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ADS's BASED ON THE 660 MeV PROTON PHASOTRON OF **JINR** FOR RESEARCH ON UTILIZATION OF PLUTONIUM

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1.Introduction

Guarantees for safe exploitation of atomic energetic plants, necessity of storing of radioactive waste and economically profitable utilization of plutonium accumulated, a danger of propagation of nuclear weapons - all these cause to turn to a much more safe trend in nuclear power engineering using accelerator driven electronuclear systems (ADSs). with proton Several types of such set-ups have been proposed and are designed now (see [1-3].where one can find out more detail bibliography). All these projects demand accelerators beam intensity around 5 - 20 μA. However, now there is no need to wait for a construction on large ADSs with high-current accelerators which is a serious technical problem. In order to study the possibilities of the new trend, the available accelerators may be used which allow one to create experimental ADSs with a neutron multiplication coefficient of K_{eff} < (0.92 - 0.95) and a heat power of several tens of kW. This would be sufficient for testing the basic ideas of electronuclear technology and for obtaining the data which will make the designing of large ADSs easy and more reliable. The use of Plutonium allows one making ADS more compact and simultaneous research on possibilities of safe utilization of this element.

2. Parameters of ADS with metallic plutonium

At JINR an ADS has been designed on the basis of the available 660-MeV proton phasotron and the plutonium zone of the IBR-30 reactor which is expected to be disassembled after start up of a new reactor IREN [4,5]. Table I gives estimated values of total neutron yield N and thermal power Q (without the power gone with γ-quanta) of such an ADS for various values of K_{eff} in case of using the full current of the JINR phasotron J=3.2 μA

Table I
Parameters of ADS with metallic plutonium

K_{eff}	N, 10^{15}	Q, kW
0.94	4.57	41.6
0.96	6.18	70.7
0.98	13.1	113

The data are related to the set-up designed in the form of a cylinder with a central tungsten target of a diameter 3.6 cm, a plutonium blanket of a size of R x L=14 x 7.2 cm, density 8 g/cm^3 and a steel cover of size 2 4 cm. The blanket is surrounded with a 10 cm tungsten reflector.

We see that in order to obtain a power of about 10 kW, that can be removed with a simple air cooling and at the same time allowing one sufficiently precise experimental research at quite safe values of $K_{eff} < 0.95$, we can restrict ourselves with a quarter intensity of the accelerated proton beam. In future, after upgrading, the set-up would be used for studding of ADS with water or metallic cooling.

Unfortunately, the difficulties related to transferring the radioactive components of the IBR-30 core and prolongation of its exploitation in connection with a delay of start up of the reactor IREN have made us consider variants of ADS based on the commercially available uranium - plutonium fuel MOX (25\%PuO2+75% natural UO2 with the density of 8.64 g/cm^3) and constructive components of the core of the reactors of a BN-600 type.

3. Parameters of ADS with MOX fuel

Fig. 1 shows a principal scheme of such an ADS with the use of a lead target and a beryllium reflector allowing one, due to reactions (n,nn'), to reduce the required MOX amount [6,7]. The core with a hexahedral cross-section is formed of standard fuel cassettes used in BN-600 reactors. Each of them contains 127 rods with MOX fuel. Besides, to fill in the emptiness in the hexahedral core, six diamond-shaped segments of the standard cassettes with 42 fuel rods (Fig.2) are used.

Inside the core three experimental channels are provided, each of them replacing 21 fuel rod. In order to increase K_{eff}, the cassettes are used without external steel cover which only remains at the external edges of the core. The ratio of the weight of fuel MOX• and the weight of iron in the thermal release rod is MOX : Fe= 1 : 0.107. In this case 0.2 cm steel wall of the fuel rods in the cassettes and the arming steel springs wrapping up these rods are taken into account. The total weight of the fuel is 114.5 kg (for a blanket of 50 cm length).

Concrete is used as radiation shielding. We assume that the installation will be placed in a separate room provided with extra radiation shielding of the environment. On the opposite side of the proton beam input the set-up is supplied with screening gamma-radiation 30 cm lead layers. A part of measuring devices will be placed behind it.

The properties of the ADS designed were simulated by Monte Carlo method on the basis of the program package CASCADE [7,8] developed at JINR. To describe the behavior of neutrons with the energies $E < 10.5$ MeV a 26-group system of reactor constants [9] was used. Calculation of K_{eff} was performed with the help of the MCNP computer program since comparative computations have shown that the use of constants of the library [9] for beryllium lessens the value of K_{eff}.

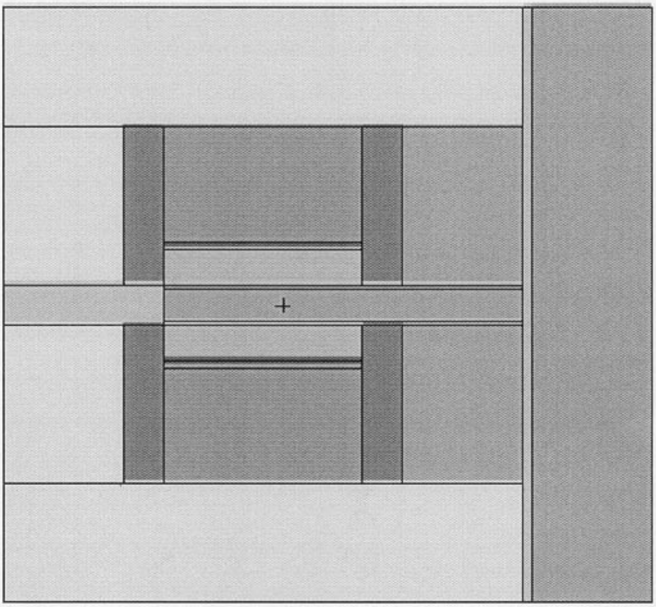


Fig. 1. cm. Longitudinal section of ADS. Central lead target in a thin steel cover is surrounded by a channel for air cooling. Core with cassettes of MOX fuel is separated by the steel cover. The core of 50 cm length is surrounded with a beryllium reflector and an external layer of concrete. Proton beam enters the target center. On the opposite end-wall there are two leaden layers of 30 cm width to take-in gamma irradiation. The total length of the installation is 160

To simplify the computations, the hexahedral core has been approximated with two homogeneous in their contents concentric cylindrical zones with internal radius (the average of the radii of the inscribed and described circles of the fuel cassette) 4.86 cm and external radii 13.9 and 15.9 cm (radius of inscribed and described circles 6-hedral core). These, the internal and peripheral, zones have 940 and 113 fuel rods. The ratio of MOX and iron concentration in the internal zone is similar to that in the fuel rod. In the peripheral zone including a 2 mm steel cover of the blanket and part of the beryllium screen, the ratio MOX : Fe : Be =1 : 0.66 : 1.01 (the amount of beryllium was determined by a difference of a volume of the hexahedron core and a total volume of two approximating zones).

The calculations have taken into account that the end-walls of the core have steel strengthening of the fuel rods and a reflecting 10 cm beryllium with a weight ratio of Fe : Be=1 : 0.69 filling in the gaps

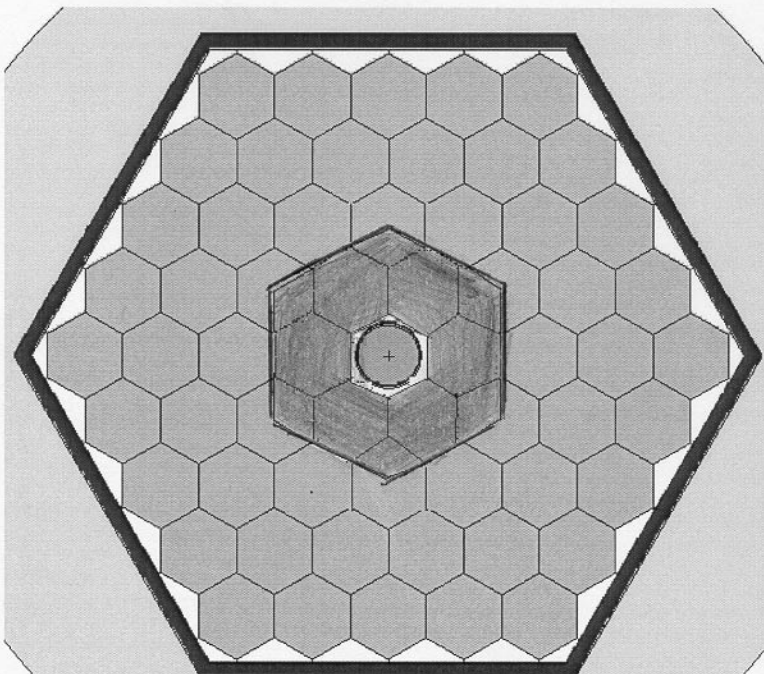
Table II presents estimated characteristics of ADS for several widths of the beryllium reflector L. All the data are presented again for 3.2 μA of the proton current with energy 660 MeV

Table II
Parameters of ADS with MOX fuel

L, cm	10	20	30	40
N, 10^{15}	0.966	1.05	1.07	1.08
Q, kW	11.7	15.4	15.5	15.6
K_{eff}	0.931	0.940	0.948	0.952

Like in the case of metallic plutonium, MOX fuel provides a way to get a thermal power of 10 - 15 kW in safe sub-critical conditions with a multiplication coefficient essentially less than unity. This conclusion are not canceled by the fact that the data of the Table II are related only to isotope ^{239}Pu while the commercial MOX fuel usually contains about 3% of isotope ^{240}Pu which lowers Keff by several hundredths and influences noticeably the value of Q. Even in this case the energy production remains within a ten of kW.

Fig. 2. Cross section of ADS. Cylindrical leaden target of 8 cm diameter inside the hexahedral core with the sides of 4.86 and 15.9 cm of length. Steel cover of the target and internal cover of the core are of 0.1 cm in width. External steel cover of the core - 0.2 cm. The width of the concrete shielding - 30 cm. The width of the beryllium reflector varies within 10 - 40 cm.



Heat production would be increased, if we would leave standard fuel cassettes and turn to a assembly free filled by the fuel rods, however, with the same distance between them as in the above considered ADS. This way a hexahedral core would be assembled, with the length of sides of 17,7 cm and containing 1398 rods. The multiplication coefficient increases by 0.015 approximately, and the heat release - by more than 20%. The MOX weight is 160.5 kg in this case.

As one of the possibilities, an ADS with two layers of standard fuel cassettes has been investigated. To construct a symmetrical hexahedral blanket, 18 full cassettes and their 12 halves are required in this case with a total weight of MOX fuel of 358.5 kg. With a 20 cm width of the beryllium reflector K_{eff}=0.96. A heat release in such a system Q=51.1 kW for the urrent 3.2 μA, neutron yield N= 3.1 10^{15}.

4. Conclusions

Our calculations show that existing accelerators with rather low intensities can be used for construction of experimental and relatively cheap ADSs with a heat power up to several tens of kW. The costs of the above considered one or two layer of standard fuel cassettes have been estimated as a million USD.

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Барашенков В.С., Полянски А., Пузынин И.В. E2-2000-131
Электроядерные системы на основе 660 МэВ фазотрона ОИЯИ для изучения утилизации плутония

Действующий в ОИЯИ 660 МэВ фазотрон с током протонного пучка 3,2 микроА позволяет создать безопасную электроядерную систему (ADS) с коэффициентом мультипликации нейтронов $K_{eff} < 0{,}95$ и тепловой мощностью 10–30 КвТ, вполне достаточной для экспериментального изучения электроядерной технологии. Подобная простая и дешевая установка позволит проверить базисные идеи широко обсуждаемого в настоящее время нового метода производства энергии и предоставит информацию, необходимую для проектирования более мощных промышленных ADS. Рассмотрены два типа подкритических ADS: с оружейным металлическим плутонием и со стандартным топливом MOX (25 %-ного плутония). Использование бериллиевого рефлектора позволяет значительно снизить количество необходимого топлива.

Работа выполнена в Лаборатории вычислительной техники и автоматизации ОИЯИ.

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Barashenkov V.S., Polanski A., Puzynin I.V. E2-2000-131
ADS's Based on the 660 MeV Proton Phasotron of JINR for Research on Utilization of Plutonium

The operating in JINR (Dubna) 660 MeV phasotron with the proton beam intensity of 3.2 μA provides a way for building a safe ADS with the coefficient of neutron multiplication $K_{eff} < 0.95$ and the heat power of 10–30 kW which is sufficient for experimental research on electronuclear technology. Such a simple and cheap set-up allows one to check up the basic ideas of the widely discussed new method of energy production and provides information which is important for designers of more powerful industrial ADSs. Two types of subcritical assemblies are considered: with weapon grade metallic plutonium rods and with standard MOX fuel rods (25 % PuO_2 + 75 % natural UO_2). A reflector with ^9Be allows one to decrease significantly the used amount of fuel.

The investigation has been performed at the Laboratory of Computing Techniques and Automation, JINR.

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