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CALCULATIONS OF NETRONIC CHARACTERISTICS OF EAP-80 REACTOR

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Проведено исследование подкритического реактора с загрузкой различного топлива в активную зону. В качестве топлива были рассмотрены композиции, изготовленные для реактора Суперфеникс, и высокообогащенное топливо, произведенное для реактора на быстрых нейтрона типа SNR. Неравномерности в энерговыделении в этом случае могут быть уменьшены за счет замены пустых топливных кассет во внешних рядах активной зоны на жидкий теплоноситель из эвтектики свинец-висмут.

BACKGROUND

The main goal of the EAP-80 reactor [1,2] is to establish and demonstrate reliable connection between the proton accelerator, the spallation module and the subcritical reactor. In other words, the reason for constructing a prototype reactor is to prove the feasibility of the subcritical device. One of the attractive features of the EAP-80 project is to make use of the nuclear fuel not claimed in commercial reactors nowadays. The fast breeder reactor program seems to be on the decline in the European community. It is naturall to look for ADS system fuel at first within this program.

The investigations performed in searching for the fuel available for utilisation in EAP-80 allowed to consider two types of the fuel:

- plutonium enriched fuel made for the Superphenix (SPX, France) breeder reactor.
- plutonium enriched fuel made for the SNR-300 (Germany) breeder reactor;

The fuel of both types is already fabricated and could in principal be used to charge the EAP-80 reactor core. The question arises at once: what kind of the existing fuel should be use for a subcritical reactor? It is possible to charge the EAP-80 core with the fuel of one type, but there exists a certain opportunity to combine these two types to find an optimal solution.

INTRODUCTION

The EAP-80 principal design was elaborated as a result of previous investigations. Nevertheless, some questions exist. For example, the EAP-80 reactor core charged with SPX fuel only does not meet the planned parameter, namely: the k_{eff} value of about 0.984 and energy production 80 MWt(h) [2]. This situation could be corrected both by application of an extra number of the SPX fuel elements and by arrangement in the core of some elements with the SNR fuel, the geometry of the core remaining unchanged.

The expected increase in the k_{eff} value in the reactor charged with different fuels could lead to rather difficult reactor refuelling procedure. Thus, the application of the alternative fuels in the EAP-80 should be investigated from several points of view. But in any case, the choice of the core configuration should be made in accordance with safety reasons only.

FUEL COMPOSITIONS

The fuel of the SNR type has been made for the German fast breeder reactor program [3]. Since this fuel was manufactured between 1978 and 1985 the original isotopic, composition has significantly changed during storage. The main nuclear transformations taking place in the SNR-300 fuel are listed below:

$$^{238}Pu \xrightarrow{\alpha} {}^{234}U\text{, } T_{1/2}\text{=87.7 years;}$$

$$^{240}Pu \xrightarrow{\alpha} {}^{236}U\text{, } T_{1/2}\text{=6564 years;}$$

$$^{241}Pu \xrightarrow{\beta^-} {}^{241}Am\text{, } T_{1/2}\text{=14.35 years;}$$

$$^{241}Am \xrightarrow{\alpha} {}^{236}Np\text{, } T_{1/2}\text{=432.1 years.}$$

At present there are two kinds of fuel bundles of the SNR-300 type available for possible usage in EAP-80. These types of the fuel were supposed to be charged in the core zone to meet the project requirements and to flatten out the radial energy distribution over the core. The enrichment of these fuels is about 24% and 35 % of PuO_2 respectively. In general, the total number of 205 fuel assemblies available for the SNR-300 makes feasible the load of the EAP-80 active region with either 1st type or 2nd type fuel only.

Nuclide transformations simulations in both types of the fuel were implemented with the ORIGEN2 [4] nuclide generation and depletion code. Some improvements were made in this code to make it suitable for solving activation task of arbitrary size, i.e. for calculations of the transformations of any nuclide compositions irradiated with arbitrary particle spectrum. The starting point was chosen to be 01.07.1996 as specified in [3]. The results of the fuel composition calculations are presented in Tables 1 and 2. As stated above, the fuel was fabricated between 1978 and 1985. For such uncertain conditions it was difficult to find reasonable values for ^{234}U, ^{236}U and ^{237}Np concentrations for the moment of 01.07.1996. So, it was supposed that concentrations of these nuclides were zero at the starting point.

Table 1

Core zone C1 (Magnox) fuel composition of the SNR-300 reactor

Material	01.07.1996	01.07.1998	01.07.2000
	Weight fractions, %		
UO_2	75.601	75.603	75.606
PuO_2	23.902	23.878	23.856
$^{237}NpO_2$	0.	0.002	0.003
$^{241}AmO_2$	0.497	0.517	0.535
	Atomic fractions relative to total U %		
^{234}U	0.	0.0005	0.001
^{235}U	0.26	0.2614	0.263
^{236}U	0.	0.0012	0.002
^{238}U	99.74	99.7369	99.734
	Atomic fractions relative to total Pu, %		
^{238}Pu	0.10	0.0985	0.097
^{239}Pu	80.26	80.3364	80.406
^{240}Pu	18.15	18.1645	18.178
^{241}Pu	0.99	0.9001	0.818
^{242}Pu	0.50	0.5005	0.501

Table 2

Core zone C2 (LWR) fuel composition of the SNR-300 reactor

Material	01.07.1996	01.07.1998	01.07.2000
	Weight fractions, %		
UO_2	64.238	64.249	64.254
PuO_2	34.604	34.521	34.442
$^{237}NpO_2$	0.	0.004	0.008
$^{241}AmO_2$	1.158	1.226	1.296
	Atomic fractions relative to total U %		
^{234}U	0.	0.003	0.006
^{235}U	0.73	0.732	0.734
^{236}U	0.	0.003	0.005
^{238}U	99.27	99.262	99.255
	Atomic fractions relative to total Pu, %		
^{238}Pu	0.37	0.366	0.36
^{239}Pu	72.15	72.329	72.486
^{240}Pu	23.28	23.330	23.384
^{241}Pu	2.56	2.331	2.122
^{242}Pu	1.64	1.644	1.648

As was found in [3] the density of the fuel for the Superphenix (SPX) reactor was 10.407 g/cm^3. To find the density value for the SNR fuels, some data were taken from reference book [6]. The following values were used for the calculations of the SNR fuel densities:

ρ (UO_2)=10.95 g/cm^3;
ρ (PuO_2)=11.44 g/cm^3;
ρ (NpO_2)=11.10 g/cm^3;
ρ (AmO_2)=11.70 g/cm^3.

The concentrations of the isotopes in the fuel of the SPX reactor are listed in Table 3 [3,5]. It is to be stressed that no correction to the isotope depletions for the SPX fuel has been made since 31.01.98.

A brief analysis of the data presented in Tables 1-3 allows one to consider SNR C1 and SPX fuels as having insignificant differences. Nevertheless, there is a possibility of the SNR C1 fuel application in the EAP-80.

Table 3

Fuel composition of the Superfenix reactor (SPX)

Material	31.01.1998
Weight fraction, %	
UO_2	79.486
PuO_2	20.035
$^{237}NpO_2$	0.0047
$^{241}AmO_2$	0.475
Atomic fraction relative to total U, %	
^{234}U	0.0043
^{235}U	0.5238
^{236}U	0.
^{238}U	99.4669
Atomic fraction relative to total Pu, %	
^{238}Pu	0.28
^{239}Pu	70.8407
^{240}Pu	24.9273
^{241}Pu	2.6509
^{242}Pu	1.3011

STRUCTURAL MATERIALS

The fuel elements in the EAP-80 reactor were assumed to be made of AISI-316 stainless steel. The composition of AISI 316 steel is presented in Table 4.

Table 4

Weight fraction composition of AISI 316 stainless steel

Fe	64.15
Cr	17.00
Ni	12.50
Mo	2.75
Mn	2.00
Si	1.00
Ti	0.60

GEOMETRY OF THE FUEL BUNDLES

Since the geometry of EAP-80 has been set definitely as regards of the reactor design, there is no reason to modify it. The principal scheme of the EAP-80 design is presented in Fig.1. The reactor core "C" is surrounded with empty fuel boxes "B" (dummy assemblies without fuel rods). The tails of the fuel elements are placed in the plenum regions "P". The EAP-80 project design of the spallation module with a window for the accelerator vacuum tube was adopted for our studies. The configuration of the vacuum tube window is discussed in [7]. The geometry layout of the fuel pins and bundles used in our calculations is presented in Tables 5 and 6. The values in parenthesis correspond to the upper plenum.

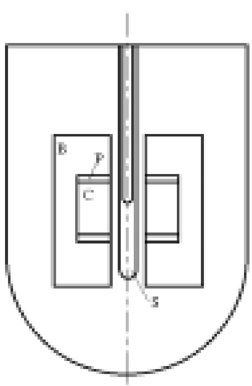

Fig.1. The EAP-80 principal scheme. "S" means the spallation module, "C" denotes the reactor core, "P" is the plenum region, "B" is the region with "boxes"

Table 5

Geometry parameters of the EAP-80 fuel rods

Active region	
External cladding radius, mm	4.250
Cladding thickness, mm	0.565
Inner cladding radius, mm	3.685
Fuel pellet outer radius, mm	3.570
Fuel pellet inner radius, mm	0.900
Active length, mm	870.0
Lower plenum region	
External cladding radius, mm	4.250
Inner cladding radius, mm	3.000(3.685)
Height, mm	162(150)

Table 6

The parameters of the EAP-80 fuel bundle

Pitch between fuel pins, mm	13.4
Box internal flat-to-flat	129.6
Box thickness, mm	2.0
Box outer flat-to-flat, mm	133.6
Bundle gap, mm	4.0
Lattice flat-to-flat, mm	137.6
Total height of the element, mm	3680.0
Active fuel region, mm	870.0

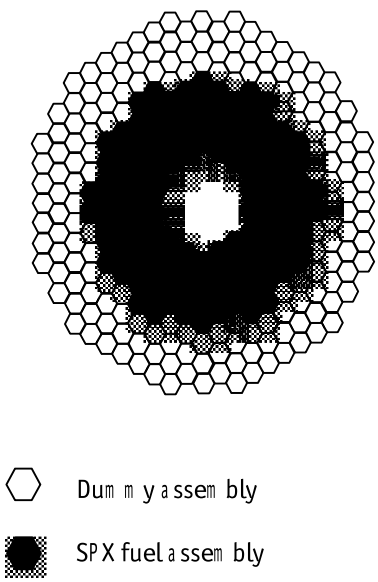

Fig.2. EAP-80 reference configuration

CALCULATIONS OF THE CRITICALITY FACTOR FOR THE REFERENCE CORE

Reactor layout

The arrangement of the fuel elements in the EAP-80 reactor is presented in Fig. 2. The fuel region of the reactor was composed of four full hexagonal rounds of the bundles, resulting in 108 elements. To improve the neutronics of the reactor, additional 12 elements were introduced in the 7th round. Thus, the total number of the fuel bundles is 120. As mentioned above, the skeleton of the fuel elements is to be filled with the Superphenix type of fissile composition (SPX), Table 3.

Nuclear data

The preliminary thermal-hydraulic calculations made allowed us to make the following conclusion: the temperatures in the reactor have several typical values. It was assumed that the averaged temperature in the fissile matrix is about 1000 K; the averaged temperature of the Pb-Bi eutectic, structural elements in all parts of the reactor except the active region (Table 4) is 550 K; and the averaged temperature of the coolant and claddings of the fuel pins and bundles in the active region is 700 K.

Due to the fact that the materials in the reactor are supposed to undergo different temperature stresses, the calculations of the neutronic characteristics of the EAP-80 should be performed on the basis of several streams of nuclear data. The most examined ENDF/B-VI library is widely used for the neutronic analysis. This library was used for the preparation of the specially formatted ACER files for various temperatures of the media for neutron transport calculations.

Neutronic calculations

The simulation of the neutron transport in the EAP-80 reactor was implemented with the MCNP/4B code. The first set of the MCNP runs was aimed at investigating the reference reactor charged with SPX fuel additionally enriched with ^{239}Pu up to 21.6%. This variant was calculated to demonstrate the possibility of EAP-80 operation at the required thermal power. The second set of the MCNP runs was performed with reference fuel enrichment (Table 3). The results of these calculations are presented in Table 8.

The data for the cold reactor (T=300 K) are presented in the second column of the Table 8. The temperatures in the third column denote the following: T_f – averaged fuel temperature, T_c – averaged temperature of the coolant and pin cladding in the core of the reactor, T_r – averaged temperature of the elements in the residual volume of the reactor.

The data presented in Table 8 demonstrate the principal possibility to reach the k_{eff} value of about 0.98. In other words, there is a solution for the EAP-80 reactor with different fuels in the core. Such a way could lead to reasonably high k_{eff} values.

Table 8

The results of the k_{eff} calculations for the reference EAP-80 fuel and additionally Pu enriched fuel

Content of SPX fuel, %	T=300 K	T_f=1000 K T_c=700 K T_r=550 K
PuO_2 – 20.035 UO_2 – 79.486 AmO_2 – 0.475 NpO_2 – 0.0047	0.94044	0.92863
PuO_2 - 21.6 UO_2 – 77.8501 AmO_2 – 0.5453 NpO_2 – 0.0046	0.96972	0.96208

CALCULATIONS OF CRITICALITY FACTOR FOR COMPLEX CORE OF EAP-80

Application of SNR-300 fuel (C2 zone, ~34% Pu)

It is proposed that the EAP-80 subcritical core be charged with SPX fuel mainly, the total number of the fuel assemblies being fixed (120). In this case there are only two possible solutions to achieve k_{eff} value of about 0.984, namely: to introduce additional bundles with SNR fuel enriched with Pu up to either 24% or 34% and to use the SNR fuel instead of the SPX fuel. The requirement that the number of the fuel assemblies should remain unchanged leads to the investigation of the second variant only.

The reasonably high Pu enrichment of the SNR C2 type (Table 2) makes possible the replacement of several SPX bundles with assemblies of this type. The safety level k_{eff} value 0.984 in the cold condition (300 K) was chosen for EAP-80 as the maximum allowable limit. Under no circumstances this level must be exceeded. The C2 fuel type bundles (the concentration of isotopes corresponds to 01.07.2000) should be sited in the core to provide the k_{eff} value of about 0.98 (or slightly more) and to flatten energy distribution over the reactor as much as possible. An additional restriction should be made on the number of SNR (C2) assemblies used. The C2 type fuel is treated only as a support to the SPX assemblies to compensate for the difference between the maximum safety level and the k_{eff} value obtained for the reactor charged with the SPX fuel only. The C2 type fuel assemblies, therefore, should be used as little as possible.

Due to neutron leakage, the “response” of the core to the new assembly introduced in various rounds of the reactor is evidently different. Moreover, the impact of one new bundle on the k_{eff} value is expected to be non-linear. Several calculations were performed to find the “response” of the core to one new bundle in installed in different rounds of the assemblies. Such data are presented in Fig.3.

The “excess of the k_{eff} value” denotes the difference between the k_{eff} value with a new bundle and the k_{eff} for the reference core loaded with SPX fuel only (Table 8). The most effective position of the C2 type fuel bundle appeared to be in the 4th round of the reactor core. The 6th and 7th rounds should be considered as the most ineffective owing to huge neutron leakage. Round number 3 has two disadvantages for the new bundle arrangement, namely: a close proximity of the spallation module with stainless steel elements and an additional heat release that leads to irregularity in the energy distribution over the reactor. Hence, rounds 4 and 5 can be considered for arrangement of the new SNR C2 bundles.

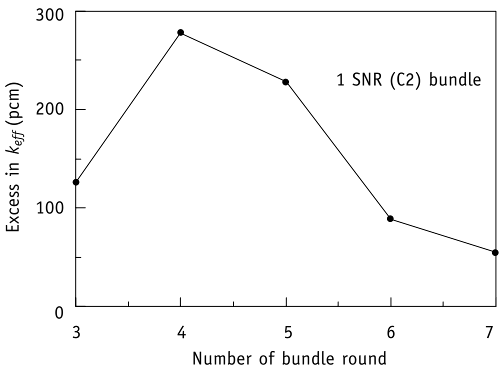

Fig.3. Impact of one SNR C2 fuel bundle sited in different reactor rounds

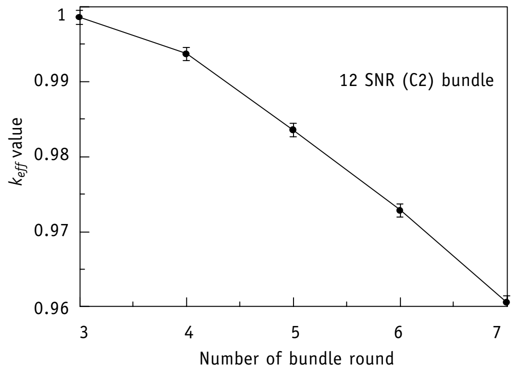

Fig. 4.The k_{eff} value for the modified EAP-80 core

The results of the calculations of the k_{eff} value for new configuration of EAP-80 are presented in Fig.4. 12 SPX assemblies were replaced with 12 SNR C2 ones in different rounds.

The data presented in Fig.3 enable one to use the above trend to find the most appropriate solution of the SNR C2 fuel arrangement in the reactor. In practice, different combinations of the C2 type bundles installed in the 4th and (or) 5th rounds, Figs. 5, 6 could lead to a reasonable k_{eff} value. Results of such calculations along with those discussed above are presented in Table 10. The data in round brackets refer to the complex temperature distribution in the reactor (see explanation to Table 8).

Table 10

The k_{eff} value calculated for the reactor with different numbers and positions of the SNR-300 C2 fuel assemblies

Number of the SNR C2 assembles					k_{eff} value
3 round	4 round	5 round	6 round	7 round	
-	-	-	-	12	0.96058
-	-	-	12	-	0.97284
-	-	12	-	-	0.98351
-	12	-	-	-	0.99367
12	-	-	-	-	0.99853
-	-	6	6	-	0.97636
-	4	4	-	-	0.97120
-	9	-	-	-	0.98085

Investigations of the neutron distributions over the core

The information about the distributions of neutrons over the reactor core enables one to enhance the reactor performance. Special MCNP runs were aimed at investigating the neutron flux distribution over the reactor active region. The general neutron source distribution for the MCNP calculations (neutron energies below 20 MeV) was obtained by CASCADE/INPE high energy transport code. 18 point detectors were introduced into the reactor skeleton. The arrangement of the detectors was chosen to have distributions of the neutrons both in the radial and longitudinal directions. 6 detectors were introduced at the top of the active region along the direction OB, Fig.6, 6 detectors were installed in the same direction but at the distance equal to j of the active region length and rest part of the detectors was installed in the middle plane of the active region in the direction OB. The distributions of the neutron fluxes obtained are presented in Fig.7. 6 SNR C2 fuel bundles

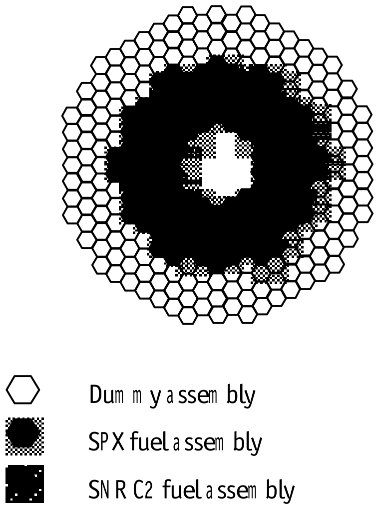

Fig. 5. EAP-80 reactor core with 12 SNR C2 fuel assembles in the 5th round

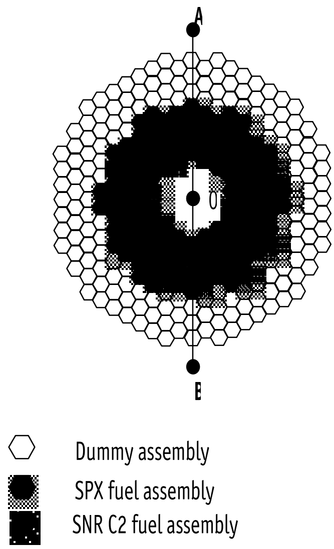

Fig. 6. EAP-80 reactor core with 9 SNR C2 fuel assembles in the 4th round

were arranged in the 5th round and another 6 bundles were placed in the 6th round (see Table 10). The neutron flux in the peripheral zone is three times less than in the first bundle round. In addition, the distributions of the thermal, resonance and fast neutrons were calculated. The following qualitative neutron groups were chosen: 0.001-10 eV - thermal neutrons, 10 eV- 0.1 MeV – resonance neutrons and above 0.1 MeV – fast neutrons. The results of the calculations are presented in Figs.9-11.

The data presented in Figs. 9-11 support the idea that the dominant energy group in the reactor is resonance one. The role of fast neutrons is significant in the rounds close to the spallation module. The share of thermal neutrons in the total flux becomes more important in the peripheral zone of the active region. The share of resonance neutrons is about 40% in the 3rd and 4th rounds and it reaches ~70% in the peripheral zone. Due to the high energy, fast and resonance neutrons can easily leak from the core. Hence, the peripheral zone of EAP-80 appeared to be rather a weak point for the reactor neutronics. There exists certain opportunity to increase the flux of the resonance neutrons in the peripheral zone by using of the reflector.

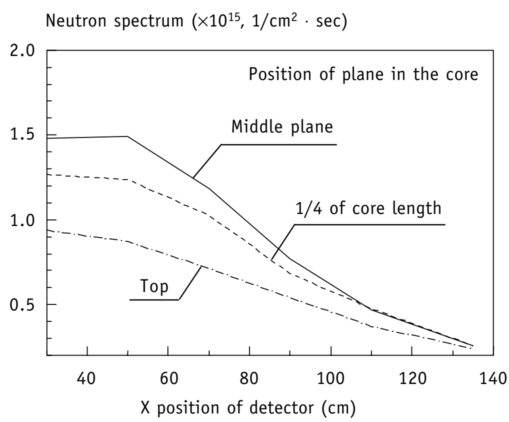

Fig. 7. Distributions of neutron flux over the reactor

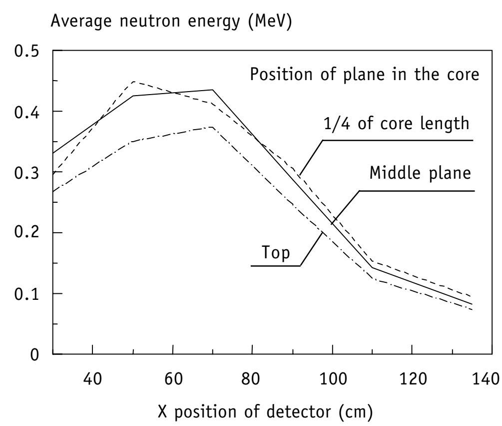

Fig. 8. Distribution of the average neutron energy over the reactor core

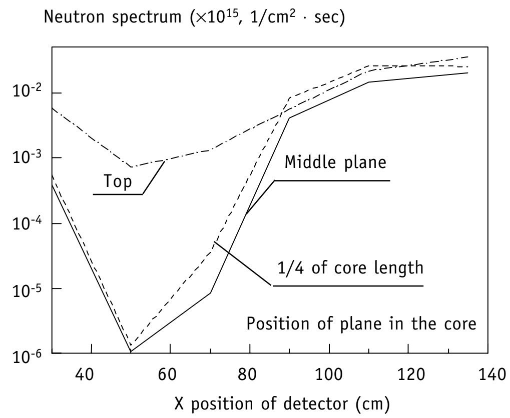

Fig. 9. Distribution of thermal neutrons over the reactor core

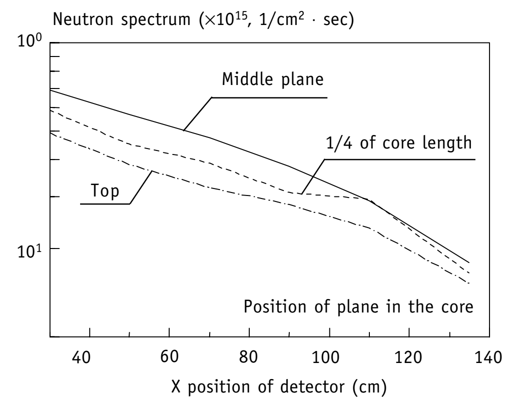

Fig. 10. Distribution of resonance neutrons over the reactor core

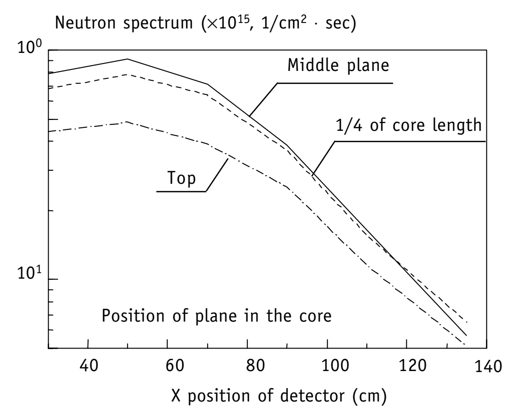

Fig. 11. Distribution of fast neutrons over the reactor core

Application of the reactor reflector

Surrounding the reactor core with a reflector enables the nuclear and thermal performances to be improved. The peripheral zone of the core is subjected to additional neutron irradiation resulting from the scattering processes in the reflector. As a result extra energy generation can be achieved due to the excess of the fission reactions. So, the reactor reflector application permits to avoid non-productive neutron leakage and to achieve additional neutron flux flattening in the core.

The layer of any material sited around the reactor reflects and returns part of the neutrons to the active zone as a result of the neutron scattering. The probability of the leakage from the reactor is greater for the fast neutrons because of their larger free paths. The returned neutron spectrum, resulting from scattering in the reflector, becomes softer. Thus, the share of the fast neutrons in the backward spectrum is less in comparison with the leakage spectrum. The probability for the neutron to be reflected to the core depends on the absorption process in the reflector. Hence, the reflector should be made of materials with good scattering characteristics such as graphite, beryllium (or its oxide) and heavy water.

The application of the liquid reflector (heavy water) in EAP-80 seems to be questionable. The material densities for graphite and beryllium are about the same (1.9 g/cm^3 and 1.848 g/cm^3 respectively). The comparison of the elastic scattering cross sections for these media, Fig.12, demonstrate certain advantage of the beryllium over the graphite.

For safety reason the beryllium reflector was assumed to be enclosed in stainless steel cylindrical container with 0.5 cm walls thickness. This container was placed around the reactor core (outside of the dummy assemblies). The basic variant for comparison was chosen to be the core with 12 SNR (C2) bundles replacing the SPX assembles in the 5th round, Fig. 5. The results of the calculations are presented in

Fig.13. A slight increase in the k_{eff} value around 5 cm ^{9}Be thickness could result from additional neutron generation in the $^9Be(n,2n)2\alpha$ reaction. But all these results can be regarded as a negative effect for the reactor neutronics in any case. The dummy bundle rounds unusual for the commercial reactor appeared to act as additional neutron absorbers. Intermediate and low energy neutrons, being scattered over the beryllium reflector and having lower energy as result, have a higher probability of absorption in the stainless steel elements of the dummy assemblies. This idea can be supported by comparison of the absorption cross sections for ^{56}Fe and lead isotopes, Fig.14.

The traditional external reflector is meaningless in the EAP-80 design because of the parasitic absorption of the neutrons moving backward from reflector. As was stated in [2], lead-bismuth coolant dummy assemblies around the nuclear core lead to additional neutron losses and, as a result, to the increase in the irregularity of the heat deposit in the reactor. The outer region of the reactor (the 8th, 9th, 10th rounds and partly 7th rounds) looks as a trap for the neutrons, escaping from the core and moving backward, owing to a considerable number of the stainless steel elements.

This idea was checked in special MCNP runs. The outer rounds of the core dummy assemblies, Fig. 5, were replaced by pure Pb-Bi coolant. Thus, the core was rounded up with pseudo cylindrical coolant layer. The number and arrangement of the SNR fuel bundles was chosen to

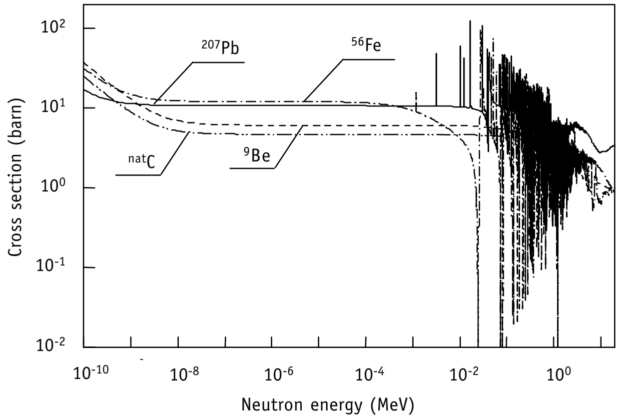

Fig.12. Elastic scattering cross sections for some nuclides, reconstructed by NJOY code

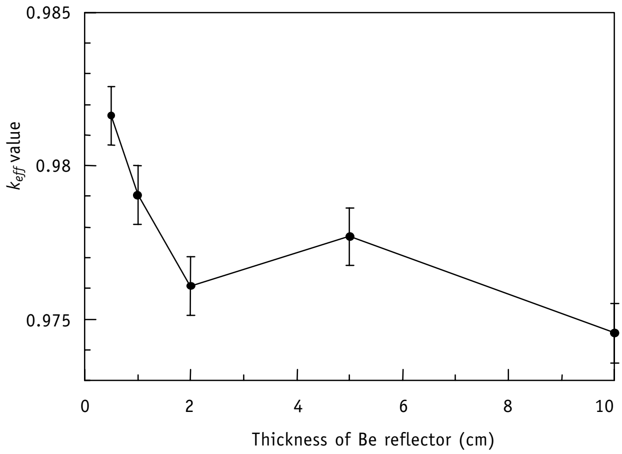

Fig. 13. k_{eff} values obtained for different ^{9}Be reactor reflector thickness

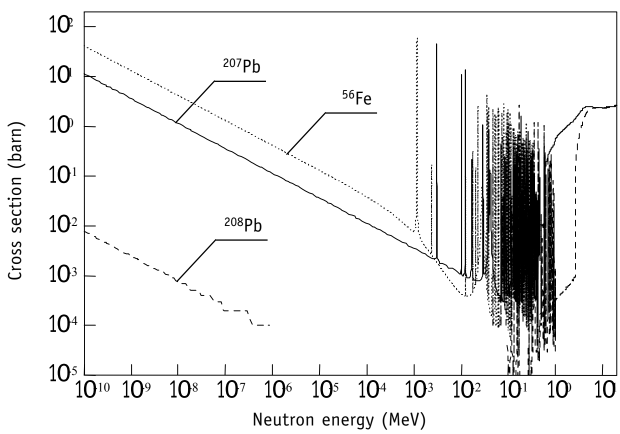

Fig.14. Absorption cross sections for some nuclides, reconstructed by NJOY code

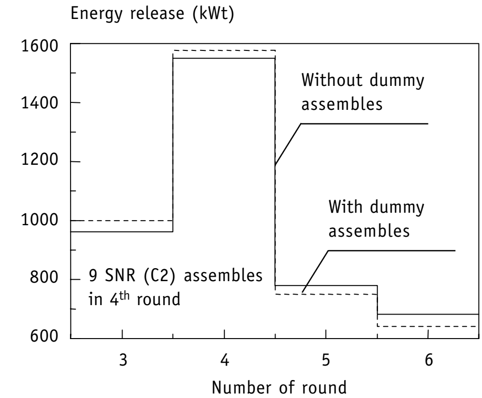

Fig. 15. Energy generation distribution in the EAP-80 modified core (0A cross section)

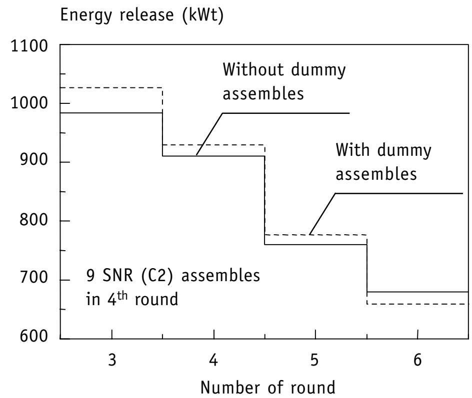

Fig. 16. Energy generation distribution in the EAP-80 modified core (0B cross section)

be as follows: 12 assemblies in the 5th round. The k_{eff} values obtained for these variants are presented in Table 11. The increase in the k_{eff} value in comparison with the variant, in which 12 assemblies were arranged in the 5th round, therefore, demonstrates that the presence of the dummy assemblies leads to serious losses of neutrons. Such a situation becomes clearer if one turns to the neutron free path value (l) for stainless steel. For instance, $\lambda\approx 1.3$ cm and 3.3 cm for 1 keV and 100 keV neutron respectively. The same values for ^{209}Bi are 0.25 cm and 0.33 cm. Taking into account that elastic scattering cross sections for stainless steel and lead isotopes are approximately the same (Fig. 12) and that absorption in steel is at least 5 times greater (Fig.14), the dummy region turned to act not as a reflector but as a good absorber of neutrons.

Table 11

Influence of the dummy zone on the reactor neutronics

Number of the dummy assembly rounds removed	k_{eff} value
0	0.98351
7th and part of 8th	0.98515
All dummy assemblies	0.99349

It was noted above that removing of dummy assemblies has a positive effect on the k_{eff} value. This, in general, could affect the energy generation distribution across the reactor core. The results obtained for the energy generation distributions in two different cores are presented. 9 SNR C2 bundles replaced SPX ones in the 4th round. The variants of the core with and without dummy assembles are compared in Figs.15,16. Two cross sections of the core were considered: 0A and 0B, see Fig.6. The data presented in Figs.15,16 refer to energy generation in one assembly for the chosen direction.

The reactor core based on no-dummy configuration ideology demonstrates some improvement of the energy distribution over the active region. Moreover, the maximum of the average neutron energy is shifted to the reactor region close to the spallation module, Fig. 17. There are lower irregularities in energy generation across the core. This fact along with increasing of the k_{eff} value in the core without a dummy region could be considered as the basis for enhancing of the fuel burn up, i.e. increasing neutron flux during routine operation.

CONCLUSION

One of the distinctive features of the EAP-80 subcritical reactor is the use of the lead-bismuth eutectic as a coolant. Such a medium makes possible the formation of the fairly intensive spectra of the resonance and fast neutrons. This, in turn, leads to involving fertile materials (such as ^{238}U and others) into the fission process.

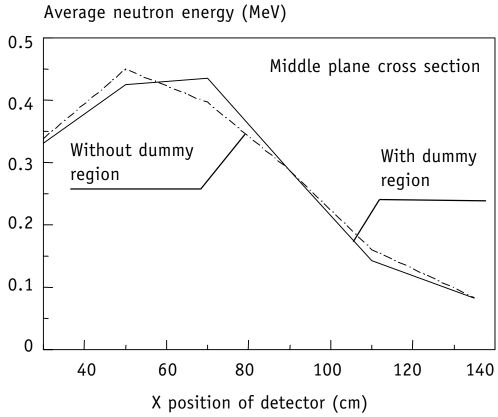

Fig.17. Distribution of average neutron energy for the core with and without a dummy region. The middle plane cross section is considered

The EAP-80 R&D work schedule assumes application of the fuels available in the European community. There are two kinds of fuel types, that could be used in the subcritical core: the SPX and SNR fuel. The former has come from the Superphenix (SPX) France fast breeder program and the latter is the German fuel for the SNR fast breeder reactor. It is proposed to charge the EAP-80 core with the SPX fuel only. The results obtained demonstrate that such a core could not meet the planned parameters. By applying the SNR fuel in addition to the SPX fuel, a subcritical reactor could be maintained with the required parameters. The SNR C2 fuel (~34% of Pu) seems to be the most suitable to be loaded in the active region instead of the SPX fuel.

The EAP-80 reactor core has a very clear resonance neutron spectrum. The arrangement of the SNR C2 fuel in the reactor leads to appearance of an irregularity in the neutron flux distribution. Traditional reactor reflectors are ineffective in this reactor due to the presence of the dummy region absorbing leaking neutrons. The results obtained demonstrate that removing the dummy zone could enhance the multiplication factor and diminish the irregularities in the core.

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Schools. Nuclear Power Engineering) – Obninsk, 2001. - 8 pages. - References, 21 titles.

In the paper some new modifications of the conventional point kinetics equations are proposed. The equations are provided an arbitrary functional, shape functions and delayed neutron precursors decay constants definitions and are intended for the description of the neutron flux evolution in nuclear reactor with fuel as an arbitrary mixture of the fissile nuclides

УДК 621.039.51

Calculational Benchmark – Test Model of BR-10 Reactor\A.V. Lyapin, N.A. Prochorova, E.P. Popov, S.V. Zabrodskaia, A.G. Tzikunov; Editorial board of Journal "Izvestia visshikh uchebnikh zavedeniy, Yadernaya energetica" (Communications of Higher Schools. Nuclear Power Engineering) - Obninsk, 2001. - 8 pages, 1 illustration, 7 tables.- References, 2 titles.

This article contains the international of fast reactor BR-10 on radioactive characteristics of irradiated materials. The purpose of this benchmark is to increase the accuracy and reliability mentioned above characteristics by comparison of different constant sets and codes.

УДК 621.039.51

Calculational Benchmark on Activation of Constructional Materials of Research Reactor AM\ R.I. Mukhamadeev, A.P. Suvorov; Editorial board of Journal "Izvestia visshikh uchebnikh zavedeniy, Yadernaya energetica" (Communications of Higher Schools. Nuclear Power Engineering) - Obninsk, 2001. - 5 pages, 2 illustrations, 4 tables.- References, 4 titles.

Description of developed calculational benchmark for the First NPP decommission is given. Two base functionals are supposed to calculate in the benchmark: 1) absolute neutron flux density (as function of neutron energy and distance from the core); 2) specific induced activity (as function of distance from the core and time after reactor shut-down).

УДК 621.039.51

Calculations of Netronic Characteristics of EAP-80 Reactor\ P. Pereslavtsev, D. Sahrai; Editorial board of Journal "Izvestia visshikh uchebnikh zavedeniy, Yadernaya energetica" (Communications of Higher Schools. Nuclear Power Engineering) - Obninsk, 2001. - 11 pages, 17 illustrations, 11 tables.- References, 8 titles.

The subcritical reactor core with different type fuels loaded was investigated. Highly enriched fuel of the German SNR fast breeder reactor as well as the Superphenix fuel can be successfully installed in the active region of the subcritical reactor. The irregularities in the heat generation naturally occurring in the core in this case could be reduced by replacing the empty fuel boxes in the outer rounds of the core with lead-bismuth eutectic.

УДК 621.039.586

Code PPRKRS Abstract\M.V. Kachtcheev; Editorial board of Journal "Izvestia visshikh uchebnikh zavedeniy, Yadernaya energetica" (Communications of Higher Schools. Nuclear Power Engineering) - Obninsk, 2001. - 5 pages.

The brief information about the program of calculation of corium interaction with VVER reactor internals and vessel under severe accident is presented. The program enables to predict the reactor vessel failure with the account of stratification of corium components.

УДК 621.311.25:621.384.01(043)

Transient Model of Two-phase Flow Heat Exchanger for NPP Simulator\A.A. Kazantsev, V.A. Levtchenko; Editorial board of Journal "Izvestia visshikh uchebnikh zavedeniy, Yadernaya energetica" (Communications of Higher Schools. Nuclear Power Engineering) - Obninsk, 2001. - 10 pages, 3 illustrations, 1 table.- References, 5 titles.

In the paper the description of a mathematical model of the two-phase flow transient heat exchanger, designed for NPP simulator is set up briefly. It was developed for real time calculations.