TECHNICAL FEATURES OF THE MR REACTOR DECOMMISSIONING

by

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Received on September 26, 2008; accepted in revised form on November 11, 2008

This paper presents a preliminary technical design for the dismantling of the MR reactor. The goal of the design is the removal of reactor components allowing the re-use of the building for a different nuclear related purpose. The sequence of segmentation procedures is established. Considerations on the size reduction and tooling are presented.

Key words: MR reactor, decommissioning, dismantling

INTRODUCTION

The project NSP/05-R73R74R82U34 funded by the UK DBERR started in March 2006 and was completed in July 2008. The purpose of the project was to develop the main decommissioning documents for the MR and GAMMA reactors consistent with international and Russian standards, including the development of the design for reactor dismantling and decontamination of process equipment.

The objective of the MR reactor decommissioning project is to identify dismantling equipment and the decommissioning methodology for the reactor, loop rooms, and redundant services to permit the refit and re-use of the building for a different nuclear related purpose [1-3]. This paper is limited to a discussion on the methodology for dismantling the reactor.

The final status (end state) of this project is that the documentation is in place to allow the Russian Research Centre "Kurchatov Institute" to proceed with procurement and implementation of the reactor decommissioning programme. The ultimate end state of the MR decommissioning programme is that the MR facility is to be left in a state suitable for some future nuclear related use [4, 5].

Nuclear Technology & Radiation Protection
Technical paper
UDC: 621.039.516
BIBLID: 1451-3994, *23* (2008), 2, pp. 79-85
DOI: 10.2298/NTRP0802079C

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CURRENT STATUS OF MR REACTOR

The MR reactor operated from 1963 until it was permanently shutdown in 1993 [6]. MR was a pressure tube pool-type materials testing reactor with a design that combined the flexibility of pool-type operations with the practicality of being able to test both materials and fuels in independently serviced loops. MR was hence able to simulate a variety of power reactor conditions with flexibility to re-configure the core to suit a variety of experimental needs. The layout of the MR reactor is shown in fig. 1.

The MR reactor is currently in the final shutdown mode following its initial shutdown in 1993 and the subsequent transfer to nuclear safe state in 1996. The removal of fuel was completed by 1996 with the exception of one of the test loop fuel elements. How-

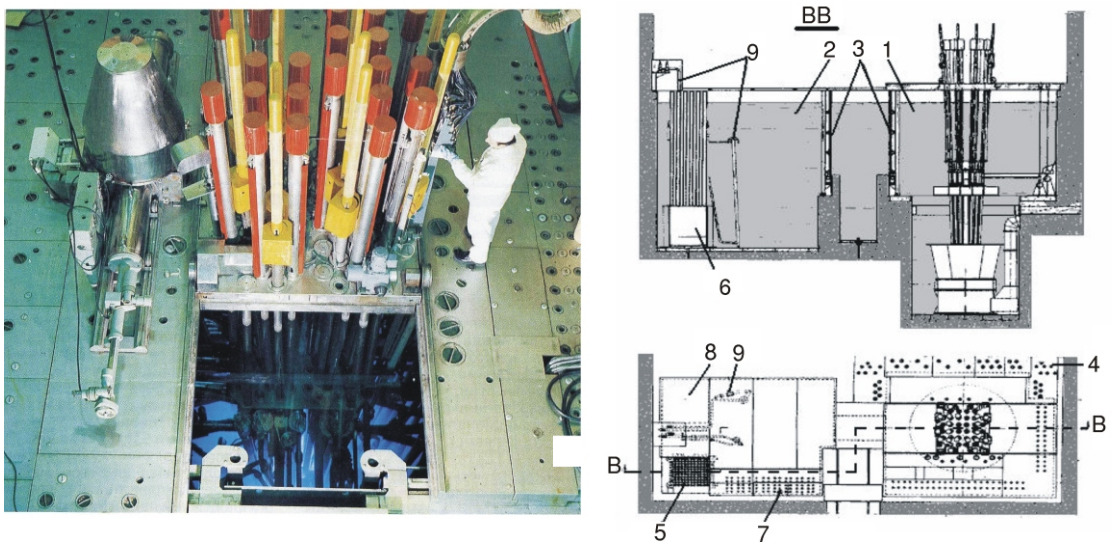

Figure 1. MR reactor: left – view from above, right – plan and horizontal cross-section (BB) of reactor pool and storage pool
1 – reactor pool, 2 – storage pool, 3 – lock gate, 4 – shielding slabs over loop channel connections with the loop, 5 – gamma irradiator tube plate, 6 – gamma irradiator chamber, 7 – FA channel retrieved from reactor, 8 – tank containing equipment for underwater cutting of channels of any type, 9 – loop FA channel retrieved from reactor

ever, this element will be removed prior to decommissioning work commencing. Some operational work in support of decommissioning has already started. Some equipment which is free from activity and contamination has been removed using standard industrial equipment. The facility has been under care and maintenance since the reactor was defuelled.

Decommissioning the MR facility will present some special problems associated with the following features of the facility:

– the close proximity of a densely populated urban environment,
– the presence of the RFT reactor which is entombed in the MR reactor hall,
– the reactor having been shut down for a long time (since 1993),
– the nine experimental loop installations in basement rooms around the reactor,
– the high levels of contamination in the reactor's experimental loops,
– technological systems situated in the complex of buildings,
– building 37/2 which contains a hot laboratory, sharing the special drainage and ventilation systems with the reactor, building 109 – the store for spent fuel assemblies.

The reactor hall comprises a reactor pool, a storage pool to store spent fuel assemblies (SFA) and the loop rigs, a dry storage for control and protection system (CPS) rods, and a RFT reactor shaft with a steel vessel and reactor internals, with graphite blocks in the core and in the reflector. The top of the RFT reactor vessel is covered with a layer of concrete and a further steel slab shielding over it. According to the global decommissioning strategy for the RRC KI reactors, the RFT shaft housing the reactor internals should be dismantled together with the MR dismantling.

Under the shielding slabs in the reactor hall, there are primary system and loop rig pipelines which run from the core to the process rooms housing primary and loop rig equipment. The loop rigs were used for fuel element testing, sometimes to destruction, and water chemistry experiments and are therefore heavily contaminated. The rig pipelines which connect to loop rigs located in the basement rooms have the same level of contamination and hence will have an impact on the radiation levels in the areas where they are laid in the reactor hall beneath removable steel shielding.

The driver fuel and most of the experimental fuel has been removed from the reactor, the remaining fuel will be removed before decommissioning commences. On the basis of the vertical dose rate profile in the reactor vessel it is thought that there are some fuel fragments at the bottom of the reactor. This has made it difficult to estimate the inventory of activation products in the reactor components. Work has been carried out to remove and dispose of sections of loop rigs from the storage pond which has reduced the background dose rates in the reactor hall. The background dose rate is now sufficiently low to allow preparation work to be carried out for the remote decommissioning equipment that will be required to carry out dismantling and packaging of the reactor core components.

The lack of information on the radioactive inventory of activated materials within the reactor and the potential presence of fuel fragments mean that a precautionary approach has been taken in planning the

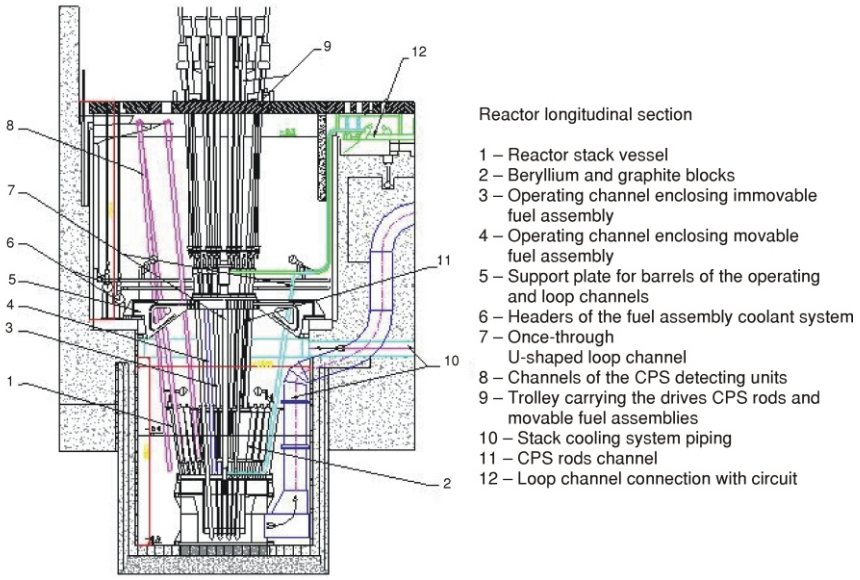

Figure 2. Vertical section of reactor MR

dismantling of the reactor. The radiological conditions in the reactor hall allow access until active components are removed from the reactor tank.

DISMANTLING SEQUENCE

Following a study on the types of tooling available and the construction of the reactor (fig. 2), it has been deemed that the reactor decommissioning will be achieved using a top down approach. Fortunately, much of the reactor can be dismantled by "reverse installation"; however, several components will require to be cut away from the reactor and some component size reduction will be required [7]. It is considered that several cutting options will be available in many cases, offering a flexible solution, when taking into account the range of tooling available from the requirements of the overall project.

Where practicable, the components requiring size reduction will use the pond water as shielding where prudent to do so using long handled tools. Alternatively, size reduction may be carried out in the main reactor hall to allow direct placement in waste boxes prior to the transfer of the packages to the interim storage. If the components are size reduced in the reactor hall then localised containment and shielding will be provided and remotely operated equipment will be used as necessary. Strippable coatings may be used to reduce the spread of contamination and small self contained local extract systems with integral, safe change HEPA filtration may be used to remove airborne containmantion close to the point of generation.

Cold cutting techniques will be used to size reduce items outside the pond to limit the generation of airborne radioactive contamination. Only where a component is considered to be contamination free will hot cutting techniques be used unless the cutting is carried out below the water level.

When size reducing in the pond, care must be taken to ensure that visibility is not reduced beyond working level, the item being cut free is secured from dropping down further into the pond, the ventilation system can cope with the bubbling gas evolution, splashing of contaminated water will not occur, and aerosols are not generated.

In many cases there are several options for cutting the various components, and the tooling most likely to be used has been indicated in the section descriptions. Note however that cutting will only be carried out in the pond where high radiation levels are anticipated from activated components. Where radiation levels are low, the components will be removed from the pond and size reduced within the containment this way contamination of the pond water is avoided as much as possible. The proposed sequence of dismantling is presented below.

Due to an absence of drawings for the various components, it was assumed that the primary means of cutting out of the pond would be bandsaw supported by diamond wire cutting for the upper plate. Components cut in the water were assumed to be cut using plasma cutting techniques as the fine particulate and fume would be contained within the water. To prevent the pond water becoming too highly active for operators to come near, the water will be continually circulated through the pond water clean-up system which incorporates filters and ion exchange columns.

The decommissioning of the reactor will follow a top down approach removing in turn.

Removal of safety control systems (fig. 3a). The safety control systems are made up of a series of 115 mm

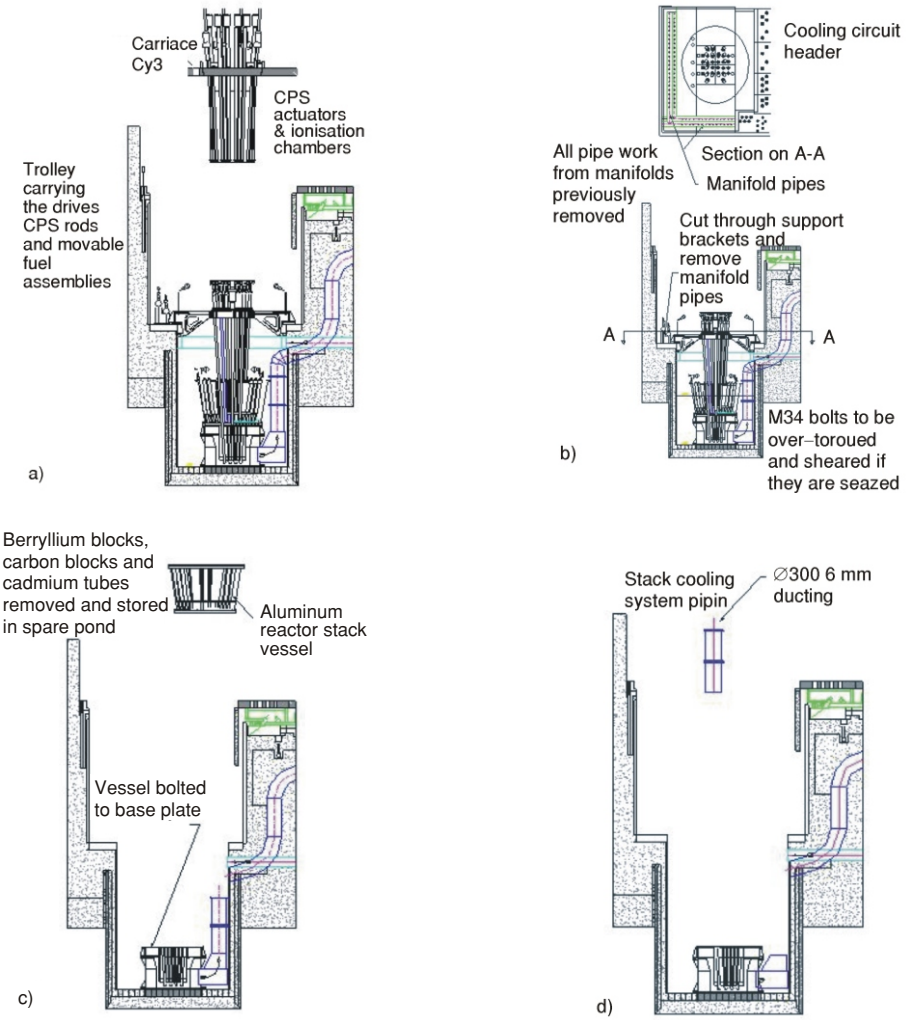

Figure 3. Separate dismantling stages

diameter stainless steel tubes extending from the reactor upper plate, protruding above the reactor pond into the main reactor hall. The systems are connected to the reactor via a shield plate. The shield plate is constructed of mild steel clad with stainless steel. The combined shield plate and control systems are essentially clean (only mildly contaminated) weighing approximately 10 tonnes. The disconnection and removal of the assembly from the reactor is easily achieved using the existing operating procedures and is carried out routinely when changing fuel. However, due to access constraints, the assembly will have to be size reduced or dismantled into a series of components to allow transfer of the individual components from the reactor hall. Equipment – with the exception of the shield block, almost all of the units can be unbolted and cut up *in situ* if required:

– band saws would be a suitable tool for the size reduction of the tubes, and
– diamond wire cutting or transfer to the site size reduction facility to use water-jetting would be suitable size reduction techniques for the shield plate.

Removal of cooling manifolds (fig. 3b). There are two cooling manifolds of 219 mm nominal bore stainless steel pipes. The pipes have 70 mm diameter stubs and contain a series of valves. The connections to the loops are/will have been already removed. Similarly, the valves are operated by a series of valve spindles that protrude above the reactor floor level; these spindles have already been removed. The cooling manifolds are welded to the reactor pond wall by a series of 6 mm brackets. In order to remove the cooling manifolds the brackets will have to be cut and if possible cut without damaging the stainless steel pond lining (thought to be approximately 3 mm thick). The cooling manifolds are not thought to contain significant amounts of activated products so it is assumed that the cooling manifolds will only be mildly contaminated. The cutting of the cooling manifold brackets can be achieved either by plasma arc cutting or cropping. Cropping offers the better solution as there is less likelihood of damaging the pond wall and is a far cleaner process; however, without the accurate dimen-

sional information, the selection of the best cutting technique has been deferred until access to the manifolds is achieved.

Removal of upper plate. The upper plate is a stainless steel plate bolted to the reactor pond by 8 M34 bolts. In order to remove the upper plate, the bolts have to be removed either by unscrewing, over-torqueing or by cutting of the bolt heads. In practice, the best way of removing the bolts will be to use an over-torque device that will shear the bolt head automatically if the bolt fails to unscrew. If the device rounds the bolt head then more aggressive technique like plasma arc cutting or even spark erosion may be required to cut the bolt head. Before transferring the upper plate from the reactor hall, the upper plate will have to be size reduced. An ideal method for the size reduction will be to use diamond wire cutting.

Removal of cooling ducts. The cooling duct is a stainless steel circular structure located over the reactor vessel. The cooling duct is bracketed to the side of the pond wall. The brackets will have to be cut to remove the duct. Once the duct is removed the reactor ventilation duct can be removed. The ventilation duct is a 300 mm diameter and 6 mm thick plate. The duct can be unbolted from the reactor but may have to be cut as the duct penetrates the wall. It is probable that the same method used to remove the cooling manifolds will be used for the removal of these ducts. The size reduction of the ducts is likely to be by bandsaw.

Removal of carbon and beryllium blocks. The reactor vessel contains a total of 216 carbon and beryllium blocks. These blocks are removed as a part of normal operations and the removal equipment is readily available. As long term storage of the carbon and beryllium blocks is a problem, the blocks will be transferred to the adjacent reactor storage pool until a final disposal option is found.

Removal of reactor vessel (fig. 3c). After the beryllium and carbon blocks have been removed the aluminum reactor vessel can be removed. The reactor vessel is bolted to the base plate. As per the upper plate, the reactor vessel can be removed using the techniques described above. The size reduction of the reactor vessel may be achieved by plasma arc cutting while the vessel is still within the reactor pool allowing the pond water to act as a radiation shield and contamination trap.

Duct removal (fig. 3d). Once the reactor vessel has been removed, the remainder of the ducting is revealed and can be separated from its brackets and removed.

Slab and protector unit. This unit sits below the reactor vessel. There is no further information available on this unit; however, it is anticipated that underwater plasma arc cutting will be used to size reduce.

Grate and support for cadmium cans. This unit sits within the base plate. There is no further information available on this unit; however, it is anticipated that underwater plasma arc cutting will be used to size reduce.

Graphite cooling pipelines. These are likely to be removed along with the base plate.

Base plate. The base plate is a stainless steel construction and is fixed to the bottom of the pond by 8 M32 bolts. The bolt heads are accessible and can be removed using standard tools and extensions. However, the techniques identified above for the removal of the upper plate will also apply to the base plate. Underwater plasma arc cutting is likely to be the technique used to size reduce the base plate.

Removal of water from reactor pool. The fuel pond water will be continually treated throughout the decommissioning process using the existing ion exchange and filtration unit. On completion of the reactor decommissioning the remaining water will be treated and sampled until the contamination levels are acceptable for discharge down the active drain. It is possible that there will be a requirement to reduce the upper water level of the pond during decommissioning activities to facilitate the removal of some parts of the reactor. If this proves necessary, work within the pond will cease to allow any sludge or solids to precipitate out and the ion exchange system will continue to operate and will be targeted at the upper areas of the pond until sampling shows that the activity levels have dropped sufficiently to permit discharge of the required volumes to occur.

Final decision on size reduction methods. The final decisions on some of the size reduction methods may be postponed until the mock-up facilities are in place or until the detailed drawings of the components and their fixings and interactions are available as only then will the best method be apparent where the constraints presented by the tightness of the space and the limited visibility can be fully appreciated. In those circumstances, a method which seemed obvious previously may prove to be entirely unworkable due to *e. g.* an unknown protrusion which will block access for the preferred tool, or a similar effect caused by the relative positions of different components. Visibility is another issue where something may look very feasible when viewing a sketch, but in fact will not be possible because the operator will not have the adequate visibility to operate the equipment effectively. For these reasons, the tooling recommended for the removal and size reduction of the reactor components should be taken as indicative based on the experiences of effective use elsewhere in similar situations. Their effectiveness in the MR reactor can only be proven either in a faithful mock-up or in the reactor itself.

Completion. When the work to dismantle the reactor and the loop room equipment has been completed, all of the areas will be monitored and detailed mapping of residual contamination will be carried out. The removal of the contaminated areas by scabbling or cutting will be carried out to a point where any remain-

ing contamination is within acceptable levels, these levels to be set by the Kurchatov Institute. Final monitoring will take place to leave a record of the end state/handover state for the facility.

RADIATION PROTECTION

The lack of information on the dose rates from reactor components means that a precautionary approach to radiation protection is necessary for workers undertaking dismantling operations. However, the reactor hall does not present the same problems of accessibility as the underground loop rooms.

Dose rates in the loop rooms, measured in 1996 after fuel removal, were up to 50 mSv/h although, based on the ^{60}Co to ^{137}Cs ratio, these were estimated to have falled to 10 mSv/h by the time dismantling commences. While these dose rates are not life threatening, routine operations would soon exceed regulatory limits and only brief exposures are possible during the initial preparation [8]. The background dose rates in the reactor hall are less than 25 mSv/h and therefore allow routine operations with some limit on occupancy. However, since the pipelines to the loop rigs lie in shielded ducts in the reactor hall, similar dose rates will be encountered during their removal. In addition, some reactor components may be activated (although low activation materials and neutron shielding have been used) and may be contaminated or contain fuel debris. Therefore, the dismantling procedures must allow from high dose rate items.

The integral crane can be operated remotely from outside the reactor hall, the closed circuit TV can be modernized and extended without incurring excessive doses and there is room to manoeuvre one or more remotely operated vehicles such Brokk demolition machines fitted with suitable cutting equipment such as hydraulic shears and handling equipment such as the Predator manipulator arm. These can be controlled from outside the reactor hall in a low dose rate area.

The structure of the reactor hall provides sufficient shielding to protect against external radiation from any reactor component and also provides a ventilated containment to prevent uncontrolled releases of airborne contamination. An engineered route is available for transferring waste containers from the reactor hall to either the radioactive waste handling building or directly to the interim storage pending future transfer to the radon waste repository.

Three types of waste boxes are available depending on the external radiation from the waste. If possible, an estimate will be made of the activity of each component and the appropriate type of waste package will be prepared. When a component has been freed ready to be lifted out of the reactor pool, dose rates will be monitored continuously as it is lifted using either long reach monitors or remote sensors while the crane is operated from outside the reactor hall. If the dose rate is too high for the container prepared then the component can simply be returned to the reactor pool and the waste box can be changed for a different type.

The dose rates from filled waste boxes must comply with the limits for transport; however, these limits are based on short term exposures during transport and workers may incur significant doses during handling filled waste boxes. Depending on the duration, additional shielding will be provided to protect the workers when they are fitting lids to boxes.

In addition to portable monitoring equipment, the following radiological protection monitoring will be provided:

– personal alarming dosemeters will be worn by all workers undertaking dismantling operations; these will also be used for day-to-day dose control,
– fixed gamma alarms will be located in the reactor hall with remote indication outside the entrances, and
– activity in air monitors with alarms will be located in the reactor hall with remote indication outside the entrances (it is likely that beta radiation in air monitoring will be sufficient).

Access to the reactor hall will be strictly controlled during dismantling operations and worker doses will be reviewed to ensure compliance with regulatory limits and that they are as low as reasonably achievable (ALARA) in line with the current best practice.

The engineered and organizational measures to minimize discharges to the environment and protect the public are specified together with the monitoring arrangements to confirm the effectiveness of the protective measures and detect any deterioration in performance. These protective arrangements include:

– containment, local and area extract ventilation and HEPA filtration to prevent significant releases of radioactive material to the atmosphere and discharge through the 60 m MR stack to minimise the environmental effects of any discharges,
– airborne activity monitoring after the filters and at the site boundary to detect any deterioration in efficiency of the protective measures,
– the use of dry processes and the existing active liquid effluent treatment plant and monitoring of sewage prior to discharge to prevent any environmental discharges of liquid radioactive effluent,
– use of dust suppression techniques and strippable coatings to minimise the spread of surface contamination supported by the contamination monitoring of equipment and outside areas to identify surface contamination and initiate procedures to prevent further spread, and

– initial and refresher training of workers in decommissioning techniques and emergency procedures in compliance with radiation safety regulations.

CONCLUSIONS

The purpose of the project is to develop the main decommissioning documents for MR and GAMMA reactors consistent with advanced international and Russian standards. This is considered the basic part of decommissioning planning for these research nuclear reactors located at the Russian Research Centre "Kurchatov Institute", which allows implementing the safe, timely and cost-effective decommissioning. The authors acknowledge the funding given for this project (NSP/03-R73R74R82U34) by the UK DBERR Nuclear Safety Program.

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ТЕХНИЧКЕ КАРАКТЕРИСТИКЕ ДЕКОМИСИЈЕ МР РЕАКТОРА

Приказан је прелиминарни технички нацрт уклањања МР реактора. Сврха плана је да се одстрањивањем делова реактора омогући поновно коришћење зграде за различите нуклеарне потребе. Успостављен је редослед процедура уситњавања делова и приказани су поступци редукције обима и начин обраде.

Кључне речи: МР реактор, докомисија, уклањање