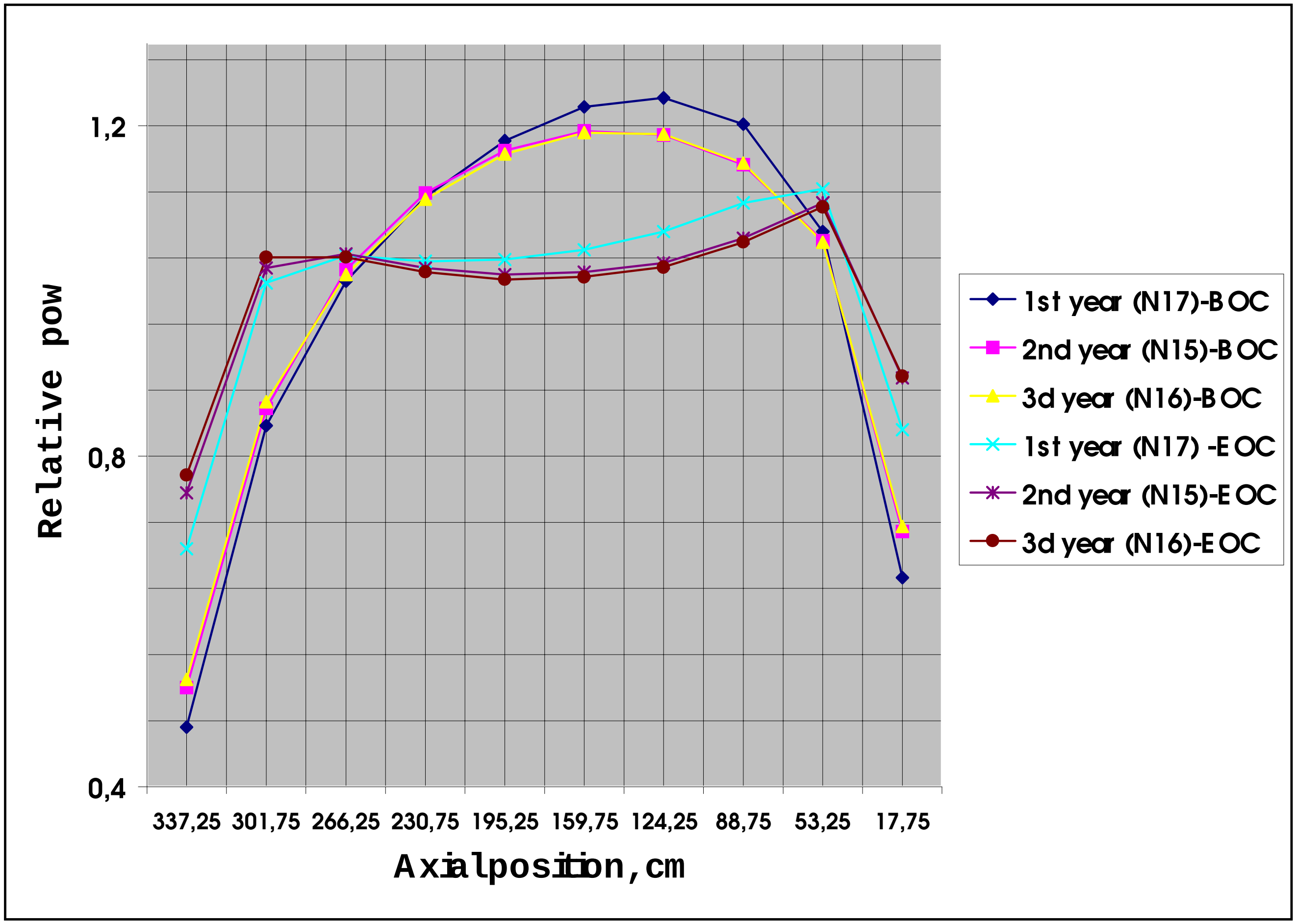


Fig.7a. Axial Power Distribution in MOX LTAs

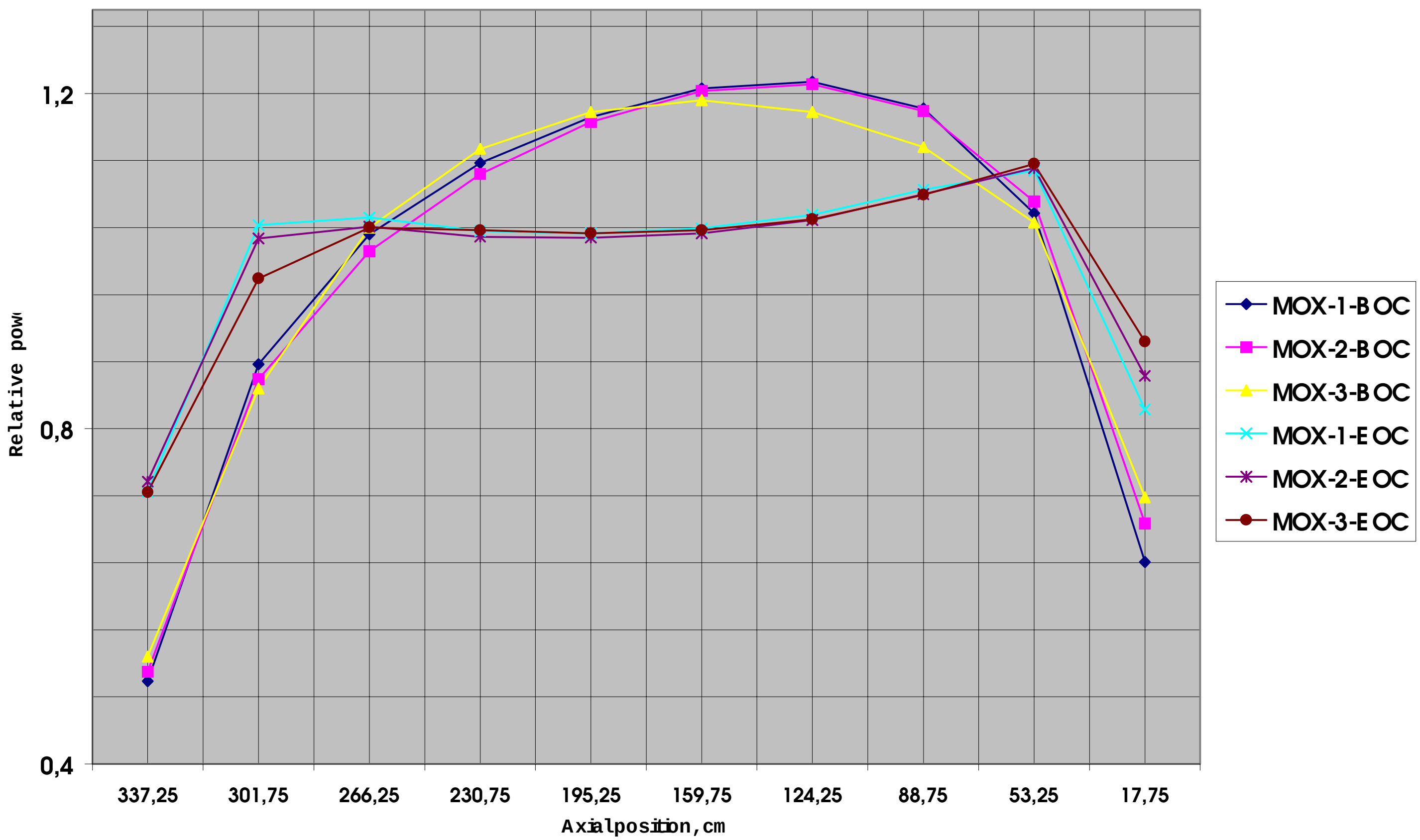


Fig.8. Assembly-by-Assembly Burnup, Power and Temperature Drops Distributions. Equilibrium Cycle for Uranium Reference Core with Boron BPRs.Core 60° Sector

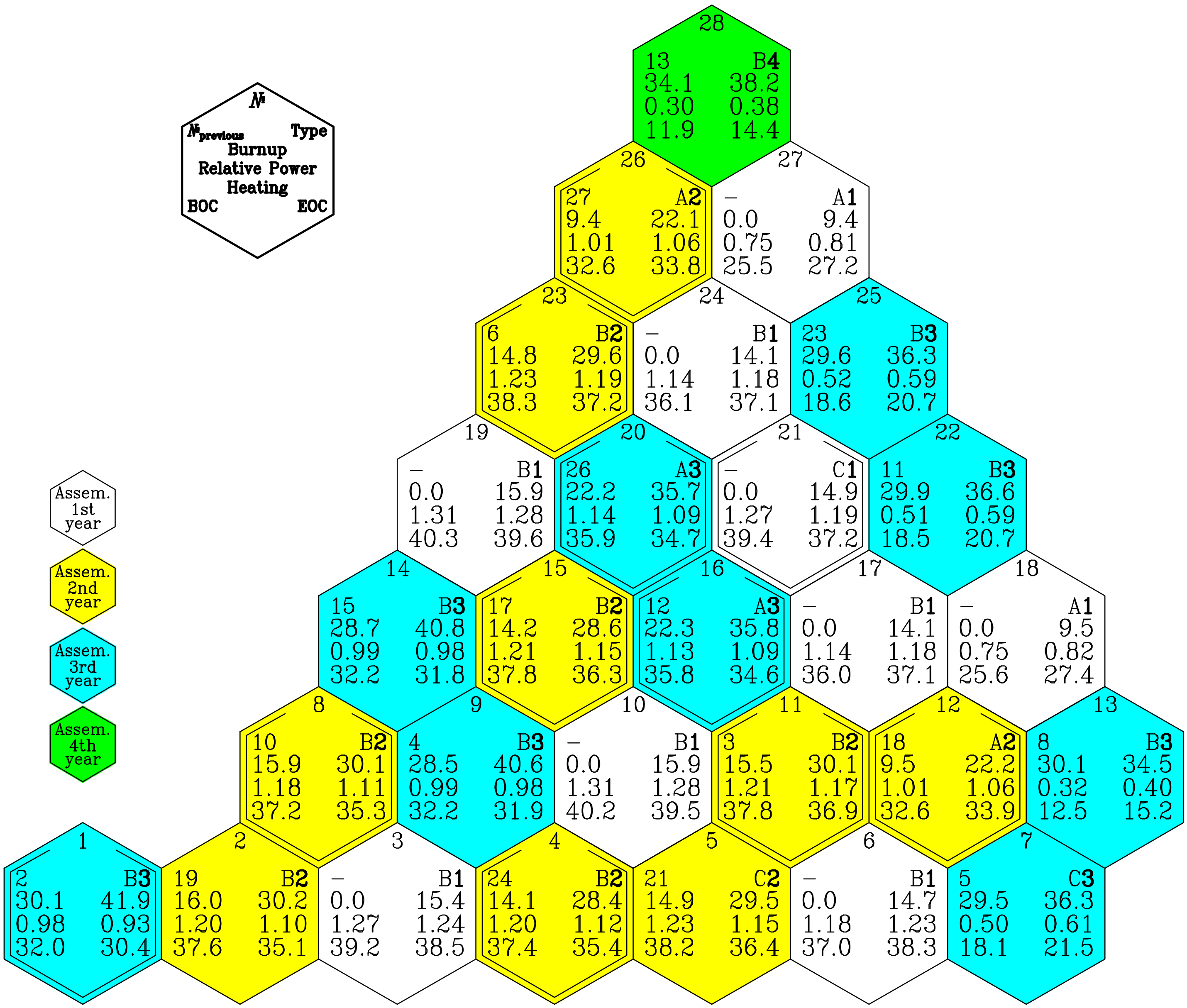


Fig.9. Assembly-by-Assembly Maximum Linear Pin Power Distribution in BOC. Equilibrium Cycle for Uranium Reference Core with Boron BPRs.Core 60° Sector

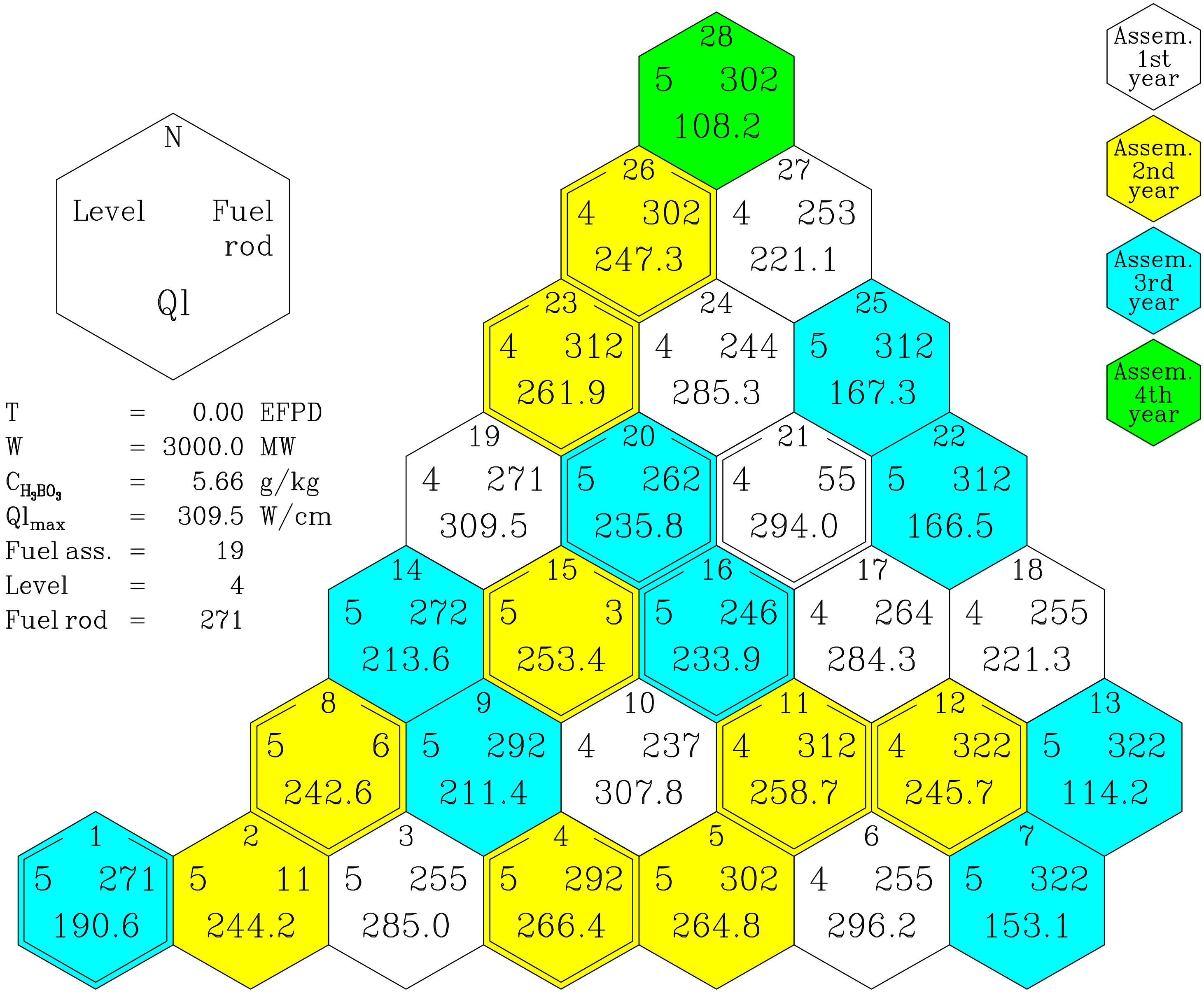


Fig.10. Assembly-by-Assembly Maximum Linear Pin Power Distribution in EOC. Equilibrium Cycle for Uranium Reference Core with Boron BPRs.Core 60° Sector

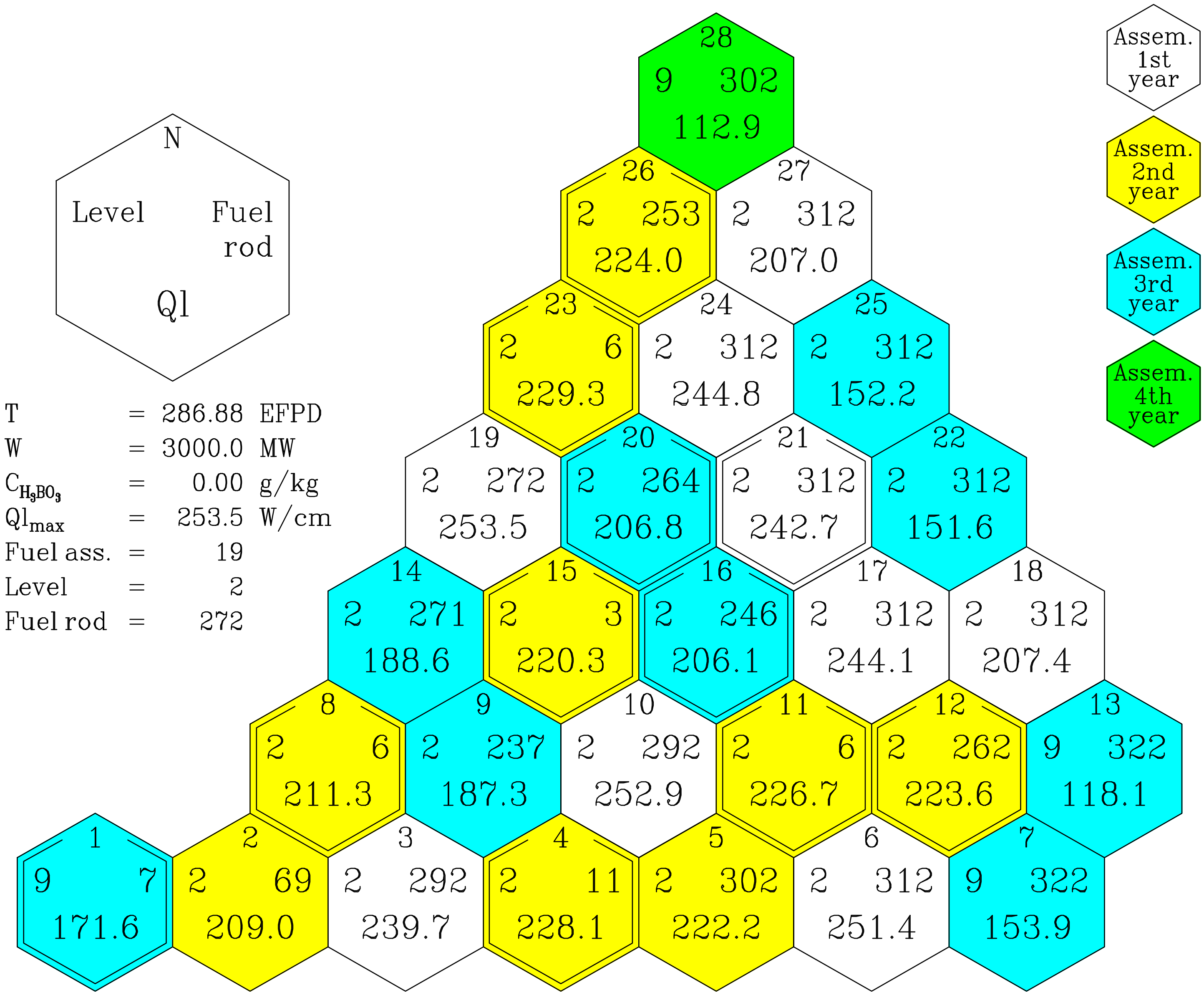
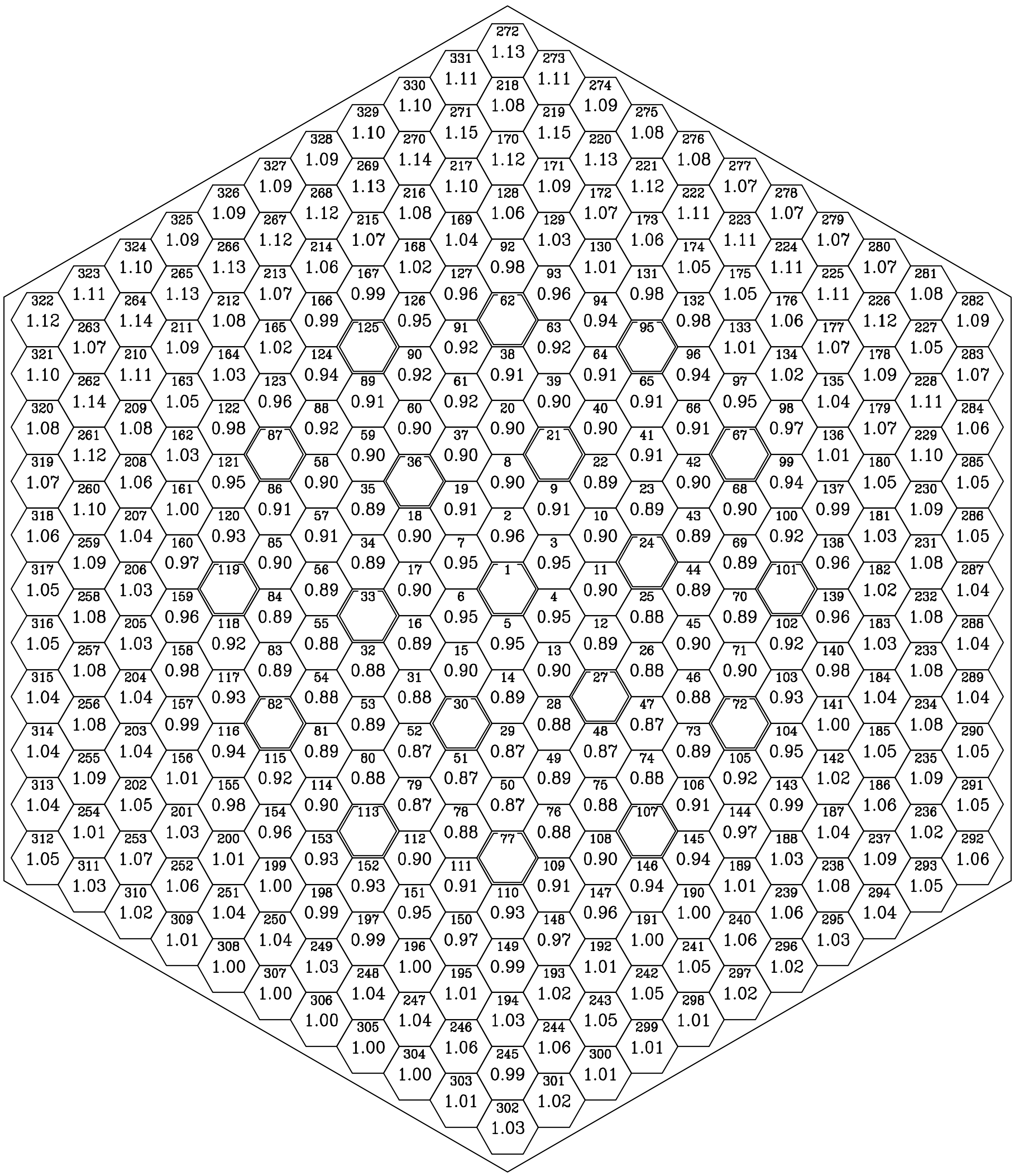
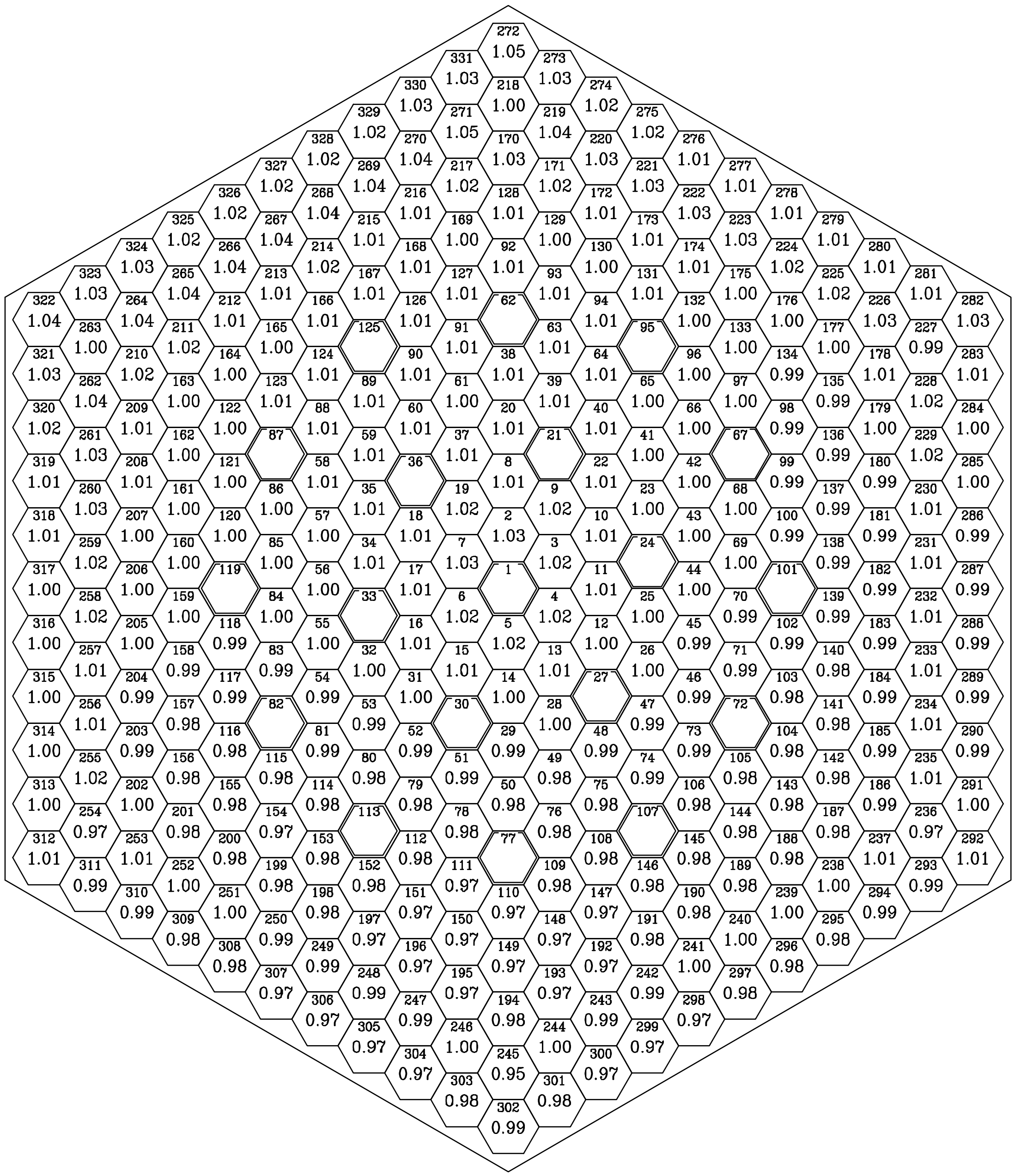


Fig.11. Pin-by-Pin Power Distribution in the Most Powered Assembly in BOC. Equilibrium Cycle for Uranium Reference Core with Boron BPRs



T	0.00	EFPD
W	3000.0	MW
$C_{H_3BO_3}$	5.66	g/kg
Ql_{max}	309.5	W/cm
Fuel assembly	19	
Level	4	
Fuel rod	271	
Kk_{max}	1.15	

Fig.12. Pin-by-Pin Power Distribution in the Most Powered Assembly in EOC. Equilibrium Cycle for Uranium Reference Core with Boron BPRs



T	286.88	EFPD
W	3000.0	MW
$C_{H_3BO_3}$	0.00	g/kg
Ql_{max}	253.5	W/cm
Fuel assembly	19	
Level	2	
Fuel rod	272	
Kk_{max}	1.05	

Fig.13. Control Rods Grouping

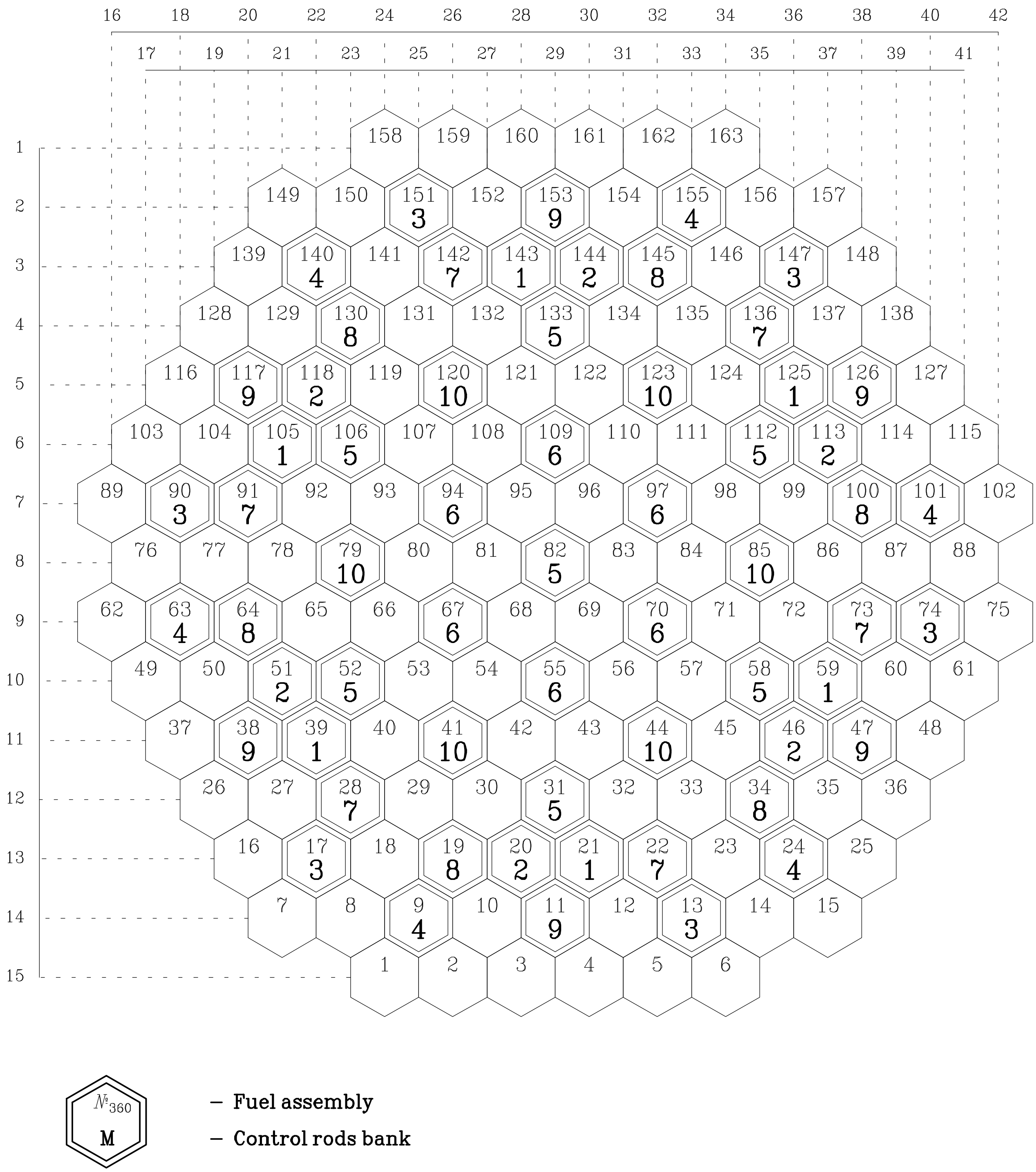


Fig.14. Reloading Scheme.
First Cycle with 3 MOX LTAs

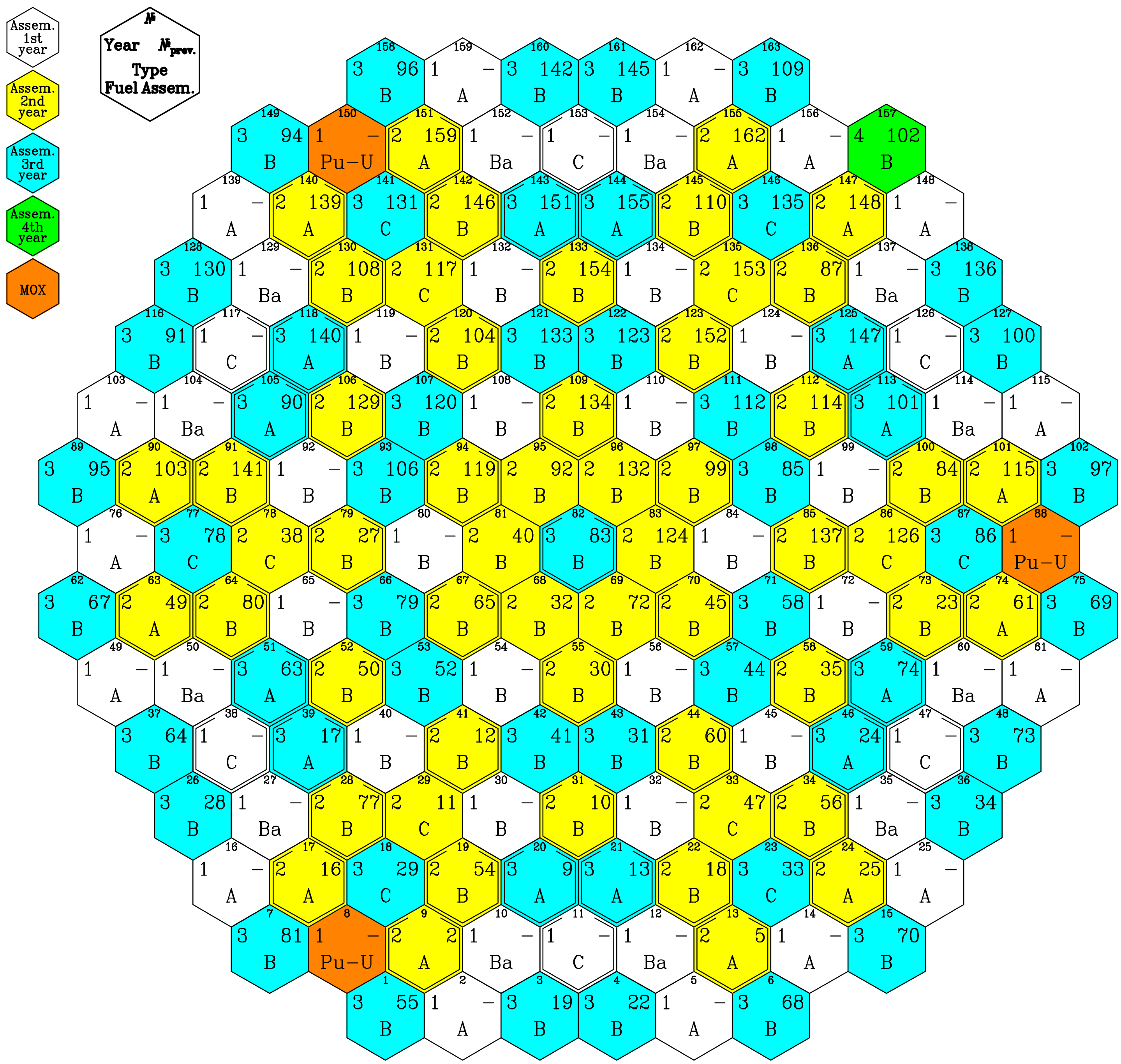


Fig.15. Assembly-by-Assembly Power Distribution.
First Cycle with 3 MOX LTAs 100%Pu (4.2-3.0-2.0)

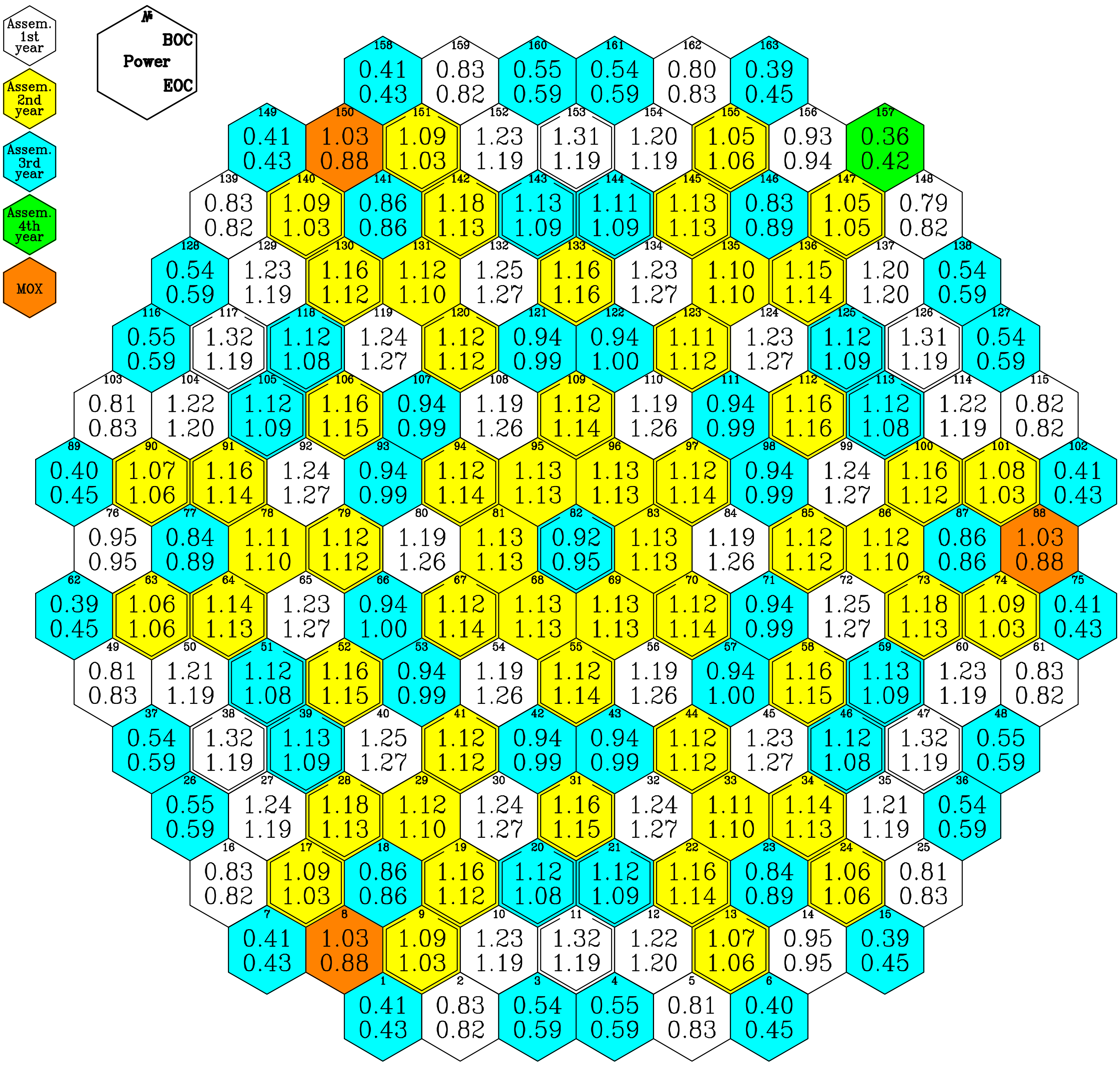


Fig.16. Assembly-by-Assembly Burnup Distribution.
First Cycle with 3 MOX LTAs 100%Pu (4.2-3.0-2.0)

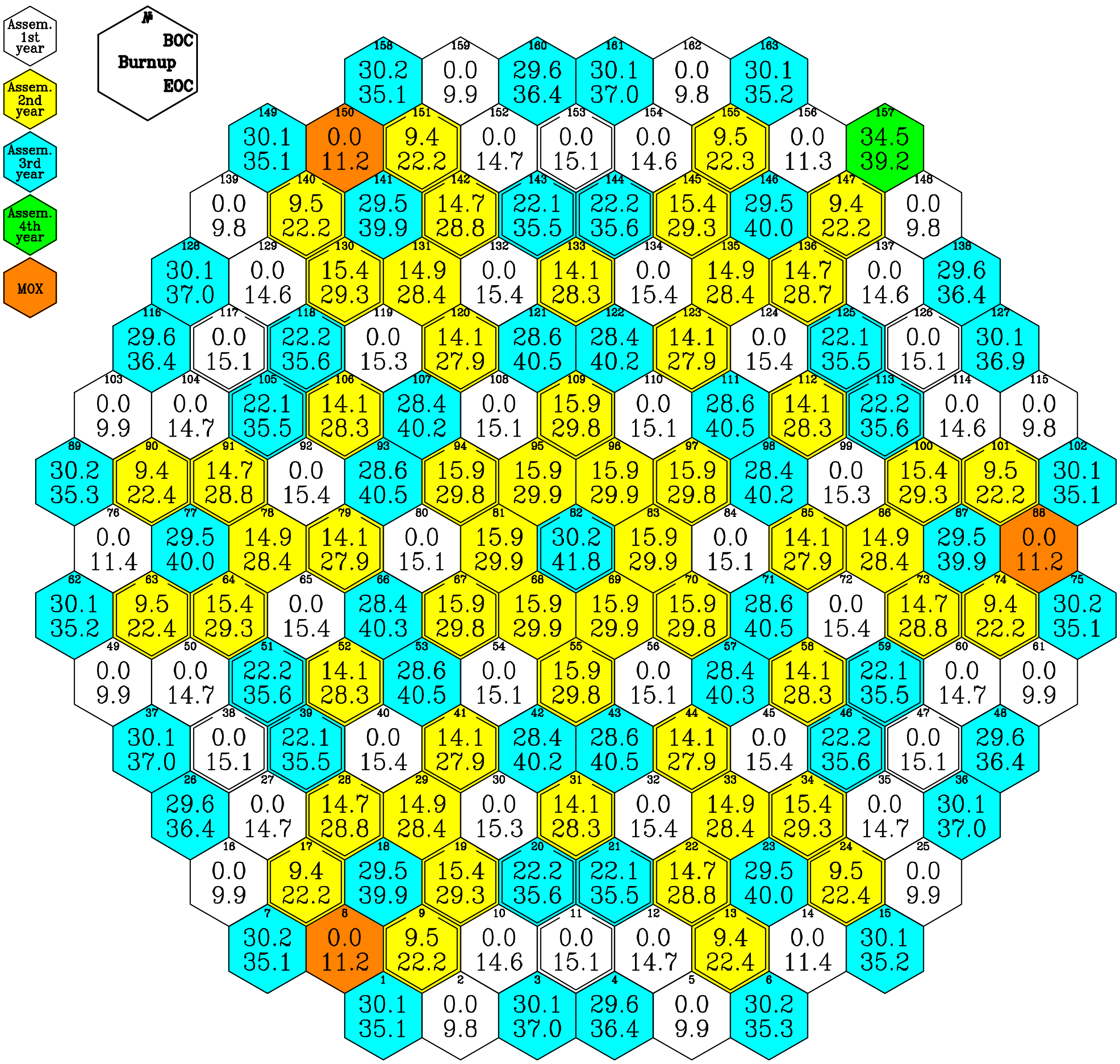


Fig.17. Assembly-by-Assembly Temperature Drop Distribution. First Cycle with 3 MOX LTAs 100%Pu (4.2-3.0-2.0)

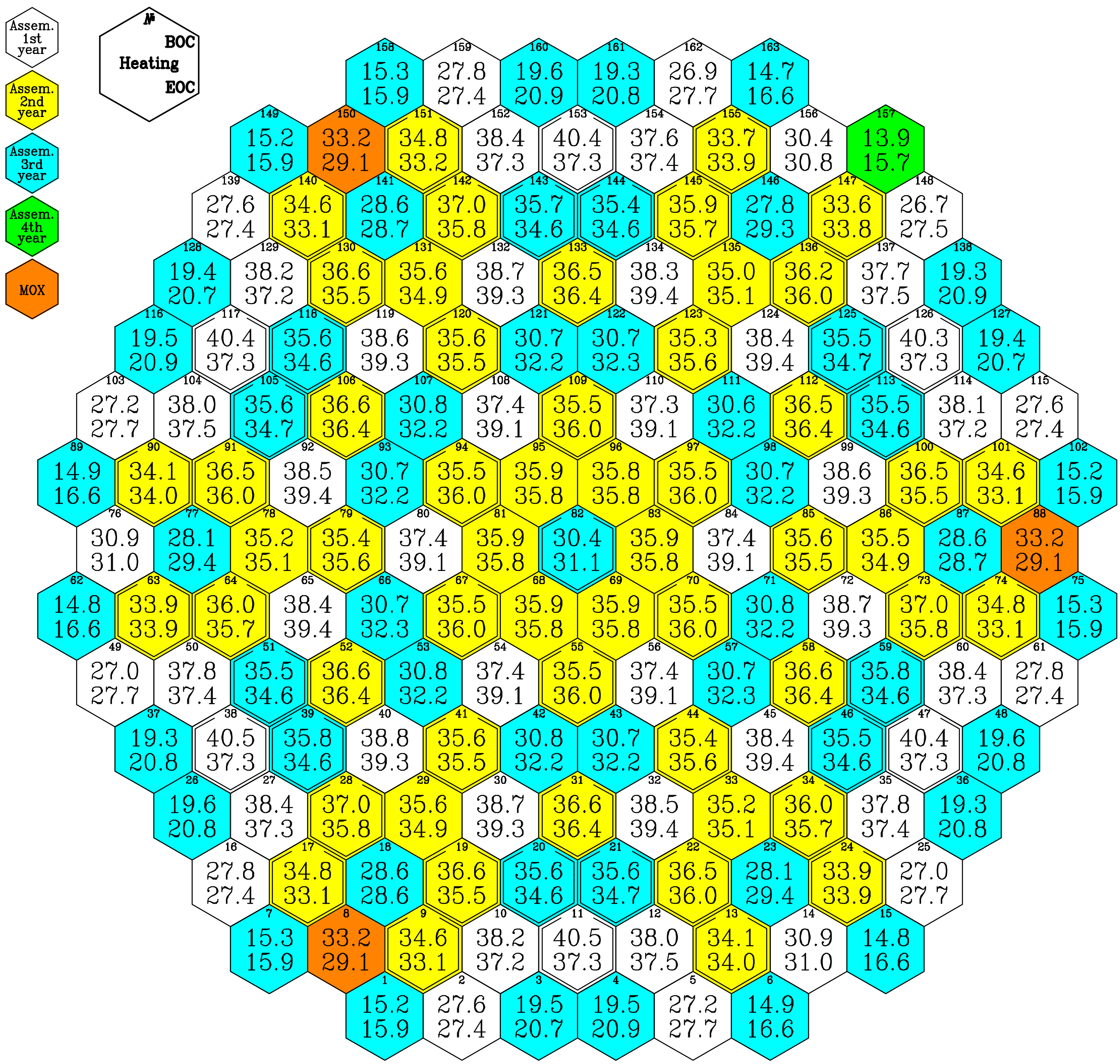
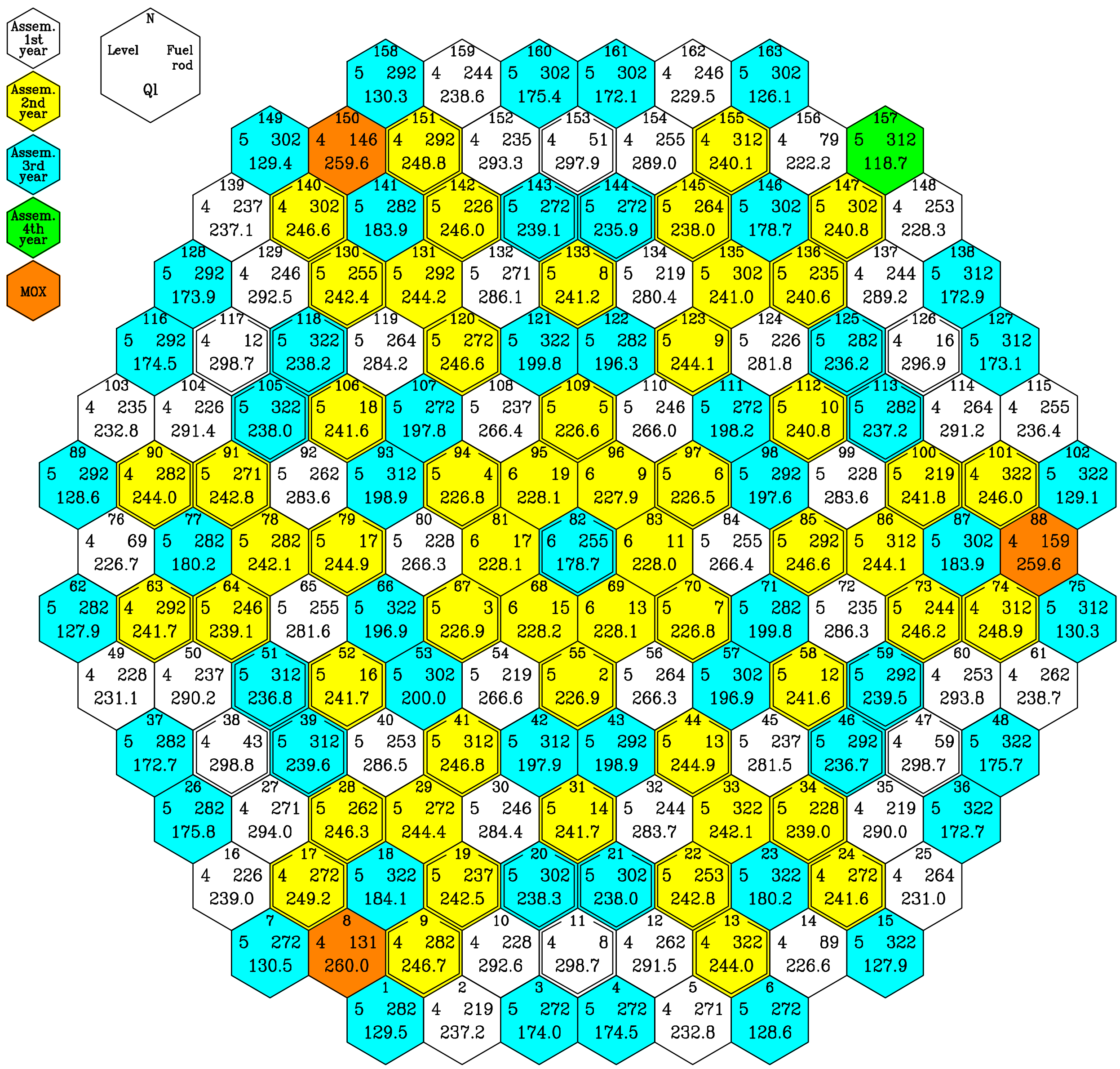
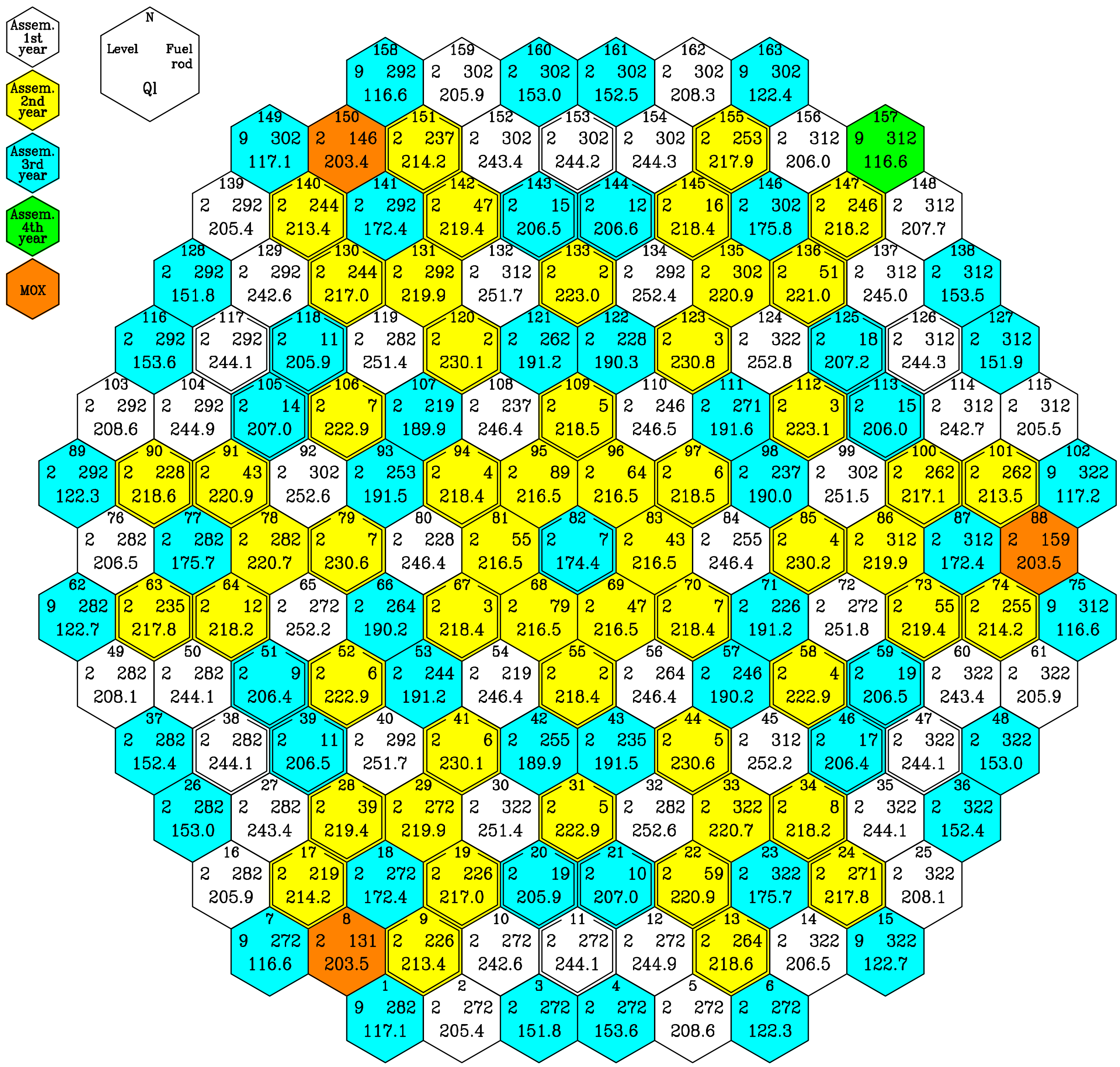


Fig.18. Assembly-by-Assembly Maximum Linear Pin Power Distribution in BOC. First Cycle with 3 MOX LTAs 100%Pu (4.2-3.0-2.0)



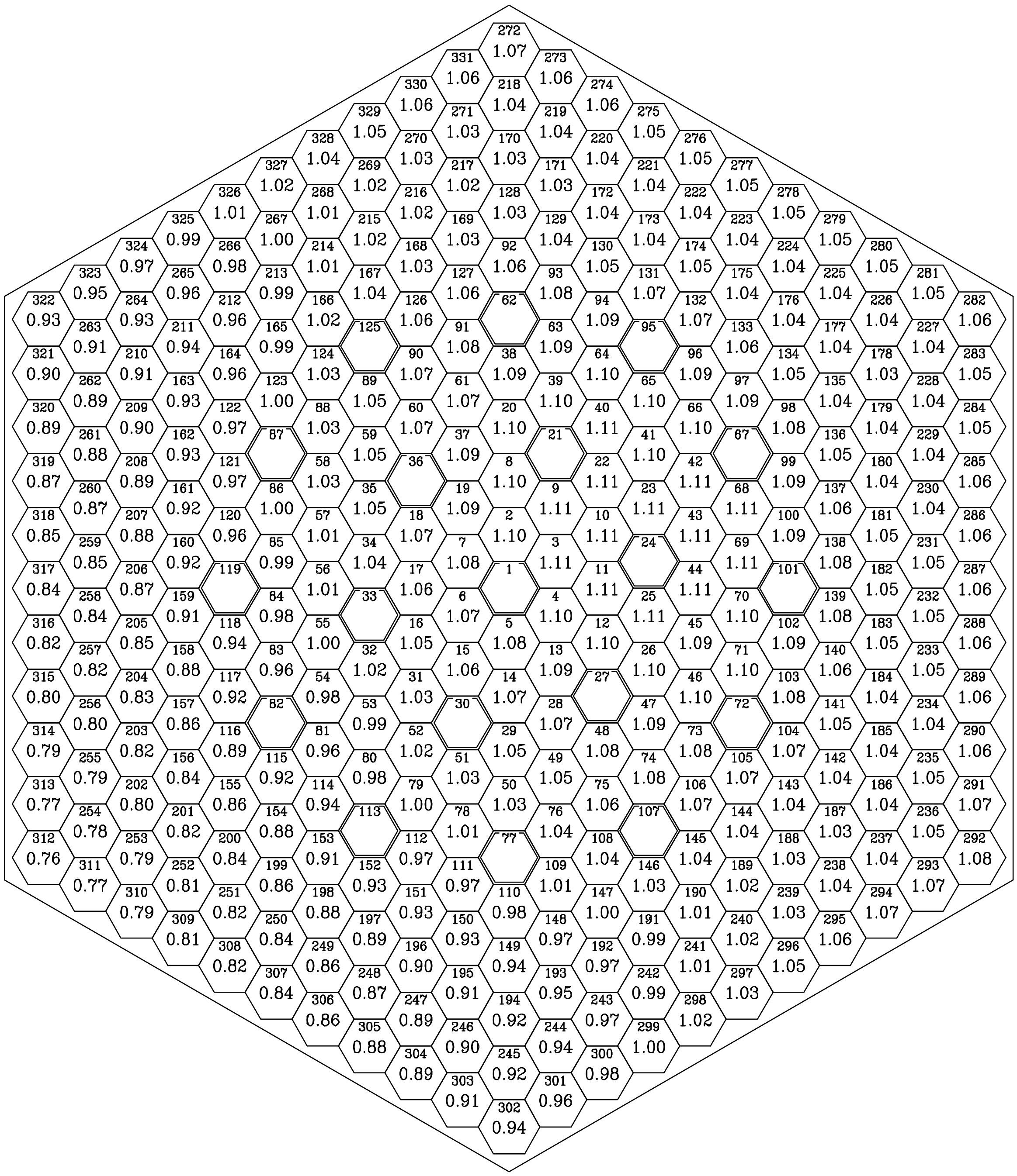
T	=	0.00	EFPD
W	=	3000.0	MW
$C_{H_3BO_3}$	=	5.78	g/kg
Ql_{max}	=	298.8	W/cm
Fuel ass.	=	38	
Level	=	4	
Fuel rod	=	43	

Fig.19. Assembly-by-Assembly Maximum Linear Pin Power Distribution in EOC. First Cycle with 3 MOX LTAs 100%Pu (4.2-3.0-2.0)



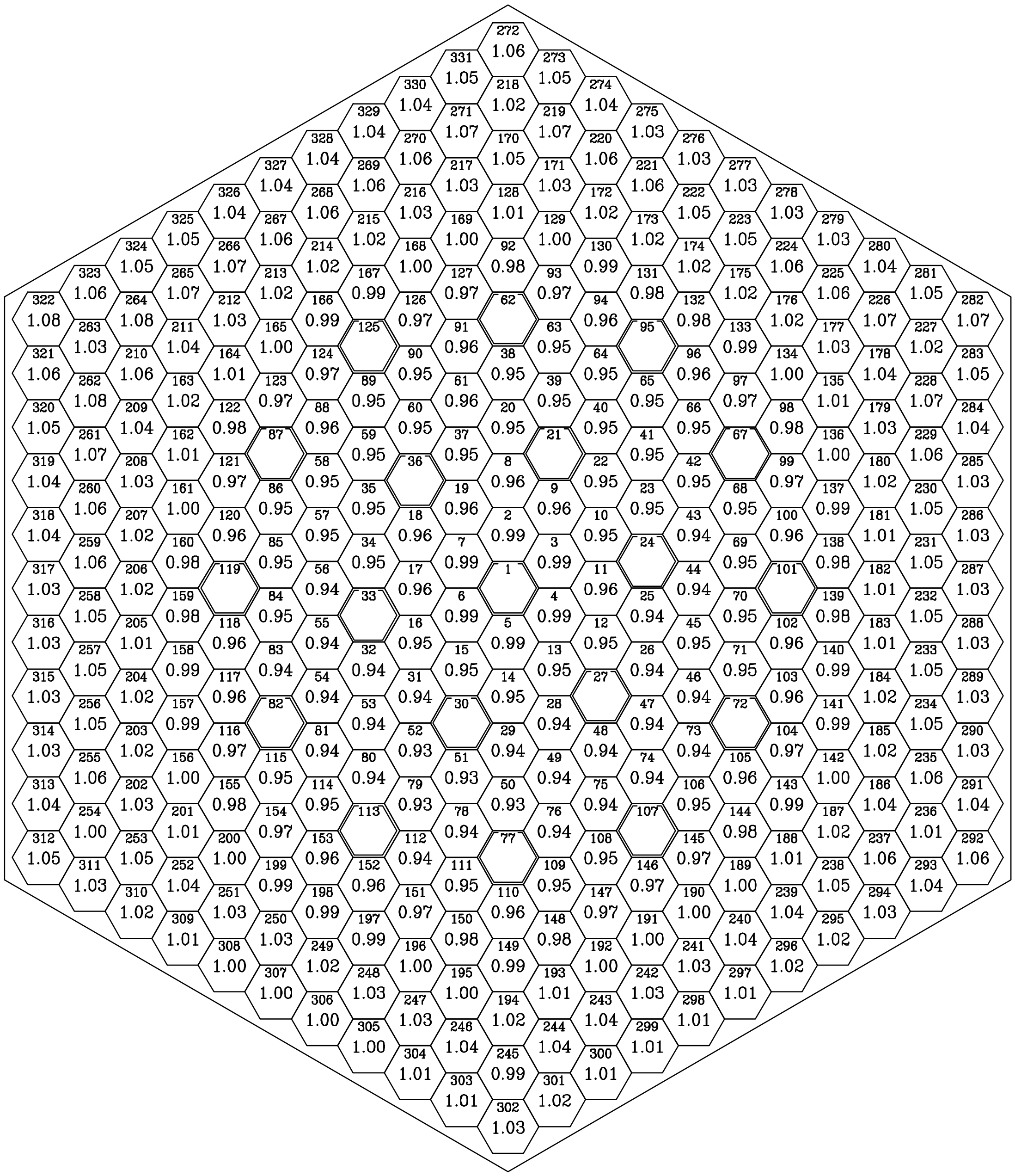
T	=	285.83 EFPD
W	=	3000.0 MW
$C_{H_3BO_3}$	=	0.00 g/kg
Ql_{max}	=	252.8 W/cm
Fuel ass.	=	124
Level	=	2
Fuel rod	=	322

Fig.20. Pin-by-Pin Power Distribution in the Most Powered Assembly in BOC. First Cycle with 3 MOX LTAs 100%Pu (4.2-3.0-2.0)



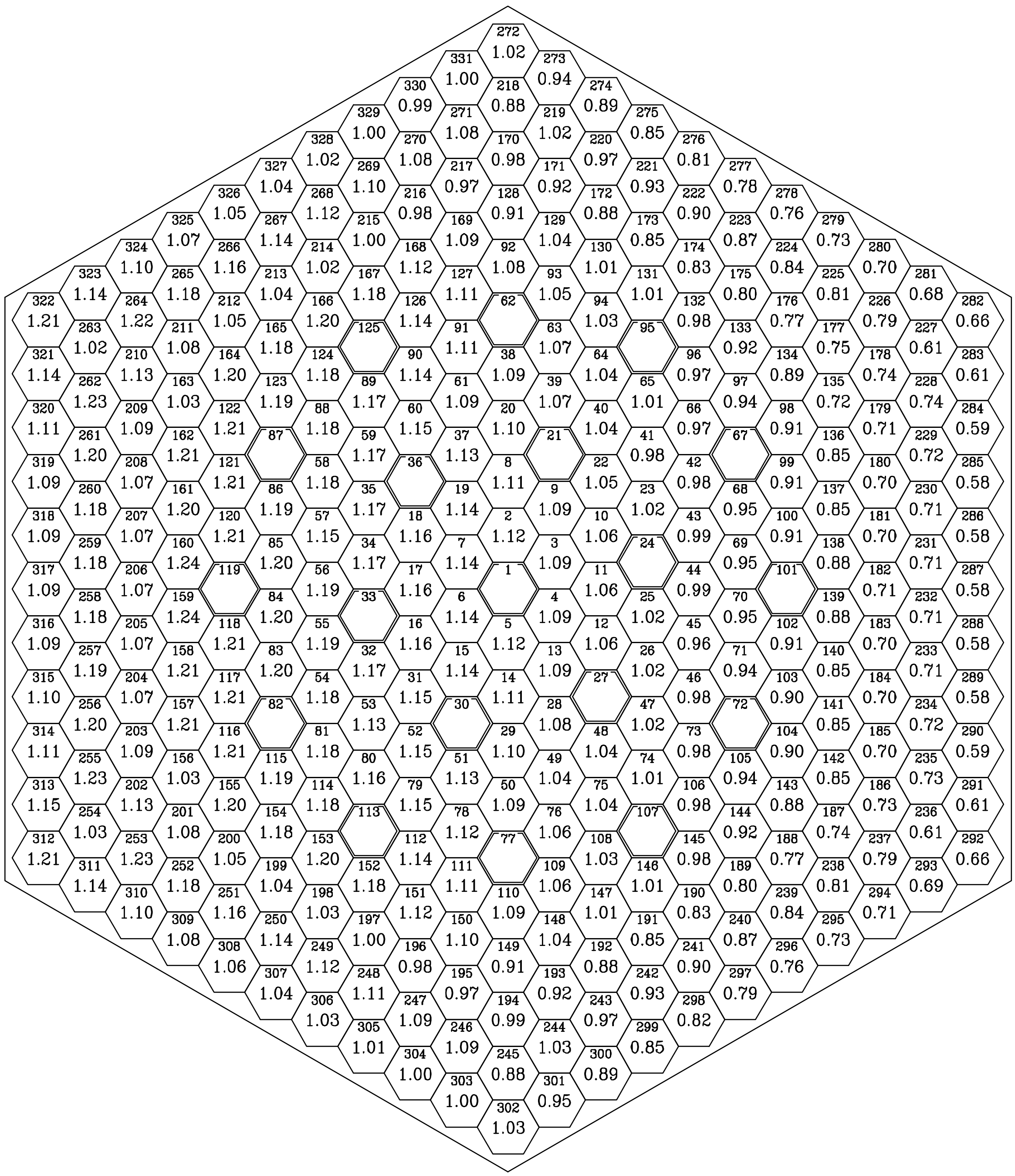
T	0.00	EFPD
W	3000.0	MW
$C_{H_3BO_3}$	5.78	g/kg
Ql	298.8	W/cm
Fuel assembly	38	
Level	4	
Fuel rod	43	
Kk_{max}	1.11	

Fig.21. Pin-by-Pin Power Distribution in the Most Powered Assembly in EOC. First Cycle with 3 MOX LTAs 100%Pu (4.2-3.0-2.0)



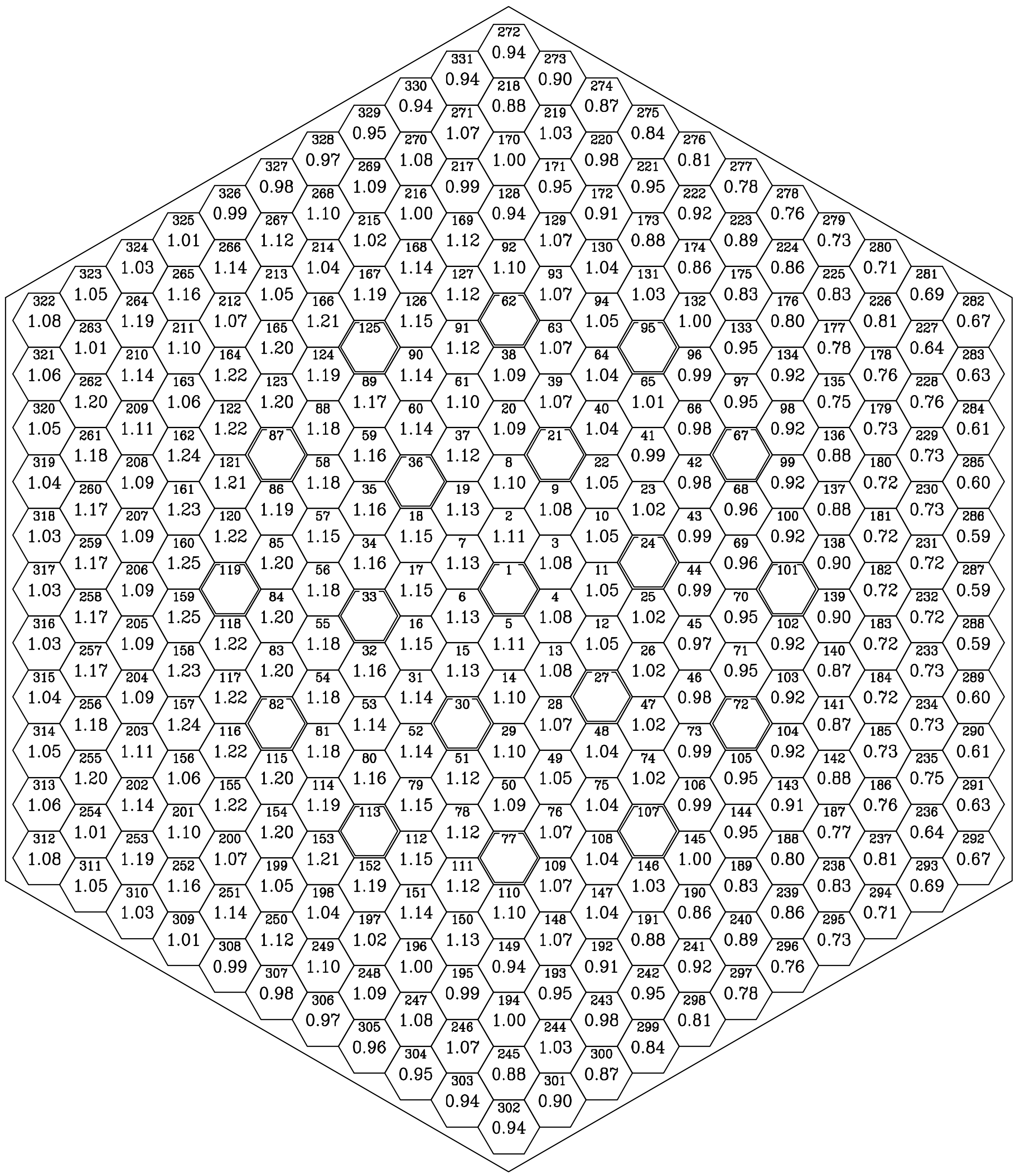
T	285.83	EFPD
W	3000.0	MW
$C_{H_3BO_3}$	0.00	g/kg
Burnup	18.8	
Fuel assembly	124	
Level	4	
Fuel rod	264	
Kb_{max}	1.08	

Fig.22. Pin-by-Pin Power Distribution in MOX LTA in BOC. First Cycle with 3 MOX LTAs 100%Pu (4.2-3.0-2.0)



T	0.00	EFPD
W	3000.0	MW
$C_{H_3BO_3}$	5.78	g/kg
Ql	259.6	W/cm
Fuel assembly	88	
Level	4	
Fuel rod	159	
Kk_{max}	1.24	

Fig.23. Pin-by-Pin Power Distribution in MOX LTA in EOC. First Cycle with 3 MOX LTAs 100%Pu (4.2-3.0-2.0)



T	285.83	EFPD
W	3000.0	MW
$C_{H_3BO_3}$	0.00	g/kg
Ql	194.0	W/cm
Fuel assembly	88	
Level	4	
Fuel rod	159	
Kk_{max}	1.25	

Fig.24. Assembly-by-Assembly Power Distribution.
First Cycle with 3 MOX LTAs of "Island" Type (Pu3.8-2.8, U-3.7)

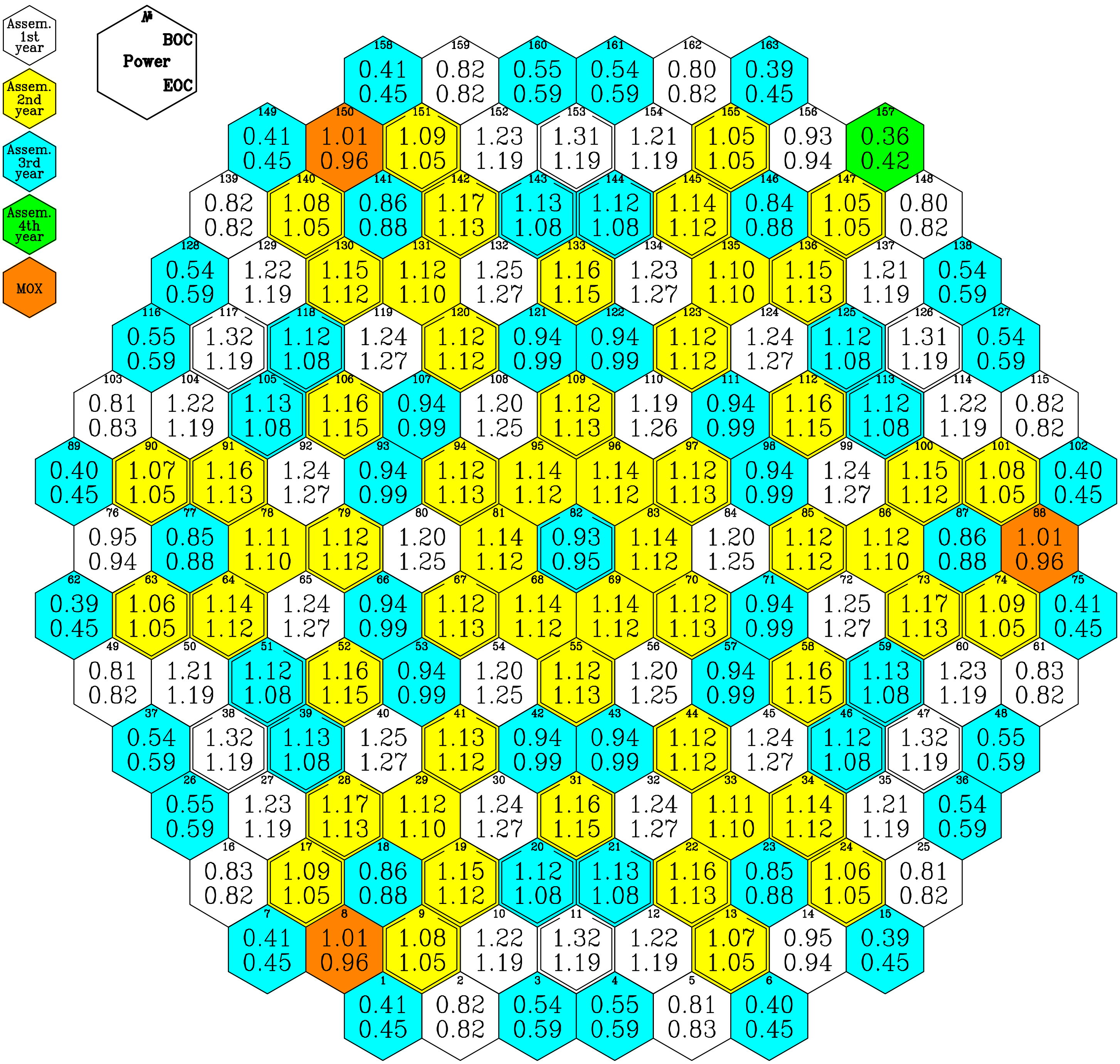


Fig.25. Assembly-by-Assembly Burnup Distribution.
First Cycle with 3 MOX LTAs of "Island" Type (Pu3.8-2.8, U-3.7)

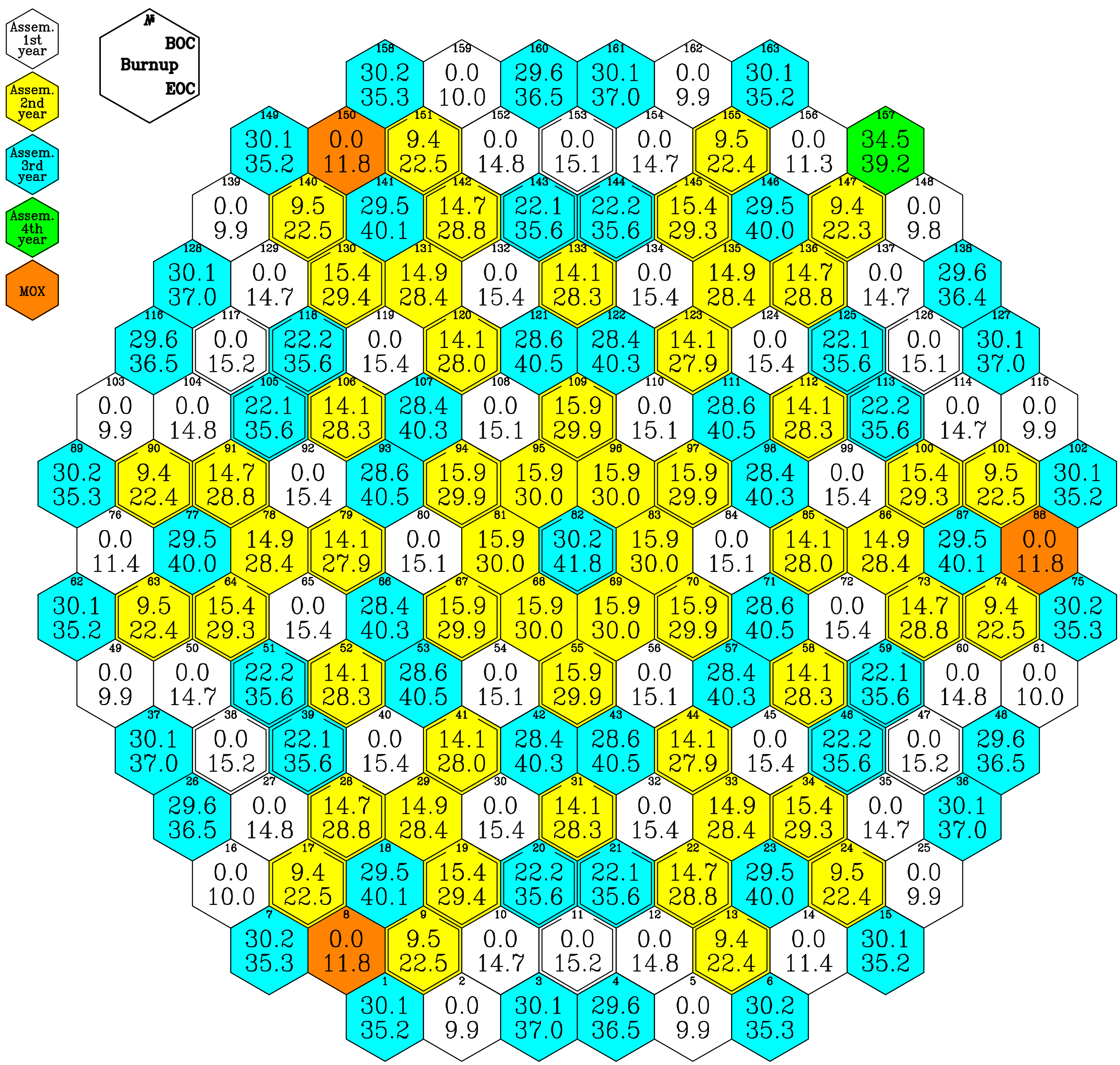


Fig.26. Assembly-by-Assembly Temperature Drop Distribution. First Cycle with 3 MOX LTAs of "Island" Type (Pu3.8-2.8, U-3.7)

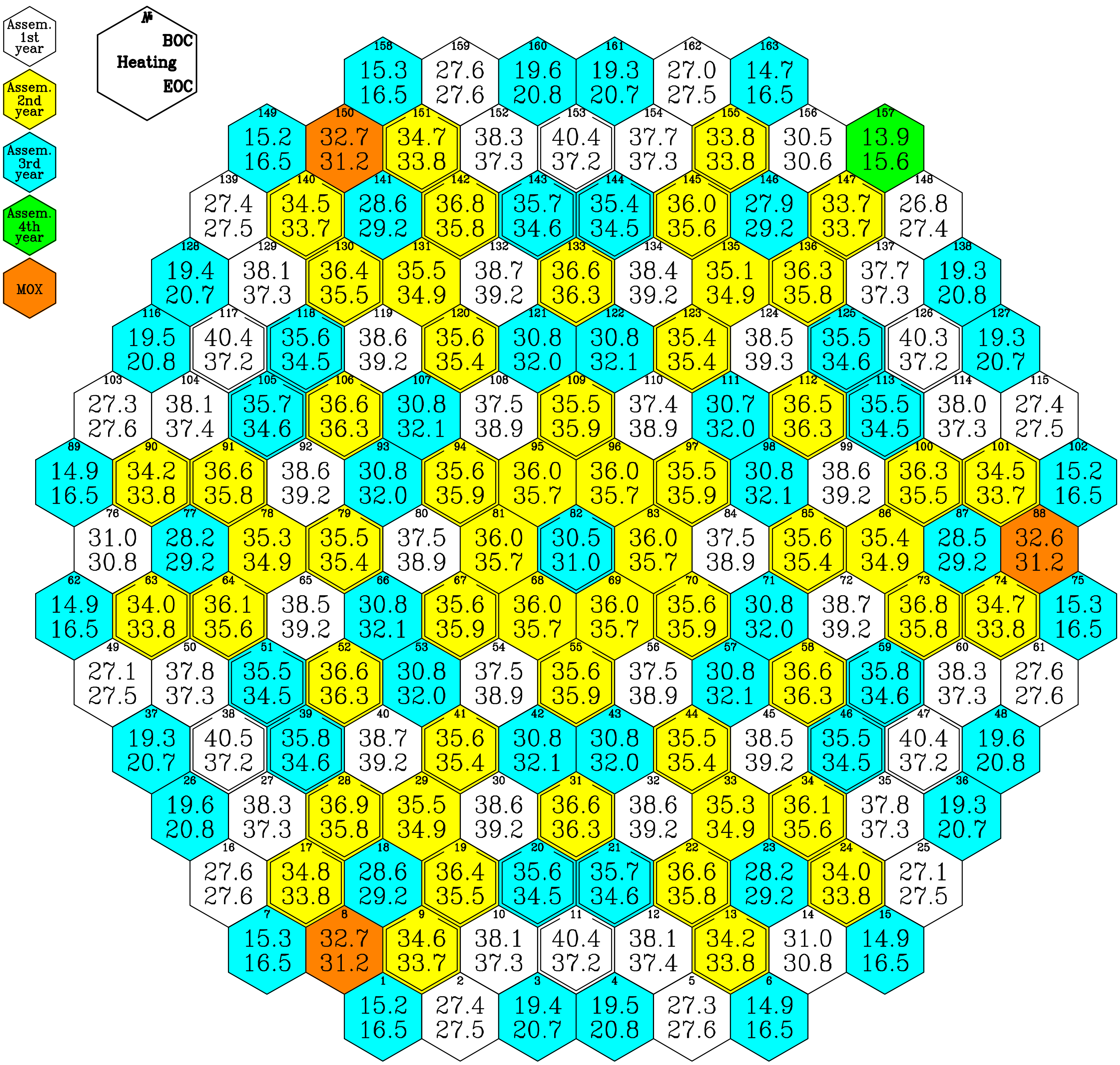
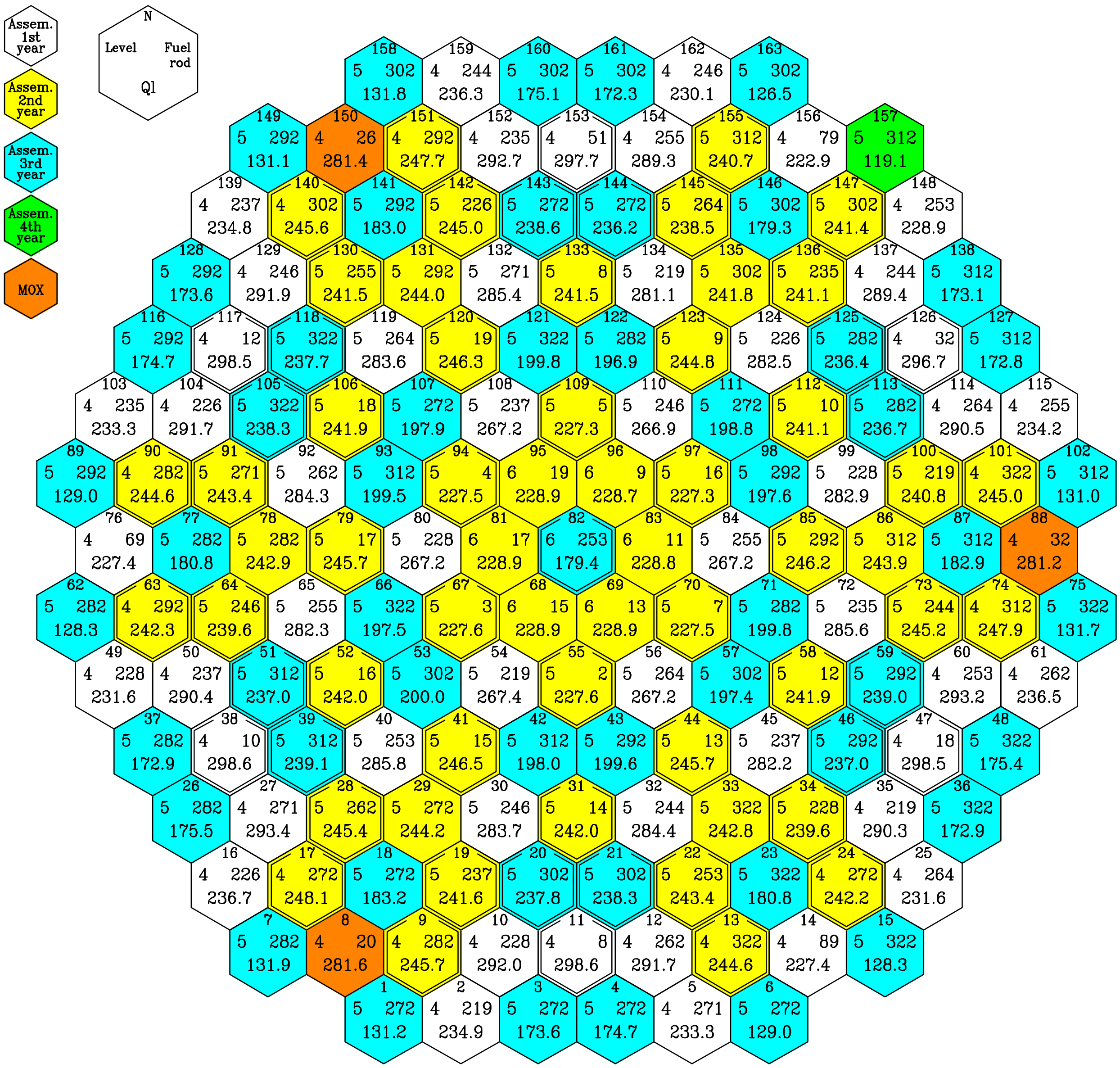
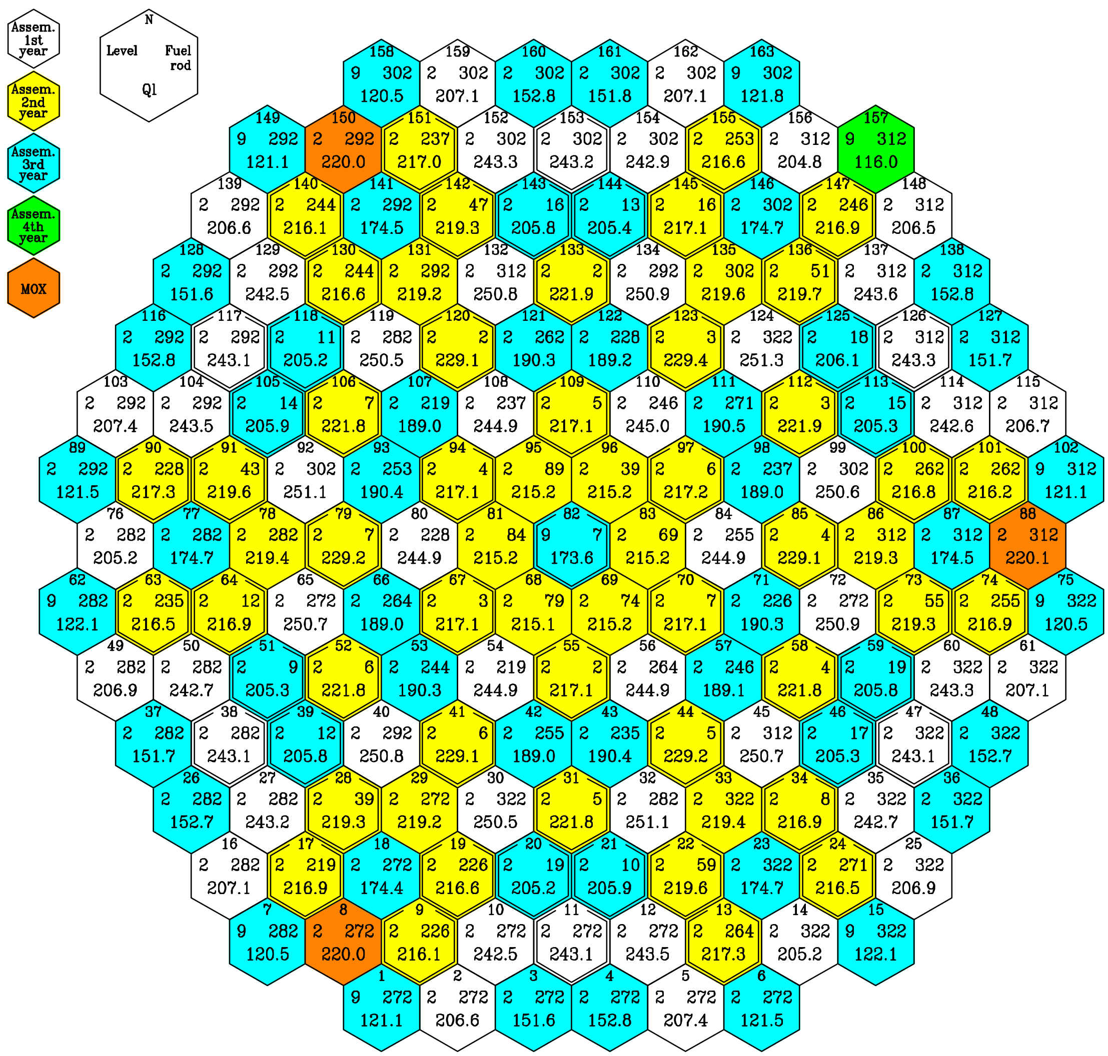


Fig.27. Assembly-by-Assembly Maximum Linear Power Distribution in BOC. First Cycle with 3 MOX LTAs of "Island" Type (Pu3.8-2.8-U3.7)



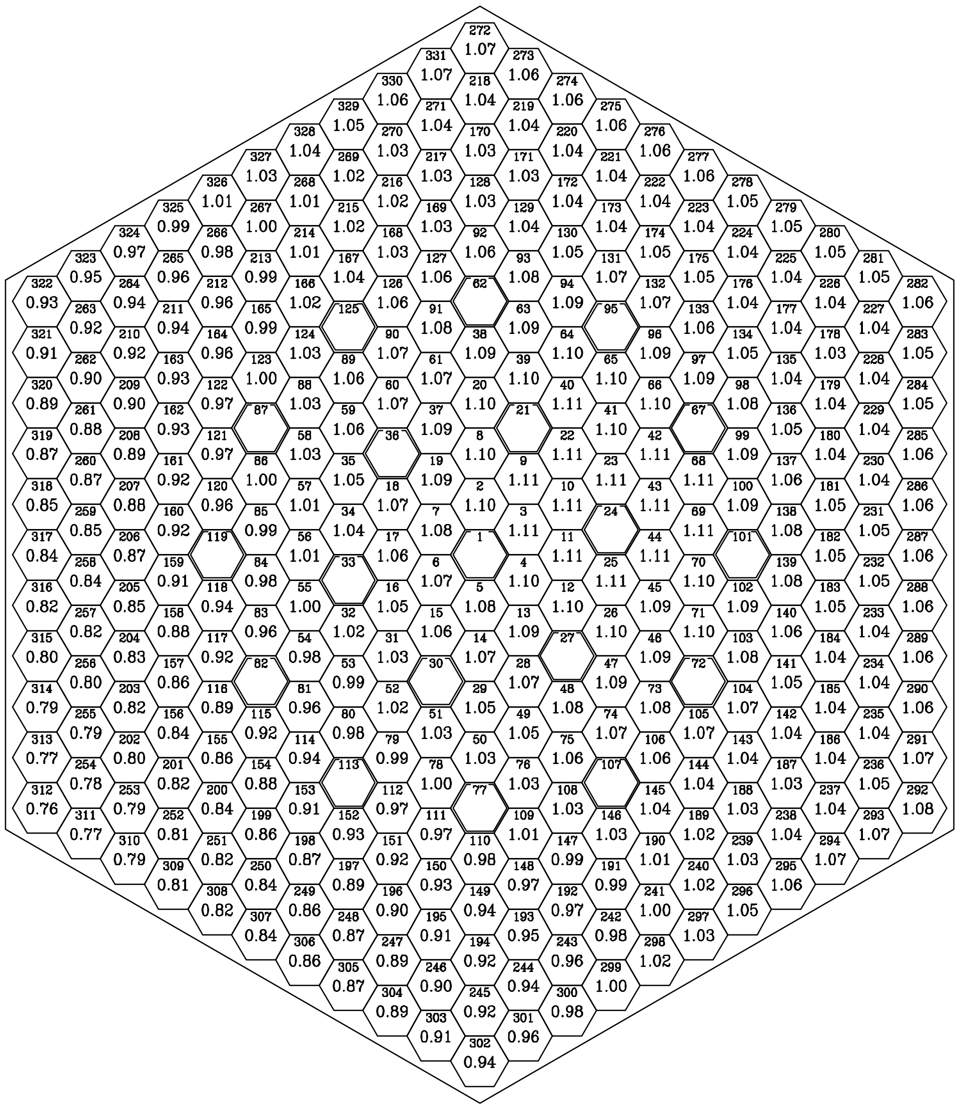
T	=	0.00	EFPD
W	=	3000.0	MW
$C_{H_3BO_3}$	=	5.77	g/kg
Ql_{max}	=	298.6	W/cm
Fuel ass.	=	38	
Level	=	4	
Fuel rod	=	10	

Fig.28. Assembly-by-Assembly Maximum Linear Power Distribution in EOC. First Cycle with 3 MOX LTAs of "Island" Type (Pu3.8-2.8-U3.7)



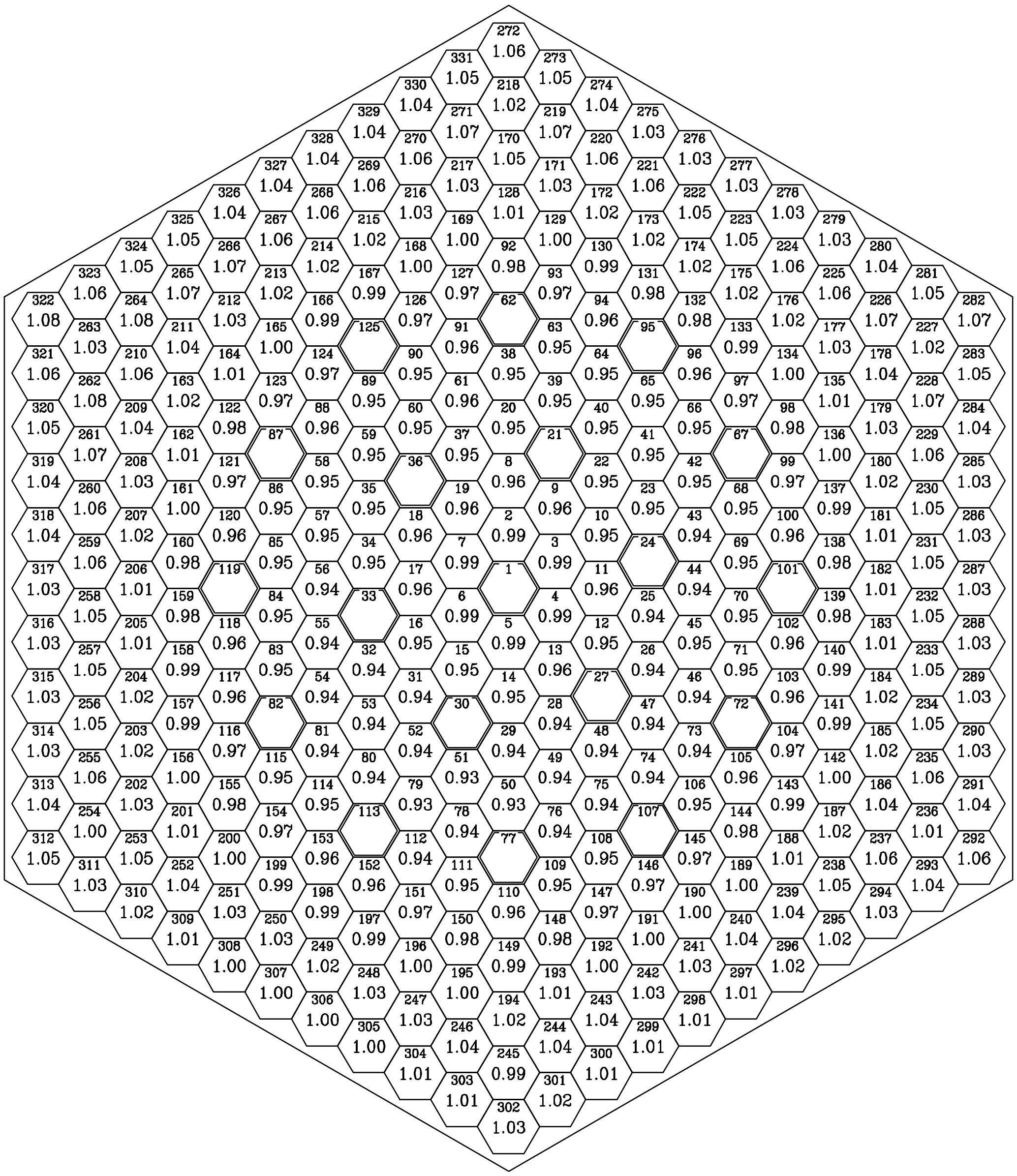
T = 287.40 EFPD
W = 3000.0 MW
$C_{H_3BO_3}$ = 0.00 g/kg
Ql_{max} = 251.3 W/cm
Fuel ass. = 124
Level = 2
Fuel rod = 322

Fig.29. Pin-by-Pin Power Distribution in the Most Powered Assembly in BOC. First Cycle with 3 MOX LTAs of "Island" Type (Pu3.8-2.8, U-3.7



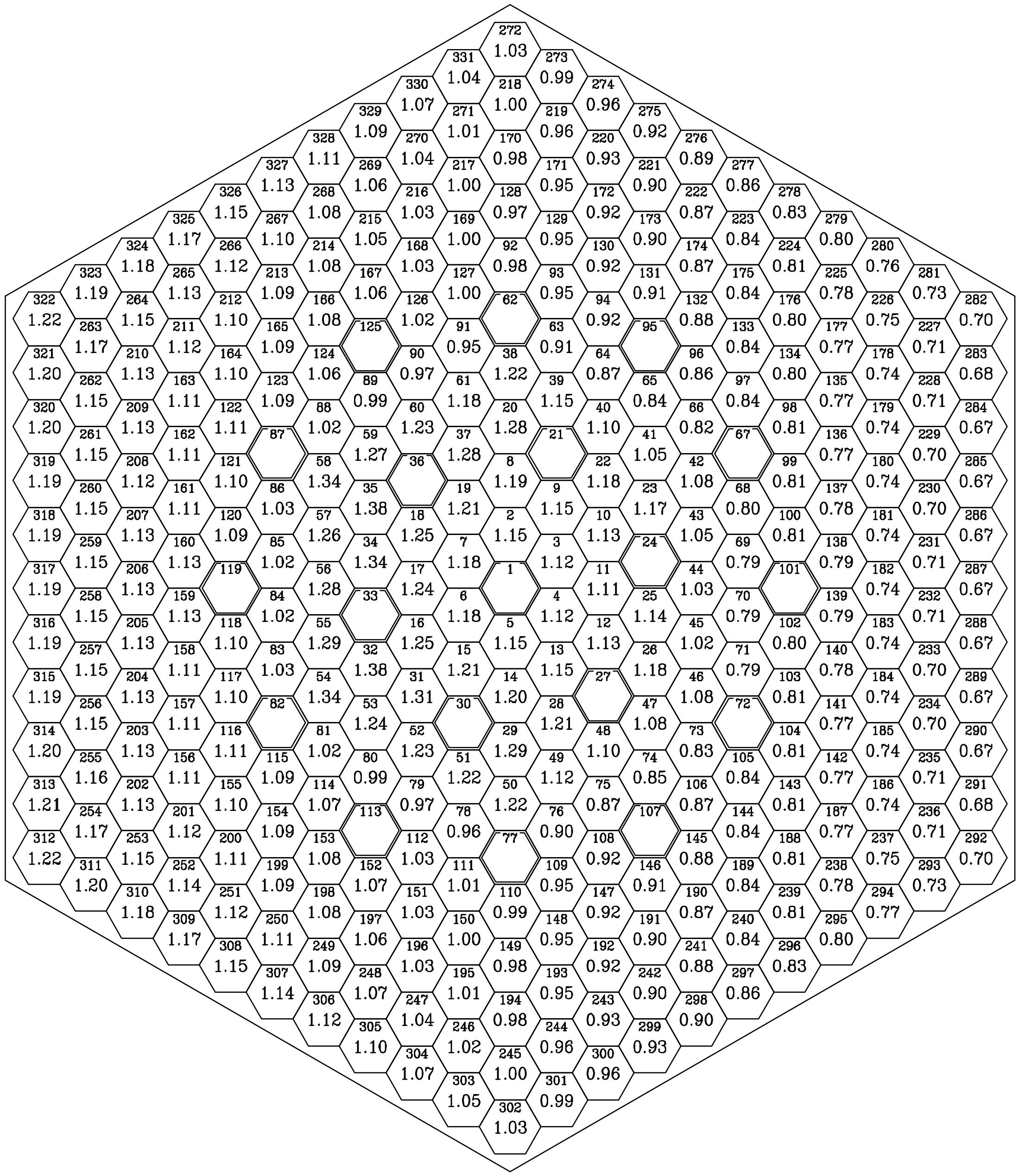
T	0.00	EFPD
W	3000.0	MW
$C_{H_3BO_3}$	5.77	g/kg
Ql	298.6	W/cm
Fuel assembly	38	
Level	4	
Fuel rod	10	
Kk_{max}	1.11	

Fig.30. Pin-by-Pin Power Distribution in the Most Powered Assembly in EOC. First Cycle with 3 MOX LTAs of "Island" Type (Pu3.8-2.8, U-3.7)



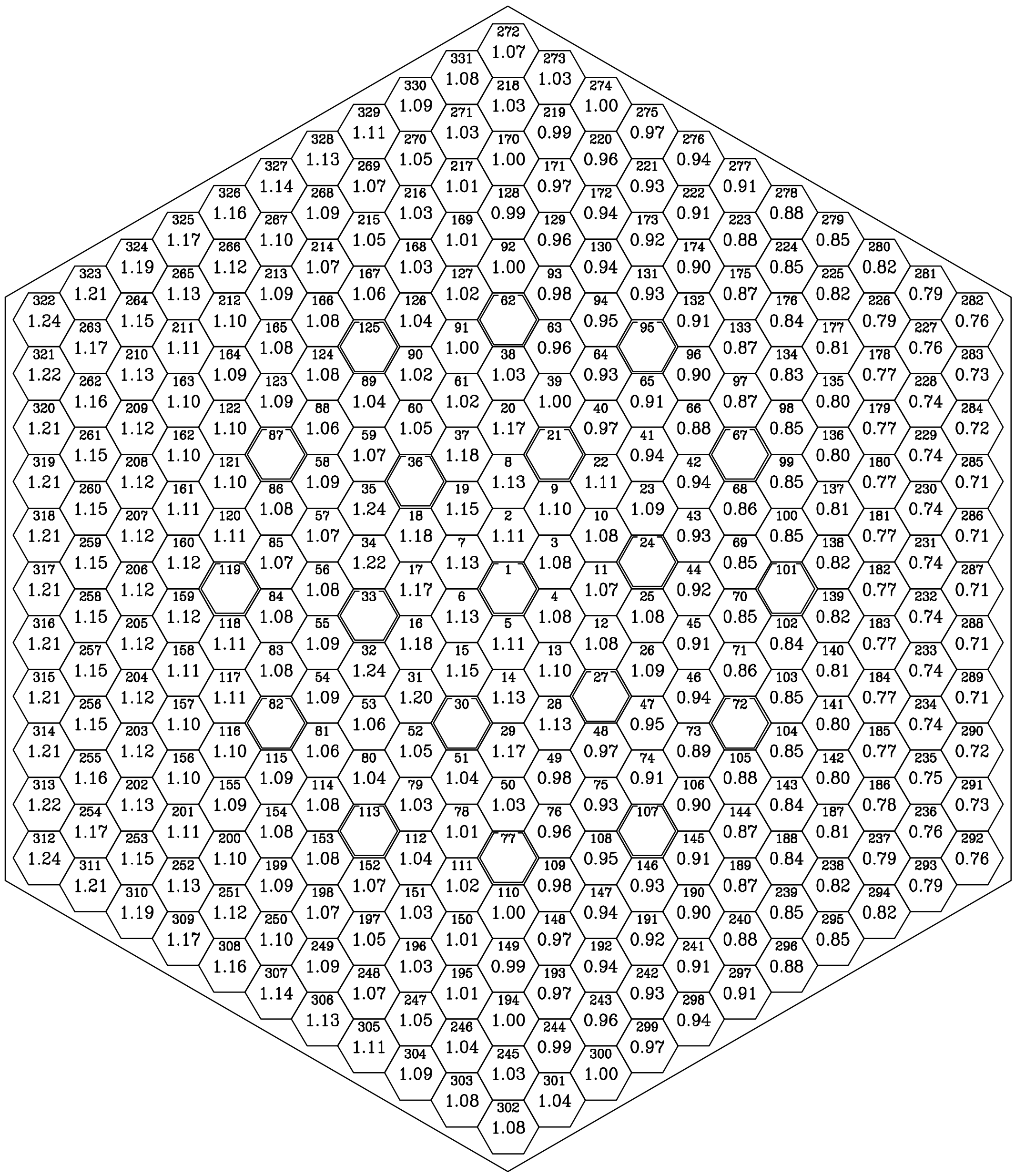
T	287.40	EFPD
W	3000.0	MW
$C_{H_3BO_3}$	0.00	g/kg
Burnup	18.8	
Fuel assembly	124	
Level	4	
Fuel rod	264	
Kb_{max}	1.08	

Fig.31. Pin-by-Pin Power Distribution in MOX LTA in BOC. First Cycle with 3 MOX LTAs of "Island" Type (Pu3.8-2.8, U-3.7)



T	0.00	EFPD
W	3000.0	MW
$C_{H_3BO_3}$	5.77	g/kg
Ql	281.2	W/cm
Fuel assembly	88	
Level	4	
Fuel rod	32	
Kk_{max}	1.38	

Fig.32. Pin-by-Pin Power Distribution in MOX LTA in EOC. First Cycle with 3 MOX LTAs of "Island" Type (Pu3.8-2.8, U-3.7)



T	287.40	EFPD
W	3000.0	MW
$C_{H_3BO_3}$	0.00	g/kg
Ql	208.7	W/cm
Fuel assembly	88	
Level	4	
Fuel rod	312	
Kk_{max}	1.24	

Fig.33. Reloading Scheme.
Second Cycle with 3 MOX LTAs

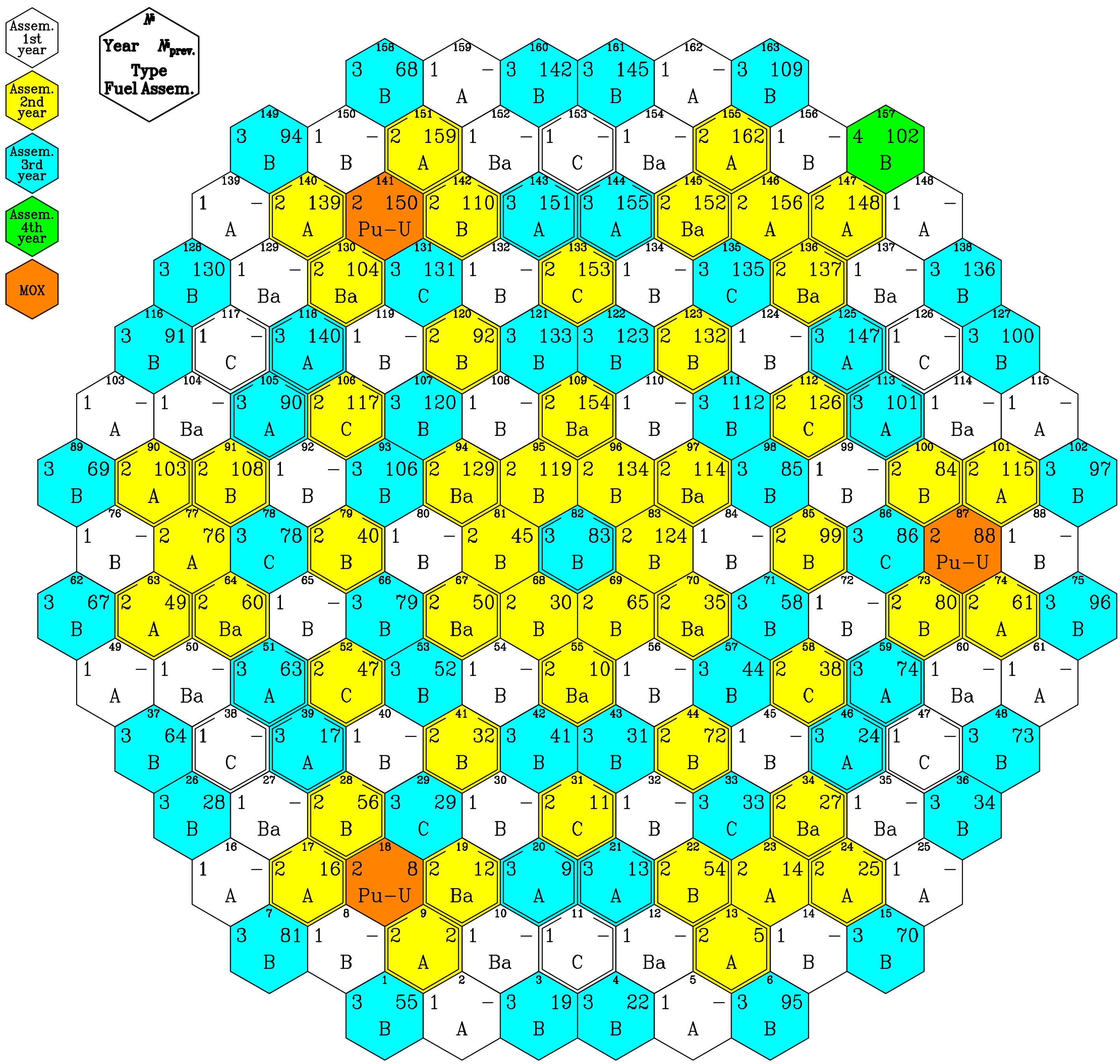


Fig.34. Assembly-by-Assembly Power Distribution.
Second Cycle with 3 MOX LTAs 100%Pu (4.2-3.0-2.0)

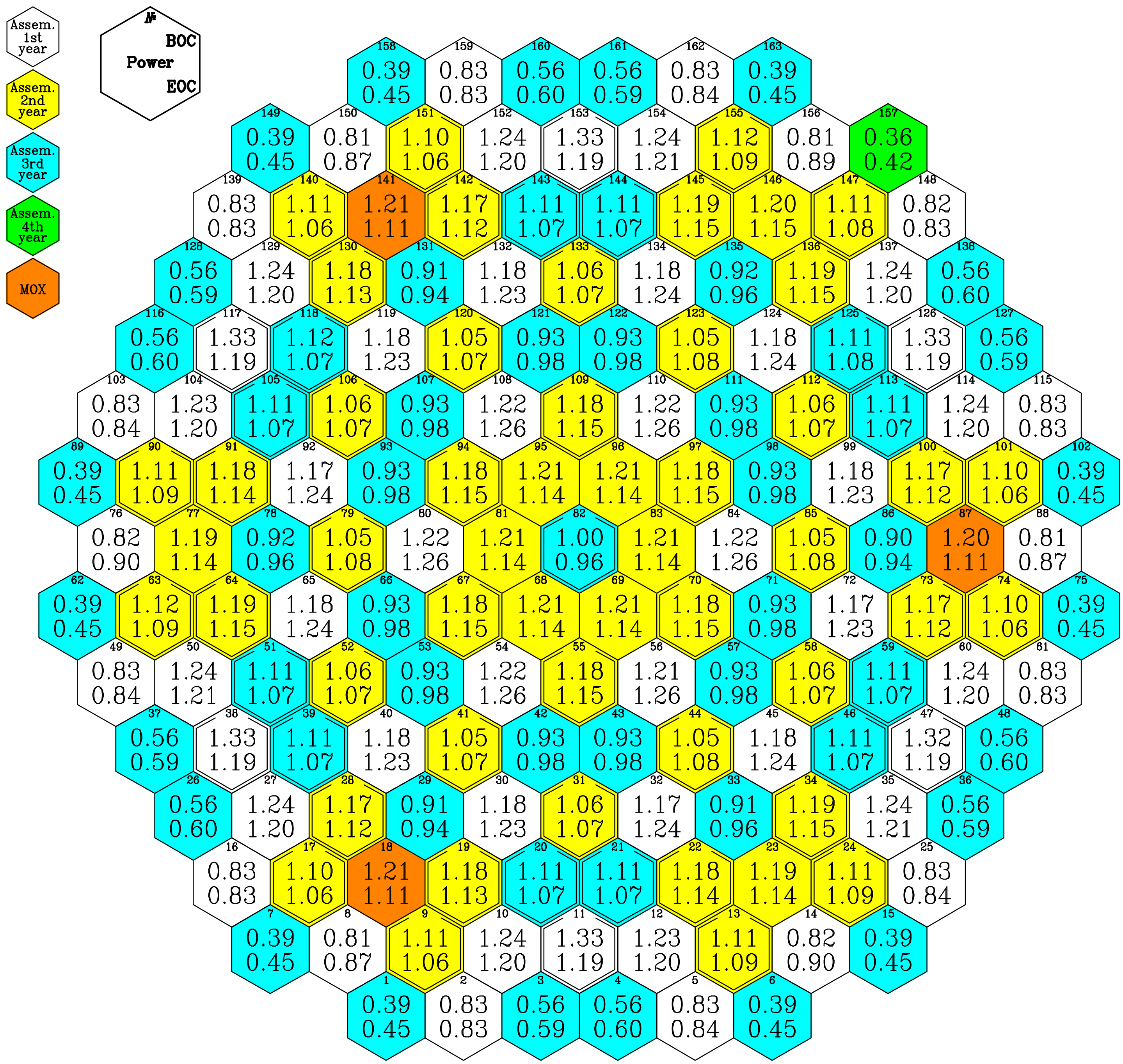


Fig.35. Assembly-by-Assembly Temperature Drop Power Distribution. Second Cycle with 3 MOX LTAs 100%Pu (4.2-3.0-2.0)

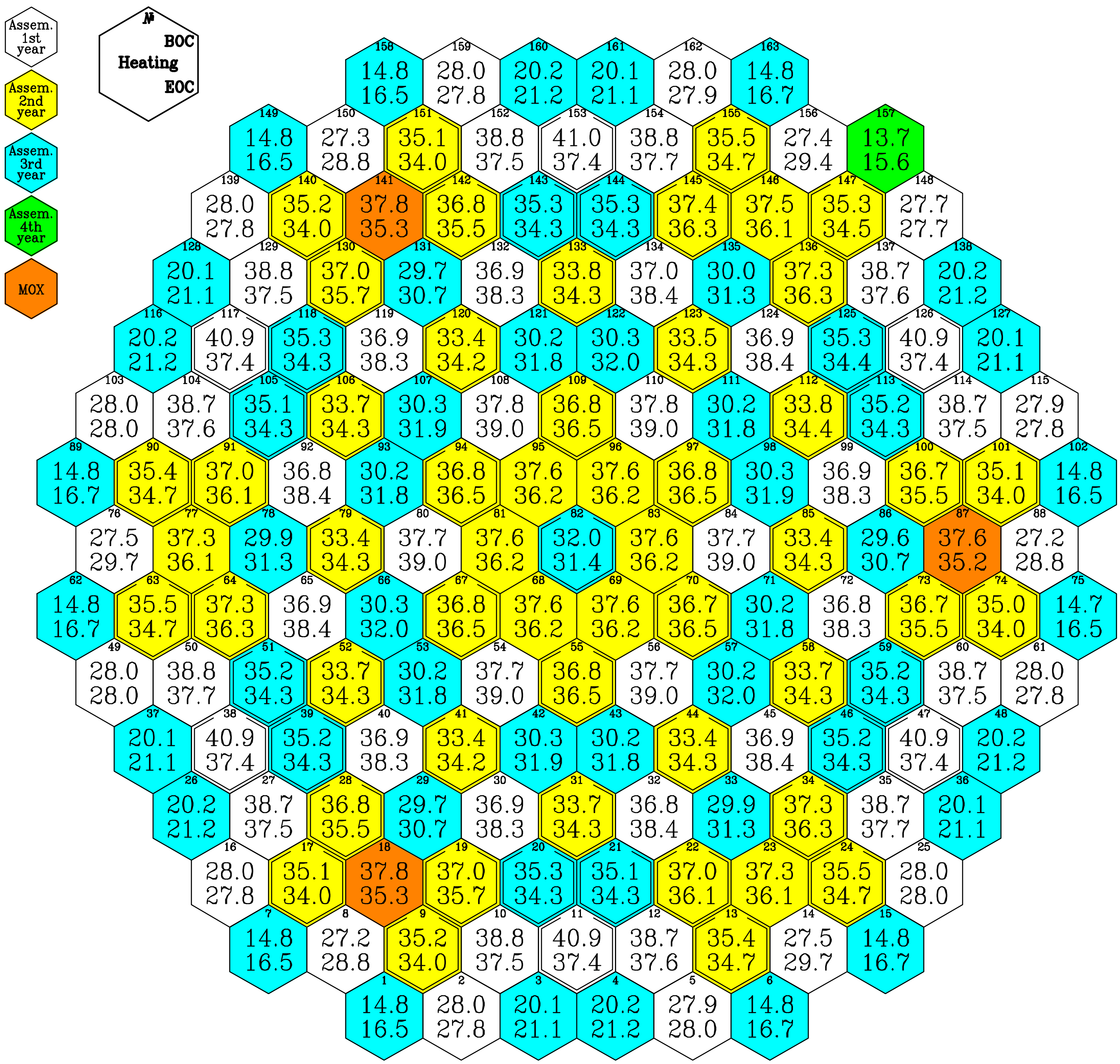


Fig.36. Assembly-by-Assembly Burnup Distribution.
Second Cycle with 3 MOX LTAs 100%Pu (4.2-3.0-2.0)

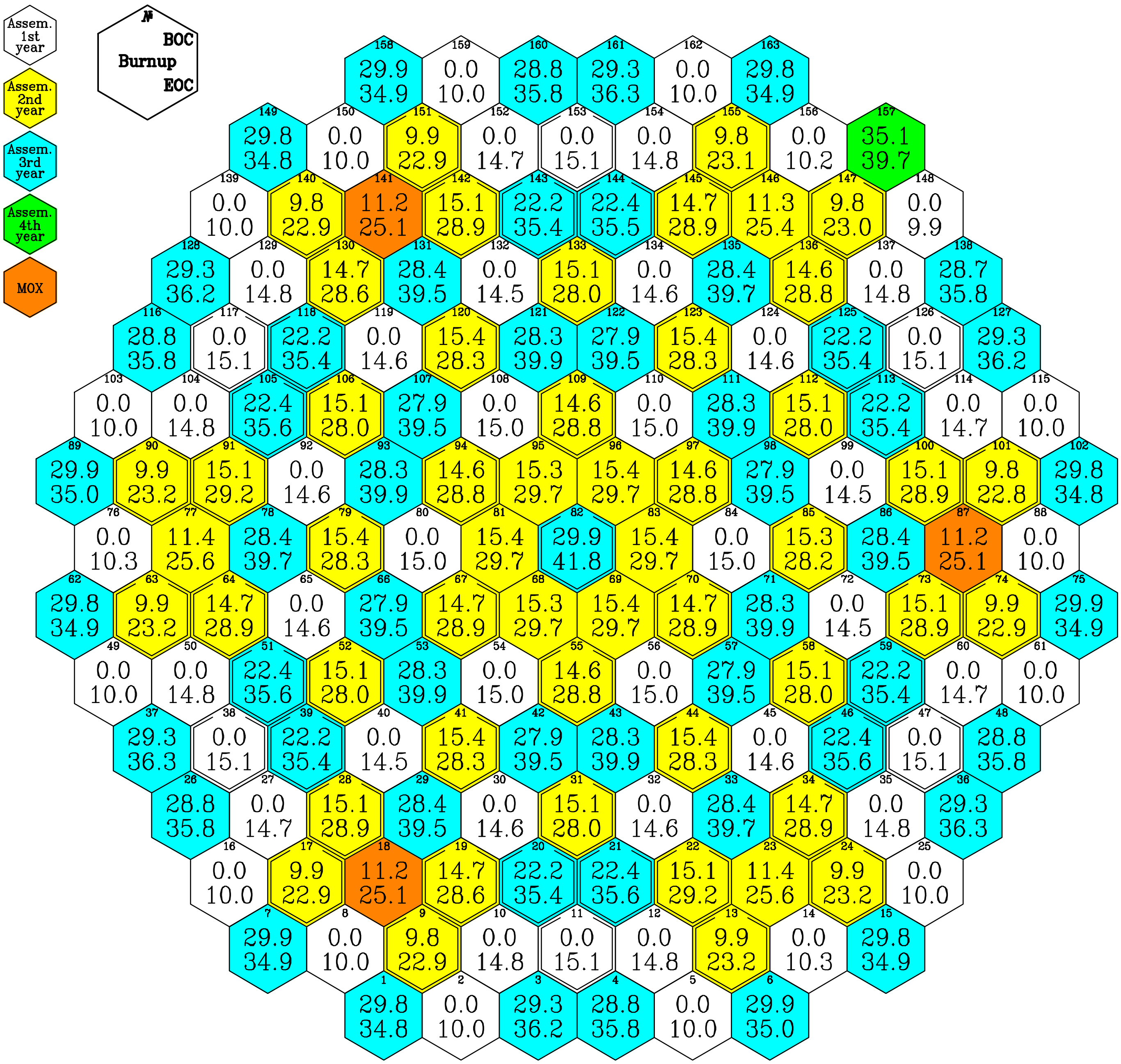
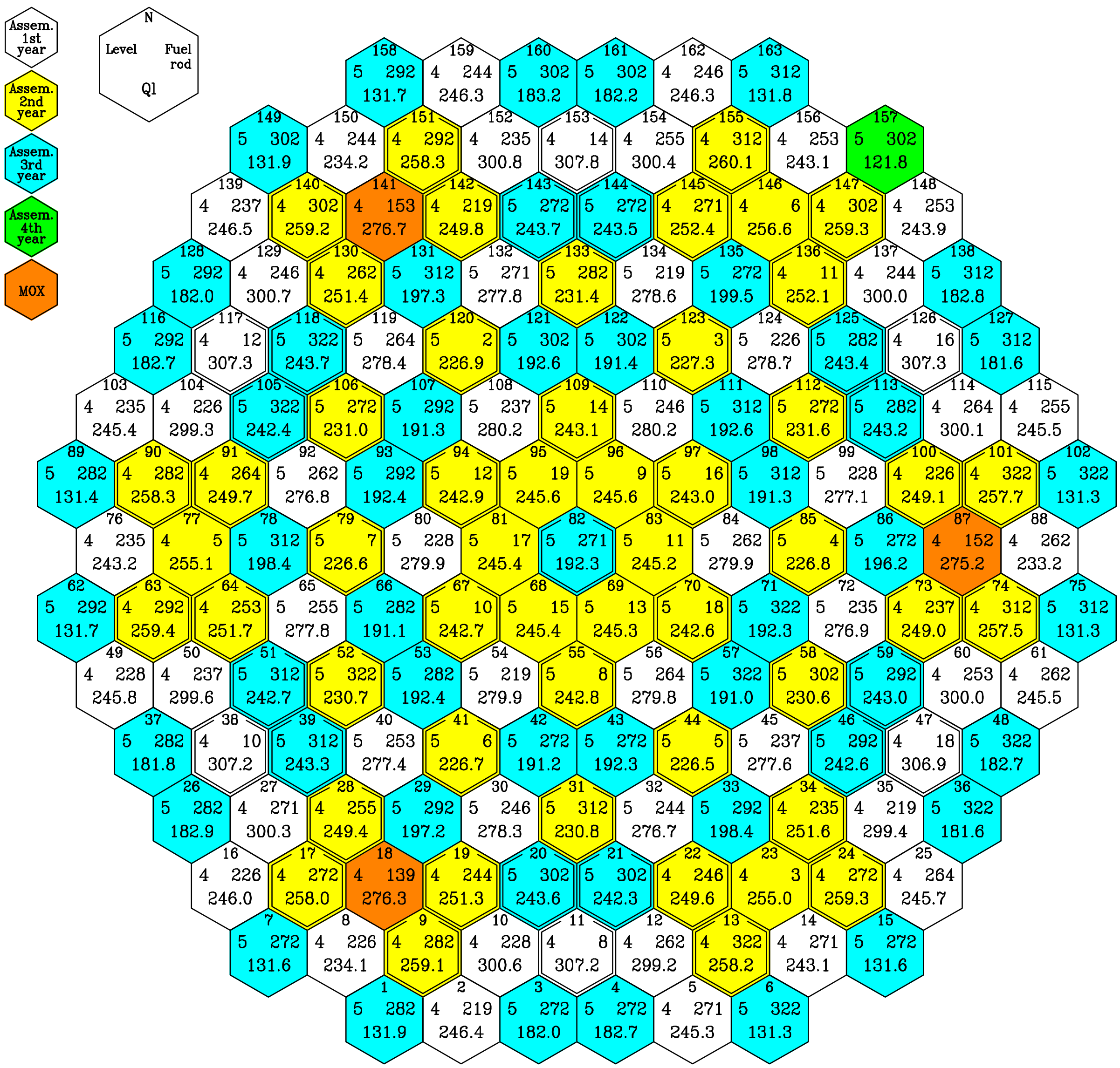
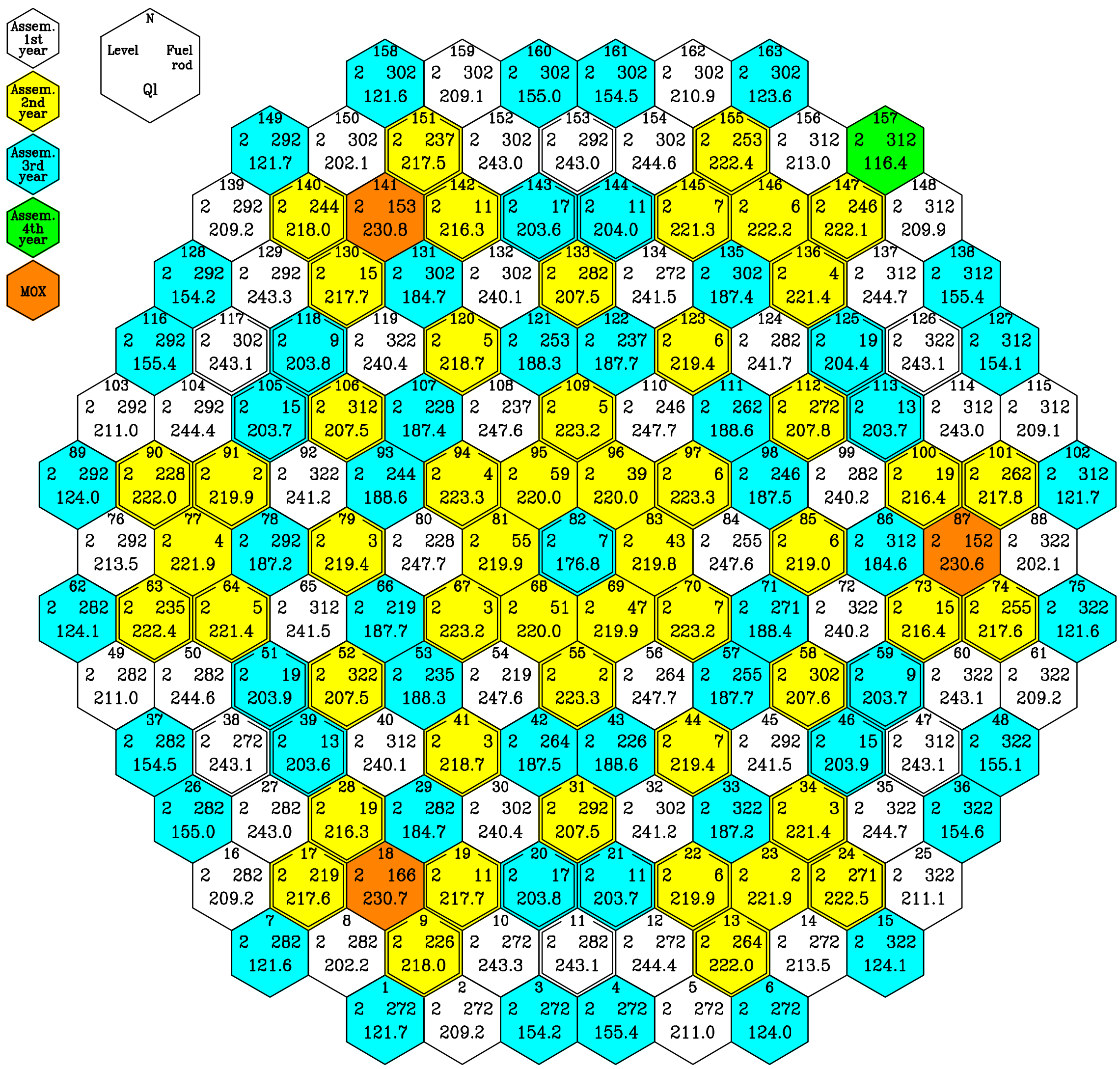


Fig.37. Assembly-by-Assembly Maximum Linear Pin Power Distribution in BOC. Second Cycle with 3 MOX LTAs 100%Pu (4.2-3.0-2.0)



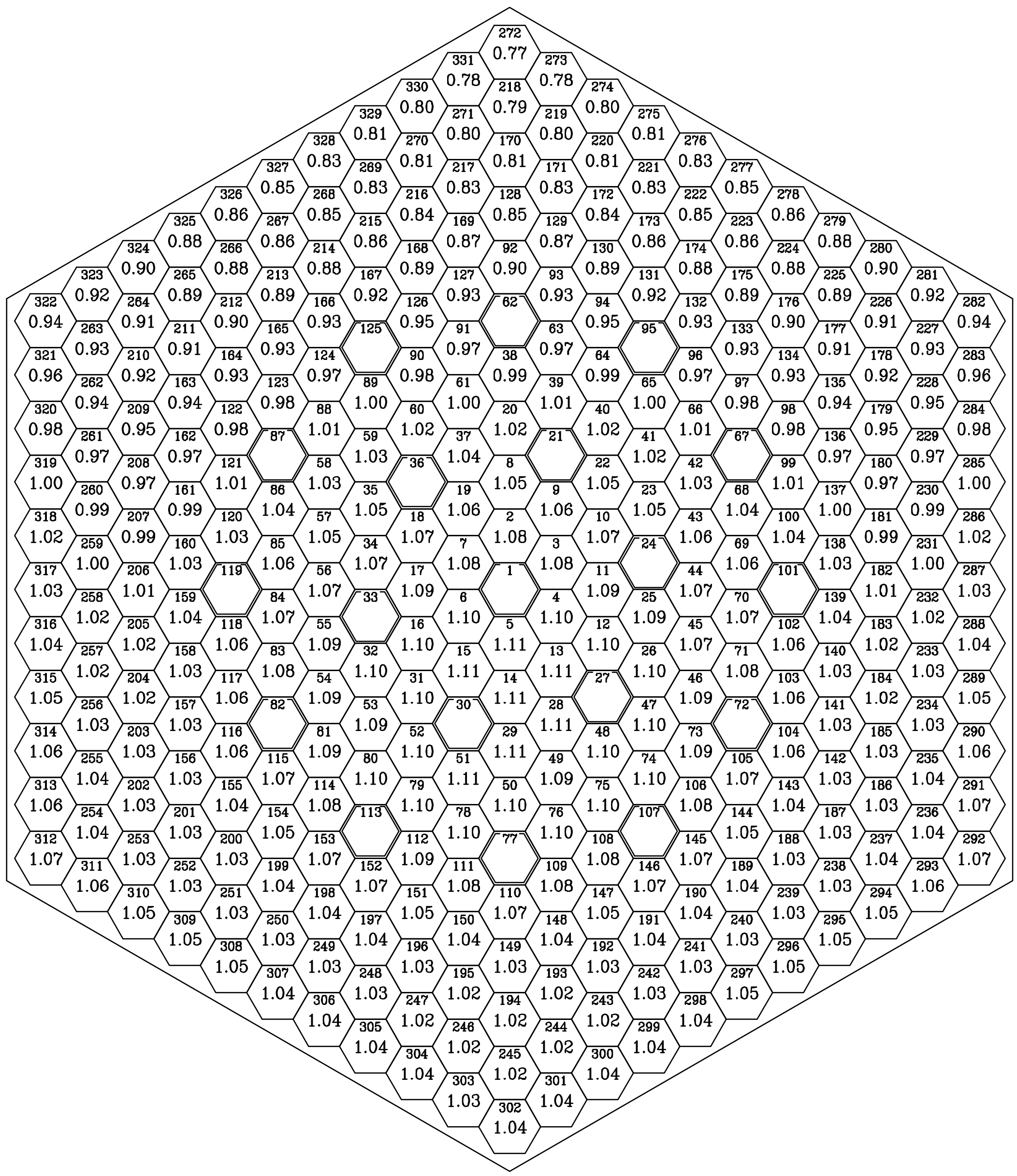
T	=	0.00	EFPD
W	=	3000.0	MW
$C_{H_3BO_3}$	=	5.67	g/kg
Ql_{max}	=	307.8	W/cm
Fuel ass.	=	153	
Level	=	4	
Fuel rod	=	14	

Fig.38. Assembly-by-Assembly Maximum Linear Pin Power Distribution in EOC. Second Cycle with 3 MOX LTAs 100%Pu (4.2-3.0-2.0)



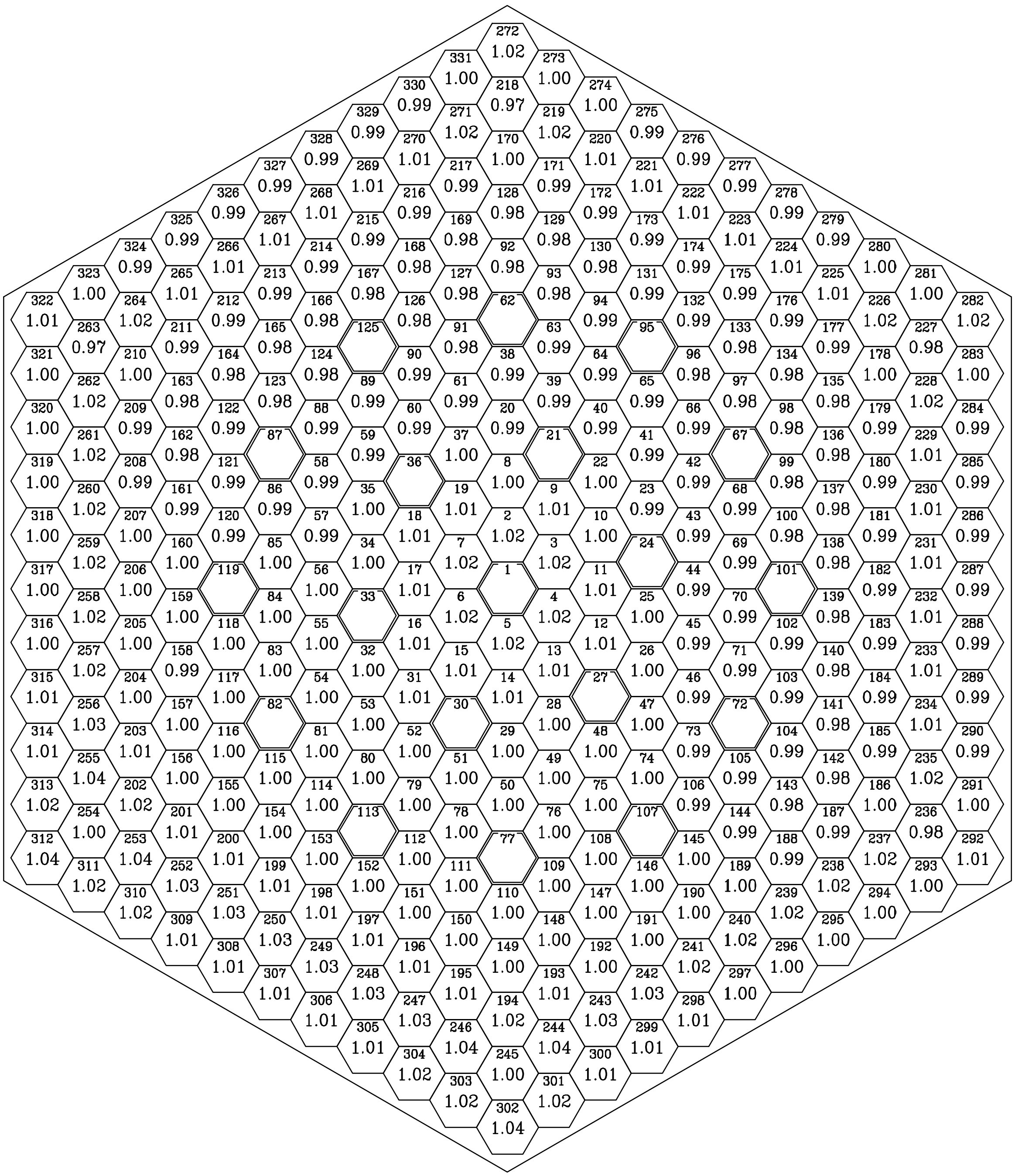
T	=	283.52	EFPD
W	=	3000.0	MW
$C_{H_3BO_3}$	=	0.00	g/kg
Ql_{max}	=	247.7	W/cm
Fuel ass.	=	56	
Level	=	2	
Fuel rod	=	264	

Fig.39. Pin-by-Pin Power Distribution in the Most Powered Assembly in BOC. Second Cycle with 3 MOX LTAs 100%Pu (4.2-3.0-2.0)



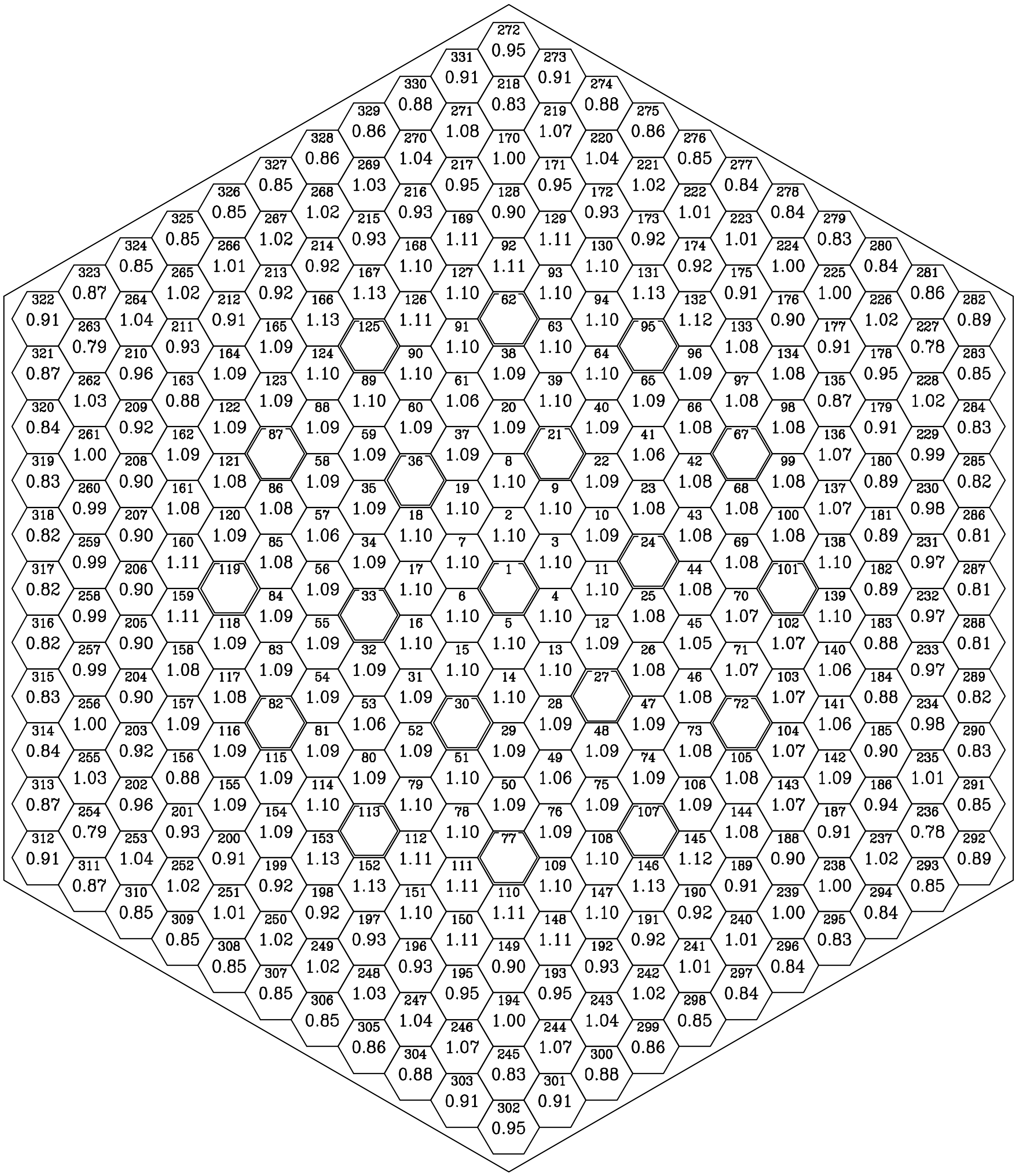
T	0.00	EFPD
W	3000.0	MW
$C_{H_3BO_3}$	5.67	g/kg
Ql_{max}	307.8	W/cm
Fuel assembly	153	
Level	4	
Fuel rod	14	
Kk_{max}	1.11	

Fig.40. Pin-by-Pin Power Distribution in the Most Powered Assembly in EOC. Second Cycle with 3 MOX LTAs 100%Pu (4.2-3.0-2.0)



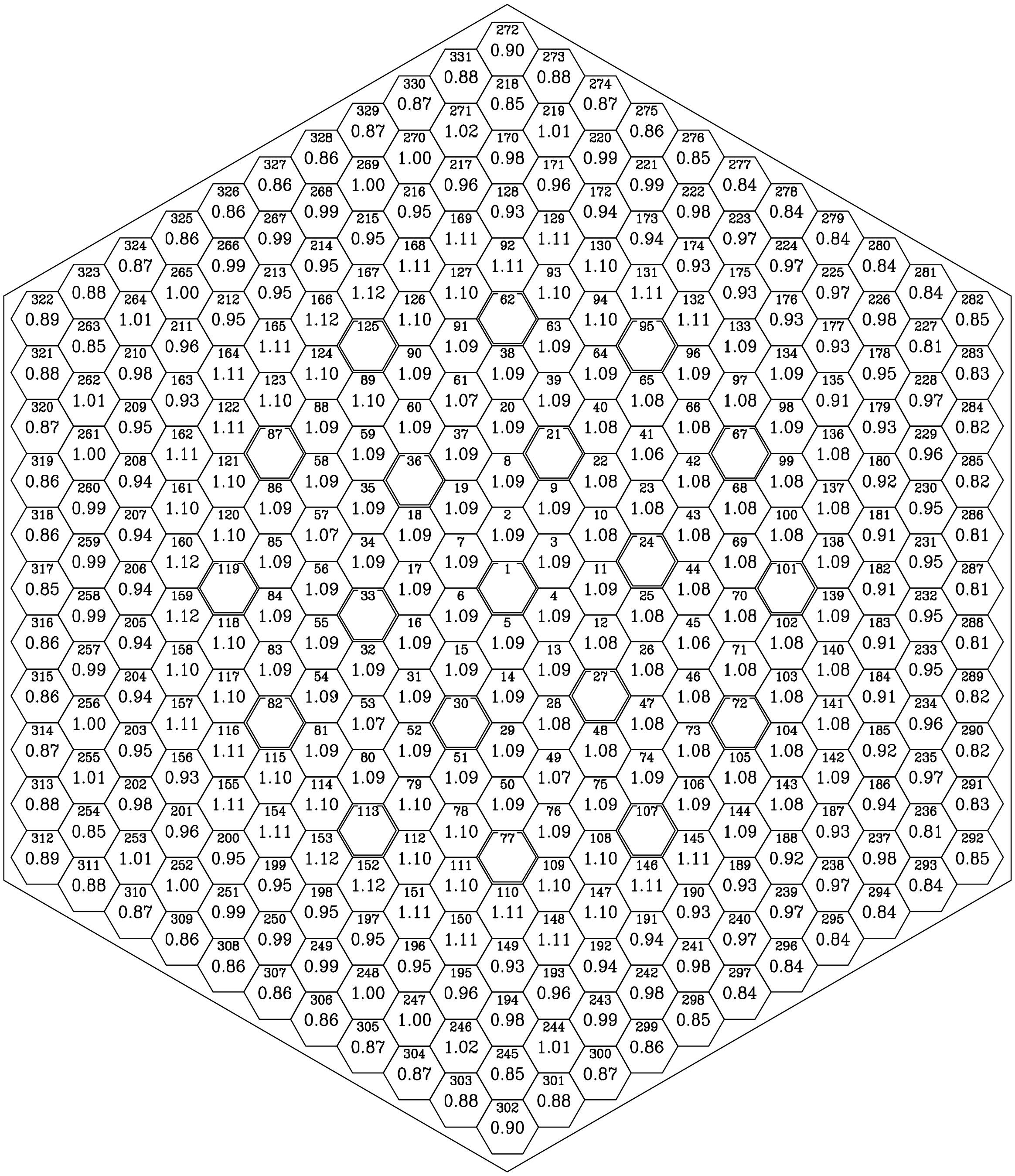
T	283.52	EFPD
W	3000.0	MW
$C_{H_3BO_3}$	0.00	g/kg
Ql	234.3	W/cm
Fuel assembly	110	
Level	4	
Fuel rod	246	
Kk_{max}	1.04	

Fig.41. Pin-by-Pin Power Distribution in MOX LTA in BOC. Second Cycle with 3 MOX LTAs 100%Pu (4.2-3.0-2.0)



T	0.00	EFPD
W	3000.0	MW
$C_{H_3BO_3}$	5.67	g/kg
Ql	275.2	W/cm
Fuel assembly	87	
Level	4	
Fuel rod	152	
Kk_{max}	1.13	

Fig.42. Pin-by-Pin Power Distribution in MOX LTA in EOC. Second Cycle with 3 MOX LTAs 100%Pu (4.2-3.0-2.0)



T	283.52	EFPD
W	3000.0	MW
$C_{H_3BO_3}$	0.00	g/kg
Ql	217.9	W/cm
Fuel assembly	87	
Level	4	
Fuel rod	152	
Kk_{max}	1.12	

Fig.43. Assembly-by-Assembly Power Distribution.
Second Cycle with 3 MOX LTAs of "Island" Type (Pu3.8-2.8-U3.7)

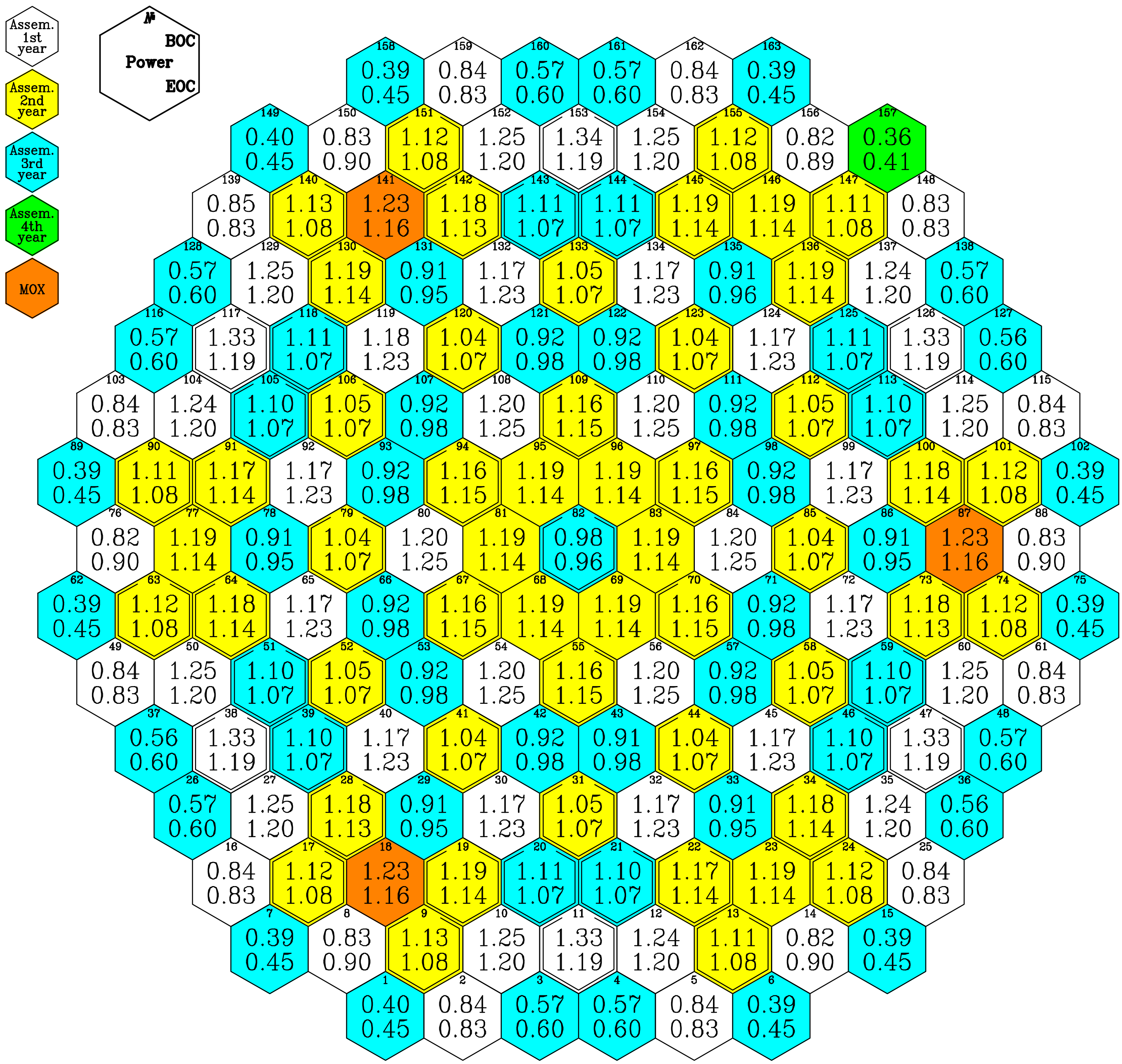


Fig.44. Assembly-by-Assembly Burnup Distribution.
Second Cycle with 3 MOX LTAs of "Island" Type (Pu3.8-2.8-U3.7)

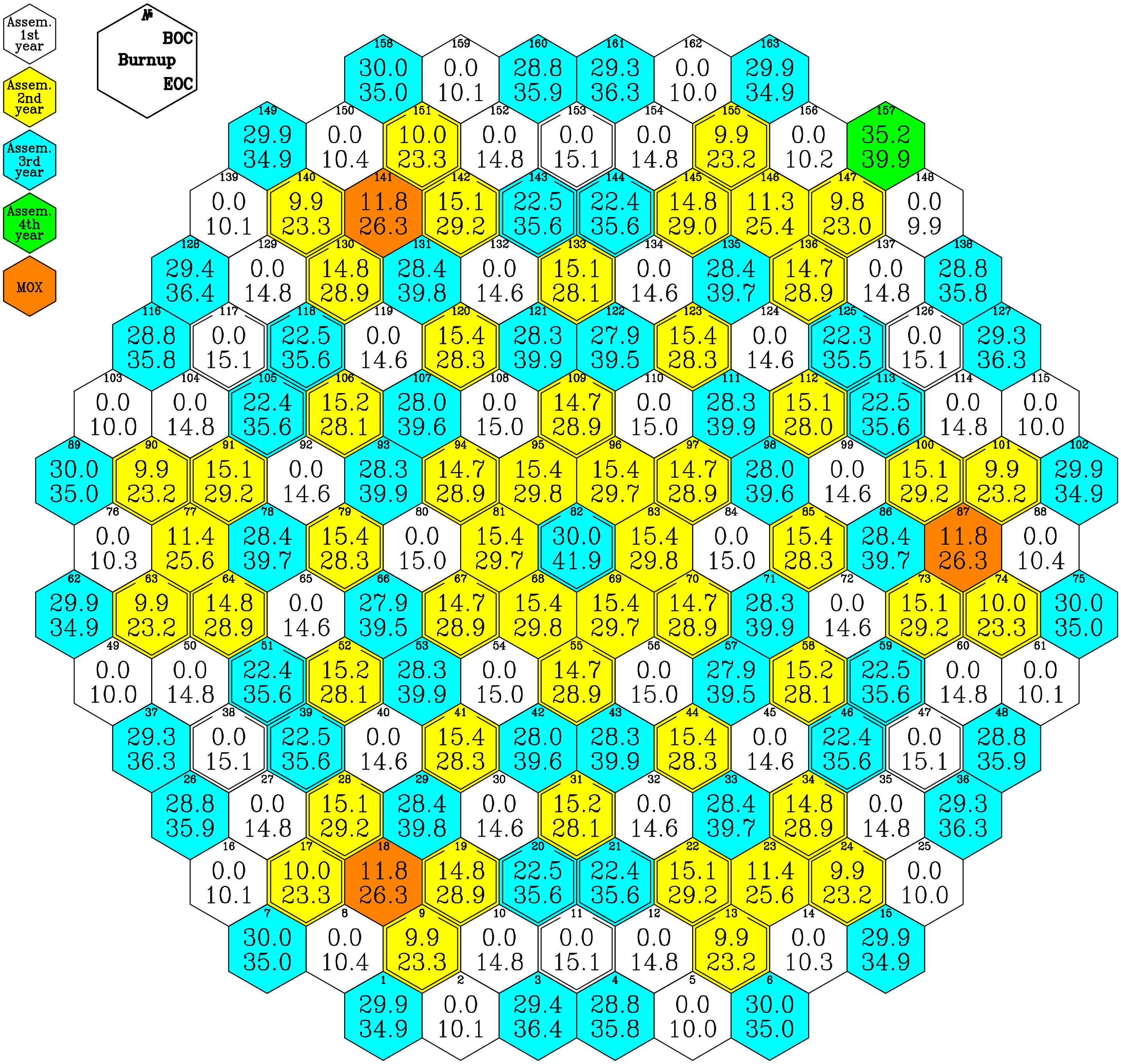


Fig.45. Assembly-by-Assembly Temperature Drop Distribution.
Second Cycle with 3 MOX LTAs of "Island" Type (Pu3.8-2.8-U3.7)

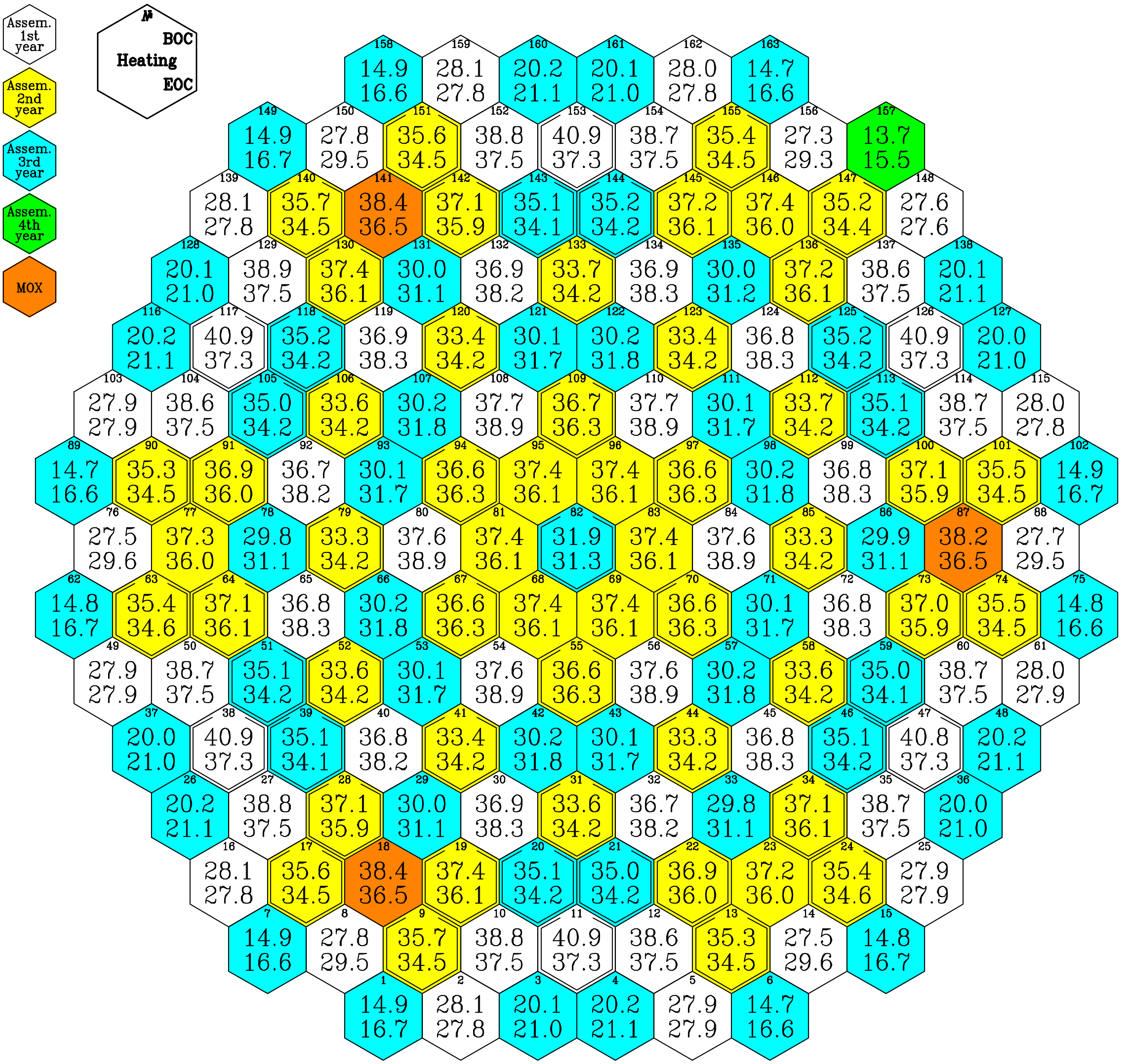
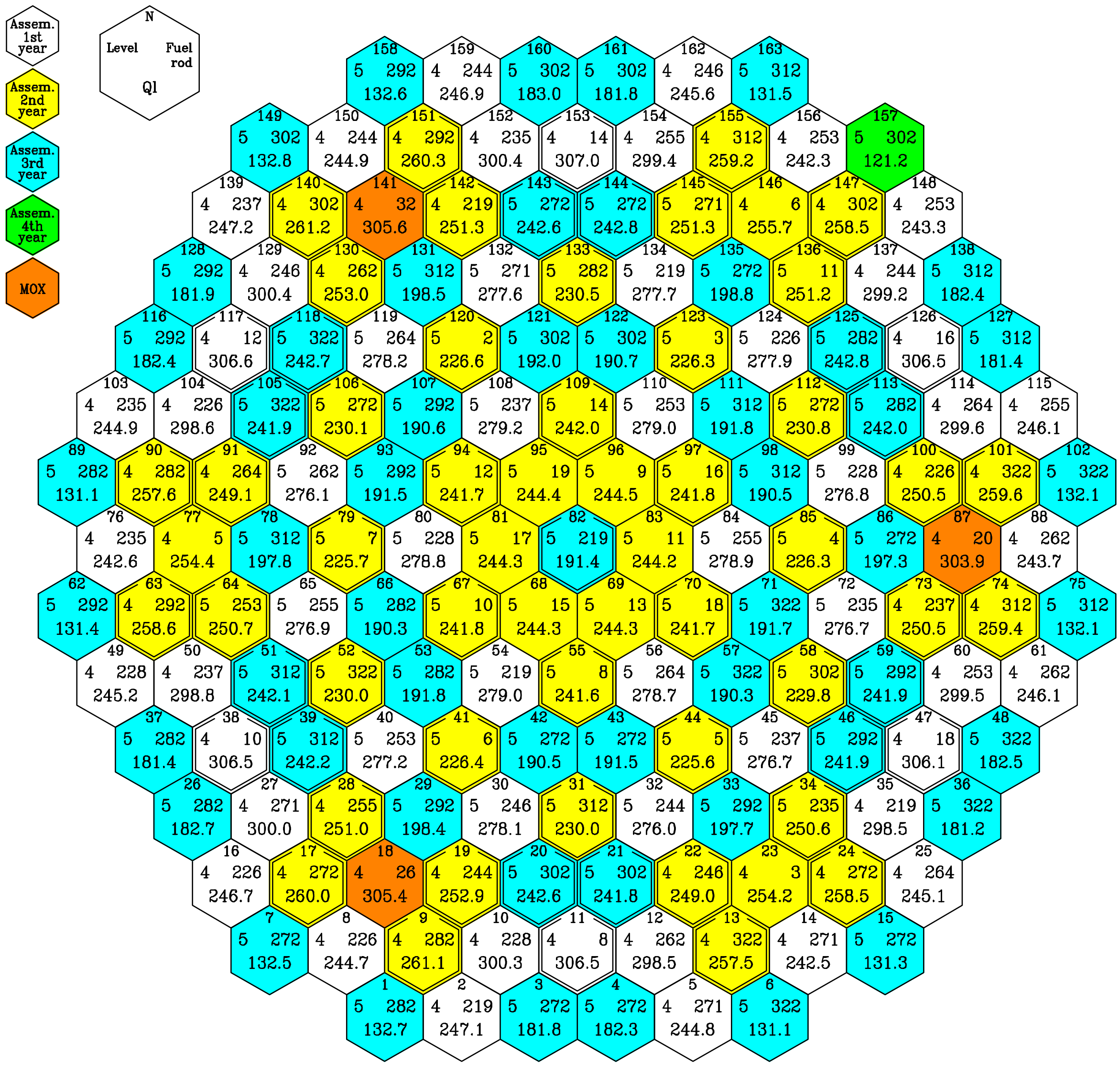
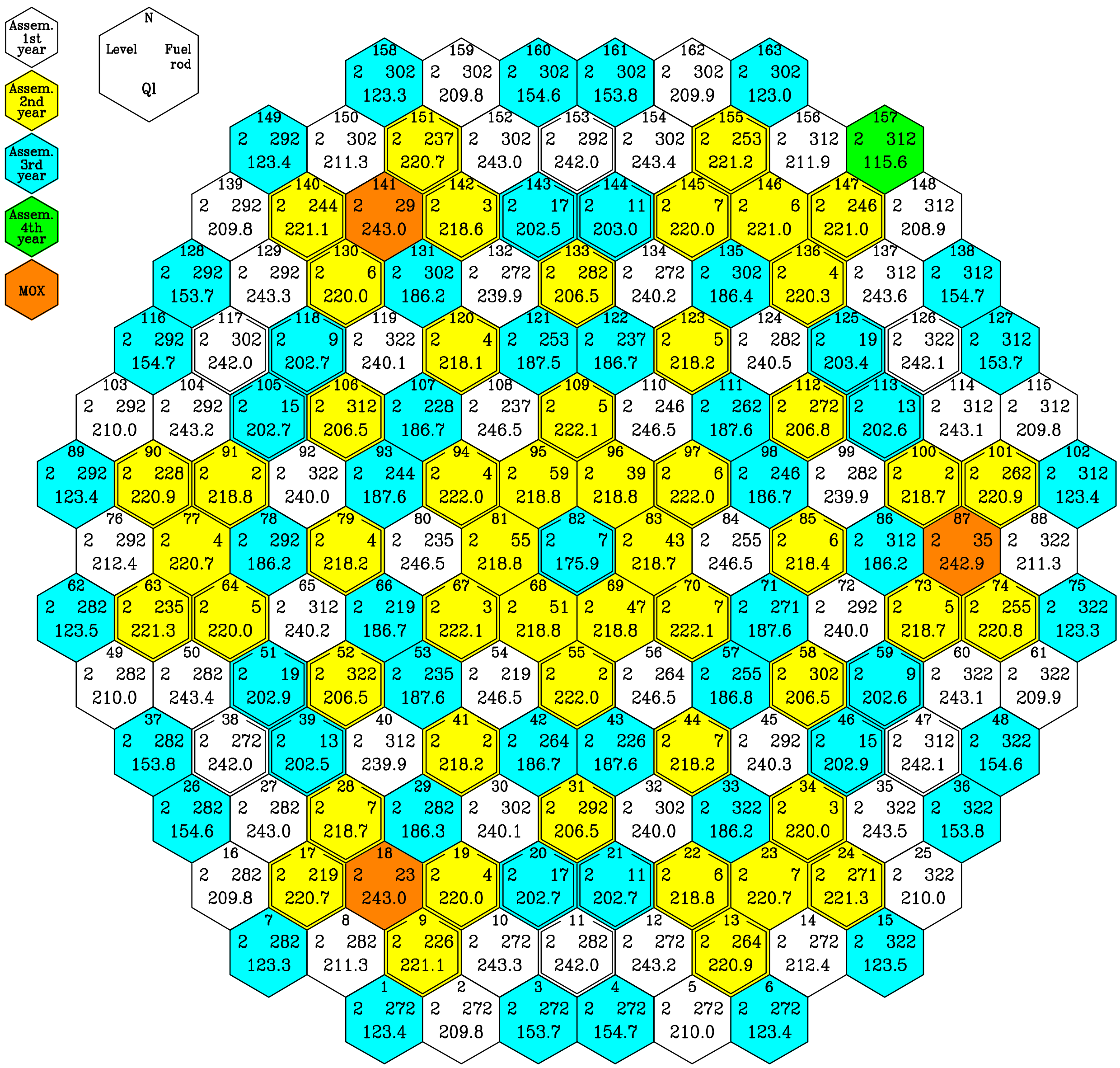


Fig.46. Assembly-by-Assembly Maximum Linear Pin Power Distribution in BOC. Second Cycle with 3 MOX LTAs of "Island" Type (Pu3.8-2.8-U3.7)



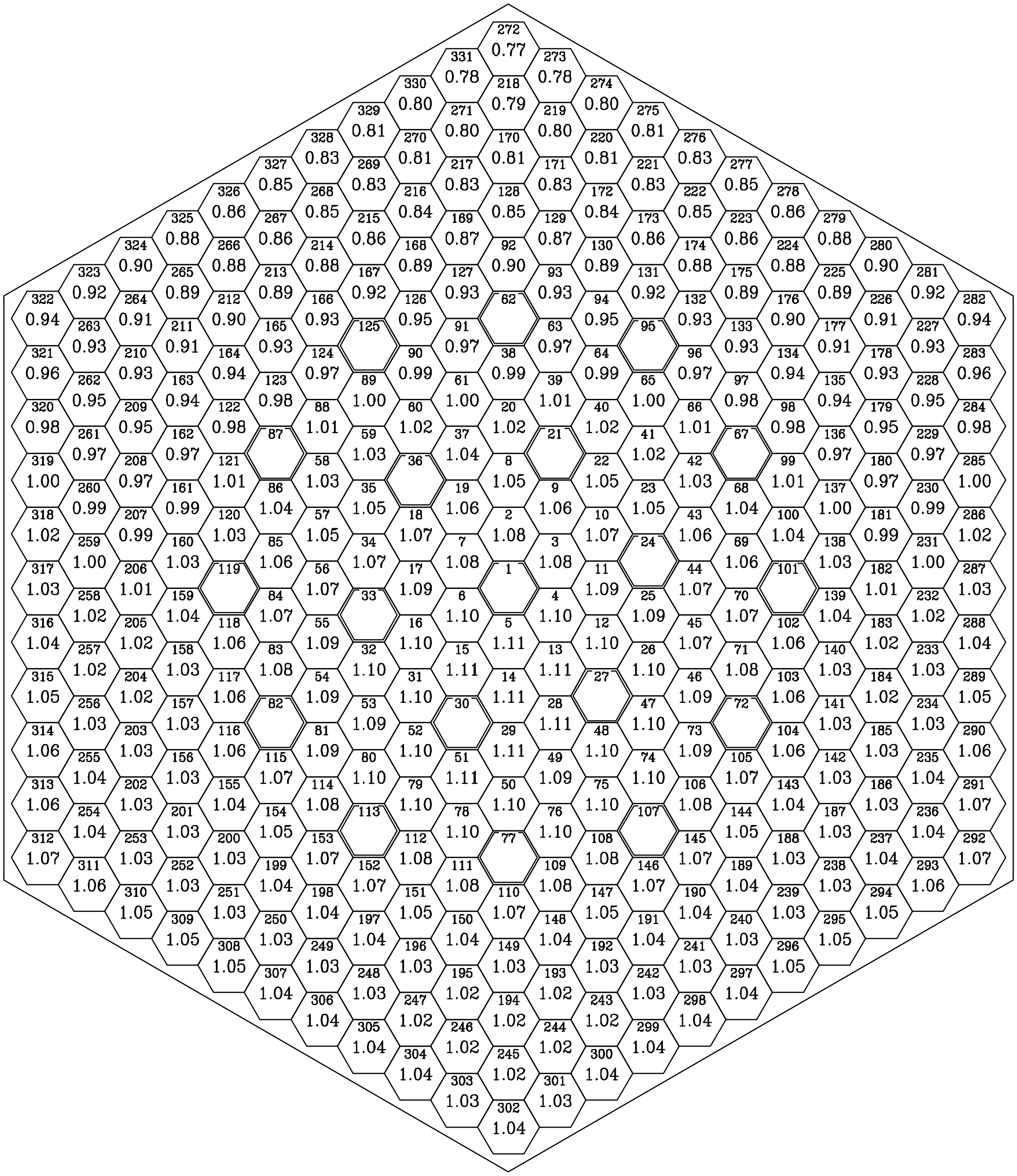
T	=	0.00	EFPD
W	=	3000.0	MW
$C_{H_3BO_3}$	=	5.66	g/kg
Ql_{max}	=	307.0	W/cm
Fuel ass.	=	153	
Level	=	4	
Fuel rod	=	14	

Fig.47. Assembly-by-Assembly Maximum Linear Pin Power Distribution in EOC. Second Cycle with 3 MOX LTAs of "Island" Type (Pu3.8-2.8-U3.7)



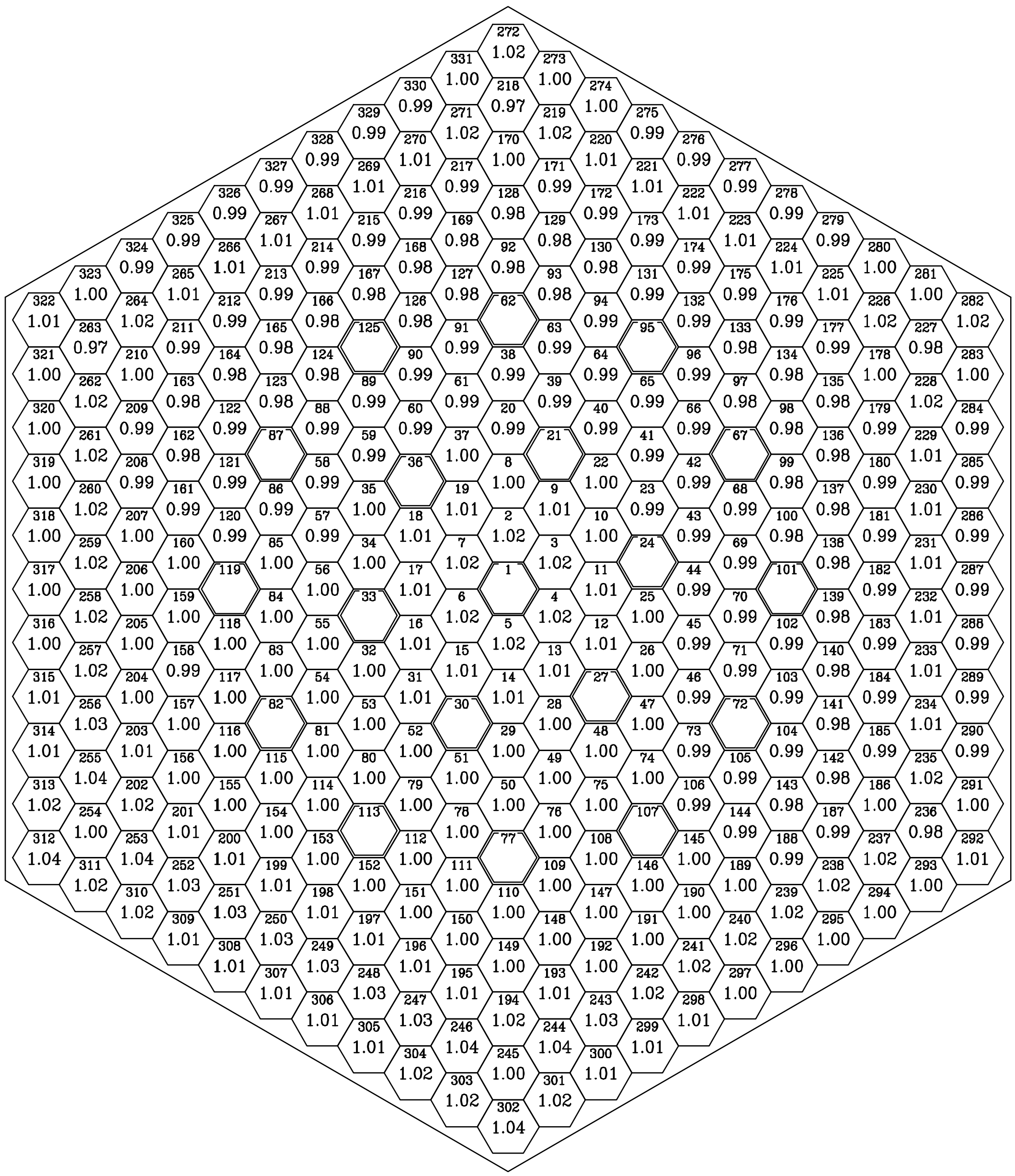
T	=	284.85	EFPD
W	=	3000.0	MW
$C_{H_3BO_3}$	=	0.00	g/kg
Ql_{max}	=	246.5	W/cm
Fuel ass.	=	56	
Level	=	2	
Fuel rod	=	264	

Fig.48. Pin-by-Pin Power Distribution in the Most Powered Assembly in BOC. Second Cycle with 3 MOX LTAs of "Island" Type (Pu3.8-2.8-U3.7)



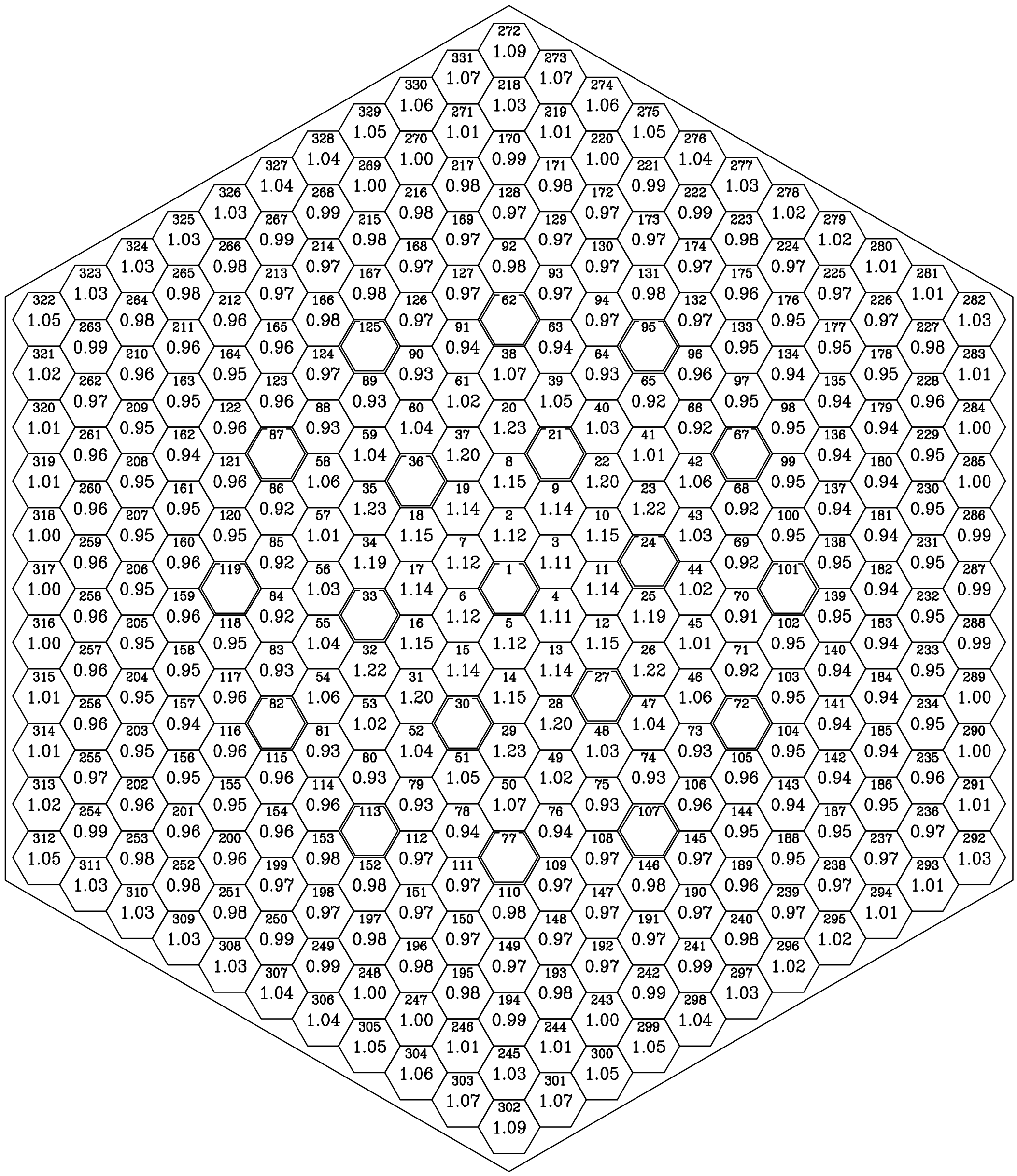
T	0.00	EFPD
W	3000.0	MW
$C_{H_3BO_3}$	5.66	g/kg
Ql	307.0	W/cm
Fuel assembly	153	
Level	4	
Fuel rod	14	
Kk_{max}	1.11	

Fig.49. Pin-by-Pin Power Distribution in the Most Powered Assembly in EOC. Second Cycle with 3 MOX LTAs of "Island" Type (Pu3.8-2.8-U3.7)



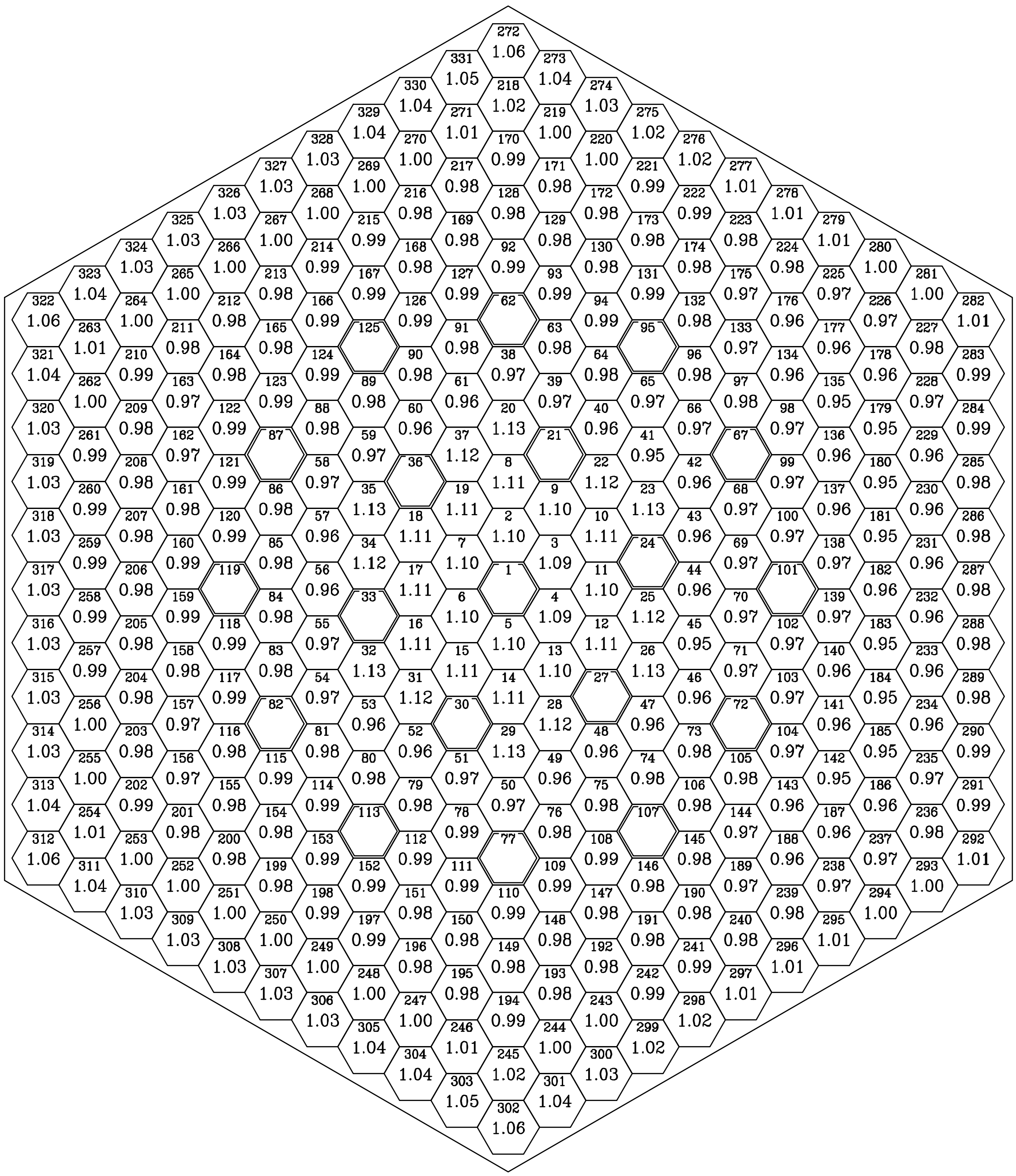
T	284.85	EFPD
W	3000.0	MW
$C_{H_3BO_3}$	0.00	g/kg
Ql	233.2	W/cm
Fuel assembly	110	
Level	4	
Fuel rod	246	
Kk_{max}	1.04	

Fig.50. Pin-by-Pin Power Distribution in MOX LTA in BOC. Second Cycle with 3 MOX LTAs of "Island" Type (Pu3.8-2.8-U3.7)



T	0.00	EFPD
W	3000.0	MW
$C_{H_3BO_3}$	5.66	g/kg
Ql	303.9	W/cm
Fuel assembly	87	
Level	4	
Fuel rod	20	
Kk_{max}	1.23	

Fig.51. Pin-by-Pin Power Distribution in MOX LTA in EOC. Second Cycle with 3 MOX LTAs of "Island" Type (Pu3.8-2.8-U3.7)



T	284.85	EFPD
W	3000.0	MW
$C_{H_3BO_3}$	0.00	g/kg
Ql	228.3	W/cm
Fuel assembly	87	
Level	4	
Fuel rod	35	
Kk_{max}	1.13	

Fig.52. Reloading scheme.
Third Cycle with 3 MOX LTAs

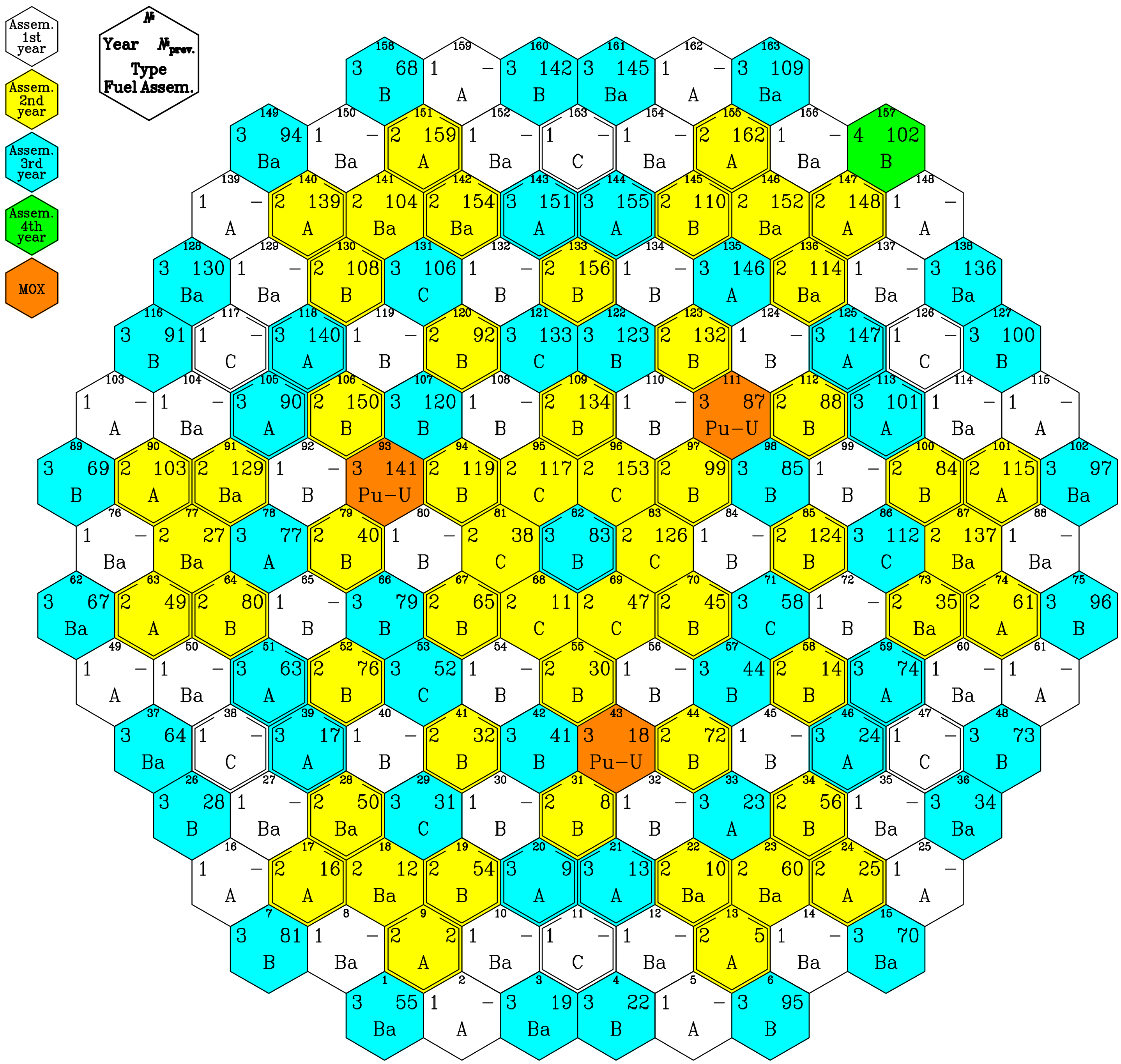


Fig.53. Assembly-by-Assembly Power Distribution. Third Cycle with 3 MOX LTAs 100%Pu (4.2-3.0-2.0)

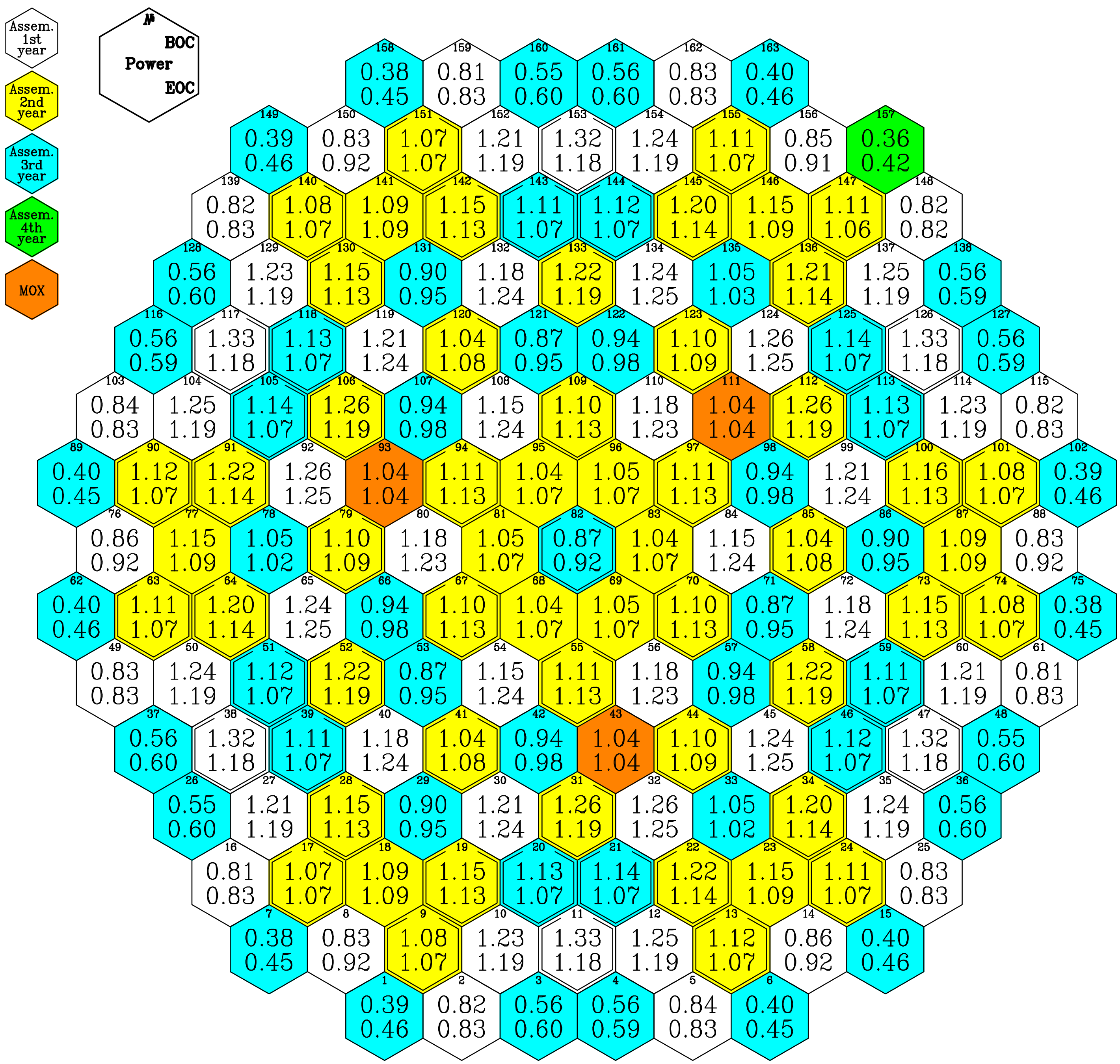


Fig.54. Assembly-by-Assembly Burnup Distribution.
Third Cycle with 3 MOX LTAs 100%Pu (4.2-3.0-2.0)

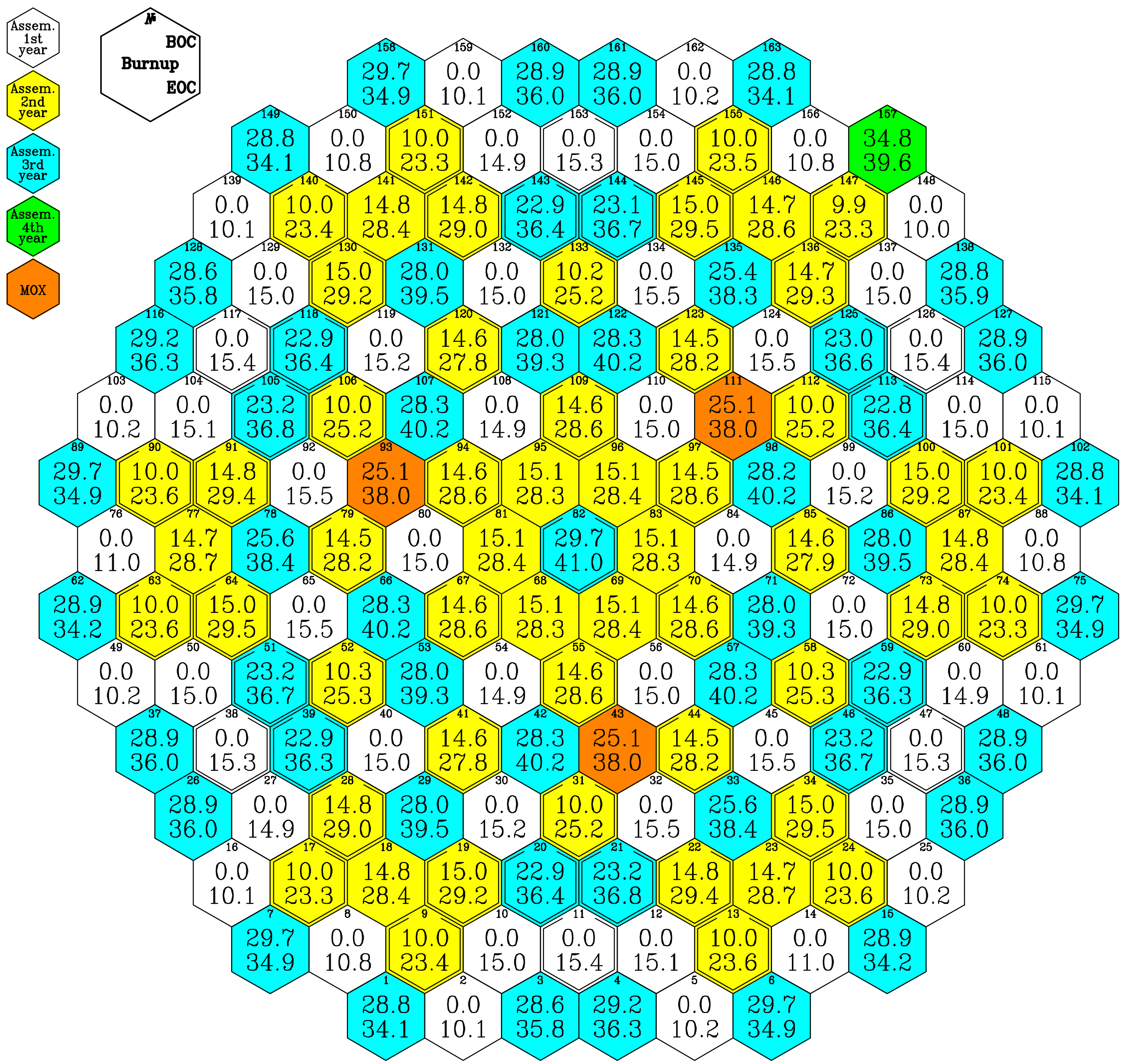


Fig.55. Assembly-by-Assembly Temperature Drop Distribution.
Third Cycle with 3 MOX LTAs 100%Pu (4.2-3.0-2.0)

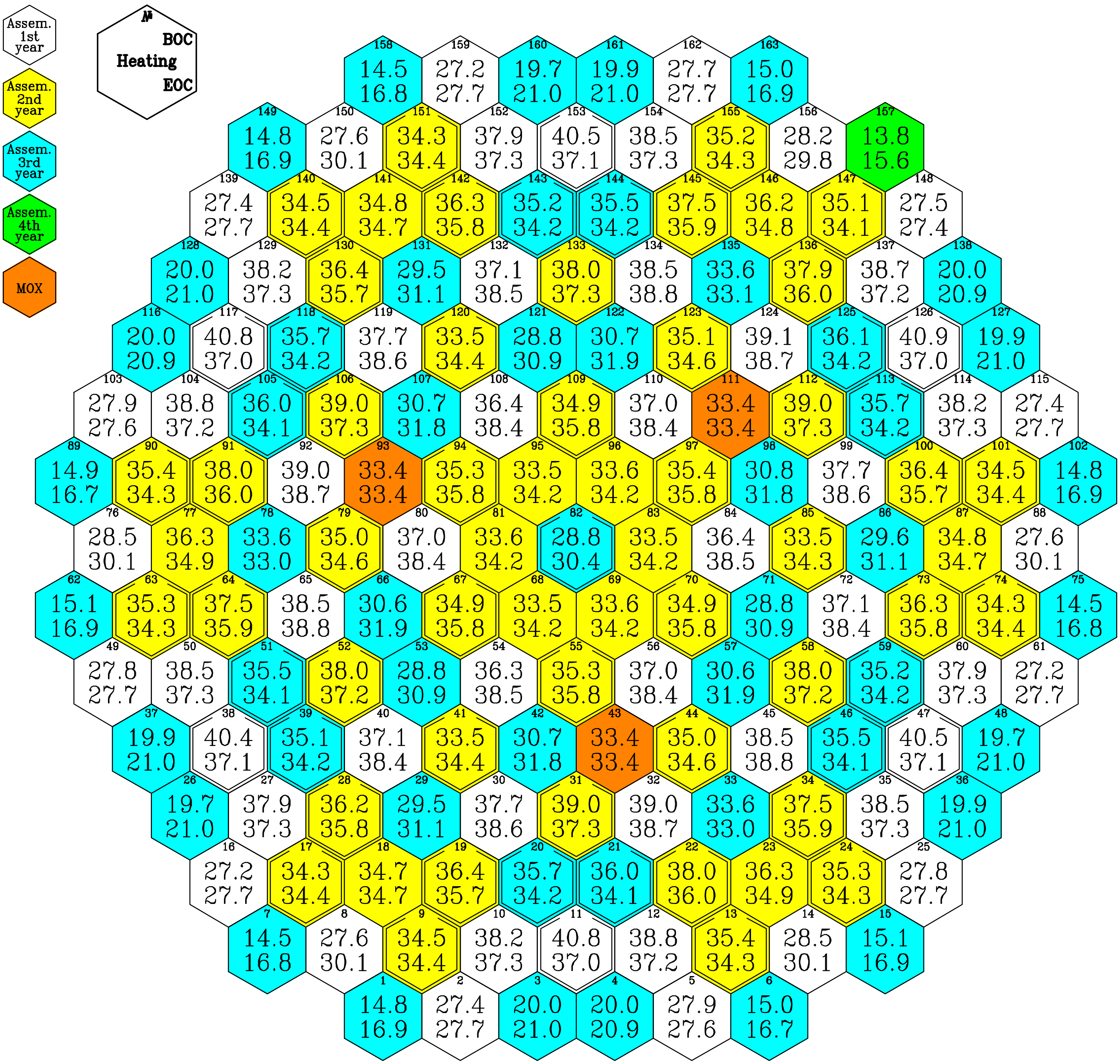
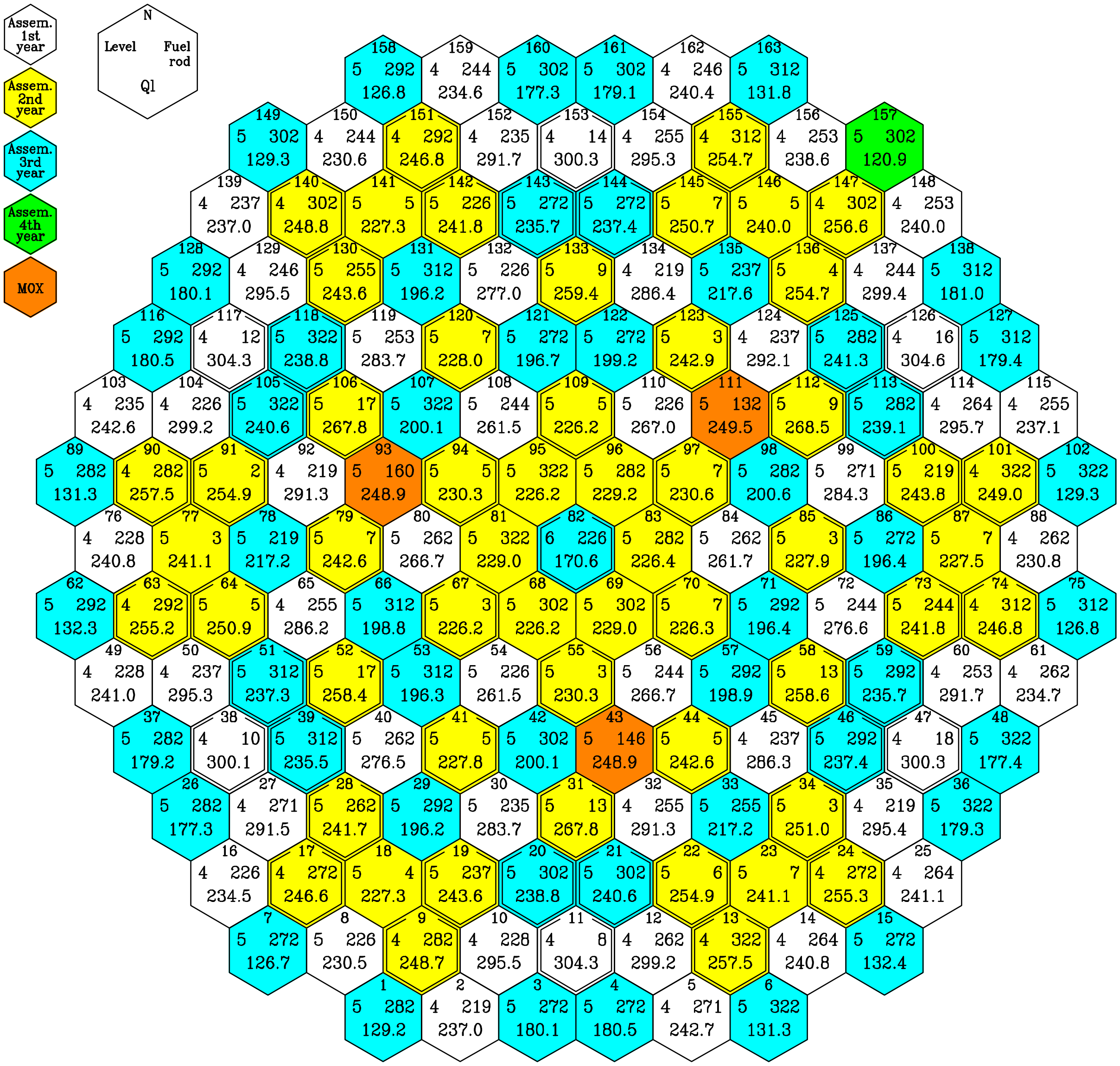
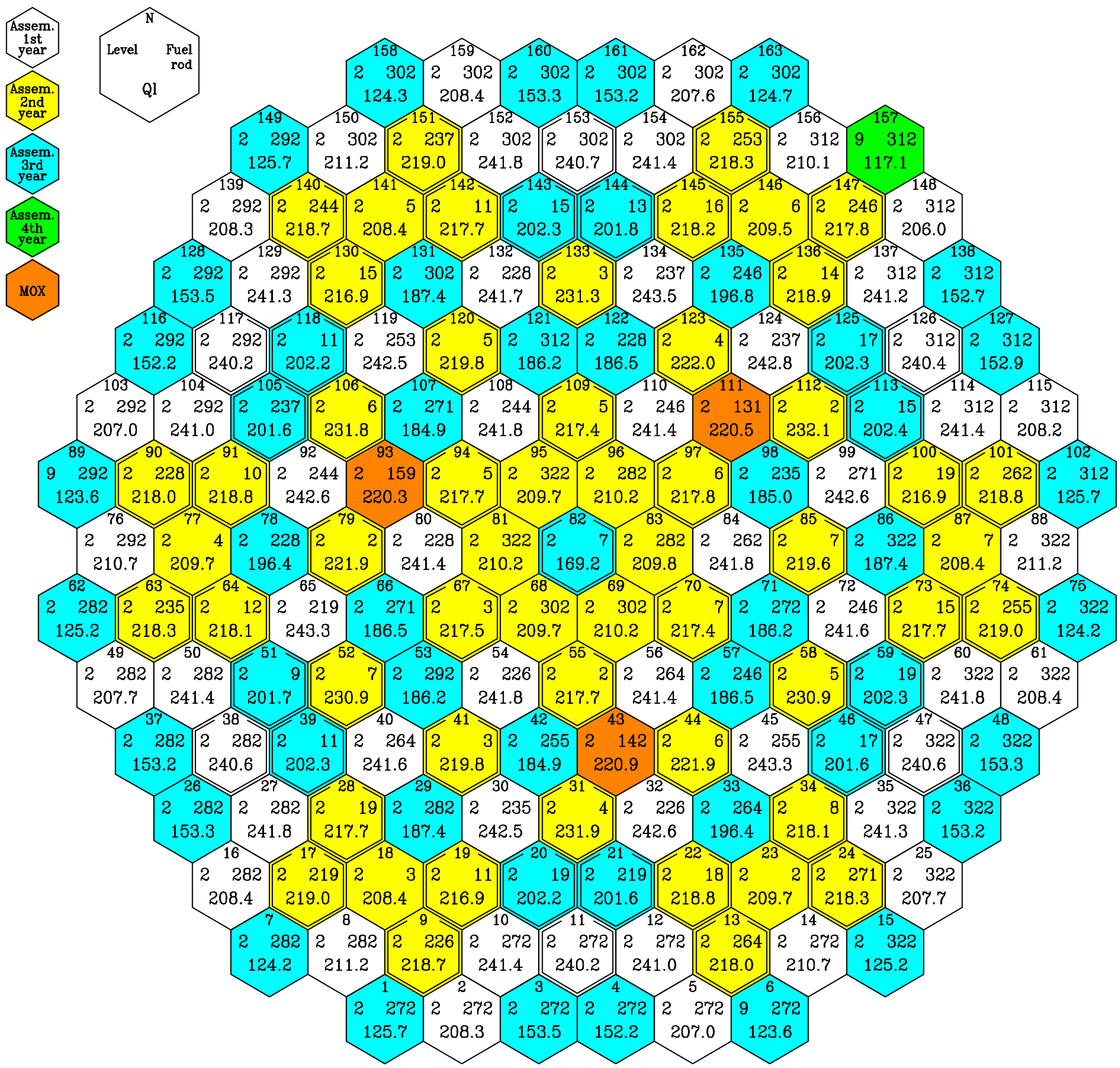


Fig.56. Assembly-by-Assembly Maximum Linear Pin Power Distribution in BOC. Third Cycle with 3 MOX LTAs 100%Pu (4.2-3.0-2.0)



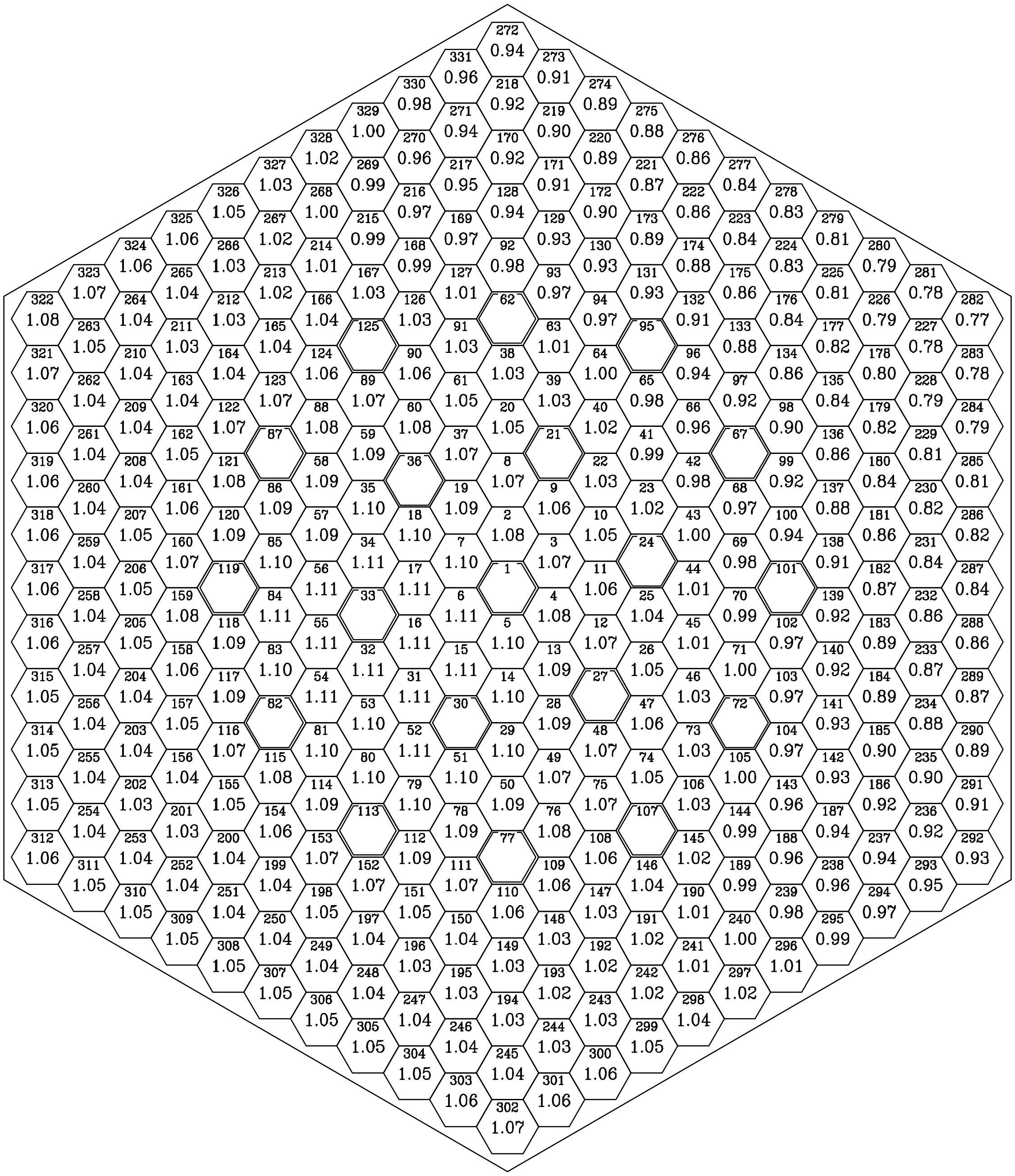
T	=	0.00	EFPD
W	=	3000.0	MW
$C_{H_3BO_3}$	=	5.81	g/kg
Ql_{max}	=	304.6	W/cm
Fuel ass.	=	126	
Level	=	4	
Fuel rod	=	16	

Fig.57. Assembly-by-Assembly Maximum Linear Pin Power Distribution in EOC. Third Cycle with 3 MOX LTAs 100%Pu (4.2-3.0-2.0)



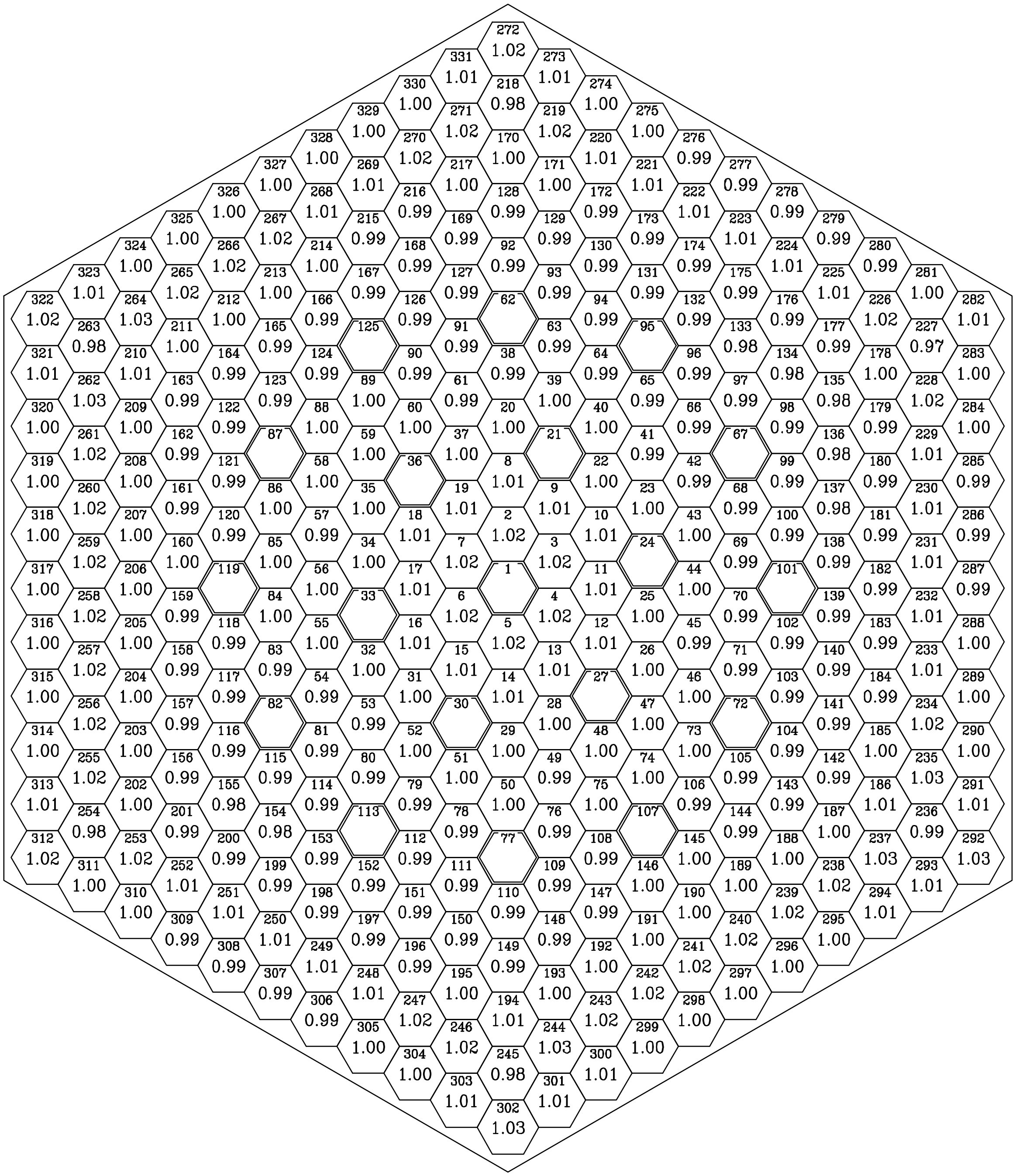
T	=	291.03 EFPD
W	=	3000.0 MW
$C_{H_3BO_3}$	=	0.00 g/kg
Ql_{max}	=	243.5 W/cm
Fuel ass.	=	134
Level	=	2
Fuel rod	=	237

Fig.58. Pin-by-Pin Power Distribution in the Most Powered Assembly in BOC. Third Cycle with 3 MOX LTAs 100%Pu (4.2-3.0-2.0)



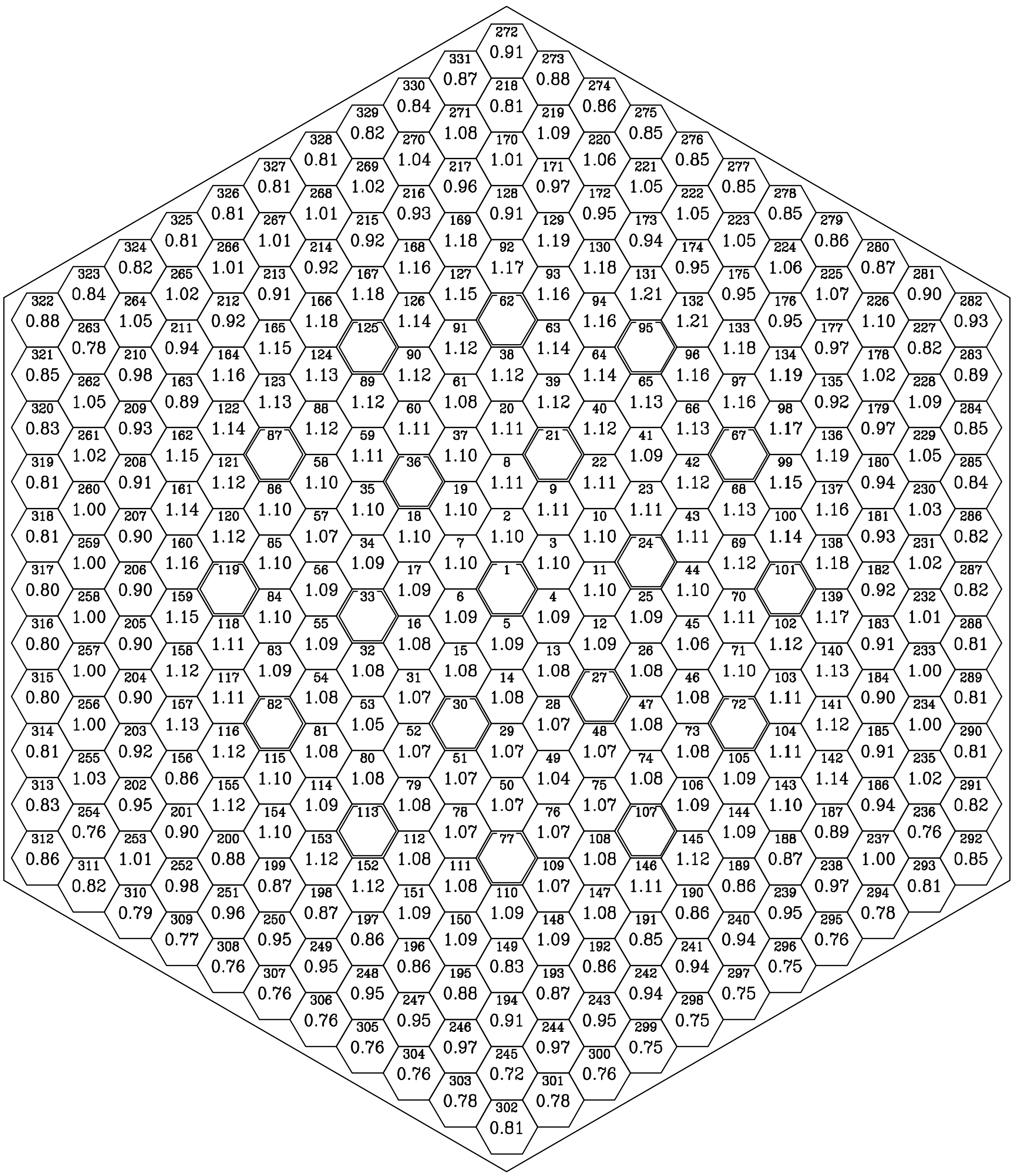
T	0.00	EFPD
W	3000.0	MW
$C_{H_3BO_3}$	5.81	g/kg
Ql	304.6	W/cm
Fuel assembly	126	
Level	4	
Fuel rod	16	
Kk_{max}	1.11	

Fig.59. Pin-by-Pin Power Distribution in the Most Powered Assembly in EOC. Third Cycle with 3 MOX LTAs 100%Pu (4.2-3.0-2.0)



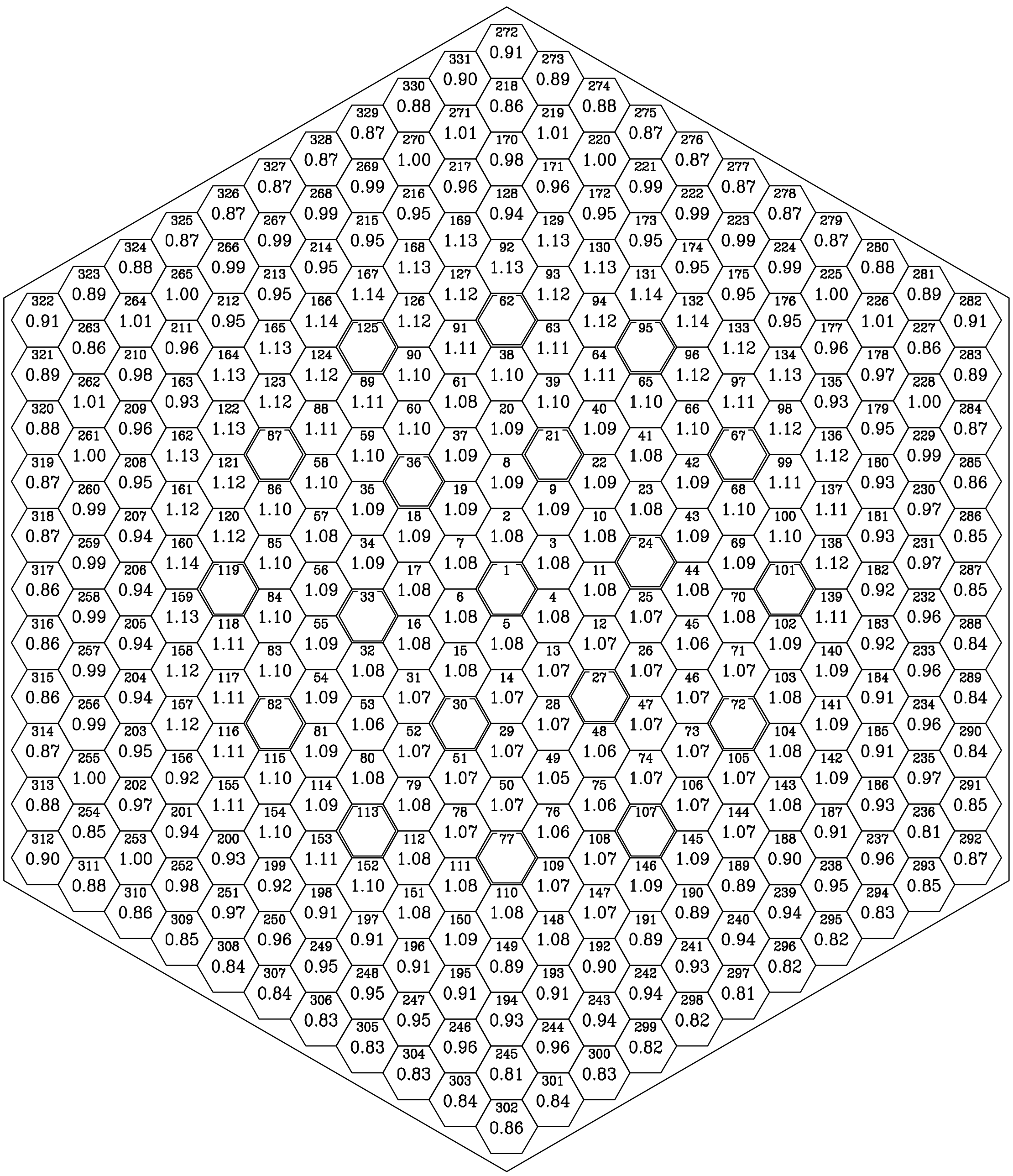
T	291.03	EFPD
W	3000.0	MW
$C_{H_3BO_3}$	0.00	g/kg
Ql	230.0	W/cm
Fuel assembly	134	
Level	4	
Fuel rod	237	
Kk_{max}	1.03	

Fig.60. Pin-by-Pin Power Distribution in MOX LTA in BOC. Third Cycle with 3 MOX LTAs 100%Pu (4.2-3.0-2.0)



T	0.00	EFPD
W	3000.0	MW
$C_{H_3BO_3}$	5.81	g/kg
Ql	246.7	W/cm
Fuel assembly	111	
Level	4	
Fuel rod	132	
Kk_{max}	1.21	

Fig.61. Pin-by-Pin Power Distribution in MOX LTA in EOC. Third Cycle with 3 MOX LTAs 100%Pu (4.2-3.0-2.0)



T	291.03	EFPD
W	3000.0	MW
$C_{H_3BO_3}$	0.00	g/kg
Ql	207.5	W/cm
Fuel assembly	111	
Level	4	
Fuel rod	131	
Kk_{max}	1.14	

Fig.62. Assembly-by-Assembly Power Distribution.
Third Cycle with 3 MOX LTAs of "Island" Type (Pu3.8-2.8-U3.7)

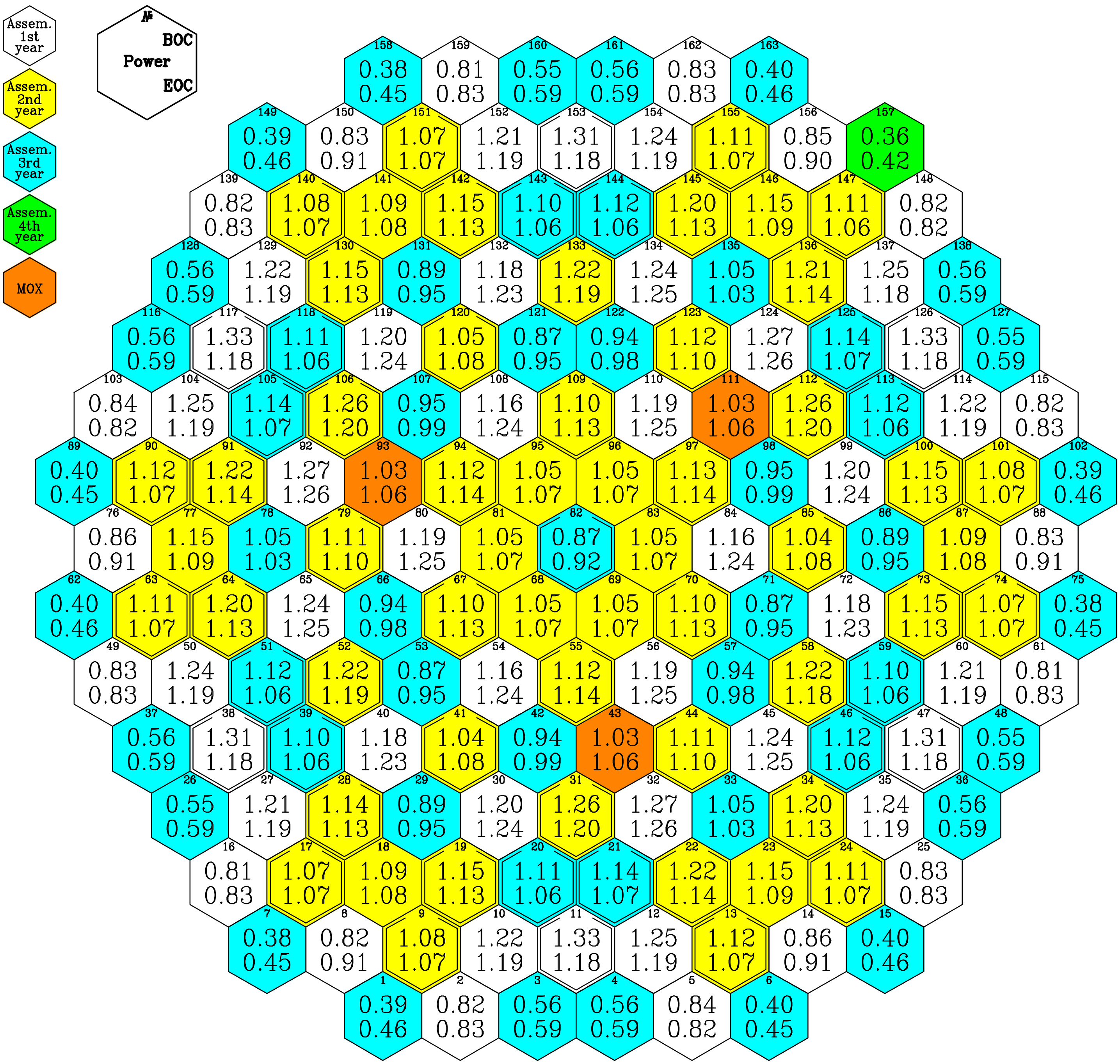


Fig.63. Assembly-by-Assembly Burnup Distribution.
Third Cycle with 3 MOX LTAs of “Island” Type (Pu3.8-2.8-U3.7)

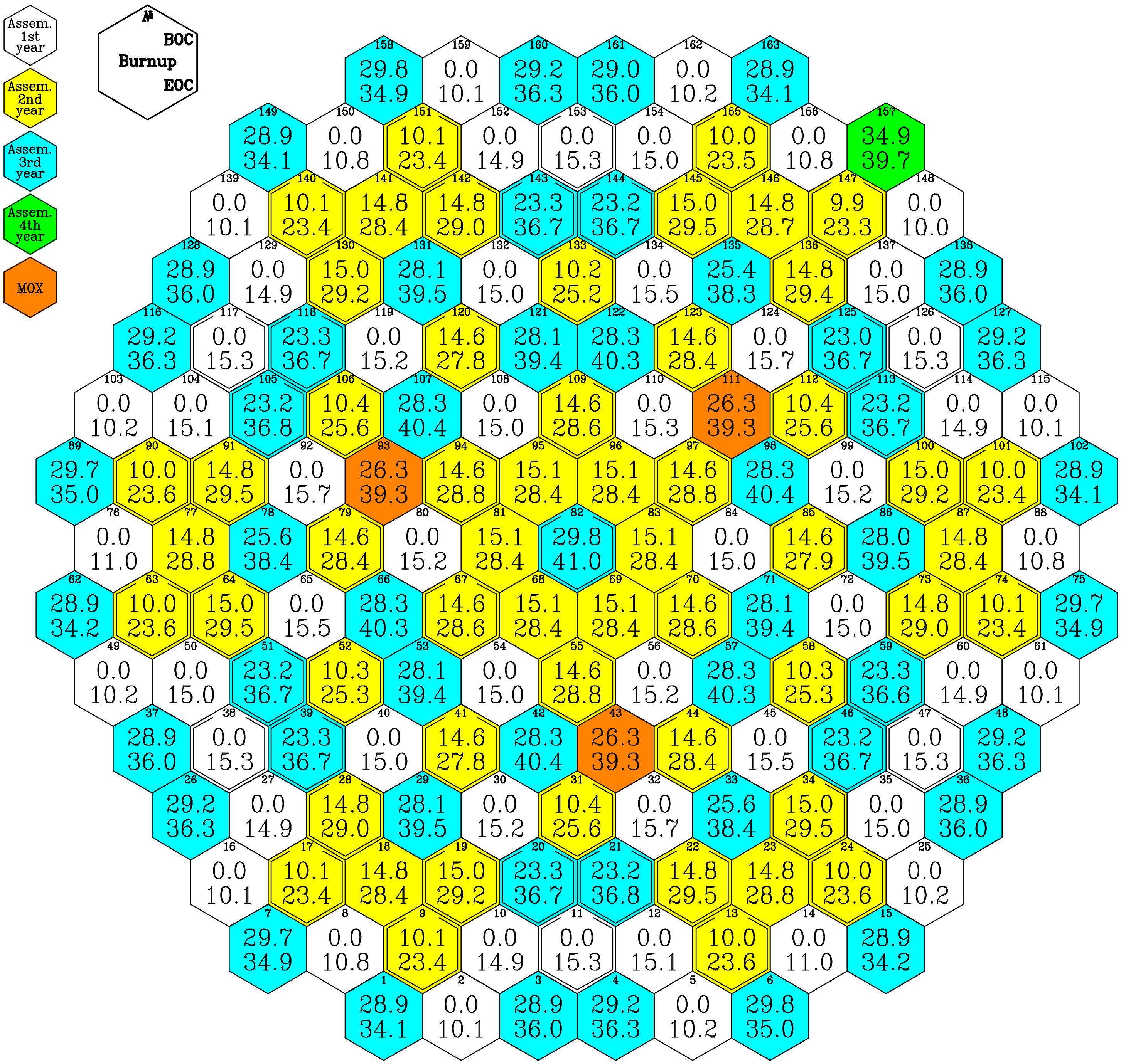


Fig.64. Assembly-by-Assembly Temperature Drop Distribution.
Third Cycle with 3 MOX LTAs of "Island" Type (Pu3.8-2.8-U3.7)

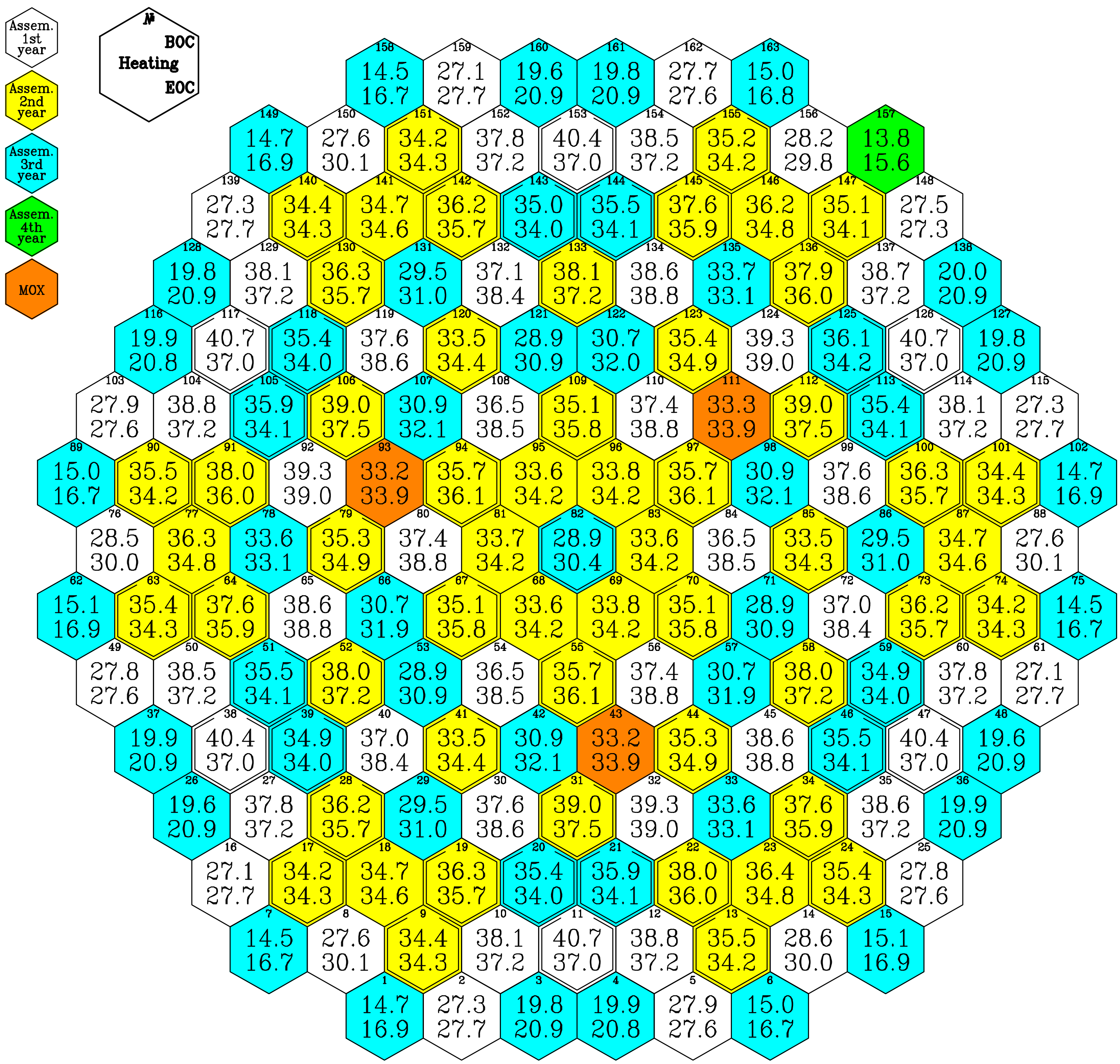
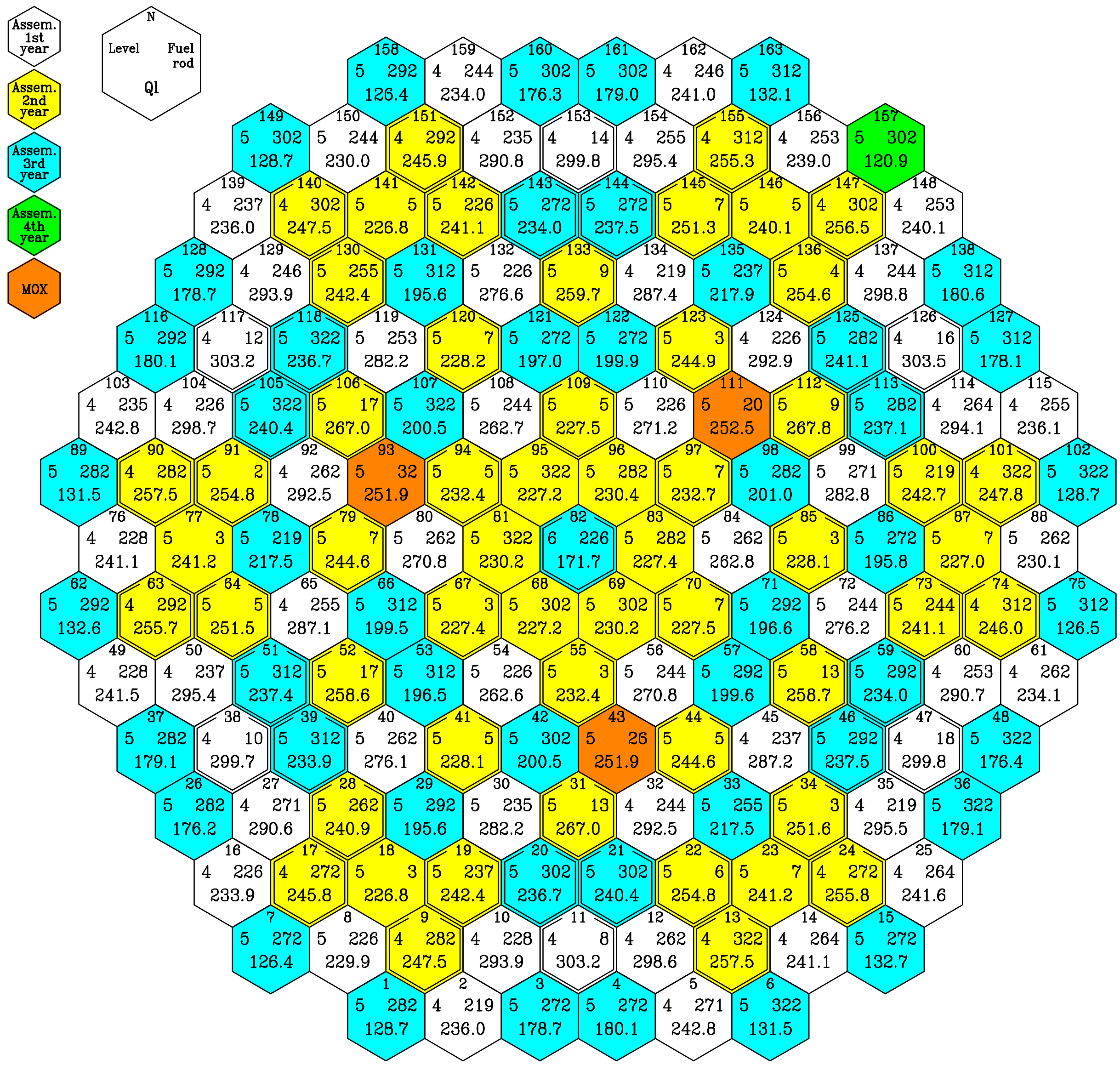
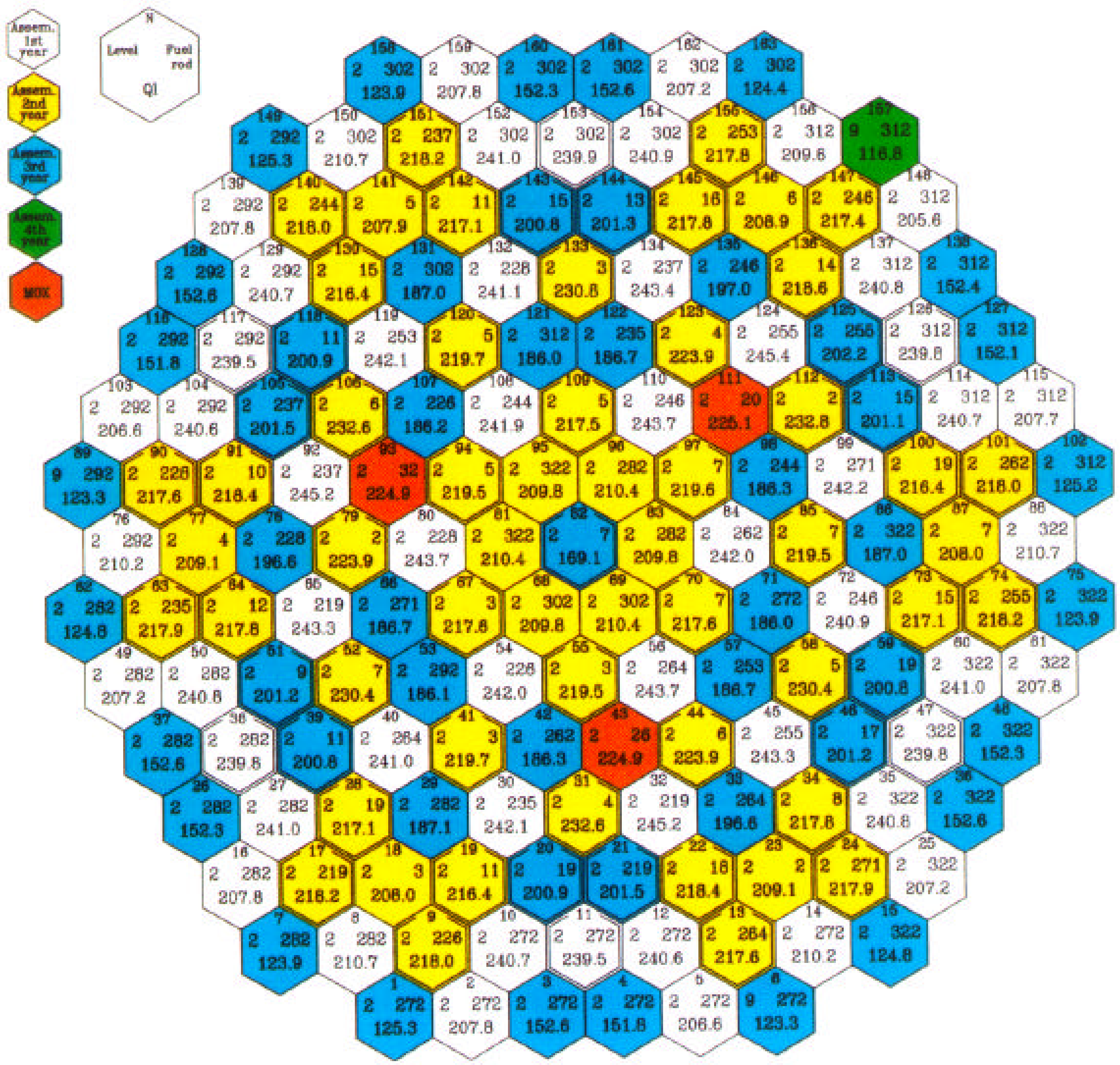


Fig.65. Assembly-by-Assembly Maximum Linear Power Distribution in BOC. Third Cycle with 3 MOX LTAs of “Island” Type (Pu3.8-2.8-U3.7)



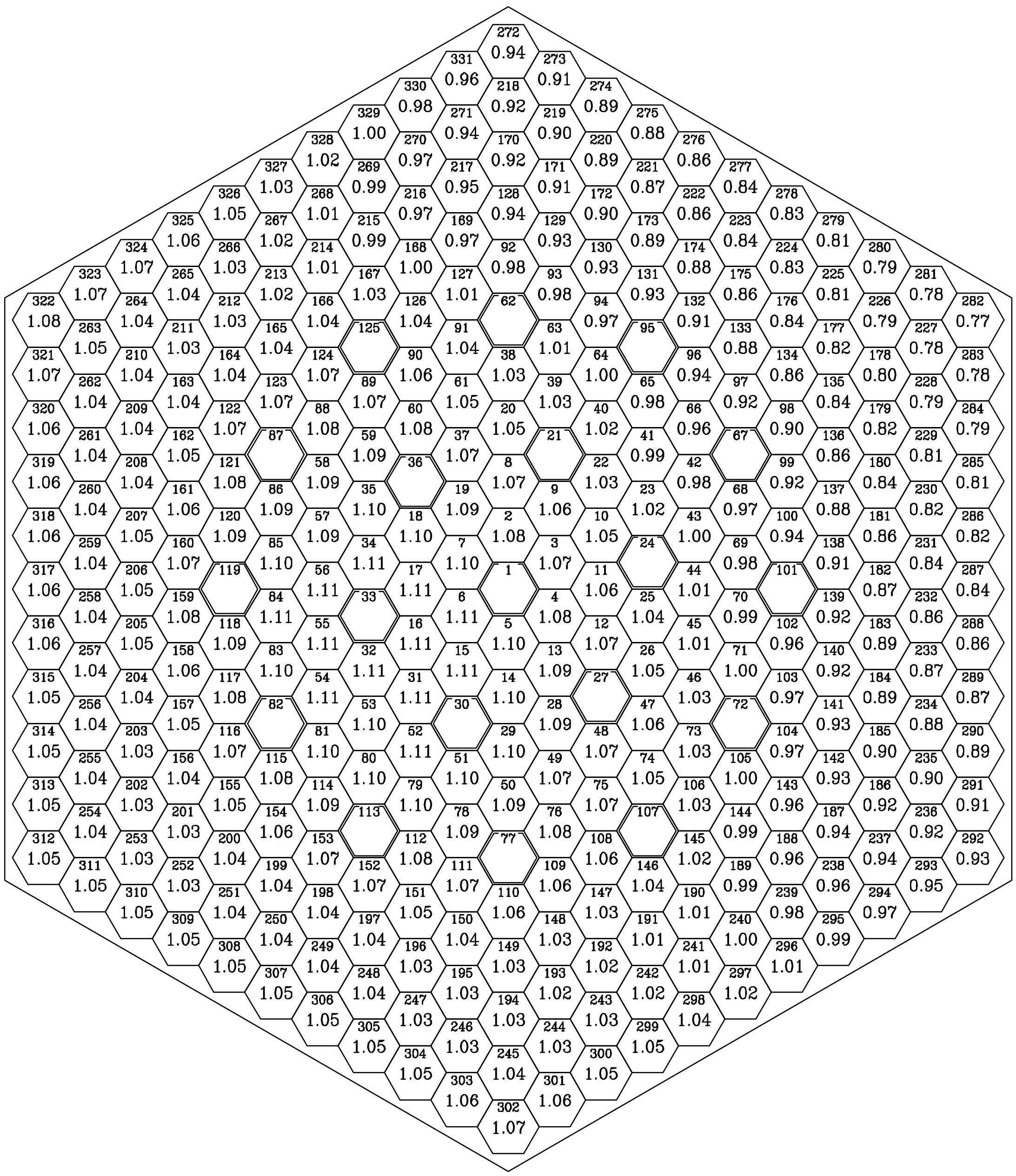
T	=	0.00 EFPD
W	=	3000.0 MW
$C_{H_3BO_3}$	=	5.79 g/kg
Ql_{max}	=	303.5 W/cm
Fuel ass.	=	126
Level	=	4
Fuel rod	=	16

Fig.66. Assembly-by-Assembly Maximum Linear Power Distribution in EOC. Third Cycle with 3 MOX LTAs of "Island" Type (Pu3.8-2.8-U3.7)



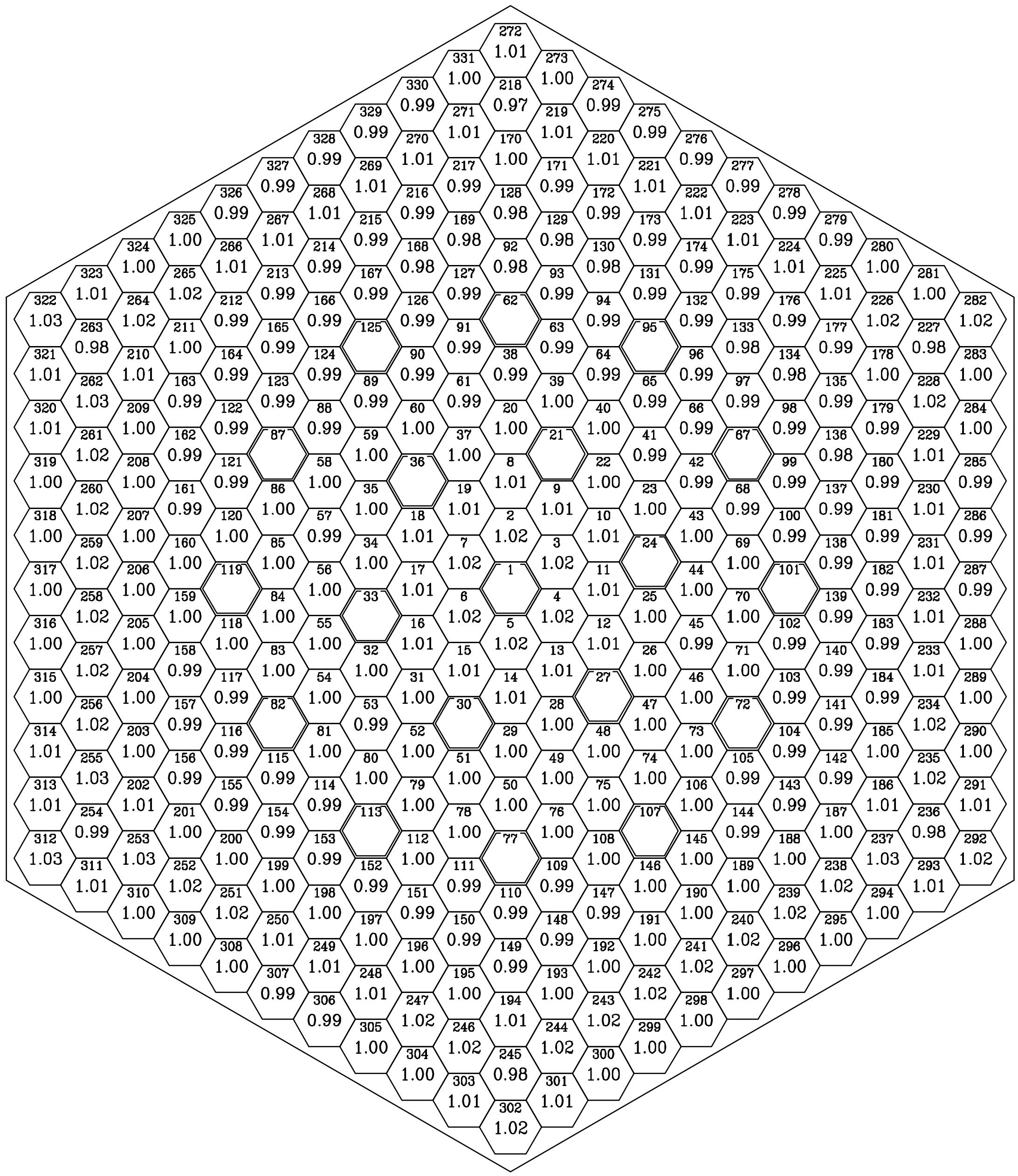
T	=	291.18	EFPD
W	=	3000.0	MW
$C_{H_3BO_3}$	=	0.00	g/kg
Ql_{max}	=	245.4	W/cm
Fuel ass.	=	124	
Level	=	2	
Fuel rod	=	255	

Fig.67. Pin-by-Pin Power Distribution in the Most Powered Assembly in BOC. Third Cycle with 3 MOX LTAs of "Island" Type (Pu3.8-2.8-U3.7)



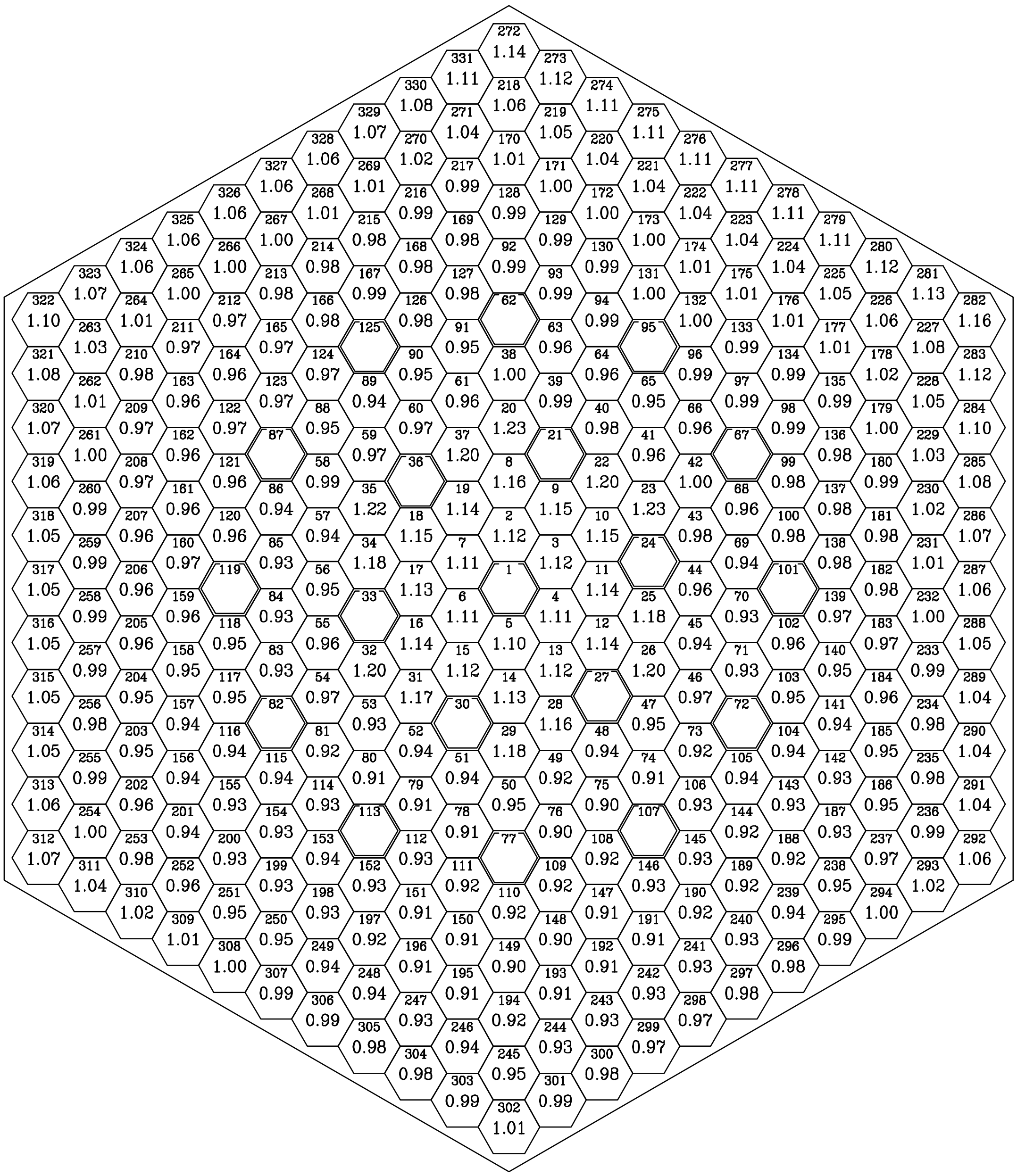
T	0.00	EFPD
W	3000.0	MW
$C_{H_3BO_3}$	5.79	g/kg
Ql_{max}	303.5	W/cm
Fuel assembly	126	
Level	4	
Fuel rod	16	
Kk_{max}	1.11	

Fig.68. Pin-by-Pin Power Distribution in the Most Powered Assembly in EOC. Third Cycle with 3 MOX LTAs of "Island" Type (Pu3.8-2.8-U3.7)



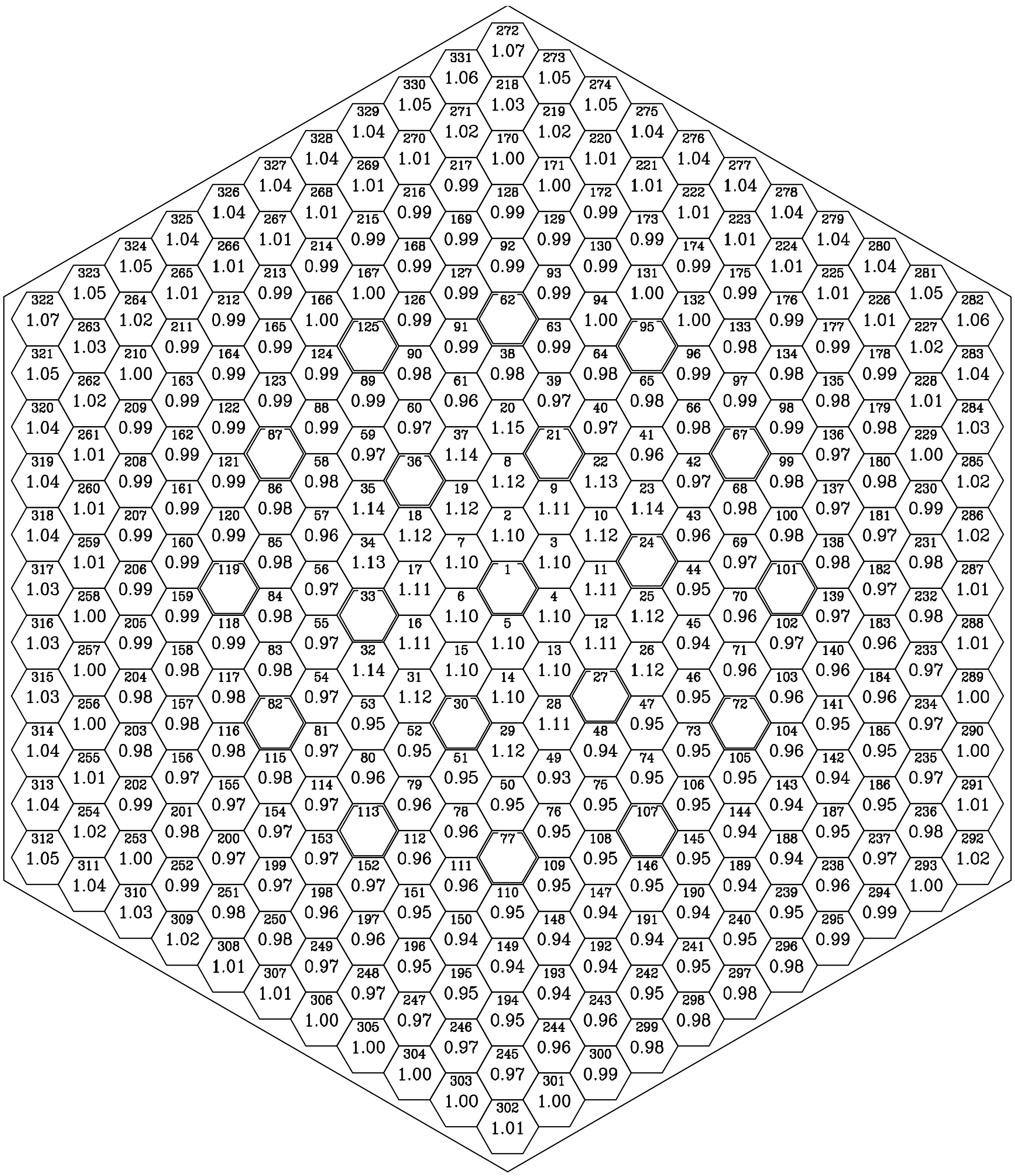
T	291.18	EFPD
W	3000.0	MW
$C_{H_3BO_3}$	0.00	g/kg
Ql_{max}	245.4	W/cm
Fuel assembly	124	
Level	2	
Fuel rod	255	
Kk_{max}	1.03	

Fig.69. Pin-by-Pin Power Distribution in MOX LTA in BOC. Third Cycle with 3 MOX LTAs of "Island" Type (Pu3.8-2.8-U3.7)



T	0.00	EFPD
W	3000.0	MW
$C_{H_3BO_3}$	5.79	g/kg
Ql	249.1	W/cm
Fuel assembly	111	
Level	4	
Fuel rod	20	
Kk_{max}	1.23	

Fig.70. Pin-by-Pin Power Distribution in MOX LTA in EOC. Third Cycle with 3 MOX LTAs of "Island" Type (Pu3.8-2.8-U3.7)



T	291.18	EFPD
W	3000.0	MW
$C_{H_3BO_3}$	0.00	g/kg
Ql	210.8	W/cm
Fuel assembly	111	
Level	4	
Fuel rod	20	
Kk_{max}	1.15	

Comments from ORNL staff on the report, *Kinetics Parameters of VVER-1000 Core with 3 MOX Lead Test Assemblies to be used for Accident Analysis Codes*

1. Page 18: The notations for the Xe and Sm concentrations are ambiguous. The units are noted as 10^{24} per cubic centimeter, but the comment notes that the element symbol value refers to different states of the core, i.e., fission product poison is absent, equilibrium. Since the Xe and Sm content of 1 cubic centimeter of fuel could never be equal or greater than $1(10^{24})$ for reactor conditions, it is assumed that if the value is less than 1, the interpretation is units of 10^{24} per cubic centimeter, but if equal to or greater than 1, the interpretation is as noted in the comments column.

2. Page 62, Fig. 9: The axial levels in this and subsequent figures correspond to those in Table 18 (level 4 = 124.25 cm, level 2 = 53.25 cm, etc.).

3. Page 28–4, Tables 3–9: The symbol given for the prompt neutron lifetime (l_{im}) does not match that given in Table 1 (λ_{im}, i.e. $lamba_{im}$) but is assumed to be intended to be the same.

4. Page 24, Table 2: From the magnitude of the boron reactivity coefficient given here it appears that its units are pcm/ppm-boron, while the values given in Tables 3–9 appear to be pcm/ppm-boric acid (as noted in Table 1). The reader should note that the values in Table 2 are not provided with units consistent with similar values reported elsewhere in the report.

5. The axial location z = 0 is at the bottom of the fueled region of the core. Note that in the axial power distribution figures (7 and 7a), the values for the bottom of the core are at the right of the figure.

6. This report is the deliverable for FY 1999 Annual Operating Plan Task 10.2.2.1, milestone e. This milestone also had the internal ORNL designation of 99-2.

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