MLR REACTOR

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ABSTRACT

The Material Testing Loop Reactor (MLR) development was commenced in 1991 with the aim of updating and widening Russia's experimental base to validate the selected directions of further progress of nuclear power industry in Russia and to enhance its reliability and safety. The MLR reactor is the pool-type one. As coolant it applies light water and as side reflector beryllium. The direction of water circulation in the core is upward. The core comprises 30 FA arranged as hexagonal lattice with the 90-95 mm pitch. In the core sited are the central materials channel and six loop channels. The reflector included up to 11 loop channels. The reactor power - 100 MW. The average power dencity of the core is 0.4 MW/l, maximal - 1.0 MW/l. Maximum neutron flux density in the core (E>0.1 MeV) - $7{\bullet}10^{14}$ n/cm^{2}s, in the reflector (E<0.625 eV) - $5{\bullet}10^{14}$ n/cm^{2}s. In 1995, due to the lack of funding the MLR designing was suspended.

1. Introduction

In the former Soviet Union the 10 MW RPT reactor, started up in 1952 at the Atomic Energy Institute (now RRC "Kurchatov Institute"), modernized in 1958 with the increase of its power up to 20 MW, has ensured up to 1962 loop tests of fuel elements (FE) and fuel assemblies (FA) and diverse fuel and structural materials. The MR 20 MW materials testing multiloop reactor was commissioned in 1963 at the RRC "KI" (to replace the RPT reactor). It was modernized in 1967-1970 with the increase of its power up to 40 MW. The MR reactor and reactors, constructed at the RIAR (Dimitrovgrad): the SM-2 50 MW tank type reactor started up in 1961 and modernized in 1965 with the increase of its power up to 75 MW and in 1974 up to 100 MW, and the MIR 100 MW materials testing multiloop reactor started up in 1966, for the last 30 years were the basis of the experimental base for radiation testing of FE and materials in the frames of research programs for creating and development of nuclear power industry in Russia.

Due to ageing of the main experimental base in Russia the Ministry of Atomic energy and industry in 1990 has taken the decision on its updating and further progress. In connection with this decision in 1991, RRC "KI" and SSC-RF-IPPE developed Technical Requirements for the new 100 MW Materials Testing Loop Reactor (MLR) project design - using light water as moderator and coolant and beryllium as side reflector. The MLR construction at the existing IPPE site located near Obninsk was planned to be completed by the year 2000.

Based on these Technical Requirements, the Experimental and Design Bureau (OKBM) with the participation of RRC "KI" and SSC-RF-IPPE have first developed Technical Proposal to follow up in 1994 with the Preliminary Conceptual design of MLR. In 1995 due to the lack of funding the MLR designing was suspended.

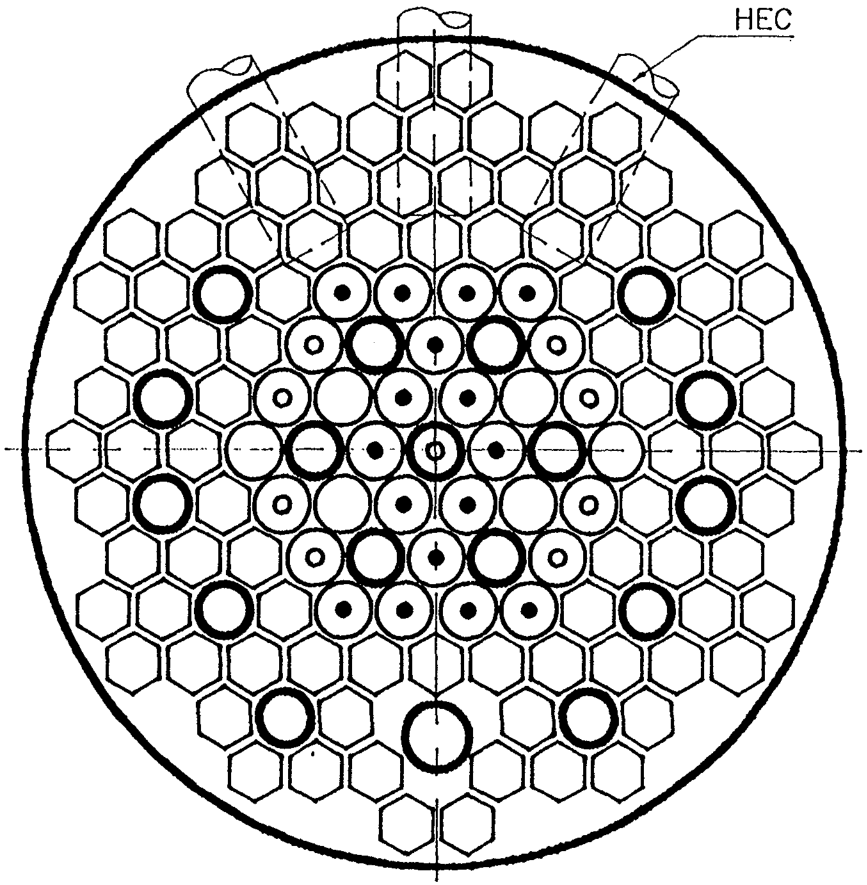
2. Purpose of the reactor

The MLR reactor will considerably widen the possiblities for radiation testing of fuel elements and materials with the aim of obtaining the necessary data to validate the selected directions of development of nuclear power industry in Russia after 2000 and to enhance its realibility and safety.
In particular, the MLR reactor will ensure:
- testing of FE and FA of light water cooled reactors (VVER);
- testing of FE and FA of perspective liquid metal cooled reactors;
- testing of assemblies with thermoionic conversion of thermal energy into the electric one;
- radiation testing of materials by fast neutron flux density equaling to $5 \bullet 10^{14} n/cm^2 s$ which mainly applies the aims of creating and updating the thermal reactors, as well as the study of fundamental aspects of radiation materials reseach;
- neutron radiography of FE, FA and other devices.

The MLR location near Obninsk having a number of Scientific Institutes which use radiation for their research will allow to widen the possibilities of its utilization by means of:
- creating the medical complex using fast neutron beem;
- arranging the production of various radioisotopes;
- creating the complex of radiation devices for activation analysis;
- creating the complex for testing nuclear instrumentation.

3. Core and reflector

As is shown in Fig.1, in the MLR reactor core the 30 FA are located in a hexagonal lattice with 90-95 mm pitch (depending on fuel element type in FA). The two possible types of FE are considered: tubular-type and pin-type ones. The use in the meats of both tubular and pin type FE of UO_2-Al was intended, which is widely applied now in most research, test and other Russian reactors. Aiuminium alloy is used as FE claddings. The cross-section of FA with FE of tubular type is shown in Fig.2. Final choice of FE type for the MLR reactor FA will be made after the study of their fabrication technology and the appropriate testing. The height of the reactor core is chosen to provide the conditions for the representability of FE and FA testing and is equal to 100 cm.
In some FA in the special channels the absorber rods of the control and rpotection system (shim-safety and regulating rods) are located. In part the regulating rods can also be located in the reflector. The use of burnable poisons incorporated in the FA components to compensate some part of reactivity margin is provided.
In the reactor`s peripheral reflector the beryllium blocks of hexagonal section are used. They are located with the same pitch as the FA. The beryllium blocks have the central holes up to 50 mm in diameter in which the ampoule channels or beryllium plugs are located. The special beryllium blocks will be used for location of horizontal channel`s parts comprising in the reactor vessel boundes. The thickness of the reflector is 40 cm. The reactor core and reflector are located in the open vessel, which provide free access for placing the loop channels and other experimental devices, as well as larger reactor`s adaptability while the experimental programs change. Main characteristics of the MLR reactor are presented in Table 1.



- Fuel Assembly
- Fuel Assembly with shim–safety rod
- Fuel Assembly with experimental channel (ampoule)
- Loop channel
- Central channel for material testing
- Beryllium block

HEC – Horizontal esperimental channel

Figure 1. Horizontal section of the MLR reactor core and reflector.

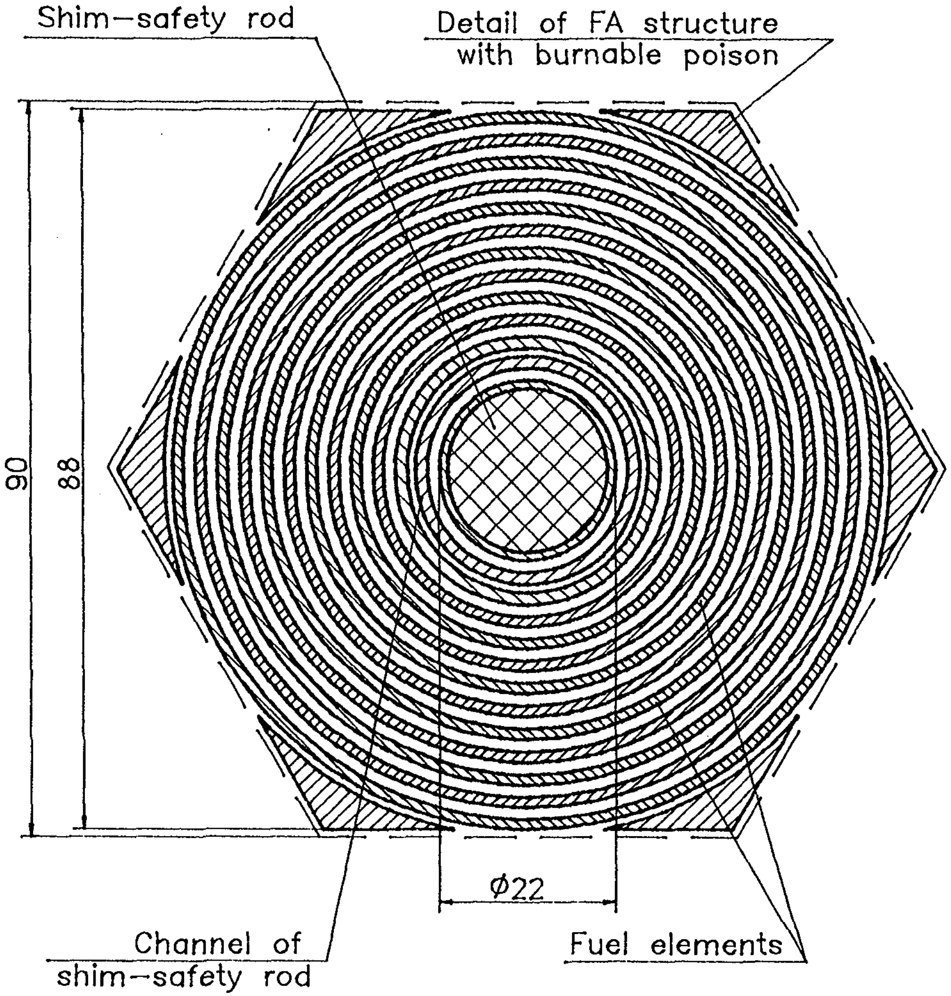


Figure 2. Cross–section of the FA with tubular–type fuel elements.

Table 1. Main Characteristics of the MLR reactor

1. Thermal power, MW	100
2. Fuel assemblies number in the core	30
3. Diameter of the core, cm	~60
4. Height of the core, cm	100
5. Uranium enrichment, %	19.75
6. Uranium-235 concentration in the core, g/l	~100
7. Power density in the core, kW/l:	
- average	400
- maximum	1000
8. Maximum density of neutron flux, m^{-2} s^{-1}:	
- fast (E>0.1 MeV) in the core	$7 \bullet 10^{18}$
- thermal (E<0.625 eV) in reflector	$5 \bullet 10^{18}$
9. Water pressure, MPa:	
- at the core inlet	0.7-0.9
- at the core outlet	0.2
10. Water velocity in FA gaps, m/s	10
11. Water temperature, °C:	
- at the core inlet	40
- at the core outlet	77
12. Maximum temperature of FE cladding, °C	100-110
13. Duration of the cycle, day	-28

4. Experimental devices

As is shown in Fig.1 in the MLR reactor core there are:
- the central channel for material testing 90 mm in dia;
- 6 loop channels 90 mm in dia;
- up to 8 ampoule channels within the FA 40-50 mm in dia.

In the reactor reflector up to 11 loop channels may be installed. The outside diameter of these channels can be different: 90-150 mm. Moreover into the beryllium blocks holes the ampoules with isotope targets or material samples 40-50 mm in diameter can be installed.

To provide the necessary conditions of a FE testing in the loop channels (pressure, temperature, flow rate of coolant and others) the 11 loop facilities are envisaged.

So far as at the SSC IPPE only one BR-10 reactor with beem tubes operates, run from 1958, at the MLR reactor the 3 beem tubes are envisaged:
- for neutron investigations;
- medical for neutron therapy;
- for neutron radiography.

5. Cooling system

In terms of traditional core cooling scheme, adopted for the majority of pool type research reactors, water in the core moves downward. In this case water velocities in the gaps between fuel elements of FA are no more then 5-6 m/s, since the pressure drop in the core must not exceed water column height in the pool above the core.

In the MLR reactor core the water moves upward. Within this scheme is no limitations specified above. So far, water velocities in the FA gaps can be drastically increased and, hence, the power density in the core can be raised. In order to prevent the FA rising at water movement in the core from

bottom upward in the MLR reactor the FA cooling scheme is adopted, which is analogous to the one used in the sodium cooled reactors. Under this scheme the FA fuel elements must be placed into the casing hermetically joint with the FA`s tail.
The MLR reactor vessel is installed at the pool bottom 12 m in depth and has the lower pressure chamber, in which the primary circuit water is fed under pressure of 0.7 MPa. The primary circuit water has 3 branches. In each branch there is the centrifugal pump providing the flow rate of 300 kg/s. From the pressure chamber the greater part of water moves upward cooling fuel elements of the FA. The part of the water gets into the pool penetrating through annular slitts between the FA tails and the pressure chamber bottom. Going out from the core water is mixed with the water coming from pool through upper open part of the reactor vessel and by discharge pipelines the water gets into the hold-up tank. From the hold-up tank the water gets into the heat exchangers between the primary and secondary (intermediate) circuits. From there the water is fed by the pumps into the pressure chamber of the reactor vessel. Descending from the pool into the reactor vessel the water flow locks-in the outlet of water from the reactor vessel into the pool.
When the primary circuit pumps are stopped the FA cooling in the core is fulfilled by natural circulation of the pool water through the FA. To provide this on the pressure pipelines there are the valves to be opened at the pumps stop.
Through the appropriate heat exchangers the heat from all of the loop facilities` circuits is also transfered to water of the secondary circuit. On its turn the heat of the secondary circuit is transfered to the third circuit, having the cooling towers for dissipating of heat into the atmosphere.

6. Conclusion

After the shut down in 1993 of the MR reactor at the RRC "KI" the Russia`s experimental base for radiation testing of a fuel elements and materials is provided mainly by:
- the SM-3 reactor (SM-2 after the modification of 1991) with sufficiently high fast neutrons fluxes densities;
- the MIR multiloop reactor, which, however, after the 30 years, operation, needs radical reconstruction to continue its further utilization;
- the IVV-2M pool type reactor 15 MW at Sverdlovsk branch of RDIPE started up in 1966.

The MLR reactor creation should not be considered as an alternative to other Russia`s reactors with loop ficilities. The MLR reactor, however, may essentialy renovate and widen the experimental base in central part of Russia in order to validate the selected directions of Russia`s nuclear power industry development after 2000.
The geografical closeness to the MLR reactor of the two leading Scientific Centers (IPPE and RRC "KI") and a number of R&D institutes creates the premises of its worth utilization, including the possibility of foreign countries` participation in works.

7. References

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