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# CALCULATIONS OF NEUTRON FIELD FUNCTIONALS IN THE HEAVY WATER FUEL CELL OF ELECTRONUCLEAR FACILITY.

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CALCULATIONS OF NEUTRON FIELD FUNCTIONALS IN THE HEAVY WATER FUEL CELL OF ELECTRONUCLEAR FACILITY: Preprint ITEP 39-96/

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Neutron field modeling results for the cell of the heavy water blanket of a facility for long-living radioactive waste transmutation are presented. The composition of a liquid fuel contains the isotopes: Pu38÷42, Am41, Am43, Cm42÷48. Results of neutron field functionals calculations are obtained for the cell as in the real cell geometry as in the homogenizated one.These results are compared and analyzed. Neutron field simulations are performed under the reactor code MCU.

Fig. - 9, ref. - 6.

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Investigation of radioactive waste transmutation in a system "accelerator + target with heavy water blanket" (see, for example, [ 1,2 ] ) includes a necessary stage - calculation of neutron field functionals in the cell of a heavy water blanket.

For neutron field modeling it is adopted the geometry of a hexahedral cell (see Fig.1, [ 2 ]) with a pitch of 30 cm in a infinite lattice. The fuel composed of heavy water slurry (or $D_2O$-solution) of transmuted isotopes: Pu-38,39,40,41,42, Am-41,43, Cm-42,43,44,45,46,47,48. For suppression of a heavy water dissociation under action of fission fragments the compound of 2-valent copper is added to a fuel. In the blanket it is provided circulation of the liquid fuel between the central tube of a cell (zone 1) and thin tubes (zone 11). Zirconium tubes (zones 2,4,8,10) have 1%-admixture of Nb, the admixture of niobium in a load-bearing tube (zone 6) is equal 2.5 %. The heavy water has 0.5%-impurity of a light water. In the zones 3 and 5 the heavy the water is a heat-transport medium and it is pumped under the pressure of ~100 atmospheres and has the density - $\gamma$ =1.0 g/cm$^3$. The heavy water moderator (zone 9) is without pressure and has the density $\gamma$ =1.1 g/cm$^3$.

The temperature mode of operations: zone 9 - 80 °C, other zones - 300 °C.

The neutron field modeling was executed under the reactor code MCU (Monte Carlo method) verificated in calculations of about 300 experimental assamble [3]. In calculations it was assumed mirror reflection on the boundaries of a cell. The results of modeling are presented in detail on the figures and in the tables with the purpose of maintenance of reproducibility of calculations.

In table 1 are presented: isotope composition of fuel zones; number of neutrons captured on different isotopes; number of fissions; number of secondary neutrons ( i.e. product of number of instant neutrons on fission macrocross section - $\nu\Sigma_f$ ); as well as - sum on zones. Here and further the nuclear concentration is given in units - $10^{24}$ nuclei/cm$^3$, all results are normalized on a source neutron. Similarly, in table 2 are listed results for zones without a fuel .

In table 3 are presented calculated values of neutron fluxes in zones for thermal neutrons with $E_n$ < 0.465 eV and epithermal one with $E_n$ > 0.465 eV. The jump of a flux in the zone 7 (heat-insulated gap) is explained by small statistics in this zone.

It was constructed figures 2÷8 for representation about the contribution of each isotope of a fuel zone to considered functionals (number of captures, fissions, secondary neutrons) depending on neutron energy. The scale of neutron energy is given in 26-group BNAB format [ 4 ] for $E_n \leq 10.5$ MeV.

In Fig. 2 are presented number of captured neutrons on nonfissionable fuel isotopes in the zone 11 ( the zone of thin fuel tubes) depending on the number of neutron energy group. In Fig. 3 and 4 data these functions are given for fissionable isotopes of this fuel zone.

In Fig. 5 and 6 are given the variation of dynamics for number of fissions of plutonium, americium and curium isotopes as function of neutron

group energy. Similarly, on Fig. 7 and 8 are presented the dynamics for number of secondary neutrons in view of them fission spectra. Clearly that some functions are discontinued on a some group ( for example, Am-243 in Fig. 5 ), when the functional becomes very small.

In tables 1 and 2 of the Appendix are listed group values for capture, fission and number of secondary neutrons for isotopes of the zone 11 ( as well as functionals sumed over the groups), i.e. the values of the figures 2÷8.

With the purpose of simplification of a geometry it was performed the homogenization of zones 1, 2, 3, 10, 11 and for the such simplified cell (see Fig.9) it was carried out the such calculations.

In table 4 are presented number of captures, fissions and secondary neutrons for isotopes of a unique fuel zone 1, and in table 5 are given number of captures on isotopes in the other zones. In table 6 are tabulated neutron fluxes for the homogenizated cell.

In table 7 are compared number of captures, fissions and secondary neutrons on isotopes in the whole cell for the real and homogenizated geometry. The summary values are specified for fissionable and nonfissionable isotopes separately. Discrepancy for isotopes Sm-249,251 and Cm-243 are the most significant. The main reason - in restriction on minimum concentration at calculation under the MCU ( i.e. is allowed concentration not less than 1. E-9 ). The concentration of Sm-249,251 and Cm-243 in a real geometry must be following: 9.157E-10, 1.254E-9 and 1.321E-9. The recalculation for the homogenizated cell gives the following concentration: 5.344E-10, 8.897E-10, 7.708E-10. In view of restrictions on minimum concentration, in calculations the following values are used: for the real geometry - 1. E-9, 1.524E-9 and 1.321E-9; for homogenizated one - 1. E-9, 1. E-9 and 1. E-9, respectively. Clearly, that the simplification of a geometry leads to some distortions. For example, the homogenization

of zirconium tubes (zone 10) for a fuel and homogenization of the central zirconium tube (zone 2) reduce probability of capture on Zr and Nb nuclei.

Decreasing concentration of fissionable isotopes at change from a real to a homogenizated cell reduces self-shielding of resonance isotopes. More obviously it is displayed for isotopes with strong resonances at significant concentration of these isotopes in a fuel. In table 8 are presented epicadmium resonance integrals (for infinite dilution) of fission and radiative capture for plutonium and americium isotopes. The calculations were performed under the code NJOY [ 5 ] with the bottom boundary $E_n$ =0.465 eV. Self-shielding is the most displayed for isotopes Pu-240 ( resonance integral $I_{n\gamma}$ = 8475.0 b), Pu242 ($I_{n\gamma}$=1117.9 b) and Am-243 ($I_{n\gamma}$=1365.6 b) in the real geometry. Really, the capture of neutrons on these isotopes in the real geometry is less than in the homogenizated geometry, but number of fissions (and, accordingly, secondary neutrons ) in a real geometry is more on 7.5 ÷13.2 % than in homogenizated one. Resonance integrals of Am-241 ($I_{n\gamma}$ = 1670.5 b) and Cm-243 ($I_{n\gamma}$ = 1609±103 b [ 6 ] ) are large too. However, concentrations of these isotopes are less by 2 ÷ 3 order and, hence, the self-shielding effect is considerably reduced.

The summary values of captures, number of fissions and secondary neutrons are distinguished not more than 0.3 %. The fluxes in identical zones (zones 4÷9 in the real geometry and zones 2÷7 in the homogenizated cell) differ not more than 2.8 % (except for the zone of a heat insulated gap). The $k_\infty$ -values for lattices is made up of cells in real and homogenizated geometry differ by ~0.3 % approximately ( see table 9 where different evaluations of $k_\infty$ are listed). The presented results are obtained at statistics: 645000 histories - for the real geometry and 540000 histories - for homogenizated one.

Up to the stated above work the calculations for cells in the real

geometry (Fig.1) but with the unique fuel isotope - Pu-239 were performed.Let us present a part of results of these calculations. In table 10 are given the similar functionals (i.e. the same as considered above) on isotopes of all zones of the cell. The different evaluations of $k_\infty$ for such lattice with unique fuel isotope - are given in the table 11. These results are obtained at statistics - 480000 histories.

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Table 1

| ZONES with FUEL for REAL GEOMETRY | | | | |
|---|---|---|---|---|
| ZONE | NUCLEAR CONCENTRATION | NUMBER of CAPTURES | NUMBER of FISSIONS | NUMBER of SECONDARY NEUTRONS |
| 1 | H 1.203E-4 | .5272E-03 | | |
| | D 6.003E-2 | .4157E-03 | | |
| | O 3.007E-2 | .1550E-02 | | |
| | CU 2.371E-5 | .1217E-02 | | |
| | RH05 1.081E-8 | .2292E-02 | | |
| | SM49 1.000E-9 | .1184E-02 | | |
| | SM51 1.524E-9 | .2291E-03 | | |
| | PU38 2.543E-8 | .1576E-03 | .5421E-05 | .1580E-04 |
| | PU39 6.847E-6 | .4350E-01 | .8990E-01 | .2599E+00 |
| | PU40 9.129E-6 | .5217E-01 | .5412E-04 | .1699E-03 |
| | PU41 2.382E-6 | .1400E-01 | .3906E-01 | .1139E+00 |
| | PU42 2.159E-5 | .1167E-01 | .6602E-04 | .2107E-03 |
| | AM41 1.767E-8 | .2190E-03 | .2467E-05 | .7954E-05 |
| | AM43 6.225E-6 | .1099E-01 | .2142E-04 | .8146E-04 |
| | CM42 4.829E-8 | .1273E-04 | .2129E-05 | .7442E-05 |
| | CM43 1.321E-9 | .2330E-05 | .1124E-04 | .3857E-04 |
| | CM44 1.796E-5 | .8267E-02 | .4543E-03 | .1612E-02 |
| | CM45 1.804E-7 | .7350E-03 | .4338E-02 | .1531E-01 |
| | CM46 1.431E-6 | .9343E-04 | .1317E-04 | .5158E-04 |
| | CM47 3.691E-8 | .4338E-04 | .6872E-04 | .2503E-03 |
| | CM48 3.721E-8 | .6026E-05 | .4616E-06 | .1725E-05 |
| | | Σ=.1493E+00 | Σ=.1340E+00 | Σ=.3916E+00 |
| 11 | H 1.203E-4 | .7760E-03 | | |
| | D 6.003E-2 | .6126E-03 | | |
| | O 3.007E-2 | .1407E-02 | | |
| | CU 2.371E-5 | .1782E-02 | | |
| | RH05 1.081E-8 | .3374E-02 | | |
| | SM49 1.000E-9 | .1692E-02 | | |
| | SM51 1.524E-9 | .3468E-03 | | |
| | PU38 2.543E-8 | .2350E-03 | .7907E-05 | .2301E-04 |
| | PU39 6.847E-6 | .6130E-01 | .1288E+00 | .3725E+00 |
| | PU40 9.129E-6 | .8103E-01 | .5724E-04 | .1771E-03 |
| | PU41 2.382E-6 | .2016E-01 | .5636E-01 | .1643E+00 |
| | PU42 2.159E-5 | .1784E-01 | .5936E-04 | .1890E-03 |
| | AM41 1.767E-8 | .3180E-03 | .3538E-05 | .1139E-04 |
| | AM43 6.225E-6 | .1575E-01 | .1903E-04 | .7226E-04 |
| | CM42 4.829E-8 | .1819E-04 | .2895E-05 | .1006E-04 |
| | CM43 1.321E-9 | .3420E-05 | .1644E-04 | .5639E-04 |
| | CM44 1.796E-5 | .1132E-01 | .5977E-03 | .2103E-02 |
| | CM45 1.804E-7 | .1097E-02 | .6468E-02 | .2283E-01 |
| | CM46 1.431E-6 | .1250E-03 | .1525E-04 | .5878E-04 |
| | CM47 3.691E-8 | .6247E-04 | .9903E-04 | .3606E-03 |
| | CM48 3.721E-8 | .8035E-05 | .5586E-06 | .2050E-05 |
| | | Σ=.2193E+00 | Σ=.1925E+00 | Σ=.5627E+00 |

Table 2

| ZONES free of FUEL for REAL GEOMETRY | | | | | |
|---|---|---|---|---|---|
| ZONE | NUCLEAR CONCENTRA-TION | NUMBER of CAPTURES | ZONE | NUCLEAR CONCENTRA-TION | NUMBER of CAPTURES |
| 2 | Zr 4.209E-2<br>Nb 5.445E-4 | .9120E-02<br>.8908E-03 | 7 | O 1.100E-7 | .2425E-09 |
| 3 | H 1.203E-4<br>D 6.003E-2<br>O 3.007E-2 | .7737E-03<br>.6108E-03<br>.1302E-02 | 8 | Zr 4.209E-2<br>Nb 5.445E-4 | .3962E-01<br>.3625E-02 |
| 4 | Zr 4.209E-2<br>Nb 5.445E-4 | .2700E-01<br>.2547E-02 | 9 | H 1.323E-4<br>D 6.603E-2<br>O 3.308E-2 | .6409E-02<br>.5071E-02<br>.3460E-02 |
| 5 | H 1.203E-4<br>D 6.003E-2<br>O 3.007E-2 | .8865E-03<br>.7005E-03<br>.8278E-03 | 10 | Zr 4.209E-2<br>Nb 5.445E-4 | .3635E-01<br>.3461E-02 |
| 6 | Zr 4.145E-2<br>Nb 1.361E-3 | .1380E+00<br>.3255E-01 | | | |

Table 3

| Neutron Fluxes in Zones of the Cell in the Real Geometry | | | | | | | |
|---|---|---|---|---|---|---|---|
| Zone | Description of zones | Flux for epithermal and thermal neutrons | | Zone | Description of zones | Flux for epithermal and thermal neutrons | |
| | | $E_n$>.465ev | $E_n$<.465ev | | | $E_n$>.465ev | $E_n$<.465ev |
| 1 | fuel in the central tube | .1078E+02 | .1937E+02 | 7 | heat insulated gap | .3623E+01 | .1548E+02 |
| 2 | Zr-Nb central tube for fuel | .7426E+00 | .1473E+01 | 8 | Zr-Nb calandre | .1754E+01 | .6048E+01 |
| 3 | $D_2O$ between thin tubes for fuel | .1157E+02 | .2761E+02 | 9 | cold $D_2O$ moderator | .4545E+02 | .1809E+03 |
| 4 | Zr-Nb tube containing all fuel tubes | .1532E+01 | .4339E+01 | 10 | thin Zr-Nb tubes for fuel | .2464E+01 | .5832E+01 |
| 5 | cooled $D_2O$ | .9879E+01 | .3025E+02 | 11 | fuel in the thin tubes | .1181E+02 | .2771E+02 |
| 6 | load-bearing Zr-Nb tube | .6645E+01 | .2196E+02 | | | | |

Table 4

| ZONE with FUEL for HOMOGENIZATED CELL | | | | | |
|---|---|---|---|---|---|
| ZONE | NUCLEAR CONCENTRATION | | NUMBER of CAPTURES | NUMBER of FISSIONS | NUMBER of SECONDARY NEUTRONS |
| 1 | H | 1.098E-4 | .2046E-02 | | |
| | D | 5.478E-2 | .1614E-02 | | |
| | O | 2.745E-2 | .4095E-02 | | |
| | CU | 1.384E-5 | .3010E-02 | | |
| | ZR | 3.678E-3 | .4432E-01 | | |
| | NB | 4.758E-5 | .4226E-02 | | |
| | RH05 | 6.308E-9 | .5688E-02 | | |
| | SM49 | 1.000E-9 | .4925E-02 | | |
| | SM51 | 1.000E-9 | .6523E-03 | | |
| | PU38 | 1.484E-8 | .3947E-03 | .1334E-04 | .3885E-04 |
| | PU39 | 3.996E-6 | .1048E+00 | .2191E+00 | .6333E+00 |
| | PU40 | 5.328E-6 | .1356E+00 | .1036E-03 | .3213E-03 |
| | PU41 | 1.390E-6 | .3424E-01 | .9556E-01 | .2786E+00 |
| | PU42 | 1.260E-5 | .3037E-01 | .1113E-03 | .3544E-03 |
| | AM41 | 1.031E-8 | .5387E-03 | .6009E-05 | .1934E-04 |
| | AM43 | 3.633E-6 | .2689E-01 | .3572E-04 | .1356E-03 |
| | CM42 | 2.818E-8 | .3095E-04 | .4966E-05 | .1728E-04 |
| | CM43 | 1.000E-9 | .7480E-05 | 3603E-04 | .1236E-03 |
| | CM44 | 1.048E-5 | .1957E-01 | .1034E-02 | .3643E-02 |
| | CM45 | 1.053E-7 | .1840E-02 | .1087E-01 | .3836E-01 |
| | CM46 | 8.354E-7 | .2173E-03 | .2716E-04 | .1050E-03 |
| | CM47 | 2.154E-8 | .1062E-03 | .1683E-03 | .6128E-03 |
| | CM48 | 2.171E-8 | .1402E-04 | .9815E-06 | .3614E-05 |
| | | | Σ=.4252E+00 | Σ=.3271E+00 | Σ=.9556E+00 |

Table 5

| ZONES FREE of FUEL for HOMOGENIZATED CELL | | | | | | | |
|---|---|---|---|---|---|---|---|
| ZONE | NUCLEAR CONCENTRA-TION | | NUMBER of CAPTURES | ZON E | NUCLEAR CONCENTRA-TION | | NUMBER of CAPTURES |
| 2 | Zr | 4.209E-2 | .2638E-01 | 5 | O | 1.100E-7 | .1529E-09 |
| | Nb | 5.445E-4 | .2509E-02 | | | | |
| 3 | H | 1.203E-4 | .8642E-03 | 6 | Zr | 4.209E-2 | .3860E-01 |
| | D | 6.003E-2 | .6827E-03 | | Nb | 5.445E-4 | .3558E-02 |
| | O | 3.007E-2 | .8854E-03 | | | | |
| 4 | Zr | 4.145E-2 | .1347E+00 | 7 | H | 1.323E-4 | .6266E-02 |
| | Nb | 1.361E-3 | .3182E-01 | | D | 6.603E-2 | .4957E-02 |
| | | | | | O | 3.308E-2 | .3515E-02 |

Table 6

| Neutron Fluxes in Zones for the Homogenizated Cell | | | | | | | |
|---|---|---|---|---|---|---|---|
| Zone | Description of zones | Flux for epithermal and thermal neutrons | | Zone | Description of zones | Flux for epithermal and thermal neutrons | |
| | | $E_n$>.465ev | $E_n$<.465ev | | | $E_n$>.465ev | $E_n$<.465ev |
| 1 | central homogenizated zone with fuel | .3666E+02 | .8069E+02 | 5 | heat insulated gap | | .9232E+01 |
| 2 | Zr-Nb tube containing homogenizated zone | .1558E+01 | .4236E+01 | 6 | Zr-Nb calandre | .1768E+01 | .5886E+01 |
| 3 | cooled $D_2O$ | .1002E+02 | .2951E+02 | 7 | cold $D_2O$ moderator | .4591E+02 | .1768E+03 |
| 4 | load-bearing Zr-Nb tube | .6719E+01 | .2142E+02 | | | | |

Table 7

| Total Balance of Isotope Reactions | | | | | | |
|---|---|---|---|---|---|---|
| Isotope | Cell in the Real Geometry | | | Homogenizated Cell | | |
| | capture | fission | $\nu\Sigma_f$ | capture | fission | $\nu\Sigma_f$ |
| H | .9372E-02 | .0000E+00 | .0000E+00 | .9176E-02 | .0000E+00 | .0000E+00 |
| D | .7411E-02 | .0000E+00 | .0000E+00 | .7254E-02 | .0000E+00 | .0000E+00 |
| O | .8547E-02 | .0000E+00 | .0000E+00 | .8495E-02 | .0000E+00 | .0000E+00 |
| CU | .3000E-02 | .0000E+00 | .0000E+00 | .3010E-02 | .0000E+00 | .0000E+00 |
| ZR | .2501E+00 | .0000E+00 | .0000E+00 | .2440E+00 | .0000E+00 | .0000E+00 |
| NB | .4308E-01 | .0000E+00 | .0000E+00 | .4211E-01 | .0000E+00 | .0000E+00 |
| RH05 | .5666E-02 | .0000E+00 | .0000E+00 | .5688E-02 | .0000E+00 | .0000E+00 |
| SM49 | .2876E-02 | .0000E+00 | .0000E+00 | .4925E-02 | .0000E+00 | .0000E+00 |
| SM51 | .5759E-03 | .0000E+00 | .0000E+00 | .6523E-03 | .0000E+00 | .0000E+00 |
| $\Sigma$(for non-fissionable isotopes)= | .3306E+00 | | | .3253E+00 | | |

Continuation of the Table 7

| Total Balance of Isotope Reaction | | | | | | |
|---|---|---|---|---|---|---|
| Isotope | Cell in the Real Geometry | | | Homogenizated Cell | | |
| | capture | fission | $\nu\Sigma_f$ | capture | fission | $\nu\Sigma_f$ |
| PU38 | .3926E-03 | .1333E-04 | .3881E-04 | .3947E-03 | .1334E-04 | .3885E-04 |
| PU39 | .1049E+00 | .2187E+00 | .6324E+00 | .1048E+00 | .2191E+00 | .6333E+00 |
| PU40 | .1332E+00 | .1114E-03 | .3469E-03 | .1356E+00 | .1036E-03 | .3213E-03 |
| PU41 | .3418E-01 | .9542E-01 | .2782E+00 | .3424E-01 | .9556E-01 | .2786E+00 |
| PU42 | .2951E-01 | .1254E-03 | .3997E-03 | .3037E-01 | .1113E-03 | .3544E-03 |
| AM41 | .5370E-03 | .6006E-05 | .1934E-04 | .5387E-03 | .6009E-05 | .1934E-04 |
| AM43 | .2675E-01 | .4045E-04 | .1537E-03 | .2689E-01 | .3572E-04 | .1356E-03 |
| CM42 | .3093E-04 | .5024E-05 | .1750E-04 | .3095E-04 | .4966E-05 | .1728E-04 |
| CM43 | .5750E-05 | .2768E-04 | .9496E-04 | .7480E-05 | .3603E-04 | .1236E-03 |
| CM44 | .1959E-01 | .1052E-02 | .3715E-02 | .1957E-01 | .1034E-02 | .3643E-02 |
| CM45 | .1830E-02 | .1081E-01 | .3815E-01 | .1840E-02 | .1087E-01 | .3836E-01 |
| CM46 | .2185E-03 | .2842E-04 | .1104E-03 | .2173E-03 | .2716E-04 | .1050E-03 |
| CM47 | .1057E-03 | .1678E-03 | .6109E-03 | .1062E-03 | .1683E-03 | .6128E-03 |
| CM48 | .1406E-04 | .1020E-05 | .3775E-05 | .1402E-04 | .9815E-06 | .3614E-05 |
| Σ (for fissile isotopes)= | .3513E+00 | .3265E+00 | .9543E+00 | .3546E+00 | .3271E+00 | .9556E+00 |

Table 8

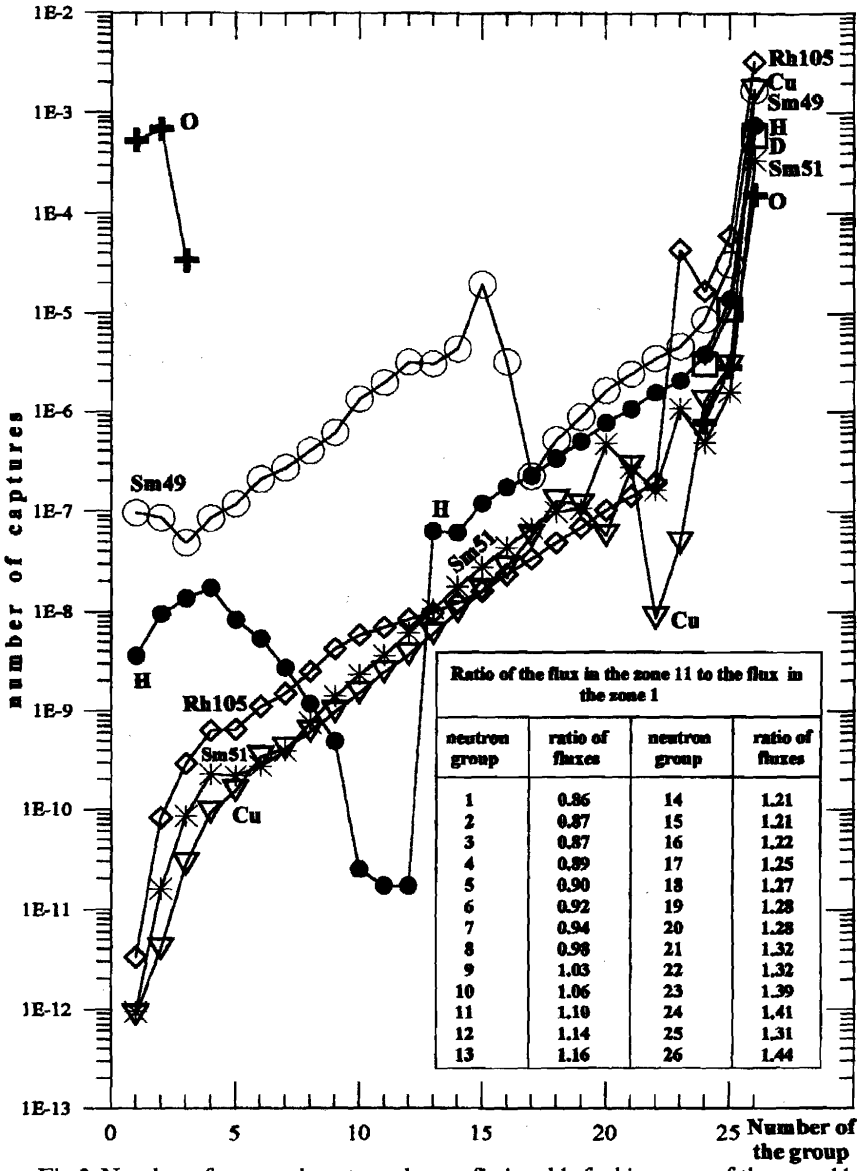
| Resonance Integrals for Infinite Dilution | | | |
|---|---|---|---|
| ISOTOPE | $I_{nf}$, b | $I_{n\gamma}$, b | DATA SOURCE |
| Pu-238 | 30.19 | 147.39 | ENDF/B-IV |
| Pu-239 | 320.48 | 203.05 | ENDF/B-IV |
| Pu-240 | 9.37 | 8474.0 | JENDL-2 |
| Pu-241 | 591.04 | 128.28 | ENDF/B-IV |
| Pu-242 | 5.69 | 1117.9 | JENDL-2 |
| Am-241 | 19.63 | 1670.5 | ENDF/B-IV |
| Am-243 | 3.91 | 1365.6 | ENDF/B-IV |

Table 9

| $k_\infty$ – values for the cell in the real geometry and homogenizated cell | | |
|---|---|---|
| $k_\infty$ – estimation | Real Geometry | Homogenization |
| $k_{Brissenden}$ | .95210E+00( 39) | .95486E+00( 38) |
| $k_{combined}$ | .95311E+00( 85) | .95472E+00( 90) |
| $k_{collision}$ | .95424E+00(131) | .95562E+00(150) |
| $k_{absorption}$ | .95262E+00( 95) | .95446E+00( 96) |

Table 10

| CELL in the REAL GEOMETRY with $^{239}$Pu - FUEL | | | | |
|---|---|---|---|---|
| ZONE | NUCLEAR CONCENTRATION | NUMBER of CAPTURES | NUMBER of FISSIONS | NUMBER of SECONDARY NEUTRONS |
| 1 | H 1.203E-4<br>D 6.003E-2<br>O 3.007E-2<br>PU39 6.847E-6 | .8956E-03<br>.7087E-03<br>.1084E-02<br>.7210E-01 | .1505E+00 | .4350E+00 |
| 2 | ZR 4.209E-2<br>NB 5.445E-4 | .1455E-01<br>.1320E-02 | | |
| 3 | H 1.203E-4<br>D 6.003E-2<br>O 3.007E-2 | .1254E-02<br>.9928E-03<br>.9660E-03 | | |
| 4 | ZR 4.209E-2<br>NB 5.445E-4 | .4166E-01<br>.3703E-02 | | |
| 5 | H 1.203E-4<br>D 6.003E-2<br>O 3.007E-2 | .1391E-02<br>.1102E-02<br>.6715E-03 | | |
| 6 | ZR 4.145E-2<br>NB 1.361E-3 | .2108E+00<br>.4704E-01 | | |
| 7 | O 1.100E-7 | .1132E-09 | | |




| Ratio of the flux in the zone 11 to the flux in the zone 1 | | | |
|---|---|---|---|
| neutron group | ratio of fluxes | neutron group | ratio of fluxes |
| 1 | 0.86 | 14 | 1.21 |
| 2 | 0.87 | 15 | 1.21 |
| 3 | 0.87 | 16 | 1.22 |
| 4 | 0.89 | 17 | 1.25 |
| 5 | 0.90 | 18 | 1.27 |
| 6 | 0.92 | 19 | 1.28 |
| 7 | 0.94 | 20 | 1.28 |
| 8 | 0.98 | 21 | 1.32 |
| 9 | 1.03 | 22 | 1.32 |
| 10 | 1.06 | 23 | 1.39 |
| 11 | 1.10 | 24 | 1.41 |
| 12 | 1.14 | 25 | 1.31 |
| 13 | 1.16 | 26 | 1.44 |

Fig.2. Number of captured neutrons by nonfissionable fuel isotopes of the zone 11 depending on the group number of neutron energy.

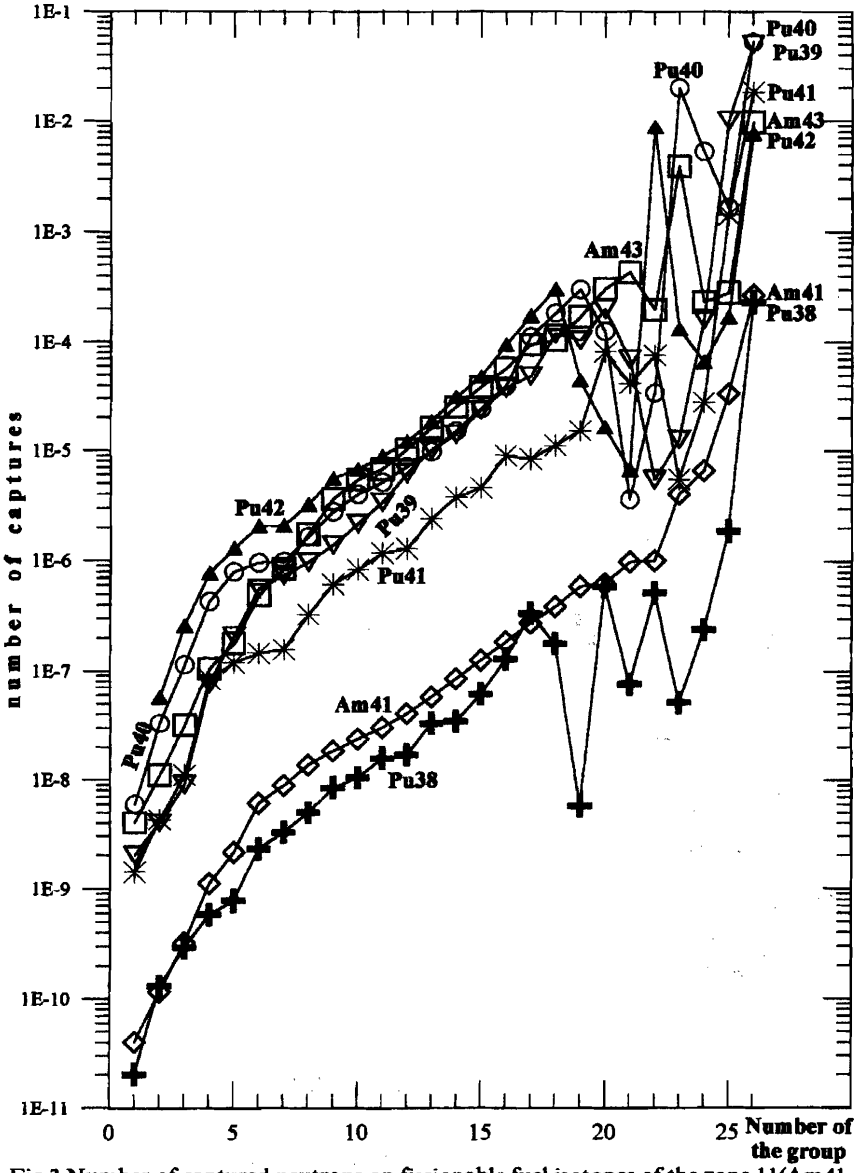



Fig.3.Number of captured neutrons on fissionable fuel isotopes of the zone 11(Am41, Am43 и Pu38,39,40,41,42) depending on the group number of neutron energy.

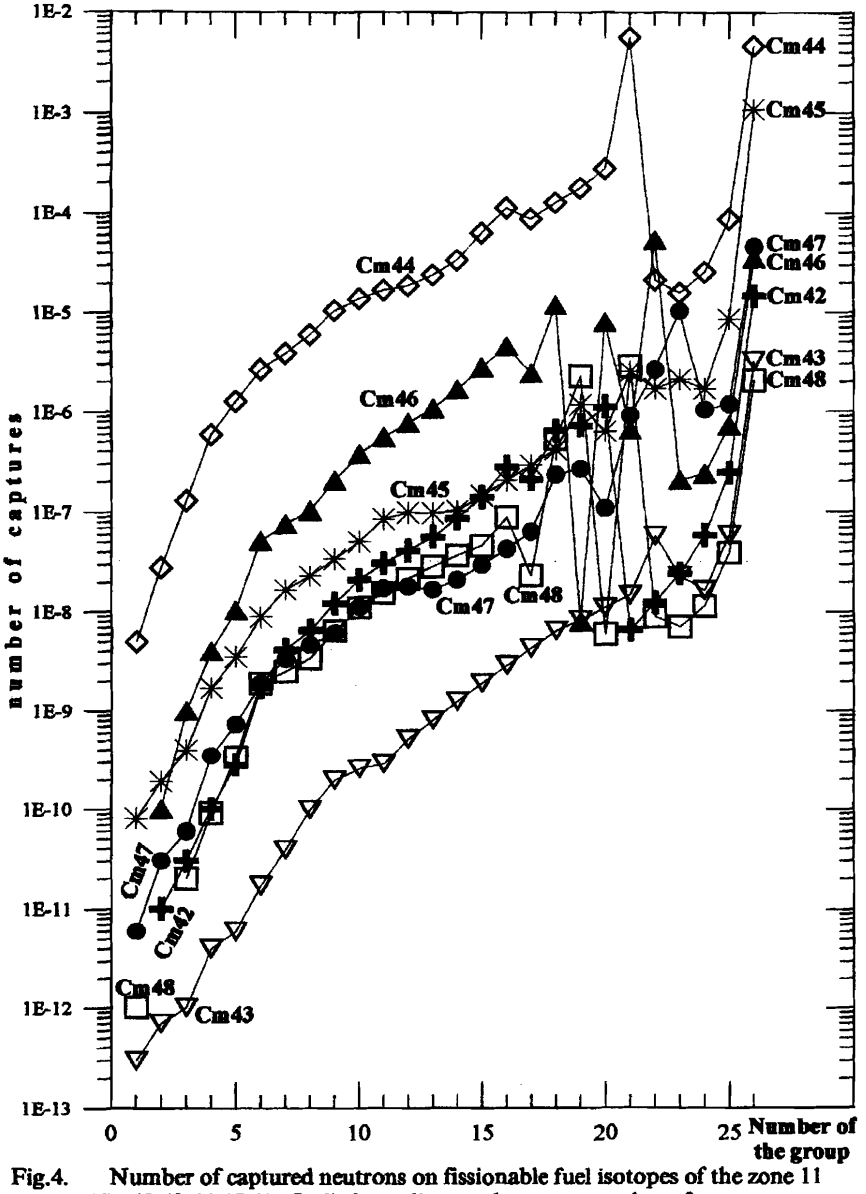



Fig.4. Number of captured neutrons on fissionable fuel isotopes of the zone 11 (Cm42,43,44,45,46,47,48) depending on the group number of neutron energy.

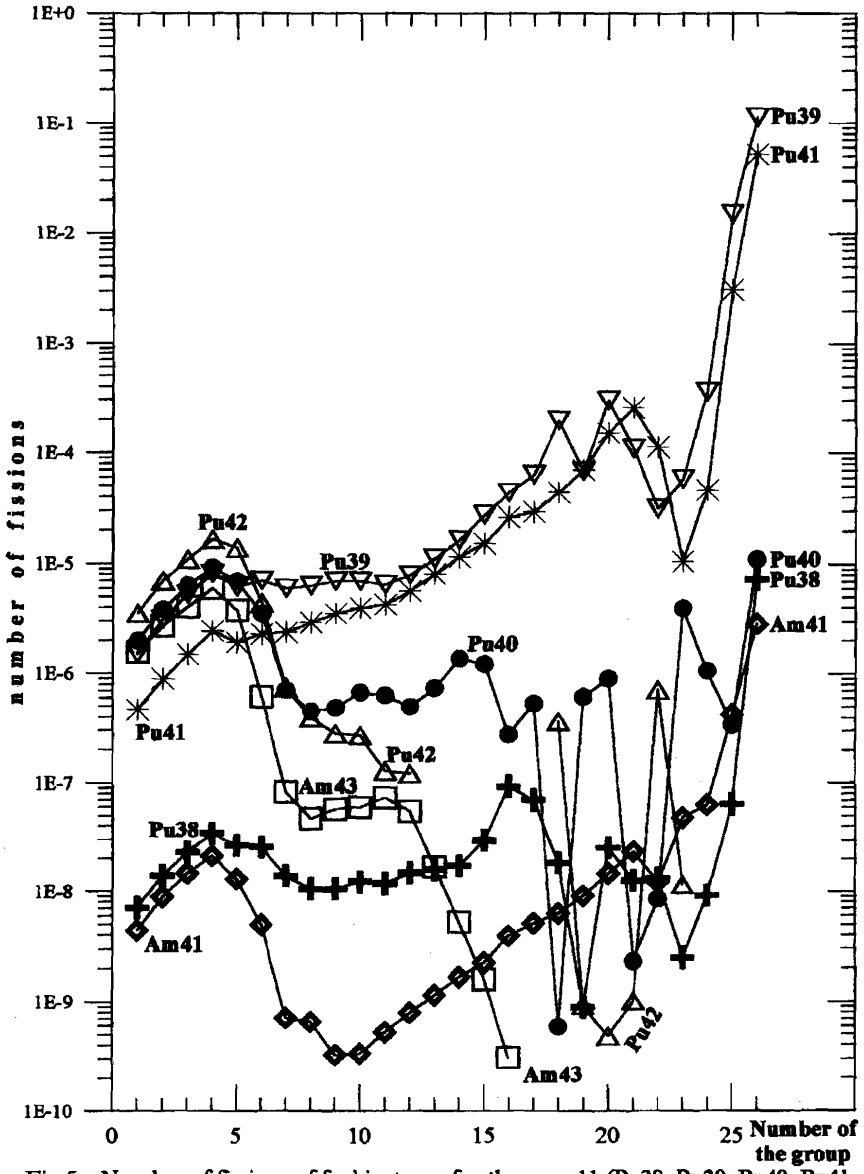



Fig.5. Number of fissions of fuel isotopes for the zone 11 (Pu38, Pu39, Pu40, Pu41, Pu42, Am41, Am43) depending on the group number of neuton energy.

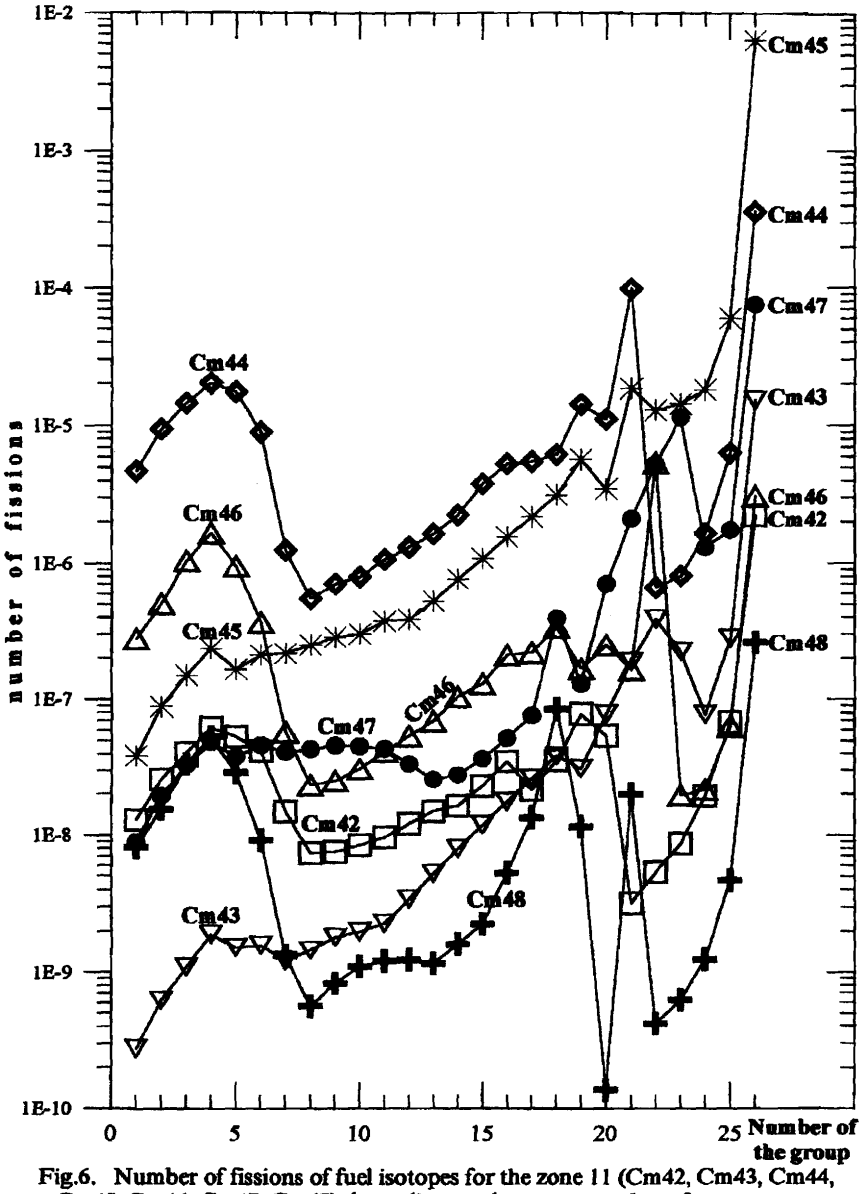



Fig.6. Number of fissions of fuel isotopes for the zone 11 (Cm42, Cm43, Cm44, Cm45, Cm46, Cm47, Cm48) depending on the group number of neutron energy.

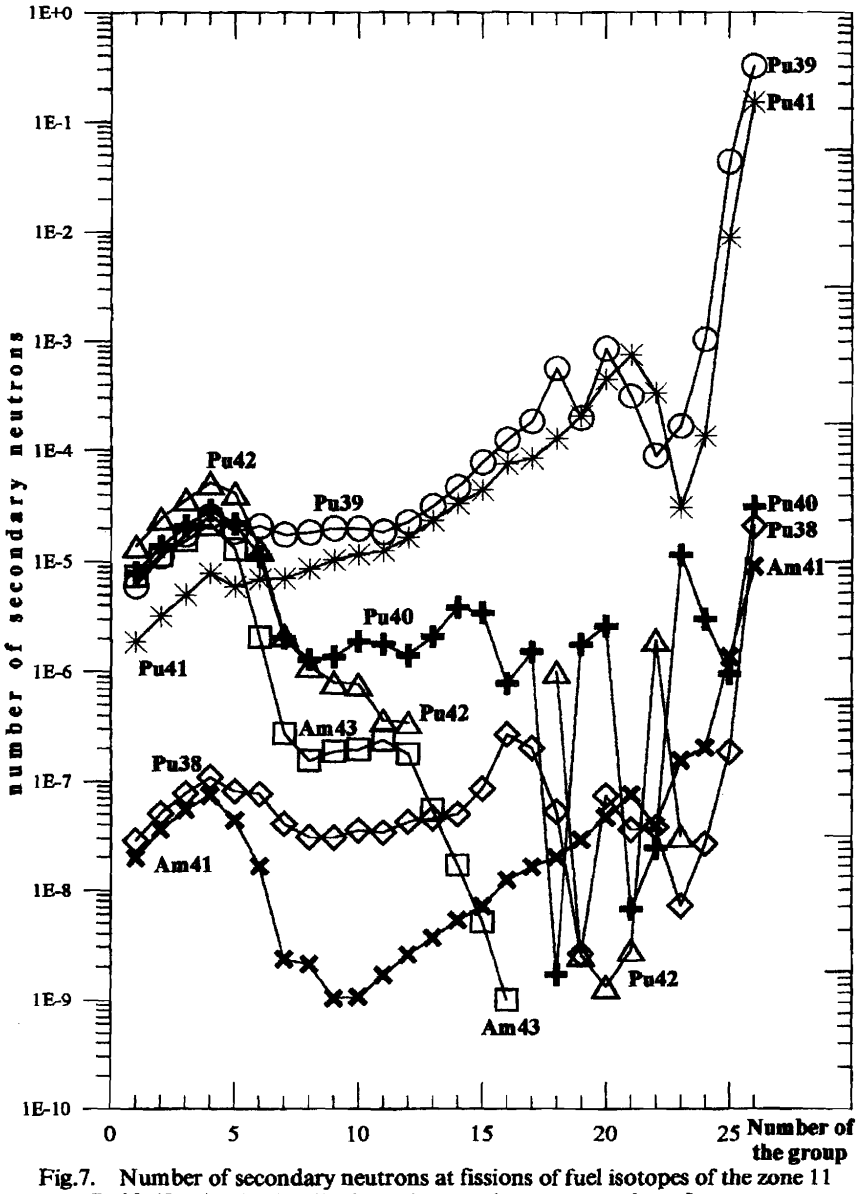



Fig.7. Number of secondary neutrons at fissions of fuel isotopes of the zone 11 (Pu38-42, Am41, Am43) depending on the group number of neutron energy.

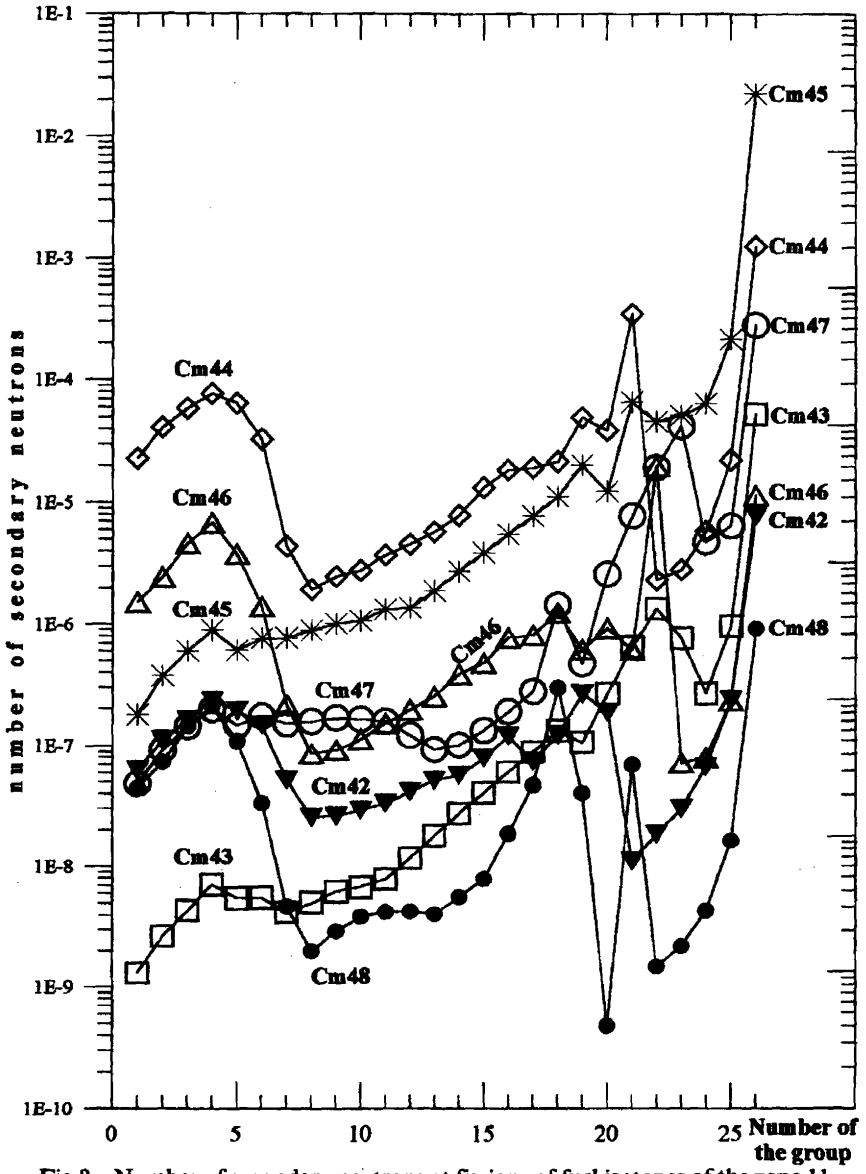



Fig.8. Number of secondary neutrons at fissions of fuel isotopes of the zone 11 (Cm42,43,44,45,46,47,48) depending on the group number of neutron energy.

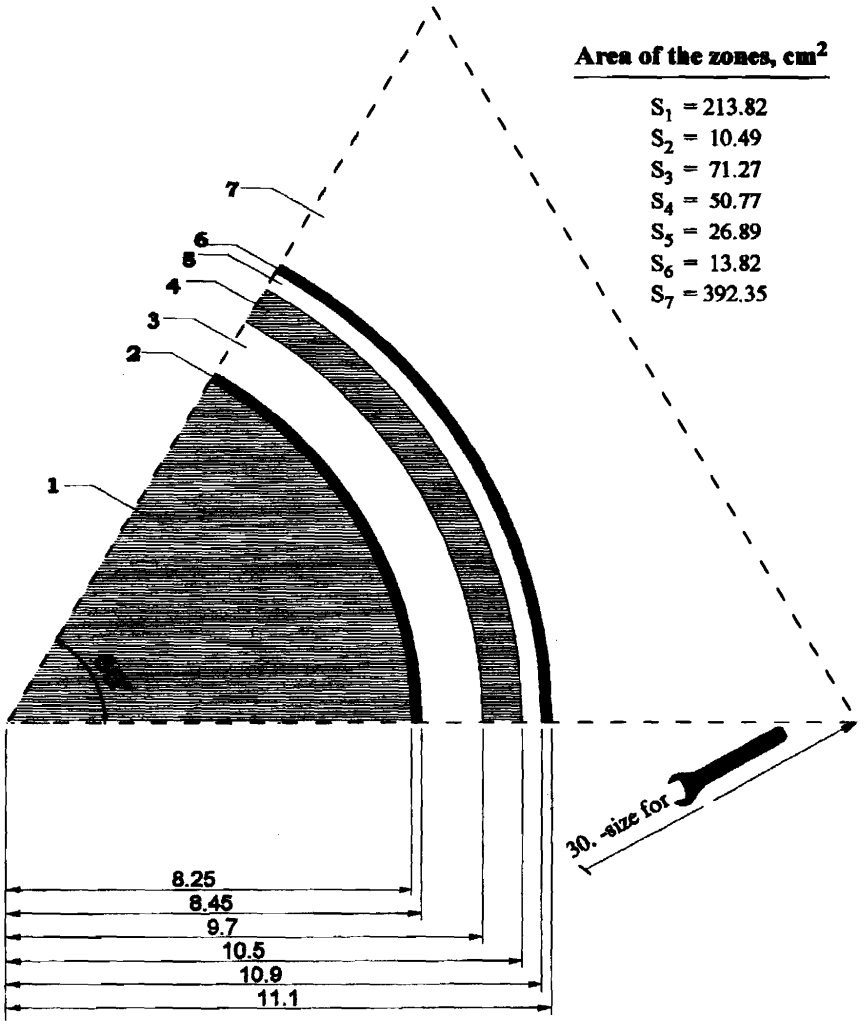



Fig.9. Geometry of the homogenizated cell (dimensions in cm).
1 - zone of homogenization ( fuel + $D_2O$ + zirconium-niobium tubes ); 2 - tube separated flows of heat transport heavy water; 3 - cooled volume of heat transport heavy water (zone of heat removal); 4 - load-bearing tube; 5 - heat-insulated gap; 6 - calandre tube; 7 - cold moderator ($D_2O$).

## Appendix

Table 1

**GROUP VALUES for CAPTURE REACTION RATES for NONFISSIONABLE ISOTOPES of the ZONE 11**

| Group | H | D | O | Cu | Rh-105 | Sm-49 | Sm-51 |
|---|---|---|---|---|---|---|---|
| 1 | .3593E-08 | .0000E+00 | .5267E-03 | .9699E-07 | .3317E-11 | .8693E-12 | .9351E-12 |
| 2 | .9547E-08 | .0000E+00 | .6904E-03 | .8704E-07 | .8220E-10 | .4012E-11 | .1598E-10 |
| 3 | .1365E-07 | .0000E+00 | .3397E-04 | .4905E-07 | .2952E-09 | .2813E-10 | .8638E-10 |
| 4 | .1734E-07 | .0000E+00 | .0000E+00 | .8618E-07 | .6352E-09 | .9390E-10 | .2271E-09 |
| 5 | .8300E-08 | .0000E+00 | .0000E+00 | .1196E-06 | .6545E-09 | .1544E-09 | .2199E-09 |
| 6 | .5337E-08 | .0000E+00 | .0000E+00 | .2111E-06 | .1101E-08 | .3426E-09 | .2766E-09 |
| 7 | .2710E-08 | .0000E+00 | .0000E+00 | .2732E-06 | .1490E-08 | .4187E-09 | .3957E-09 |
| 8 | .1171E-08 | .0000E+00 | .0000E+00 | .4044E-06 | .2503E-08 | .6216E-09 | .7569E-09 |
| 9 | .4946E-09 | .0000E+00 | .0000E+00 | .6171E-06 | .4232E-08 | .9788E-09 | .1402E-08 |
| 10 | .2533E-10 | .0000E+00 | .0000E+00 | .1336E-05 | .5836E-08 | .1525E-08 | .2306E-08 |
| 11 | .1726E-10 | .0000E+00 | .0000E+00 | .1958E-05 | .7021E-08 | .2444E-08 | .3653E-08 |
| 12 | .1726E-10 | .0000E+00 | .0000E+00 | .3186E-05 | .8466E-08 | .3714E-08 | .6138E-08 |
| 13 | .6451E-07 | .0000E+00 | .0000E+00 | .3046E-05 | .9854E-08 | .6059E-08 | .1071E-07 |
| 14 | .6252E-07 | .0000E+00 | .0000E+00 | .4377E-05 | .1236E-07 | .1003E-07 | .1782E-07 |
| 15 | .1212E-06 | .0000E+00 | .0000E+00 | .1953E-04 | .1634E-07 | .1637E-07 | .2825E-07 |
| 16 | .1763E-06 | .0000E+00 | .0000E+00 | .3223E-05 | .2377E-07 | .2809E-07 | .4430E-07 |
| 17 | .2300E-06 | .0000E+00 | .0000E+00 | .2267E-06 | .3410E-07 | .5736E-07 | .6905E-07 |
| 18 | .3402E-06 | .0000E+00 | .0000E+00 | .5252E-06 | .4942E-07 | .1287E-06 | .9975E-07 |
| 19 | .5040E-06 | .0000E+00 | .0000E+00 | .8830E-06 | .7045E-07 | .1171E-06 | .1068E-06 |
| 20 | .7703E-06 | .0000E+00 | .0000E+00 | .1627E-05 | .1038E-06 | .5830E-07 | .4754E-06 |
| 21 | .1064E-05 | .0000E+00 | .0000E+00 | .2412E-05 | .1435E-06 | .2795E-06 | .2758E-06 |
| 22 | .1558E-05 | .0000E+00 | .0000E+00 | .3480E-05 | .1960E-06 | .8686E-08 | .1654E-06 |
| 23 | .2056E-05 | .0000E+00 | .0000E+00 | .4606E-05 | .4343E-04 | .4886E-07 | .1070E-05 |
| 24 | .3839E-05 | .3058E-05 | .7804E-06 | .8638E-05 | .1663E-04 | .1275E-05 | .4846E-06 |
| 25 | .1384E-04 | .1102E-04 | .2813E-05 | .3114E-04 | .5993E-04 | .2923E-05 | .1568E-05 |
| 26 | .7513E-03 | .5985E-03 | .1527E-03 | .1690E-02 | .3253E-02 | .1687E-02 | .3423E-03 |
| Σ= | .7760E-03 | .6126E-03 | .1407E-02 | .1782E-02 | .3374E-02 | .1692E-02 | .3468E-03 |

## Appendix

Table 2

**GROUP VALUES for REACTION RATES for FISSILE ISOTOPES of the ZONE 11**

| | Pu-238 | | | Pu-239 | | |
|---|---|---|---|---|---|---|
| GROUP | NUMBER of CAPTURES | NUMBER of FISSIONS | NUMBER of SECONDARY NEUTRONS | NUMBER of CAPTURES | NUMBER of FISSIONS | NUMBER of SECONDARY NEUTRONS |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1 | .2000E-10 | .7100E-08(113) | .2855E-07( 45) | .2000E-08 | .1495E-05( 24) | .5986E-05( 95) |
| 2 | .1300E-09 | .1396E-07( 12) | .5056E-07( 44) | .4000E-08 | .3115E-05( 27) | .1111E-04( 10) |
| 3 | .2900E-09 | .2307E-07( 14) | .7750E-07( 47) | .9000E-08 | .5272E-05( 32) | .1745E-04( 11) |
| 4 | .5800E-09 | .3437E-07( 16) | .1092E-06( 5) | .7600E-07 | .8138E-05( 37) | .2552E-04( 12) |
| 5 | .7800E-09 | .2644E-07( 11) | .8076E-07( 34) | .2080E-06 | .6118E-05( 26) | .1856E-04( 8) |
| 6 | .2280E-08 | .2566E-07( 9) | .7648E-07( 28) | .5580E-06 | .7054E-05( 26) | .2082E-04( 8) |
| 7 | .3260E-08 | .1385E-07( 5) | .4069E-07( 14) | .7440E-06 | .6002E-05( 21) | .1748E-04( 6) |
| 8 | .5030E-08 | .1056E-07( 4) | .3078E-07( 11) | .9750E-06 | .6321E-05( 22) | .1827E-04( 6) |
| 9 | .8450E-08 | .1052E-07( 3) | .3057E-07( 10) | .1400E-05 | .6947E-05( 22) | .2002E-04( 6) |
| 10 | .1050E-07 | .1221E-07( 4) | .3548E-07( 12) | .2177E-05 | .6929E-05( 23) | .1995E-04( 7) |
| 11 | .1582E-07 | .1174E-07( 4) | .3412E-07( 12) | .3427E-05 | .6463E-05( 23) | .1859E-04( 7) |
| 12 | .1693E-07 | .1472E-07( 5) | .4277E-07( 15) | .6205E-05 | .7965E-05( 30) | .2291E-04( 9) |
| 13 | .3282E-07 | .1580E-07( 6) | .4591E-07( 16) | .1016E-04 | .1108E-04( 5) | .3188E-04( 15) |
| 14 | .3450E-07 | .1714E-07( 6) | .4979E-07( 17) | .1411E-04 | .1635E-04( 9) | .4703E-04( 25) |
| 15 | .6144E-07 | .2942E-07( 11) | .8545E-07( 31) | .2385E-04 | .2748E-04( 15) | .7902E-04( 44) |
| 16 | .1293E-06 | .9269E-07( 35) | .2693E-06( 10) | .3778E-04 | .4390E-04( 27) | .1262E-03( 8) |
| 17 | .3382E-06 | .6972E-07( 80) | .2025E-06( 23) | .4919E-04 | .6411E-04( 43) | .1844E-03( 12) |
| 18 | .1797E-06 | .1821E-07( 43) | .5290E-07(124) | .1205E-03 | .1980E-03( 12) | .5690E-03( 35) |
| 19 | .5805E-08 | .8884E-09( 14) | .2581E-08( 41) | .1053E-03 | .6885E-04( 75) | .1979E-03( 21) |
| 20 | .5935E-06 | .2537E-07( 42) | .7369E-07(122) | .2012E-03 | .3003E-03( 20) | .8627E-03( 58) |
| 21 | .7613E-07 | .1250E-07( 29) | .3631E-07( 84) | .7070E-04 | .1103E-03( 11) | .3169E-03( 31) |
| 22 | .5171E-06 | .1310E-07( 14) | .3806E-07( 40) | .5480E-05 | .3150E-04( 12) | .9049E-04( 34) |
| 23 | .5138E-07 | .2470E-08( 10) | .7175E-08( 29) | .1277E-04 | .5852E-04( 24) | .1681E-03( 7) |
| 24 | .2398E-06 | .9189E-08( 38) | .2669E-07( 11) | .1635E-03 | .3630E-03( 17) | .1049E-02( 5) |
| 25 | .1890E-05 | .6414E-07( 18) | .1863E-06( 5) | .1012E-01 | .1508E-01( 4) | .4359E-01( 13) |
| 26 | .2308E-03 | .7332E-05( 11) | .2130E-04( 3) | .5030E-01 | .1124E+00( 2) | .3249E+00( 5) |
| Σ= | .2350E-03 | .7907E-05( 0) | .2301E-04( 0) | .6130E-01 | .1288E+00( 0) | .3725E+00( 0) |

| | Pu-240 | | | Pu-241 | | |
|---|---|---|---|---|---|---|
| 1 | .6000E-08 | .1989E-05( 32) | .7867E-05(125) | .1400E-08 | .4663E-06( 74) | .1872E-05( 30) |
| 2 | .3300E-07 | .3830E-05( 33) | .1364E-04( 12) | .4300E-08 | .8863E-06( 76) | .3196E-05( 28) |
| 3 | .1140E-06 | .6307E-05( 38) | .2084E-04( 13) | .1100E-07 | .1486E-05( 9) | .4990E-05( 30) |
| 4 | .4310E-06 | .9180E-05( 42) | .2868E-04( 13) | .8400E-07 | .2440E-05( 11) | .7769E-05( 36) |
| 5 | .7970E-06 | .6863E-05( 29) | .2188E-04( 9) | .1180E-06 | .1919E-05( 8) | .5892E-05( 25) |
| 6 | .9650E-06 | .3511E-05( 13) | .1101E-04( 4) | .1450E-06 | .2292E-05( 8) | .6880E-05( 25) |
| 7 | .9963E-06 | .7027E-06( 24) | .2030E-05( 7) | .1580E-06 | .2373E-05( 8) | .7030E-05( 24) |
| 8 | .1669E-05 | .4506E-06( 16) | .1293E-05( 4) | .3270E-06 | .2916E-05( 10) | .8585E-05( 30) |
| 9 | .2800E-05 | .4825E-06( 16) | .1378E-05( 4) | .6160E-06 | .3514E-05( 11) | .1031E-04( 3) |
| 10 | .4012E-05 | .6705E-06( 23) | .1912E-05( 6) | .8370E-06 | .3961E-05( 13) | .1160E-04( 4) |
| 11 | .5174E-05 | .6307E-06( 25) | .1797E-05( 7) | .1183E-05 | .4291E-05( 15) | .1256E-04( 4) |
| 12 | .7165E-05 | .4964E-06( 21) | .1414E-05( 6) | .1296E-05 | .5674E-05( 19) | .1659E-04( 6) |
| 13 | .9841E-05 | .7387E-06( 41) | .2103E-05( 12) | .2415E-05 | .8065E-05( 28) | .2358E-04( 8) |
| 14 | .1518E-04 | .1362E-05( 10) | .3878E-05( 28) | .3810E-05 | .1156E-04( 4) | .3379E-04( 12) |
| 15 | .2449E-04 | .1214E-05( 29) | .3457E-05( 83) | .4650E-05 | .1514E-04( 6) | .4426E-04( 16) |

Appendix. Continuation of the Table 2

| | Pu-240 | | | Pu-241 | | |
|---|---|---|---|---|---|---|
| GROUP | NUMBER of CAPTURES | NUMBER of FISSIONS | NUMBER of SECONDARY NEUTRONS | NUMBER of CAPTURES | NUMBER of FISSIONS | NUMBER of SECONDARY NEUTRONS |
| 16 | .3965E-04 | .2762E-06( 81) | .7865E-06(230) | .9150E-05 | .2624E-04( 10) | .7673E-04( 29) |
| 17 | .1127E-03 | .5357E-06(131) | .1525E-05( 37) | .8520E-05 | .2945E-04( 11) | .8610E-04( 33) |
| 18 | .1857E-03 | .5807E-09( 3) | .1688E-08( 7) | .1125E-04 | .4416E-04( 16) | .1291E-03( 5) |
| 19 | .3030E-03 | .6113E-06(141) | .1777E-05( 41) | .1537E-04 | .7067E-04( 40) | .2081E-03( 12) |
| 20 | .1268E-03 | .9010E-06(185) | .2619E-05( 54) | .8280E-04 | .1530E-03( 11) | .4505E-03( 32) |
| 21 | .3647E-05 | .2300E-08( 9) | .6686E-08( 26) | .4200E-04 | .2578E-03( 11) | .7593E-03( 33) |
| 22 | .3434E-04 | .8442E-08( 36) | .2454E-07( 10) | .7620E-04 | .1148E-03( 8) | .3381E-03( 23) |
| 23 | .2011E-01 | .3983E-05( 26) | .1158E-04( 8) | .5600E-05 | .1060E-04( 4) | .3120E-04( 12) |
| 24 | .5351E-02 | .1063E-05( 7) | .3026E-05( 19) | .2827E-04 | .4680E-04( 21) | .1364E-03( 6) |
| 25 | .1665E-02 | .3408E-06( 9) | .9703E-06( 27) | .1433E-02 | .3102E-02( 9) | .9043E-02( 27) |
| 26 | .5303E-01 | .1109E-04( 2) | .3158E-04( 5) | .1844E-01 | .5243E-01( 8) | .1528E+00( 2) |
| Σ= | .8103E-01 | .5724E-04( 0) | .1771E-03( 0) | .2016E-01 | .5636E-01( 0) | .1643E+00( 0) |
| | **Pu-242** | | | **Am-241** | | |
| 1 | .0000E+00 | .3533E-05( 56) | .1374E-04( 22) | .4000E-10 | .4355E-08( 69) | .1947E-07( 31) |
| 2 | .5700E-07 | .6963E-05( 60) | .2451E-04( 21) | .1150E-09 | .8896E-08( 77) | .3585E-07( 31) |
| 3 | .2600E-06 | .1099E-04( 7) | .3626E-04( 22) | .3200E-09 | .1462E-07( 9) | .5454E-07( 33) |
| 4 | .7800E-06 | .1661E-04( 8) | .5149E-04( 24) | .1110E-08 | .2109E-07( 10) | .7444E-07( 34) |
| 5 | .1310E-05 | .1383E-04( 6) | .4150E-04( 18) | .2120E-08 | .1293E-07( 6) | .4382E-07( 19) |
| 6 | .2062E-05 | .4399E-05( 16) | .1289E-04( 5) | .6140E-08 | .4950E-08( 18) | .1639E-07( 6) |
| 7 | .2108E-05 | .7441E-06( 26) | .2150E-05( 7) | .8912E-08 | .7105E-09( 2) | .2316E-08( 8) |
| 8 | .3289E-05 | .3947E-06( 14) | .1133E-05( 4) | .1370E-07 | .6461E-09( 2) | .2087E-08( 7) |
| 9 | .5635E-05 | .2818E-06( 9) | .8058E-06( 26) | .1845E-07 | .3228E-09( 1) | .1040E-08( 3) |
| 10 | .6777E-05 | .2711E-06( 9) | .7725E-06( 26) | .2369E-07 | .3328E-09( 1) | .1072E-08( 4) |
| 11 | .8924E-05 | .1275E-06( 4) | .3633E-06( 13) | .2994E-07 | .5216E-09( 2) | .1674E-08( 6) |
| 12 | .1208E-04 | .1208E-06( 4) | .3442E-06( 12) | .4053E-07 | .7908E-09( 3) | .2538E-08( 9) |
| 13 | .1852E-04 | .0000E+00( 0) | .0000E+00( 0) | .5779E-07 | .1137E-08( 4) | .3650E-08( 13) |
| 14 | .3142E-04 | .0000E+00( 0) | .0000E+00( 0) | .8540E-07 | .1653E-08( 6) | .5306E-08( 18) |
| 15 | .4894E-04 | .0000E+00( 0) | .0000E+00( 0) | .1264E-06 | .2225E-08( 8) | .7143E-08( 26) |
| 16 | .9494E-04 | .0000E+00( 0) | .0000E+00( 0) | .1865E-06 | .3885E-08( 15) | .1247E-07( 5) |
| 17 | .1754E-03 | .0000E+00( 0) | .0000E+00( 0) | .2753E-06 | .5067E-08( 20) | .1627E-07( 6) |
| 18 | .3053E-03 | .3647E-06( 71) | .1005E-05( 20) | .3914E-06 | .6246E-08( 23) | .2005E-07( 7) |
| 19 | .4520E-04 | .9222E-09( 4) | .2541E-08( 12) | .5923E-06 | .9049E-08( 36) | .2905E-07( 11) |
| 20 | .1654E-04 | .4775E-09( 2) | .1316E-08( 5) | .6224E-06 | .1455E-07( 6) | .4670E-07( 18) |
| 21 | .6756E-05 | .1023E-08( 4) | .2819E-08( 12) | .9926E-06 | .2345E-07( 9) | .7528E-07( 29) |
| 22 | .8931E-02 | .7151E-06( 63) | .1971E-05( 17) | .1015E-05 | .1221E-07( 5) | .3918E-07( 15) |
| 23 | .1344E-03 | .1156E-07( 5) | .3186E-07( 14) | .4098E-05 | .4806E-07( 19) | .1543E-06( 6) |
| 24 | .6704E-04 | .0000E+00( 0) | .0000E+00( 0) | .6675E-05 | .6328E-07( 27) | .2031E-06( 9) |
| 25 | .1710E-03 | .0000E+00( 0) | .0000E+00( 0) | .3382E-04 | .4278E-06( 12) | .1373E-05( 4) |
| 26 | .7751E-02 | .0000E+00( 0) | .0000E+00( 0) | .2689E-03 | .2849E-05( 4) | .9147E-05( 13) |
| Σ= | .1784E-01 | .5936E-04( 0) | .1890E-03( 0) | .3180E-03 | .3538E-05( 0) | .1139E-04( 0) |
| | **Am-243** | | | **Cm-242** | | |
| 1 | .4000E-08 | .1565E-05( 25) | .7347E-05(117) | .0000E+00 | .1283E-07( 20) | .6264E-07(100) |
| 2 | .1100E-07 | .2714E-05( 23) | .1137E-04( 10) | .1000E-10 | .2560E-07( 22) | .1117E-06( 10) |
| 3 | .3200E-07 | .4031E-05( 24) | .1555E-04( 9) | .3000E-10 | .4048E-07( 24) | .1631E-06( 10) |
| 4 | .1040E-06 | .5981E-05( 28) | .2168E-04( 10) | .1000E-09 | .6167E-07( 28) | .2341E-06( 11) |
| 5 | .1780E-06 | .3734E-05( 16) | .1296E-04( 6) | .2800E-09 | .5302E-07( 23) | .1930E-06( 8) |

Appendix. Continuation of the Table 2

| | Am-243 | | | Cm-242 | | |
|---|---|---|---|---|---|---|
| GROUP | NUMBER of CAPTURES | NUMBER of FISSIONS | NUMBER of SECONDARY NEUTRONS | NUMBER of CAPTURES | NUMBER of FISSIONS | NUMBER of SECONDARY NEUTRONS |
| 6 | .4900E-06 | .6100E-06( 23) | .2061E-05( 8) | .1740E-08 | .4160E-07( 15) | .1476E-06( 5) |
| 7 | .8482E-06 | .8224E-07( 28) | .2734E-06( 9) | .4160E-08 | .1473E-07( 5) | .5148E-07( 18) |
| 8 | .1762E-05 | .4704E-07( 16) | .1551E-06( 5) | .6523E-08 | .7327E-08( 25) | .2540E-07( 9) |
| 9 | .3656E-05 | .5727E-07( 19) | .1880E-06( 6) | .1218E-07 | .7502E-08( 24) | .2591E-07( 8) |
| 10 | .5455E-05 | .5979E-07( 20) | .1959E-06( 7) | .2091E-07 | .8430E-08( 28) | .2906E-07( 10) |
| 11 | .6862E-05 | .7314E-07( 25) | .2394E-06( 8) | .3085E-07 | .9611E-08( 33) | .3309E-07( 12) |
| 12 | .1023E-04 | .5467E-07( 19) | .1788E-06( 6) | .4114E-07 | .1201E-07( 4) | .4133E-07( 14) |
| 13 | .1627E-04 | .1669E-07( 6) | .5459E-07( 19) | .5668E-07 | .1483E-07( 5) | .5104E-07( 18) |
| 14 | .2541E-04 | .5176E-08( 18) | .1693E-07( 6) | .8719E-07 | .1631E-07( 6) | .5609E-07( 19) |
| 15 | .3885E-04 | .1568E-08( 6) | .5127E-08( 19) | .1401E-06 | .2282E-07( 8) | .7848E-07( 29) |
| 16 | .5755E-04 | .3044E-09( 1) | .9954E-09( 4) | .2818E-06 | .3485E-07( 13) | .1199E-06( 5) |
| 17 | .9568E-04 | .0000E+00( 0) | .0000E+00( 0) | .2105E-06 | .2133E-07( 8) | .7336E-07( 28) |
| 18 | .1050E-03 | .0000E+00( 0) | .0000E+00( 0) | .6500E-06 | .3528E-07( 13) | .1213E-06( 5) |
| 19 | .1714E-03 | .0000E+00( 0) | .0000E+00( 0) | .7226E-06 | .7713E-07( 30) | .2653E-06( 10) |
| 20 | .3070E-03 | .0000E+00( 0) | .0000E+00( 0) | .1108E-05 | .5416E-07( 21) | .1863E-06( 7) |
| 21 | .4350E-03 | .0000E+00( 0) | .0000E+00( 0) | .6580E-08 | .3183E-08( 12) | .1095E-07( 4) |
| 22 | .2000E-03 | .0000E+00( 0) | .0000E+00( 0) | .1244E-07 | .5316E-08( 20) | .1829E-07( 7) |
| 23 | .3892E-02 | .0000E+00( 0) | .0000E+00( 0) | .2437E-07 | .8630E-08( 35) | .2969E-07( 12) |
| 24 | .2345E-03 | .0000E+00( 0) | .0000E+00( 0) | .5873E-07 | .1908E-07( 8) | .6563E-07( 26) |
| 25 | .2839E-03 | .0000E+00( 0) | .0000E+00( 0) | .2424E-06 | .6779E-07( 19) | .2332E-06( 6) |
| 26 | .9864E-02 | .0000E+00( 0) | .0000E+00( 0) | .1448E-04 | .2219E-05( 3) | .7634E-05( 11) |
| Σ= | .1575E-01 | .1903E-04( 0) | .7226E-04( 0) | .1819E-05 | .2895E-05( 0) | .1006E-04( 0) |
| | **Cm-243** | | | **Cm-244** | | |
| 1 | .3000E-12 | .2718E-09( 4) | .1300E-08( 21) | .5000E-08 | .4684E-05( 75) | .2276E-04( 36) |
| 2 | .7000E-12 | .6141E-09( 5) | .2643E-08( 23) | .2800E-07 | .9371E-05( 81) | .4086E-04( 35) |
| 3 | .1000E-11 | .1086E-08( 7) | .4331E-08( 26) | .1300E-06 | .1442E-04( 9) | .5809E-04( 35) |
| 4 | .4000E-11 | .1874E-08( 9) | .7062E-08( 33) | .5900E-06 | .2013E-04( 9) | .7669E-04( 35) |
| 5 | .6000E-11 | .1507E-08( 6) | .5457E-08( 23) | .1270E-05 | .1740E-04( 7) | .6368E-04( 27) |
| 6 | .1700E-10 | .1563E-08( 6) | .5521E-08( 20) | .2630E-05 | .8920E-05( 33) | .3247E-04( 12) |
| 7 | .3900E-10 | .1203E-08( 4) | .4187E-08( 14) | .3817E-05 | .1238E-05( 4) | .4345E-05( 15) |
| 8 | .9900E-10 | .1442E-08( 5) | .4983E-08( 17) | .5910E-05 | .5472E-06( 19) | .1910E-05( 7) |
| 9 | .1960E-09 | .1801E-08( 6) | .6198E-08( 20) | .1043E-04 | .7031E-06( 23) | .2440E-05( 8) |
| 10 | .2560E-09 | .1972E-08( 7) | .6776E-08( 23) | .1364E-04 | .7892E-06( 27) | .2739E-05( 9) |
| 11 | .2890E-09 | .2280E-08( 8) | .7827E-08( 27) | .1676E-04 | .1060E-05( 4) | .3669E-05( 13) |
| 12 | .5160E-09 | .3407E-08( 12) | .1169E-07( 4) | .1868E-04 | .1306E-05( 4) | .4519E-05( 15) |
| 13 | .8070E-09 | .5202E-08( 18) | .1785E-07( 6) | .2398E-04 | .1637E-05( 6) | .5665E-05( 20) |
| 14 | .1253E-08 | .7901E-08( 27) | .2710E-07( 9) | .3360E-04 | .2240E-05( 8) | .7750E-05( 27) |
| 15 | .1910E-08 | .1183E-07( 4) | .4056E-07( 15) | .6297E-04 | .3800E-05( 14) | .1315E-04( 5) |
| 16 | .2880E-08 | .1749E-07( 7) | .5999E-07( 23) | .1117E-03 | .5265E-05( 20) | .1822E-04( 7) |
| 17 | .4310E-08 | .2586E-07( 10) | .8868E-07( 34) | .8713E-04 | .5494E-05( 21) | .1901E-04( 7) |
| 18 | .6450E-08 | .3819E-07( 14) | .1310E-06( 5) | .1273E-03 | .6179E-05( 23) | .2138E-04( 8) |
| 19 | .8300E-08 | .3075E-07( 12) | .1055E-06( 4) | .1775E-03 | .1413E-04( 6) | .4889E-04( 19) |
| 20 | .1100E-07 | .7734E-07( 30) | .2653E-06( 10) | .2784E-03 | .1101E-04( 4) | .3809E-04( 15) |
| 21 | .1470E-07 | .1870E-06( 7) | .6414E-06( 25) | .5582E-02 | .9836E-04( 38) | .3403E-03( 13) |
| 22 | .5790E-07 | .3867E-06( 15) | .1326E-05( 5) | .2109E-04 | .6591E-06( 25) | .2280E-05( 9) |
| 23 | .2300E-07 | .2207E-06( 9) | .7570E-06( 31) | .1563E-04 | .8024E-06( 32) | .2776E-05( 11) |
| 24 | .1638E-07 | .7695E-07( 31) | .2639E-06( 11) | .2522E-04 | .1649E-05( 7) | .5704E-05( 23) |
| 25 | .5900E-07 | .2774E-06( 8) | .9514E-06( 26) | .8671E-04 | .6317E-05( 17) | .2186E-04( 6) |

Appendix. Continuation of the Table 2

| | Cm-243 | | | Cm-244 | | |
|---|---|---|---|---|---|---|
| GROUP | NUMBER of CAPTURES | NUMBER of FISSIONS | NUMBER of SECONDARY NEUTRONS | NUMBER of CAPTURES | NUMBER of FISSIONS | NUMBER of SECONDARY NEUTRONS |
| 26 | .3200E-05 | .1506E-04( 2) | .5165E-04( 8) | .4615E-02 | .5596E-05( 5) | .1244E-02( 2) |
| Σ= | .9420E-05 | .1644E-04( 0) | .5639E-04( 0) | .1132E-01 | .5977E-05( 0) | .2103E-02( 0) |

| | Cm-245 | | | Cm-246 | | |
|---|---|---|---|---|---|---|
| 1 | .8000E-10 | .3837E-07( 61) | .1784E-06( 28) | .0000E+00 | .2756E-06( 44) | .1513E-05( 24) |
| 2 | .1900E-09 | .8798E-07( 76) | .3739E-06( 32) | .1000E-09 | .5047E-06( 44) | .2443E-05( 21) |
| 3 | .4000E-09 | .1493E-06( 9) | .5971E-06( 36) | .1000E-08 | .1043E-05( 6) | .4611E-05( 28) |
| 4 | .1700E-08 | .2328E-06( 11) | .8869E-06( 41) | .4000E-08 | .1658E-05( 8) | .6832E-05( 31) |
| 5 | .3500E-08 | .1647E-06( 7) | .6062E-06( 26) | .1030E-07 | .9559E-06( 41) | .3747E-05( 16) |
| 6 | .8900E-08 | .2102E-06( 8) | .7588E-06( 28) | .5170E-07 | .3667E-06( 14) | .1394E-05( 5) |
| 7 | .1660E-07 | .2145E-06( 7) | .7658E-06( 26) | .7634E-07 | .5746E-07( 20) | .2143E-06( 7) |
| 8 | .2310E-07 | .2484E-06( 9) | .8820E-06( 31) | .1040E-06 | .2311E-07( 8) | .8527E-07( 30) |
| 9 | .3410E-07 | .2825E-06( 9) | .1000E-05( 3) | .2072E-06 | .2493E-07( 8) | .9175E-07( 30) |
| 10 | .5090E-07 | .2990E-06( 10) | .1055E-05( 4) | .3735E-06 | .3072E-07( 10) | .1128E-06( 4) |
| 11 | .8520E-07 | .3728E-06( 13) | .1316E-05( 5) | .5563E-06 | .4140E-07( 14) | .1515E-06( 5) |
| 12 | .9890E-07 | .3845E-06( 13) | .1357E-05( 5) | .7689E-06 | .5363E-07( 18) | .1963E-06( 7) |
| 13 | .9670E-07 | .5243E-06( 18) | .1851E-05( 7) | .1073E-05 | .6906E-07( 24) | .2528E-06( 9) |
| 14 | .1031E-06 | .7622E-06( 26) | .2690E-05( 9) | .1663E-05 | .1041E-06( 4) | .3810E-06( 13) |
| 15 | .1450E-06 | .1084E-05( 4) | .3827E-05( 14) | .2771E-05 | .1298E-06( 5) | .4749E-06( 17) |
| 16 | .2060E-06 | .1549E-05( 6) | .5467E-05( 21) | .4507E-05 | .2098E-06( 8) | .7677E-06( 29) |
| 17 | .2910E-06 | .2182E-05( 8) | .7704E-05( 30) | .2412E-05 | .2189E-06( 9) | .8011E-06( 31) |
| 18 | .4190E-06 | .3142E-05( 12) | .1109E-04( 4) | .1175E-04 | .3372E-06( 13) | .1234E-05( 5) |
| 19 | .1176E-05 | .5677E-05( 22) | .2004E-04( 8) | .8000E-08 | .1665E-06( 7) | .6096E-06( 24) |
| 20 | .6310E-06 | .3466E-05( 13) | .1223E-04( 5) | .7920E-05 | .2487E-06( 10) | .9103E-06( 35) |
| 21 | .2500E-05 | .1840E-04( 7) | .6496E-04( 25) | .6464E-06 | .1646E-06( 6) | .6024E-06( 23) |
| 22 | .1670E-05 | .1285E-04( 5) | .4536E-04( 17) | .5371E-04 | .5369E-05( 20) | .1965E-04( 7) |
| 23 | .2090E-05 | .1429E-04( 6) | .5045E-04( 20) | .2073E-06 | .1946E-07( 8) | .7122E-07( 29) |
| 24 | .1680E-05 | .1794E-04( 7) | .6334E-04( 25) | .2372E-06 | .2143E-07( 8) | .7842E-07( 31) |
| 25 | .8430E-05 | .5962E-04( 16) | .2104E-03( 6) | .7155E-06 | .6350E-07( 17) | .2324E-06( 6) |
| 26 | .1077E-02 | .6324E-02( 9) | .2232E-01( 3) | .3525E-04 | .3093E-05( 5) | .1132E-04( 2) |
| Σ= | .1097E-02 | .6468E-02( 0) | .2283E-01( 0) | .1250E-03 | .1525E-04( 0) | .5878E-04( 0) |

| | Cm-247 | | | Cm-248 | | |
|---|---|---|---|---|---|---|
| 1 | .6000E-11 | .8818E-08(140) | .4814E-07( 77) | .1000E-11 | .8071E-08(128) | .4455E-07( 71) |
| 2 | .3000E-10 | .1917E-07( 17) | .9222E-07( 79) | .0000E+00 | .1528E-07( 13) | .7331E-07( 63) |
| 3 | .6000E-10 | .3262E-07( 20) | .1435E-06( 9) | .2000E-10 | .3321E-07( 20) | .1437E-06( 9) |
| 4 | .3500E-09 | .4832E-07( 22) | .1981E-06( 9) | .9000E-10 | .5266E-07( 24) | .2104E-06( 10) |
| 5 | .7300E-09 | .3760E-07( 16) | .1466E-06( 6) | .3400E-09 | .2872E-07( 12) | .1085E-06( 5) |
| 6 | .1900E-08 | .4599E-07( 17) | .1739E-06( 6) | .1903E-08 | .9157E-08( 34) | .3336E-07( 12) |
| 7 | .3370E-08 | .4079E-07( 14) | .1513E-06( 5) | .2511E-08 | .1317E-08( 5) | .4696E-08( 16) |
| 8 | .4650E-08 | .4287E-07( 15) | .1573E-06( 5) | .3392E-08 | .5601E-09( 2) | .1976E-08( 7) |
| 9 | .6140E-08 | .4576E-07( 15) | .1675E-06( 5) | .6478E-08 | .8255E-09( 3) | .2897E-08( 9) |
| 10 | .1111E-07 | .4504E-07( 15) | .1644E-06( 6) | .1100E-07 | .1098E-08( 4) | .3841E-08( 13) |
| 11 | .1725E-07 | .4330E-07( 15) | .1576E-06( 5) | .1553E-07 | .1208E-08( 4) | .4222E-08( 15) |
| 12 | .1805E-07 | .3328E-07( 11) | .1212E-06( 4) | .2146E-07 | .1228E-08( 4) | .4289E-08( 15) |
| 13 | .1672E-07 | .2541E-07( 9) | .9250E-07( 33) | .2897E-07 | .1157E-08( 4) | .4040E-08( 14) |
| 14 | .2089E-07 | .2756E-07( 10) | .1003E-06( 3) | .3688E-07 | .1605E-08( 6) | .5601E-08( 19) |
| 15 | .2954E-07 | .3650E-07( 13) | .1329E-06( 5) | .4649E-07 | .2249E-08( 8) | .7850E-08( 29) |

Appendix. Continuation of the Table 2

| | Cm-247 | | | Cm-248 | | |
|---|---|---|---|---|---|---|
| GROUP | NUMBER of CAPTURES | NUMBER of FISSIONS | NUMBER of SECONDARY NEUTRONS | NUMBER of CAPTURES | NUMBER of FISSIONS | NUMBER of SECONDARY NEUTRONS |
| 16 | .4323E-07 | .5197E-07( 20) | .1892E-06( 7) | .8854E-07 | .5272E-08( 20) | .1840E-07( 7) |
| 17 | .6398E-07 | .7602E-07( 30) | .2767E-06( 11) | .2312E-07 | .1334E-07( 5) | .4655E-07( 18) |
| 18 | .2343E-06 | .3912E-06( 15) | .1424E-05( 5) | .5296E-06 | .8418E-07( 31) | .2938E-06( 11) |
| 19 | .2697E-06 | .1289E-06( 5) | .4691E-06( 18) | .2244E-05 | .1143E-07( 4) | .3990E-07( 16) |
| 20 | .1097E-06 | .7023E-06( 27) | .2556E-05( 10) | .5991E-08 | .1362E-09( 1) | .4752E-09( 2) |
| 21 | .9150E-06 | .2106E-05( 8) | .7667E-05( 29) | .2848E-05 | .1975E-07( 8) | .6894E-07( 26) |
| 22 | .2629E-05 | .5243E-05( 20) | .1908E-04( 7) | .8900E-08 | .4177E-09( 2) | .1458E-08( 6) |
| 23 | .1019E-04 | .1141E-04( 5) | .4155E-04( 17) | .7040E-08 | .6216E-09( 3) | .2170E-08( 9) |
| 24 | .1043E-05 | .1291E-05( 5) | .4701E-05( 19) | .1142E-07 | .1239E-08( 5) | .4325E-08( 17) |
| 25 | .1173E-05 | .1743E-05( 5) | .6344E-05( 17) | .3896E-07 | .4641E-08( 13) | .1620E-07( 4) |
| 26 | .4565E-04 | .7535E-04( 11) | .2743E-03( 4) | .2055E-05 | .2592E-06( 4) | .9047E-06( 13) |
| Σ= | .6247E-04 | .9903E-04( 0) | .3606E-03( 0) | .8035E-05 | .5586E-06( 0) | .2050E-05( 0) |

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