YALINA Subcritical Facility

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YALINA subcritical facility was constructed to study the physics of Accelerator Driven Systems (ADS). Similar facilities are under consideration around the world with the main aim of producing power and transmuting radioactive waste. The proposed systems use high-energy proton beams for producing spallation neutrons to drive subcritical assemblies. YALINA facility is a zero power simulation of ADS consisting of two subcritical assemblies driven by a high intensity neutron source. The first facility, YALINA-Thermal, is thermal assembly using low enriched uranium fuel, polyethylene moderator, and graphite reflector. The second is the YALINA-Booster assembly consisting of fast and thermal zones with one directional coupling from the fast to the thermal zone. The fast zone is fueled with high-enriched uranium loaded in lead material. The thermal zone is fueled with low enriched uranium loaded in polyethylene moderator. The neutronics performance, kinetics parameters, transmutation reaction rates of some long-lived nuclei have been studied at these facilities. The experimental methods developed for use in these systems are experimentally validated. The YALINA research program is focused on studying the usage of different fuel enrichments and core configurations without changing the subcritical assembly performance. The YALINA facility is described in this paper.

I. Introduction

Accelerator Driven Systems (ADS) are currently under consideration around the world for power production and transmutation of radioactive waste [1-3]. They utilize high-energy proton beams for producing spallation neutrons, which require high current accelerators [4-5]. It has been already demonstrated, both theoretically and experimentally [5, 6], that it is possible to investigate the ADS neutronics by using high intensity neutron sources such as a ^{252}Cf source or a deuteron accelerator using deuteron or tritium targets.

The subcritical facility YALINA was constructed at the Joint Institute for Power and Nuclear Research - Sosny, National Academy of Sciences of Belarus to study the neutronics of Accelerator Driven Systems [7, 8]. It consists of two subcritical assemblies, a neutron generator, and experimental equipment. This paper presents the YALINA-Thermal and YALINA-Booster assemblies

II. YALINA-Thermal

The YALINA-Thermal assembly was put into operation in the year 2000 and it has $k_{eff} < 0.98$ under any operating conditions for safety consideration. The external neutron source is a ^{252}Cf neutron source or accelerated deuterons colliding with a deuterium or tritium target for neutron production. A general view and cross section of the assembly are shown in Figures 1 and 2, respectively. The assembly consists of 20 polyethylene subassemblies that have twelve blocks each arranged axially. The block dimensions are 80×80×48 mm. The polyethylene material density is 0.923 g/cm3. Each subassembly has 16 holes for loading the EK-10 uranium dioxide fuel rods. The holes are arranged in square lattice with 20 mm spacing, which is found to be the optimum configuration for neutron multiplications using the EK-10 fuel with polyethylene moderator in a square lattice. Three experimental channels, EC1, EC2, and EC3 are embedded in the fuel zone. The experimental channel EC4 is located inside the lead target zone. The fuel zone is surrounded in the radial direction by a graphite reflector. There are two axial experimental channels, EC5 and EC6 and one radial experimental channel, EC7 in the graphite reflector. A borated polyethylene blocks are used on the front section of the fuel zone and organic glass sheet is used on the backside of the assembly and the front section of the graphite reflector. The main parameters of the YALINA-Thermal subcritical assembly are given in Table 1.

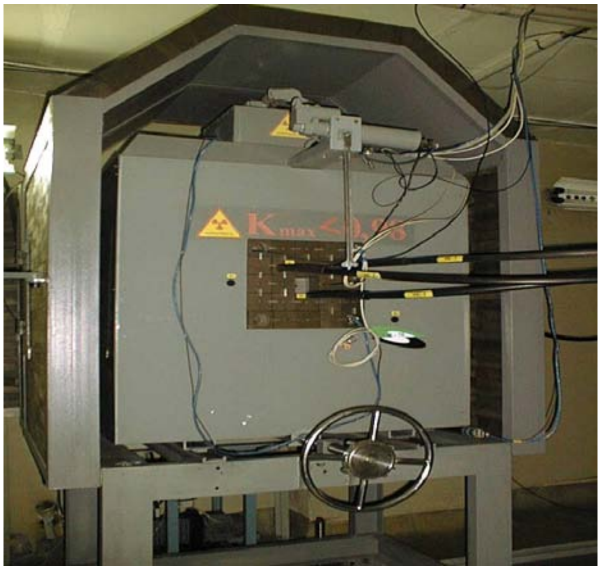

Figure 1. General view of YALINA -Thermal assembly

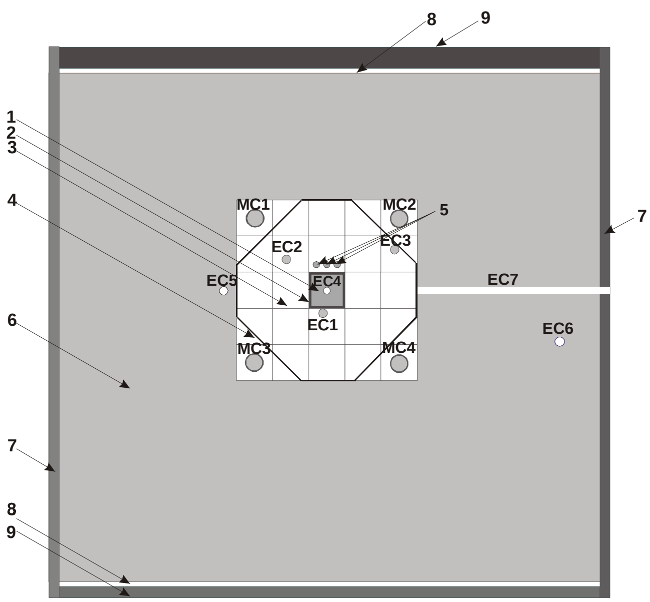

Figure 2. X-Y cross-section of the YALINA-Thermal assembly, (65 mm <Z<280 mm)
1 - lead target, 2 - stainless steel frame, 3 - core, 4 - outer boundary of fuel loading, 5 - holes for location of B_4C rods, 6 - graphite reflector, 7 - organic glass sheet, 8 -cadmium layer, 9 - upper and bottom plates made of steel with low content of carbon, EC1-EC3 - experimental channels in the core, EC4 - experimental channel in target hole, MC1-MC4 - measuring channels, EC7 radial, and EC8 axial experimental channels in reflector.

TABLE1. YALINA-Thermal Assembly Main Parameters

Target Zone	
Material	Pb
Dimensions, mm	78×78×645
Density, g/cm^3	11.34
Fuel Zone	
Moderator block dimensions, mm	80×80×576
Maximum number of fuel rods per block	16
Fuel rod pitch, mm	20
Fuel material	UO_2+MgO
Fuel material density, g/cm^3	5.042
Fuel enrichment	10%
Fuel material composition, weight fractions: - ^{235}U - ^{238}U - ^{16}O - Mg	 0.079691 0.728557 0.142022 0.049730
Clad outer diameter, mm	10
Clad thickness, mm	1.5
Clad material	Aluminum alloy
Moderator	Polyethylene
Moderator density, g/cm^3	0.923
Hole diameter, mm	11
Number of experimental channels	4
EC1-EC3 Experimental channels diameter, mm	24
EC4 Experimental channel diameter, mm	11
Graphite Radial Reflector	
Density, g/cm^3	1.67
Thickness, mm	310, 400, 526
Reflector Experimental channels	
Experimental channels: - Axial channels - axial channel diameter, mm - Radial channel - radial channel diameter, mm	 3 24 1 24
Organic glass sheet	
Organic glass density, g/cm^3	1.19
Organic glass thickness, mm	4
Axial Shielding	
Material	Borated polyethylene
Density, g/cm^3	0.983

III. YALINA-Booster

The YALINA-Booster subcritical assembly has been designed to have both fast and thermal neutron spectra within a single configuration. It has been operational since 2005 with $k_{eff} < 0.98$. A general view and cross section of the assembly are shown in Figures 3 and 4, respectively. It is driven by an external ^{252}Cf neutron source or accelerated deuterons colliding with a deuterium or tritium target for neutron production. The assembly has a central fast neutron zone surrounded by a thermal neutron zone. The fast zone (the booster zone) multiplies the external neutrons through the fission reactions of highly enriched uranium (HEU) and (n,xn) reactions of lead. The neutrons leak to the surrounding thermal zone. Between the two zones, there is an interface, called "valve" zone, consisting of two layers. The inner layer has metallic natural uranium rods and the outer layer has boron carbide rods that absorb thermal neutrons. Such "valve" zone enables fast neutrons to penetrate into the thermal zone and prevents thermal neutrons from entering the fast (booster) zone from the thermal zone. The whole assembly is surrounded by a graphite reflector and borated polyethylene wall in the radial and axial directions, respectively. The radial reflector and the backside of the thermal zone are covered by organic glass sheet. There are four axial experimental channels (EC1B, EC2B, EC3B, and EC4B) in the fast zone, three axial experimental channels in the thermal zone (EC5T, EC6T, and EC7T), two axial experimental channels in the reflector (EC8R, EC9R), and one radial experimental channel in the reflector zone (EC10R). The experimental channels are shown in Figures 3 and 4.

IV. **Experimental equipment**

The YALINA experimental equipment consists of several detectors including a ^{3}He-detector, fission chambers, and data acquisition system. The ^{3}He detector is fabricated by CANBERRA, a model number 05NHI/IK. The filling gas consists of 8 bar ^{3}He and 2 bar Kr. The gas chamber length and diameter are 10 and 9 mm, respectively. The wall thickness of the gas chamber is 0.5 mm and it is made of Ni (73%) and Cu (27%) alloy. The fission chambers have different sizes and sensitivities and used in the experimental measurements. The main parameters of the fission chambers are given in Table 2.

The YALINA Experimental program is developed to study the neutronics aspects of accelerator driven systems including kinetics characteristics, subcriticality monitoring methods, neutron spectra, neutron flux spatial distribution as a function of time, transmutation reaction rates of different isotopes. Some analytical and experimental results from the YALINA facility will be presented in accompanied papers during this conference.

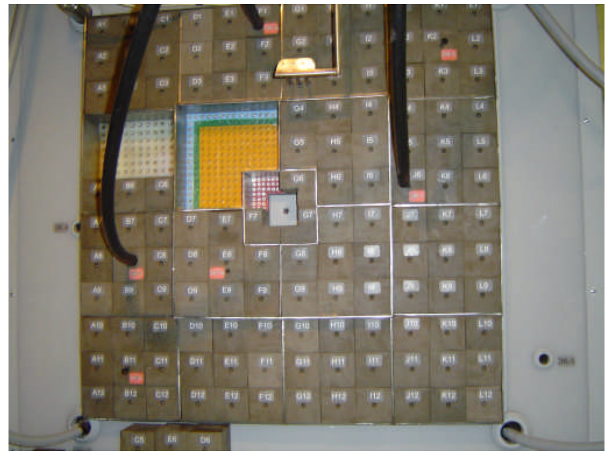

Figure 3.General view of YALINA -Booster assembly

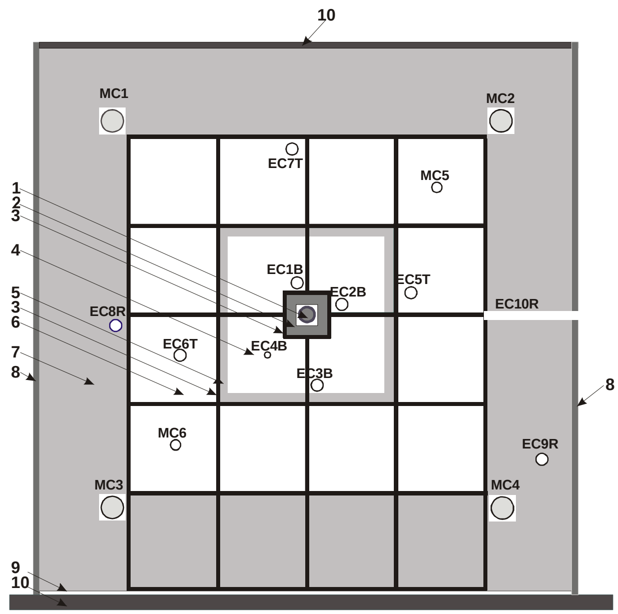

Figure 4. X-Y cross-sectional view of the YALINA-Booster assembly
1 - deuteron beam tube, 2 - inner fast (booster) zone with $U_{met.}$ of 90% enrichment in lead, 3 - stainless steel frame, 4 - outer fast (booster) zone with UO_2 of 36% enrichment in lead, 5 - thermal neutron absorber, $U_{met.(nat.)}$+B_4C, in lead, 6 - thermal zone with UO_2 of 10% enrichment in polyethylene, 7 - graphite reflector, 8 - organic glass sheet, 9 - Cd layer, 10 - steel with low content of carbon, EC1B - EC4B experimental channels in booster zone, EC5T - EC7T experimental channels in thermal zone, MC1 - MC4 measurement channels in reflector, MC5 - MC6 measurement channels in thermal zone.

In the frame work of the International Science and Technology Center (ISTC) Project number B-1341, the conversion of the YALINA-Booster to use Low Enriched

Uranium (LEU) is underway without changing the facility performance. The High Enriched Uranium (HEU) fuel zones with ^{235}U enrichment of 36% and 90% will be replaced by LEU fuel with ^{235}U enrichment of 21% in two steps. The following investigations have been started for the conversion project:

- Experimental and analytical studies to define the original subcritical facility performance with HEU fuel
- Develop new configurations with LEU fuel including
  - Changes the fast zone configuration
  - Optimize the thermal zone to maintain the original performance
- License the new configurations for the following changes
  - Replace the 90% enriched uranium fuel with 36% enriched UO_2
  - Replace the 36% enriched UO_2 with 21% enriched UO_2
- Changing the 90% enriched fuel with 36% UO_2 fuel reduces the subcriticality of the assembly. Table III shows k_{eff} as function of the number of the EK-10 fuel rods in the thermal zones when the 90% uranium fuel is replaced by 36% uranium fuel.

V. CONCLUSIONS

The YALINA subcritical facility has been constructed and operated at the Joint Institute for Power and Nuclear Research - Sosny, National Academy of Sciences of Belarus. It has been used successfully to study the physics of Accelerator Driven Systems. The current experimental program is concentrating on the conversion of the YALINA-Booster configuration to use low enriched uranium without changing its performance.

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TABLE 2. Main parameters of fission chambers CNT-5, CNT-31, and CNT-8

Fission chamber type	Diameter, mm	Detector length, mm	Sensitive detector length, mm	Isotope	Sensitive area, cm^2	Sensitive layer, (mg/cm^2)	Filling gas
CNT-5	7	70	5	^{235}U	1	1	98%Ar 2%N_2
CNT-31	32	235	200	^{235}U	500	5	98%Ar 2%N_2
CNT-8	7	70	5	^{238}U (99.275%) and ^{235}U (0.72%)	2	5	98%Ar 2%N_2

TABLE 3. k_{eff} as function of the number of EK-10 fuel rods in the thermal zone

Booster zone Enrichment	Number of EK-10 fuel rods			
	1141	1165	1177	1209
90% ^{235}U (132 rods) and 36% ^{235}U (563 rods)	0.97956±9	0.98418±7	0.98634±9	0.99218±7
36% ^{235}U (695 rods)	0.96635±8	0.97116±9	0.97356±9	0.98016±9

ACKNOWLEDGMENTS

This project is supported by the International Science and Technology Center (ISTC) and the U.S. Department of Energy, Office of Global Nuclear Material Threat Reduction (NA213), National Nuclear Security Administration.

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