IMPLEMENTATION OF RESEARCH REACTOR AGEING MANAGEMENT PROGRAMME AT KINR WWR-M REACTOR

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Introduction

WWR-M research reactor at KINR was commissioned in 1960. In recent years, the reactor has faced problems of equipment ageing. The ageing of certain components can cause problems for safe operation and even accidents. In order to ensure timely detection of the ageing problems a number of measures are introduced and provided at the reactor. The ageing management programme has been developed and implemented at the reactor. Currently, the strength calculations of the reactor vessel and the core support grid are carrying out.

Kiev Institute for Nuclear Research VVR-M reactor is pool type light water research reactor. The physical start of the reactor was on February 12 1960. Basic reactor parameters are following:

- Thermal power - 10 MWt
- Maximum number of fuel elements - 262
- Fuel element type - VVR M2
- The number of the control rods - 9 (including 3 emergency rods)
- Maximum thermal neutron flux - 10^{14}
- Amount of the personnel - 60

The research reactor is a division of Nuclear Research Institute of National Academy of Science of Ukraine and is situated in Kiev. The reactor is in operation since 1960, and it is used as a radiation source for radioisotope production, irradiation of silicon mono crystals, material testing experiments, experiments in radiobiology and experiments of nuclear physics, neutron physics and applied physics.

The reactor has nine horizontal experimental channels, thermal column, 13 vertical isotope channels in the beryllium reflector. It is possible to install 10-12 vertical channels in the reactor core.

The reactor operational schedule is 5 days per week – about 100 hours per week. Since January 2011 the reactor has operated on LEU fuel because the core conversion has been accomplished.

The reactor has been realizing the step by step modernization of the basic structures and components important to safety. In particular, the primary loop heat exchangers, secondary loop pumps and valves have been replaced. Partial renovation of the reactor ventilation system has been provided. The reactor I&C system has also been replaced as well as most of the power supply system components (Fig 1.).

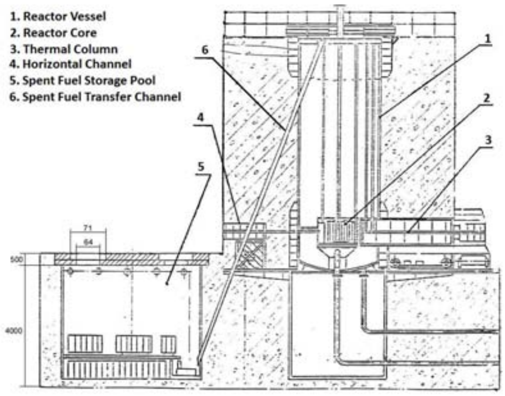

Fig 1. Reactor control room before and after refurbishment

Fig 2. WWR-M reactor elevation drawing

WWR-M reactor vessel

The main part of the reactor is reactor vessel (Fig 3.). The vessel has a cylindrical shape and is made of aluminium alloy; the thickness of the walls of the cylindrical part of the 16 mm, the diameter of the tank 2300 mm, height is 5340 mm. The bottom of the cylinder has the height 270 mm and 20mm thickness. Top of the housing ends by aluminium alloy cover 40 mm thickness. The tank up to the level of 5000mm filled with distilled water, which performs the function of the coolant, neutron moderator and biological protection. The volume of water in the vessel is 22m^3 (totally in the primary loop - 40m^3).

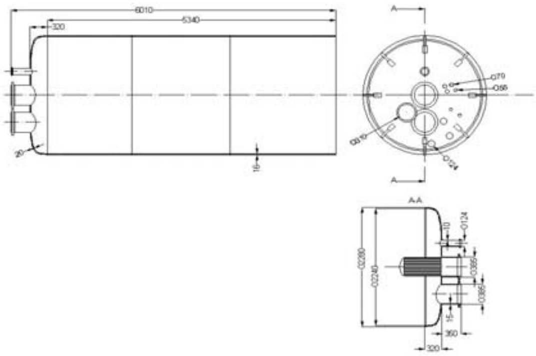

Fig 3. WWR-M reactor vessel.

The reactor core is situated at the bottom of the vessel. At the bottom of the cylindrical part of the core, on the upper edge of the conical part of the construction the support grid (Fig 4.) and guide grid are mounted. In the support grid (40 mm thickness and 760 mm diameter) there are 264 holes Ø 14 mm for fuel elements installation; horizontal holes are located at the middle of the core Ø 128mm (6 PCs) and Ø 88 mm (3pcs), which are "cups" for horizontal experimental channels.

9 "cups" for horizontal channels are welded in the reactor vessel and are the part of the vessel. The thermal column niche is welded to the reactor vessel also. Its diameter is 1150mm and its bottom is attached directly to the core.

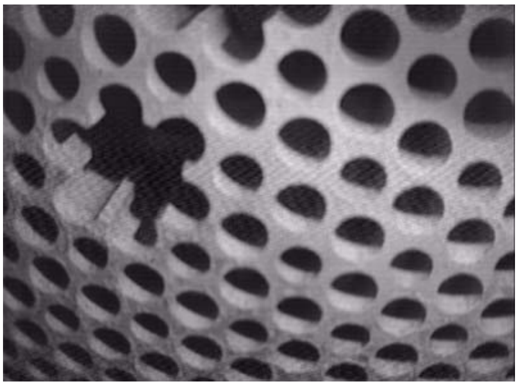

Fig 4. WWR-M reactor core support grid (view from below the core)

For reactor safe operation the following activities are performed:

- maintenance,
- control of the equipment technical condition,
- equipment cleaning and decontamination,
- timely replacement of aged components, where possible.

Control of the technical condition of the reactor vessel consists of:

- technical overview;
- periodic testing and control of reactor vessel metal;
- control of the metal condition by non destructive method;
- monitoring the reactor vessel corrosion process;
- control the integrity of the reactor vessel by water leakage detection method.

Taking into account the positive results of measurements, availability and adequacy of the relevant documentation, the reactor safety committee makes a decision on the suitability of the vessel to further safe operation, and makes the record in the appropriate section of the reactor vessel passport.

During the technical observation the results of the metal condition monitoring, results of mechanical strength test of the vessel metal samples and the results of the strength calculations of vessel and its components, including those parts that are in the stressed (in terms of neutron irradiation) fields of the core (the bottom of the horizontal experimental channels (9 PCs) and core support grid) are also taking into consideration.

WWR-M reactor primary loop.

The primary loop of the cooling system (Fig 5.) is designed for the circulation of the reactor coolant from the core to the heat exchanger and back. According to the safety criteria the primary loop cooling system assigned to the systems important to safety.

Schematic diagram of the pipelines and equipment of the primary cooling circuit of the reactor and associated auxiliary systems represented at Fig 5.

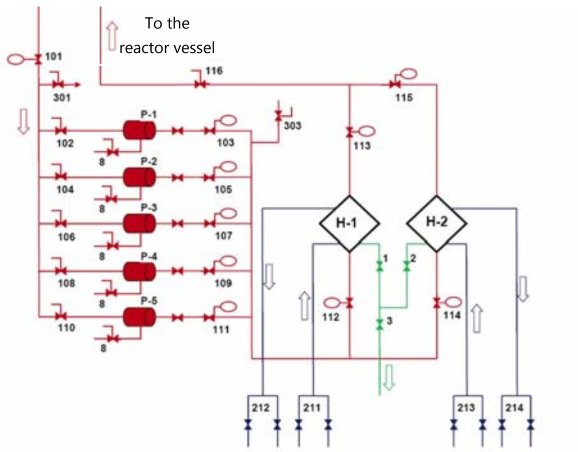

Fig 5. Schematic diagram of the pipelines and equipment of the primary cooling circuit of the reactor and associated auxiliary systems

- Primary loop pipelines (red)
- Secondary loop pipelines (blue)
- The pipelines of drainage system (green)
P1 - P5 - circulating pumps
H1, H2 - heat exchangers

The coolant (distillate water) from reactor vessel goes from top to bottom of the reactor core and beryllium reflector.

The reactor primary loop contains five pumps (three operational, two backup when the reactor operating on power 10MWt). Before each pump a valve and after it non-return valve and latch with electric drive, which allows disabling the pump for repair and maintenance are installed. Totally the primary cooling system contains 16 valves and latches.

After pumps water circulates through two heat exchangers (two parallel branches). In case of the losing outside power cooling water circulation through reactor core is provided by one of the pumps, which is powered through UPS.

The following parameters are measured in the primary cooling system:

- Water level in the reactor vessel;
- Core inlet water temperature;
- Core outlet water temperature;
- Temperature drop on the core;
- Water pressure;
- Water flow;
- Water temperature after each heat exchanger;
- The pH of water in primary cooling system;
- The specific conductivity of the water in the primary cooling system and after the filter.

Reactor primary cooling system consists of elements which have been working without replacement since 1960 and elements that have been replaced by new ones (two heat exchangers and corresponding piping).

Operational parameters of the primary cooling system:

- Coolant flow when reactor operates at 10 MW power, m^3/h	not less than 1200;
- Core inlet water temperature, °C	less than 50;
- Core outlet water temperature, °C	not more than 55;
- Temperature drop on the core, °C	not more than 6,9;
- Water pressure after pumps, kgf/cm^2	not more than 1,5;
- Water level in the reactor vessel, mm	not more than 5010;

Ageing management

Purpose of ageing management activities at WWR-M is to provide the necessary level of safety over the life cycle of a reactor, as well as maximum efficiency of its operation by organizing measures intended to a timely detection and maintaining the acceptable degradation.

The result of such actions is the development and implementation of technically and economically appropriate measures that would prevent failures caused by ageing of reactor components and structures.

The main objective of the ageing management program is establishing the scope and consistency of the organizational and technical measures to ensure the systematic and effective management of ageing buildings, equipment and pipelines of WWR-M reactor primary cooling system, which should serve as a basis for the extension of their operation. Other reactor systems (like instrumentation and control system) which are important for reactor safety have been replaced or previously reengineered; therefore, their lifetime has not run out.

It is important to create the conditions in which the metal of the reactor vessel has to meet the design values. Such conditions are strict observance of schedules the reactor vessel maintenance, keeping within the operational limits and conditions, the chemical composition of the primary cooling system water, controlling the mechanical load on the core support grid to prevent the it exeeding more than specified in the project documentation.

During the reactor normal operation the personnel task is to control and record the neutron fluence (aluminium alloy has a fluence margin > $3.6 \cdot 10^{26}$ n/m2), perform and document the results of periodic visual inspection of the accessible places, the vessel surface (inside), bottoms, horizontal channels bottoms and core support grid plate.[1]

During the periodic inspections of the support grid plate and its ultrasound thickness measurements fuel assemblies are removed from the core and placed in the spent fuel storage. This operation increases the risk of mechanical damage of the support grid plate and horizontal channels bottoms. To minimize the working time in the reactor core area only qualified personnel with suitable experience not less than 3 years is involved in such work.

The ageing of certain components can cause problems for safe operation and even accidents. For example, in the year 2011 the crack that caused the leakage of coolant in reactor primary loop pipeline was discovered. The root cause analysis of the accident showed that the accident happened due to metal fatigue caused by long-term cyclic loads. Damaged section of the pipeline has been replaced.

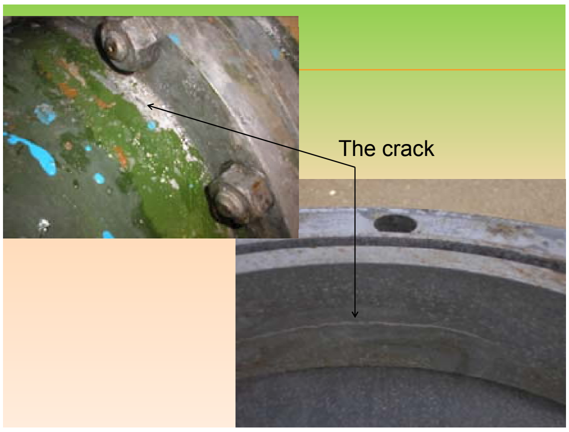

Fig 7. The crack in the reactor cooling system pipeline

Fig 8. The part of the primary cooling system pipeline replacement

To ensure timely detection of the problems concerning violations of the primary loop tightness the visual inspection of the most stressed sections of the reactor vessel and core support grid is regularly carried out. Currently, the strength calculations of the reactor vessel and the core support grid are carrying out.

In order to determine the reactor and its components lifetime it is necessary to conduct:

- technical inspection of the vessel and in its components to perform external and internal review (accessible places) and hydraulics tests;
- visually-measuring control of the reactor vessel metal in the accessible places;
- regular ultrasonic thickness measurements stipulated by the special program and compare these measurements with the results of previous measurements;
- periodic maintenance according to the schedules.

For conducting reactor vessel metal strength tests and calculating the strength of the vessel together with its components it is necessary to provide:

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[1] Fluence is calculated regarding to the reactor power, which is recorded in the appropriate technical documentation and a visual inspection is carried out according to the schedule (once in 2 years).

- analysis of the results of the irradiated samples (made from the same material as reactor vessel) strength tests;
- analysis of the corrosion of the metal of the reactor vessel;
- analysis results of the reactor vessel and its elements strength calculations;
- analysis results of research and studies of the most strenuous reactor vessel parts under neutron irradiation conditions.

The basic document for making technical decisions regarding the lifetime extension of the reactor vessel and part of the primary loop pipeline made from the aluminium alloy is the report of the evaluation of the technical state and reassign the term of operation.

On the basis of the mechanical tests of aluminium alloy irradiated samples results operating organization is planning to provide the strength calculations the reactor vessel and its components.[2]

Operating organization is also planning to estimate seismic resistance of the reactor vessel with its components.

As a conclusion it should be mentioned that implementation of the WWR-M reactor ageing management programme increases the reactor safety and allows to extend the reactor lifetime.

[2] The samples have been irradiated in Russian Federation with the flux $2.4 \cdot 10^{26}$ n/m^2. The current maximum flux on the horizontal channels bottoms is $1.1 \cdot 10^{26}$ n/m^2