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Results of the Hydraulic Testing of the New Low Enriched Core of Tajoura Research Reactor

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ABSTRACT

Due to the growing international concerns about the need to convert research reactors cores to the use of low enriched uranium fuel, Tajoura reactor core was converted from the use of the high enriched uranium fuel (HEU) to the use of low enriched uranium fuel (LEU). For this purpose, a conversion program had been put down (in 2006) which includes the recalculation of all safety related aspects, namely the neutronic and thermal hydraulic calculations. In this work the results of the hydraulic testing of the new core is provided. These parameters include the new flow rates for the new core, pressure drop, and negative pressure under the core. This task is performed experimentally. The procedure of these experiments is provided. The results of these experiments show that flow rate through the reactor core is less than that of the high enriched core, therefore it is essential to recalculate thermal hydraulic parameters of the reactor core to specify the normal values of the most important technological parameters and their operational limits. The comparison of these parameters between using the HEU and LEU fuel is provided.

INTRODUCTION

Tajoura Research Reactor is a pool type reactor. Light water is used as a moderator and a coolant. The reactor has been in operation since 1983. The reactor had been operated since that at a different levels of power using High Enriched Uranium fuel. The core consists of fuel assemblies made of concentric square fuel elements, The ИРТ-2M type 4-tube and 3-tube FA are used in the reactor. Each fuel element consists of a three layer tube, the medium layer of which (the meat) of 0.4mm thickness is made from uranium-aluminum alloy (80% enriched), and cladding of 0.8mm thickness from aluminum alloy. In the 4-tube FA except fuel elements there is a central displacement tube of 16mm diameter in place of which the experimental channel can be installed. The active reactor compact core size consists of 16 fuel assemblies, surrounded by removable beryllium units (20 units), with a lattice pitch of 71.5 mm; Stationary beryllium reflector surrounds the core. The reactor core cooling is accomplished by the water pumped through FA and reflector blocks by centrifugal pumps of the primary circuit. The cooling water is flowing down stream across the reactor core. At the reactor there is the system of technological monitoring and automation, which is providing signaling on exceeding by parameters of permissible limits and the reactor shut-down at the exceeding by parameters of safety limits (emergency settings).

Due to the growing international concerns about the use of this kind of fuel in research reactors, it has been decided to convert the reactor to the use of low enriched uranium fuel. the new fuel of the Tajoura reactor is of the IRT-4M type (Low Enrichment Uranium, 19.7 % of ^{235}U). It is an alloy (matrix) of aluminum and uranium-dioxide (UO_2–Al) with aluminum cladding. For this purpose, a conversion program has been put down which includes the recalculation of all safety related aspects, namely the neutronic and thermal hydraulic calculations. In this work the results of the hydraulic testing of the new core is provided. these tests are performed experimentally comprising the measurements of the new flow rates according to reactor core pressure drop and pressure drop under the core, where these parameters are operating the emergency protection system automatically, in case of the decrease of the water pressure drop at the reactor core under the normal value

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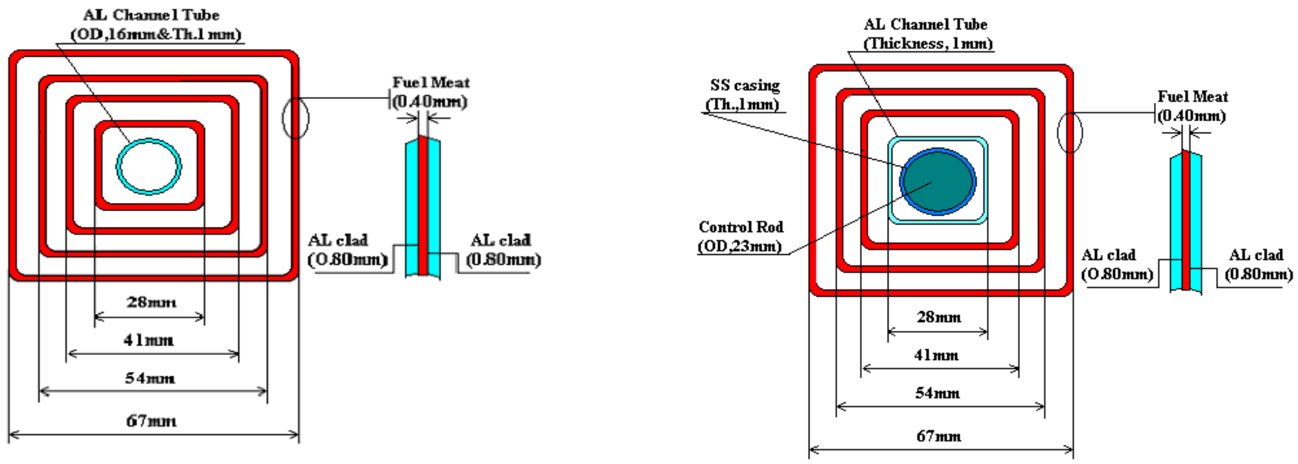
or the increase of the water pressure at the outlet of the reactor core as a result of switching off the primary circuit pumps. The hydraulic testing of the new core has been measured to establish the safety of the reactor and to put down the new operating limits. They are performed according to the written order given by the reactor chief engineer, and the procedures had been printed in steps. The results show that flow rate through the reactor core is limited to a certain value that is less than that of the high-enriched core.

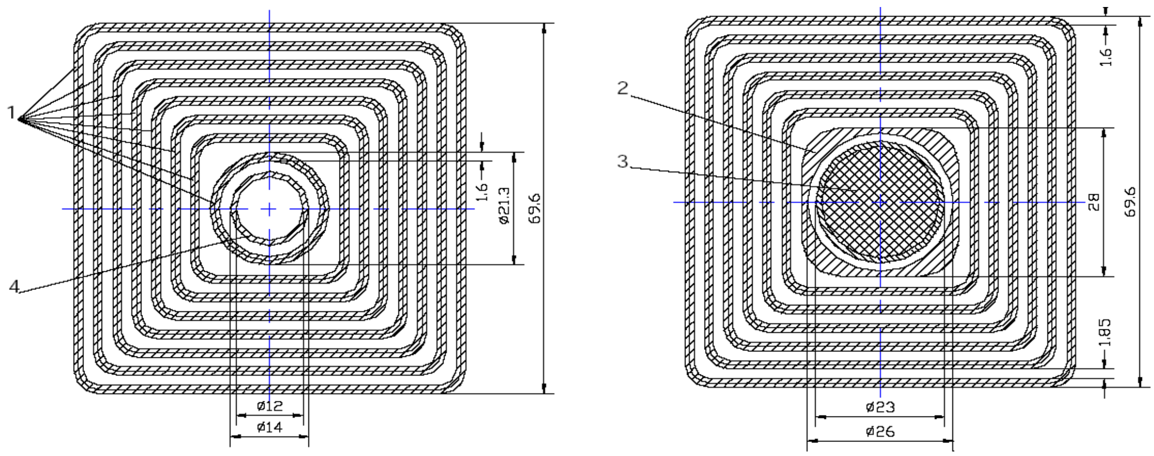
Reactor core configurations and fuel assemblies

The new core of Tajoura research reactor with LEU has a different geometry than the old high Enriched Uranium Fuel (HEU). The cross section of 3-tube and 4-tube IRT-2M type fuel assemblies used in HEU core of Tajoura Research Reactor is shown in Figure 1[1], where the cross section of 6-tube and 8-tube IRT-4M type fuel assemblies used in LEU core of Tajoura Research Reactor is shown in Figure 2 [2]. Figures 3, and 4 show the 16-fuel assembly (IRT-2M, and IRT-4M type) core configuration for the HEU fuel and the LEU fuel respectively. It was for the 10 MW reference core used for HEU, where this particular loading of the core with new fuel is for thermal hydraulic testing in which the new thermal parameters are measured such as pressure drop of reactor core and coolant flow rate which will vary with the new fuel.



4 Tube Fuel Assembly **3 Tube fuel Assembly**

Fig. (1): The IRT-2M type FA cross section



8 Tube Fuel Assembly **6 Tube fuel Assembly**

Fuel elements (plates)
2 – Channel of Control Rod
3 - Control Rod
4 – Central Displacement Tube

Fig. (2): The IRT-4M type FA cross section.

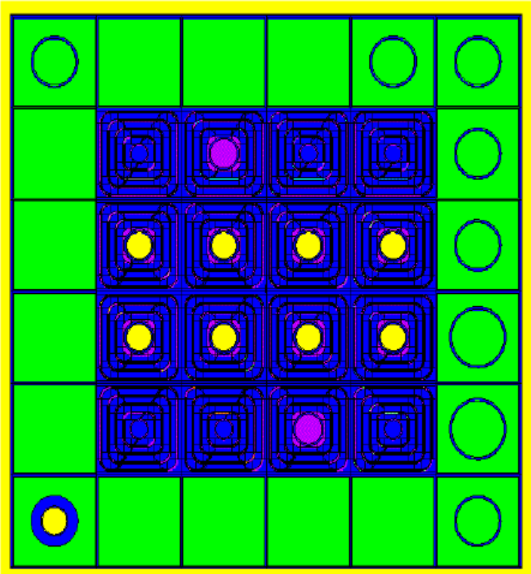


Fig. (3): HEU Core: Ten 3-tube and Six 4-tube IRT-2M Fuel Assemblies

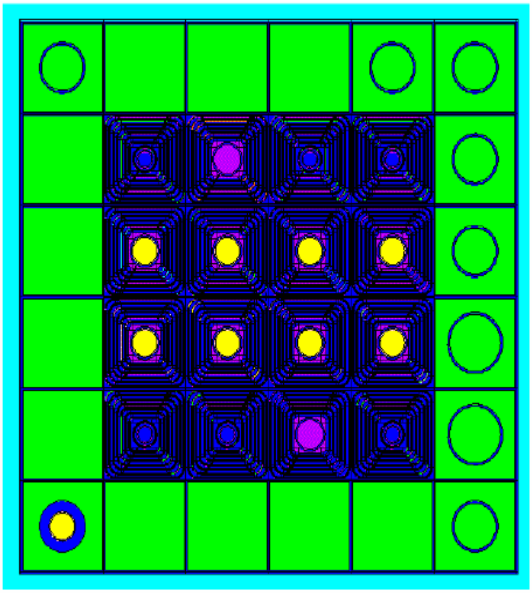


Fig. (4): LE Fuel Assemblies U Core: Ten 6-tube and IRT-4M Fuel Assemblies

Steps of Experiment

1- the program of the experiment was prepared and approved by Reactor chief engineer.
2- Calibration of instrumentation devices that measure the hydraulic parameters (such as flow rate, pressure drop under the core, pressure drop of the core).
3- The old high enriched core was loaded by 16 fuel assemblies (4 tube fuel assemblies and 3 tube fuel assemblies).
4- Special form was prepared for the purpose of data collection.
5- Secondary circuit was switched on
6- Switched on the hydro sealing pump and primary pumps respectively by steps, then get the reading of the pressure drop under the core and core pressure drop versus the flow rate which is increased each step.
7- the old fuel assembles is unloaded from the core
8- the reactor core was loaded with 16 fuel assemblies LEU. The hydraulic measurements had precisely repeated for the new configuration of the core with LEU.

RESULTS

Table (1): The results of experimental of measure the pressure drop under the core and core pressure drop versus cooling flow rates for the HEU fuel in TRR

Pump flow rate				pressure drop under the core	core pressure drop
Pump #1	Pump#2	Pump#3	Total		
350	0	0	350	0.752	0.035
450	0	0	450	0.740	0.052
550	0	0	550	0.720	0.078
630	0	0	630	0.70	0.098
625	350	0	975	0.592	0.21
622	450	0	1072	0.56	0.25
620	550	0	1170	0.52	0.29
618	630	0	1248	0.485	0.32
602	615	350	1567	0.30	0.5
598	612	450	1660	0.25	0.25
595	608	550	1753	0.2	0.595
590	602	630	1822	0.16	0.64
612	630	630	1872	0.125	0.67

Table (2): The results of experimental of measure the pressure drop under the core and core pressure drop versus cooling flow rates for the LEU fuel in TRR

Pump flow rate				pressure drop under the core	core pressure drop
Pump #1	Pump#2	Pump#3	Total		
250	0	0	250	0.74	0.04
350	0	0	350	0.715	0.07
450	0	0	450	0.69	0.1
448	0	250	698	0.6	0.21
445	0	350	795	0.54	0.27
443	0	450	893	0.47	0.332
415	250	418	1083	0.29	0.51
412	350	414	1176	0.215	0.585
410	450	412	1272	0.15	0.65
450	450	450	1350	0.1	0.695

DISSECTION

In reactor there are three pumps operating in parallel provide forced convection cooling of the core at 10 MW, each pump can provide 550 m^3/h coolant flow for the HEU fuel. At this power core pressure drop is normally 0.7 Kg_f/cm^2 and at the 0.5 Kg_f/cm^2 the reactor is will be shut down automatically where as at the power of less than 5MW the emergency protection limit is 0.2 Kg_f/cm^2, on the other hand the normal value of the pressure drop under the core is 0.1 Kg_f/cm^2 and the emergency protection limit is 0.6 Kg_f/cm^2

During the experiments a pump provides 630m^3/h which it is the maximum flow rate can it provided. Only a portion of this coolant flow goes through the fuel assemblies. As result of the new geometry of core of Tajoura research reactor with LEU where The width of water gap between fuel elements in FA is 1.85mm where as it's equal to 4.5mm in the HEU FA, this difference led to reduce the coolant flow rate for the high enriched core at the same measured pressure drop across the core. The results show that the total coolant flow rate through the fuel assemblies must be reduced to 1350m^3/h (maximum) in order to avoid entering air from the system into the primary coolant piping if the pressure drop under the core become less than 0.1 Kg_f/cm^2, therefore, velocities across the fuel element should be modified.

CONCLUSION

As a result of the conversion of the Tajoura reactor core to low enriched uranium fuel the new thermal hydraulic parameters are recorded for the new configuration, the flow rate must be reduced to maximum value of 1350m3/h ,core pressure drop is normally 0.2 Kg_f/cm^2 and at 0.5 Kg_f/cm^2 the reactor is will be shut down automatically and pressure drop under the core is normally 0.1 Kg_f/cm^2 and at 0.3 Kg_f/cm^2 the reactor is will be shut down automatically.

REFERENCES

[1] Russian document No. 30 on operation of the Tajoura nuclear reactor.

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