

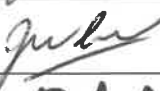


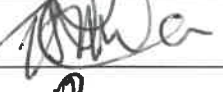


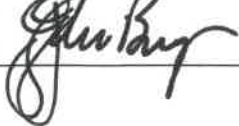


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TITLE	ISI REQUIREMENT SPECIFICATIONS FOR THE SAFARI-1 REACTOR VESSEL ASSEMBLY

AUTHORISATION

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REVISIONS

This document has been revised in accordance with the following schedule:

Rev. No.	Date approved	Nature of Revision	Prepared
00	See Title Page	First issue	SP TOLO

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1. BACKGROUND

SAFARI-1 is a 20 MW de-mineralised light water-cooled, beryllium reflected, tank-in-pool-type research reactor situated at Pelindaba West. The reactor is owned and operated by Necsa. It has been safely operated since 1965. In Service Inspection (ISI) of some of the reactor SSCs is required to ensure its integrity for safe continued use.

SAFARI-1 has developed an ISI plan (RR-ISP-2300) [4], which ensures that all systems, structures and components (SSCs) important to the safe operation of the facility and not forming part of the maintenance program are well identified and inspected. It also ensures that possible deterioration of items is detected to determine if they are acceptable for continued safe operation or remedial measures are required. It is for this reason that reactor vessel assembly has to be inspected to ensure that reactor is operated safely. Furthermore, ISI of the reactor pool and Reactor Vessel Assembly (RVA) was conducted in 2018, cracks were however not inspected and it was recommended that cracks, especially on critical areas must be inspected


2. PURPOSE

This document outlines the Inspection Requirements for the SAFARI-1 RVA. The welds of the RVA shall be inspected as per [4]. For the purpose of this (ISI), inspection will be conducted on the RVA only and other SSCs mentioned in this document will be used for ease of reference and identification of components to be inspected.

3. SCOPE

This document covers the following:

- Requirements for Inspection of welds of the Reactor Vessel Assembly on high stress areas as identified in [12].
- Responsibilities of parties to be involved in the In-service Inspection.
- Ultrasonic Testing (UT) requirements to check for any cracks, weld thickness and measurement of defect size on RVA.
- Qualifications of personnel, their responsibilities, procedures and test methods
- Deliverables

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4. RESPONSIBILITIES

4.1. SENIOR MANAGER

- SAFARI-1 Senior manager shall approve the inspection done and outcomes as reported by the service provider.

4.2. REACTOR ENGINEERING

- Reactor Engineering (RE), which will include the Reactor Support (RS), Facility Engineering (FE) and Nuclear Safety and Technology (NE) groups, shall ensure and accept all technical documentation supplied by the service provider meet SAFARI-1 requirements.
- Support/assist service provider with access to the reactor vessel as and when required.
- Assess the scope of work and final report as per contractual agreement.
- Review the work done and accept the inspection done and outcomes as reported by the service provider.

4.3. REACTOR OPERATIONS

- Reactor operations shall ensure that the reactor vessel assembly, reactor hall and all other necessary equipment are prepared for inspection and accessible to the service provider.
- Provide support with the handling of overhead crane and tooling for the inspection equipment.
- Provide access to power and compressed air as well as decontamination of equipment.

4.4. QUALITY DEPARTMENT

- The quality department will verify and validate the supplier's personnel qualifications.
- Check and
- Validate documentations and inspection methods as per [5] and [7] RR-PRG-1800) and RR-PRG-2301.

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4.5. RADIATION PROTECTION OFFICE

- Ensure that the work areas are safe to conduct the inspection and issue the necessary work and radiological permits.
- Provide the service provider with safety guide lines.
- Ensure compliance with acceptable radiation limits for personnel as stipulated in SHEQ-INS-8080 and SHEQ-INS-8090.
- Issue radiological work permit.
- Where necessary continuous invigilation.

4.6. SERVICE PROVIDER

- Shall render a service as per agreed contract.
- Shall submit Safety File to radiation protection office including all requirements.
- Perform Necsa training to work as a radiation worker.
- The service provider shall submit the required documentation concerning o equipment used, calibration certificates, SQEP'ing of personnel conducting inspections and the methodology to be followed to the RE manager.
- Submit detailed project plan, techniques and methodology once purchase order is issued.
- A comprehensive report indicating the outcomes, which shall include any deficiencies identified and provide an expert opinion on the condition of the RVA.

5. DEFINITIONS AND ABBREVIATIONS

Item	A system, structure and/or a component or part of a system.
ISI Item	An ISI Item is a component and/or an assembly of components of the highest priority that will be inspected for the safe operation of the reactor. These include items of, and items connected to, the reactor vessel and the pool liners.

6. ABBREVIATIONS

ASME	American Society of Mechanical Engineer
ISI	In- Service Inspection
ISIP	In- Service Inspection Plan

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ISO	International Organisation for Standardization
NNR	National Nuclear Regulator
PRG	Procedure
RQ	Reactor Quality
RA	Radiation Protection Group
RE	Reactor Engineering
RO	Reactor Operation
RPL	Reactor pool Liner
RR	Research Reactor
RV	Reactor Vessel
RVA	Reactor Vessel Assembly
SAR	Safety Analysis Report
SQEP	Suitably Qualified Experienced Person
UT	Ultrasonic Inspection

7. APPLICABLE DOCUMENTS AND REFERENCES

The following documents of the exact revision shown to form part of this specification to the extent specified herein. In the event of a conflict between the text of this specification and the documents cited herein, the text of this specification shall take precedence. Nothing in this specification supersedes applicable laws and regulations.

Ref	Document number		Title
[1]	ASME III	2001, A2003	ASME Boiler and Pressure Vessel Code: Rules for Construction of Nuclear Facility Components-General Requirements for Division 1 and Division 2
[2]	ASME VIII		ASME Boiler and Pressure Vessel Code: Rules for Construction of Pressure Vessel
[3]	ASME XI		Category B-N-2, Welded Core Support structures and internal attachment to the Reactor Vessel
[4]	RR-ISP-2300		In-service Inspection Plan
[5]	RR-PRG-1800	07	Procedure for Personnel Training within SAFARI-1
[6]	RR-PRG-2300	05	Procedure for Maintenance within the SAFARI-1


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			Research Reactor
[7]	RR-PRG-2301	02	Procedure for In-Service Inspection
[8]	RR-SAR-0003		SAFARI-1 Research Reactor Safety Analysis Report-Chapter 3: Site Characteristics
[9]	RR-SAR-0005	05	SAFARI-1 Research Reactor Safety Analysis Report-Chapter 5: Description of the SAFARI-1 Research Reactor
[10]	SHEQ-INS-8080		Radiation Dose Limitation
[11]	SHEQ-INS-8090		Reference Levels for Monitoring of Radiation Workers and the Work place.
[12]	IM-TR1262	0.2	Structural integrity assessment of the SAFARI-1 reactor vessel

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8. IDENTIFICATION AND FUNCTION OF ITEMS

8.1. SAFARI-1 REACTOR

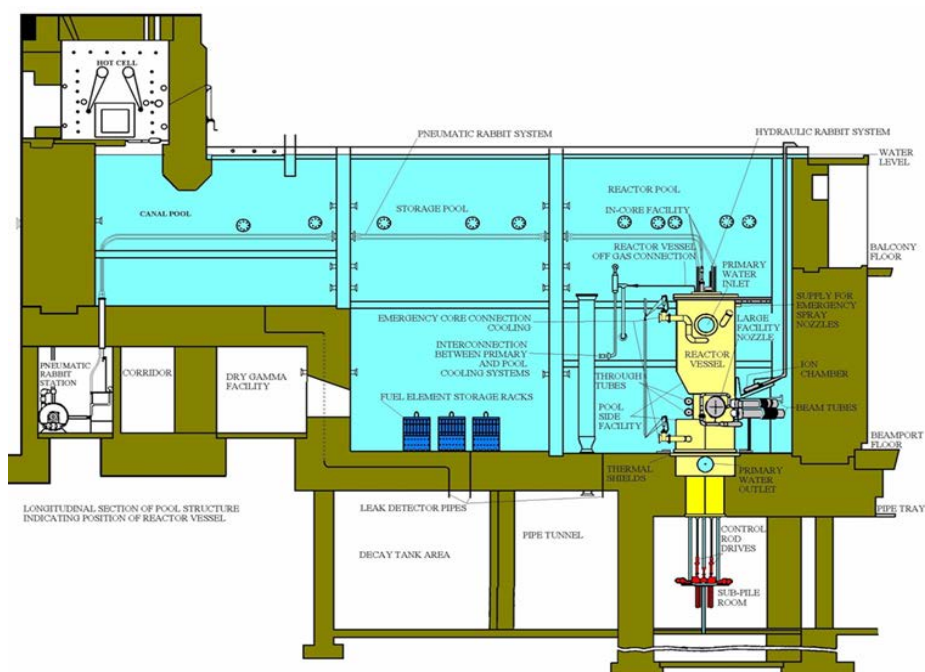



Figure 1: Section view of SAFARI-1 Reactor

Figure 1 shows the overall structure of the SAFARI-1 reactor. SAFARI-1 reactor consists of a reactor pool, canal pool and storage pool. The reactor vessel assembly, the structure in which inspection will take place, is situated on the reactor pool side as shown by the yellow in the sketch above. The walls of the reactor pool are made of ordinary concrete and high density concrete is used in the biological shielding around the reactor vessel. The reactor pool side is about 8.7m deep, 6 m long and about 3m wide.

8.2. REACTOR VESSEL ASSEMBLY

The reactor vessel assembly contains the core of the reactor, and also allows access for the control rods and provide a space for nuclear related experiments. It channels the cooling water through the reactor core and other critical components via an inlet and outlet

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pipng system. The reactor vessel assembly consists of the reactor vessel, the top cover, the lower tank coolant outlet assembly, the bottom plug and the ion chamber shields.

8.2.1. Reactor Vessel

The reactor vessel was designed following the Unfired Pressure Vessel ASME VIII standard for an internal pressure of 248 kPa(g) and a temperature of 25°C during shutdown and to 50°C degrees max during operation . It is made of welded 5052 graded aluminium cylindrical shell of 1.66 m internal diameter and average 4.52 m height between flanges. The circulation of cooling water is driven by a pressure drop between the inlet and outlet reactor vessel pipes. The pipes and flanges are made of grade 6061-T6 aluminium.

As shown in *Figure 2*, the vessel consists of three sections namely the upper section, core box and lower section. The shell thickness is 19.05 mm for the upper and lower sections and 25.4 mm for the cylindrical part of the core box section.

8.2.2. Core Box Section

Figure 3 is the core box section, which is located within the cylindrical reactor vessel with one flattened cut out face outside the core box locate on the north face, also contains a rectangular core box with a bottom grid pale housing the fuel assemblies, the control rods and other core elements. The flattened wall of the cylinder is 34,9 mm thick and forms the north wall of the rectangular core box. The core box is 650,7 mm long in the north-south direction, 698,5 mm long in the east-west direction and 825,5 mm high [9].

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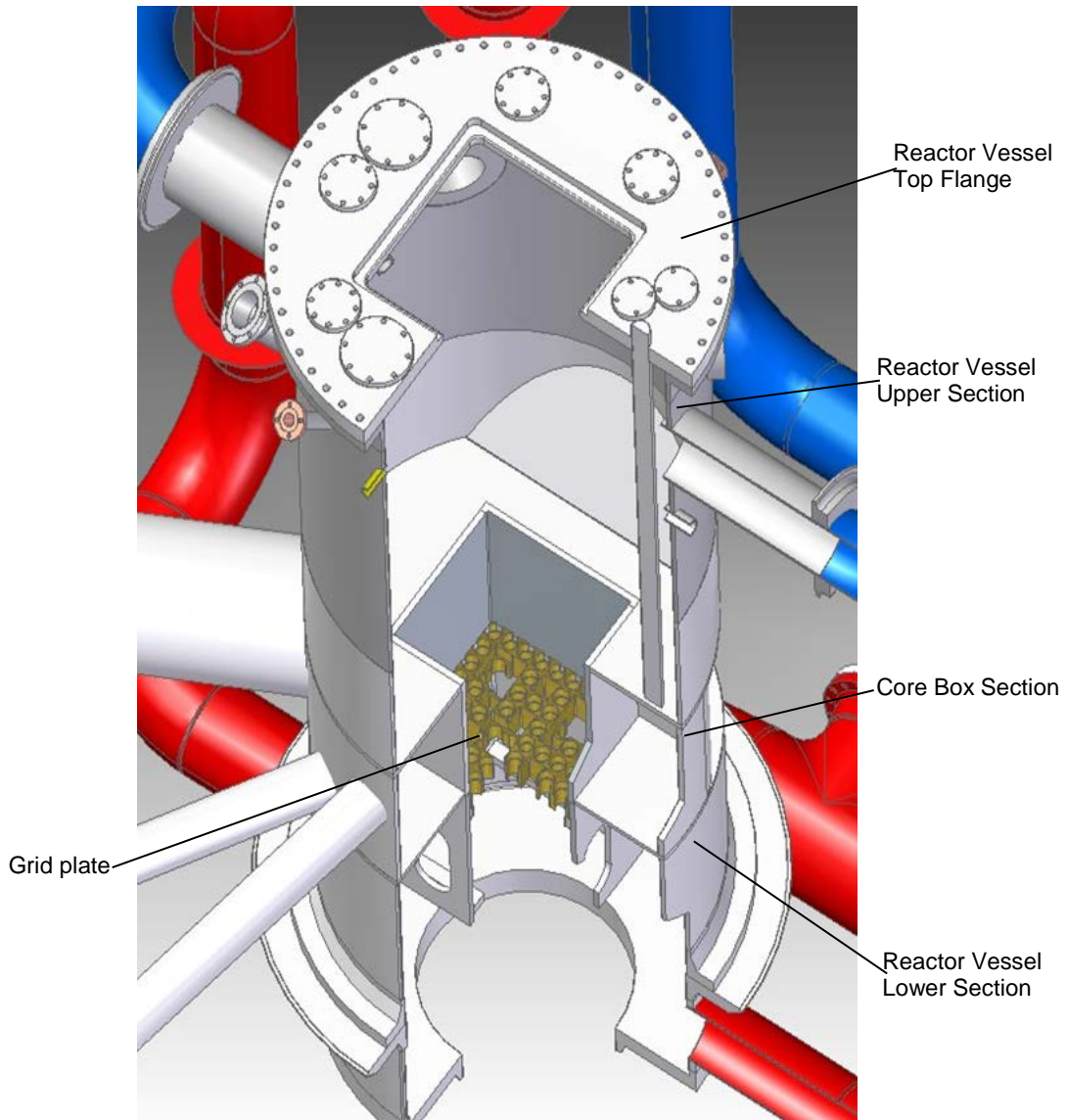


Figure 2: Reactor Vessel

As shown in *Figure 2* the bulkheads are welded to the vessel shell and to the upper and lower ends of the core box. They form a closed space around three cylindrical sides of the core box known as the "blanket region". Six beam tube nozzles and a large facility nozzle pass through the blanket region up to the core box. As shown in *Figure 3*, beam tube nozzles 1, 3, 5 and 6 are 6.35 mm thick, 174.62 mm of nominal diameter while beam tube nozzles 2 and 4 are 6.095 mm thick, 254 mm of nominal diameter. The large facility is 15.875 mm thick, 533.4 mm nominal diameter at the vessel end.

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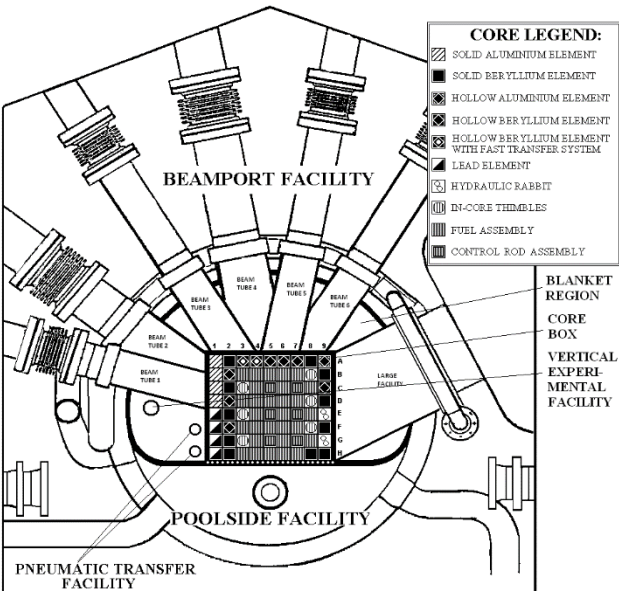


Figure 3: Top view on reactor core showing a typical core layout

Figure 4 indicates three vertical tubes (depicted by 3 grey circles) that penetrate the blanket region of which two are the pneumatic transfer facility tubes and the other one is the vertical experimental facility tube. The pneumatic transfer facility tubes are 5.5 mm thick 78 mm of nominal diameter, while the vertical experiment facility tube is 5.15 mm thick 62.7 mm of nominal diameter.

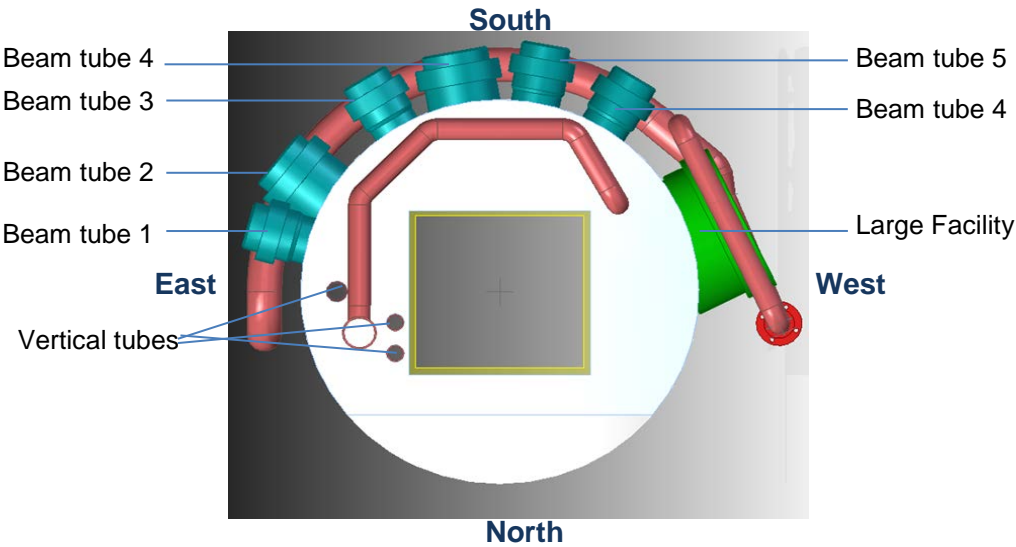




Figure 4: Top view of reactor core

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8.2.3. Lower Vessel Section

Figures 4 and 5 shows the core box lower bulkhead, the grid plate and the control rod lower bearing plate are supported by four vertical cross members. The vertical cross members are welded to the vessel shell in a form of an “egg crate”. The grid plate rests on the upper support strip welded to the inside of the cross members (*Figure 5 and Figure 6*).

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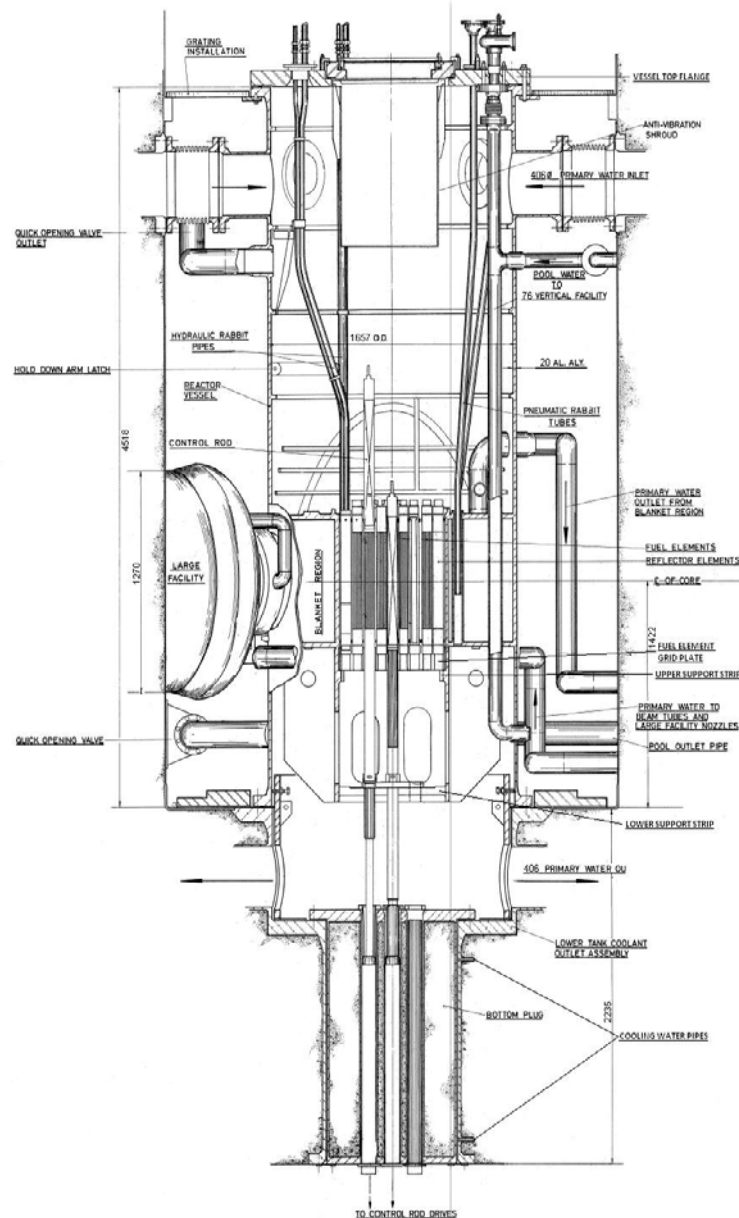


Figure 5: Section through reactor vessel showing internal components

Figure 6 shows three pipes penetrate the lower vessel section. Pipe 1 is the coolant outlet pipe from the vertical experimental facility. Pipe 2 is the pool coolant outlet that is welded into the core box lower bulkhead on the flat side of the core box section. It does not connect with anything inside the reactor vessel, but it only passes through the lower vessel section. Pipe 3 is the emergency coolant inlet. The pool coolant outlet pipe only passes through the lower vessel section.

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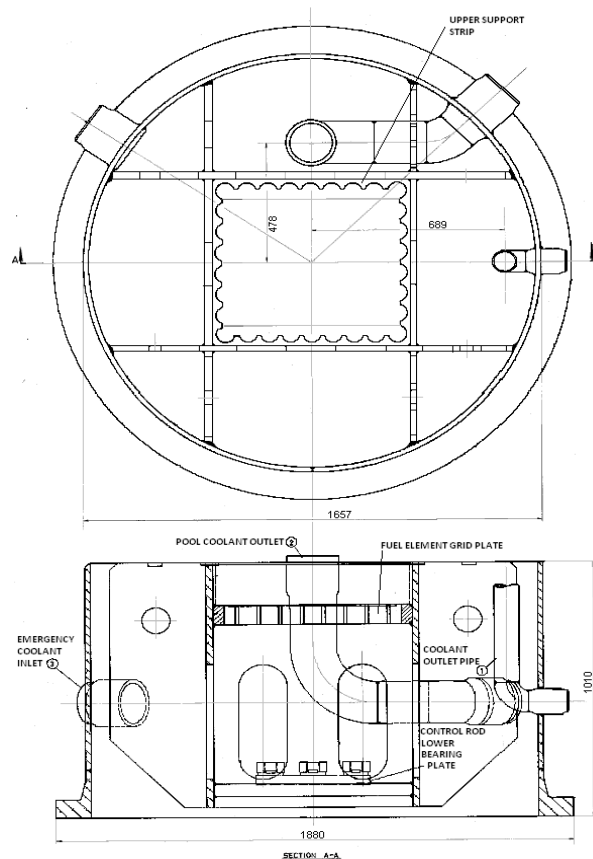


Figure 6: Plan and sectional view of lower vessel section

8.2.4. Upper Vessel Section

The upper vessel section contains a slanted portion, consisting of a flat plate welded to the upper bulkhead of the core box section and stiffened by ribs welded on the inside. This slanted portion is located above the poolside facility of the core box section and allows access to and viewing of the poolside facility experiments. The experimental apparatus installed in the reactor vessel is supported by circumferential flat rings welded inside the cylindrical portion.

8.2.5. Top Cover

As shown in Figure 6, the top cover of the reactor vessel is a 304 stainless steel plate of 101.6 mm thickness that is bolted to the vessel top flange.

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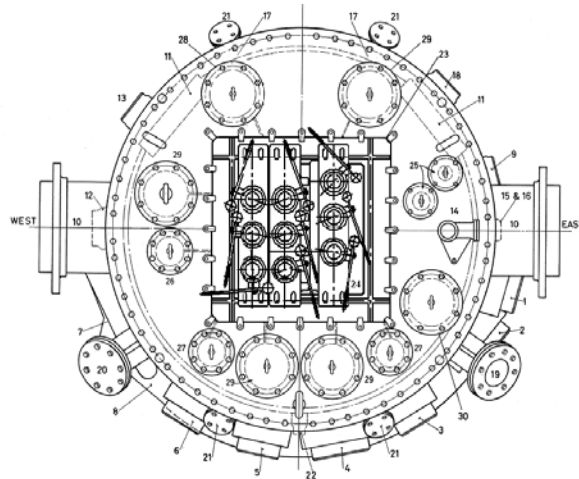


Figure 7: Plan view of reactor vessel showing vessel window and nozzles

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9. REQUIREMENTS

9.1. ITEM DEFINITION

The ISI Item specified in this document is the reactor vessel assembly (RVA).

RVA Diagram.

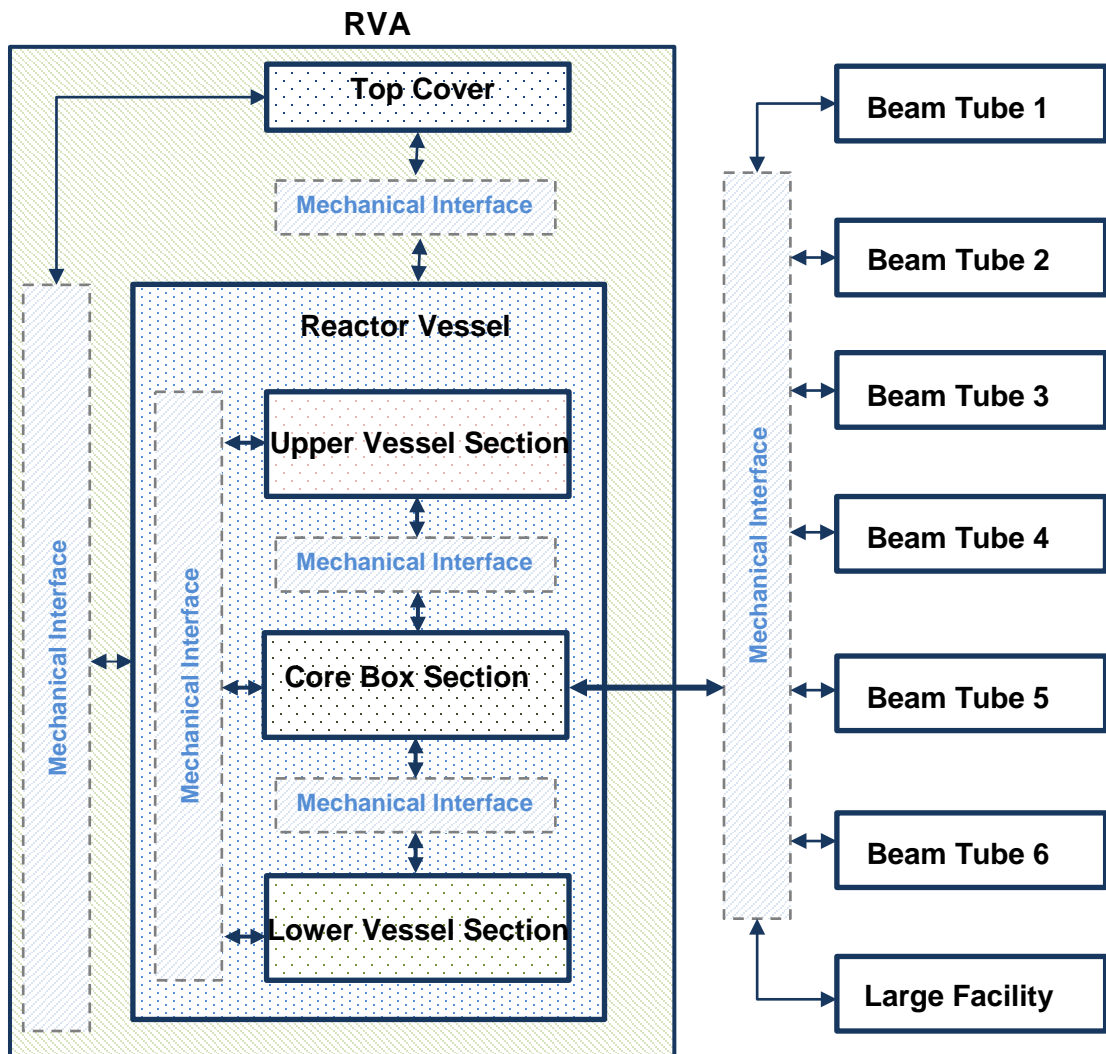



Figure 8: ISI RVA Context

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9.1.1. RVA Mechanical Interfaces

During the course of this ISI:

- a) The beam tubes and large facility nozzles are circumferentially welded to the reactor vessel shell in the core box region.
- b) The beam tubes and large facility nozzles pass through the blanket region up to the rectangular core box.
- c) The reactor vessel is made of rolled aluminium plates that are circumferentially and vertically welded to cylindrical vessel shape.
- d) The reactor vessel is circumferentially and/or vertically welded to the reactor core section.
- e) The Core Box Section is circumferentially welded to the Upper Vessel Section.
- f) The Core Box Section is circumferentially welded to the Lower Vessel Section.


➤ *Note: Although the Core Box Section, the Upper and Lower Vessel Sections are part of the reactor vessel, there is an internal mechanical interface between these reactor vessel assembly items.*

- g) The Lower Vessel section is sealed and bolted on the the lower tank coolant outlet assembly.
- h) The Lower Vessel Section supports the Core Box Lower bulkhead the grid plate and the control rod lower bearing plate through four vertical cross members.
- i) The grid plate rests on the Lower Vessel Section upper support strip welded to the inside of the cross members.

9.1.2. Accessibility

- a) The presence of lead shielding and a heavy piping system limits access to the southern side of the reactor vessel, which is practically inaccessible.
- b) There is a small gap in between the beam tube 3, 4, 5, 6 and the reactor vessel. More attention will be needed to ensure all welds are reached.

➤ *Note: Inspections of practically inaccessible areas may require special tools that will ensure that those areas are accessible.*

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9.2. PREPARATION REQUIREMENTS

9.2.1. Pre-inspection of facility

- a) The facility may be pre-inspected by the service provider with assistance of SAFARI-1 RE/RO during tender briefing and/or before commencement of the ISI.

9.2.2. Methodology to be followed

- b) Upon receipt of official purchase order, the service provider shall provide detailed project plan, techniques and methodology that will be used in preparation for execution and records kept for this ISIP.

9.2.3. Inspection duration

- c) The Service provider shall indicate to SAFARI-1 management when ready for inspection, the required duration for inspection, which shall be agreed upon by SAFARI-1. SAFARI-1 has long shutdown (12 days) of which only 8 days are available for inspection which usually take place in October of every year. On-site preparation and equipment set-up can be done before the shutdown commences.

9.3. SPECIFIC INSPECTION REQUIREMENTS

- a) UT on welds of the reactor vessel assembly, i.e. longitudinal and circumferential welds.
- b) This inspection shall check for any cracks, reduction in weld thickness as well as measurement of crack sizes on RVA.

9.3.1. ISI Item requirements specifications

RVA UT weld inspection

- a) The ISI procedure and instructions shall include a detailed schematic representation of the complete inspection of the inspected item.
 - *Note: the detailed schematic representation of the complete inspection item shall show all vertical and circumferential welds characteristics.*
- b) 10% of RVA shall be inspected as stipulated in [4], these shall include high stress areas as per Figure 9 to Figure 12.

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- *Note: Measurements can also be taken at any agreed positions with SAFARI-1 management.*
- *The bottom weld toe of the welded connection between the lower vessel stiffeners and the outer shell is the highest stressed area as per [12]*

c) Each inspection area shall be uniquely numbered for the complete inspection item.

- *Note: This unique number is recorded for traceability and future inspection reference.*

9.4. INSPECTION PERFORMANCE REQUIREMENTS

- a) UT Perpendicular material thickness shall be measured within an accuracy of $\pm 0.5\text{mm}$ as per [3].
- b) The perpendicular material thickness measurement shall be measured within the alignment angle of the probe.
- c) Service provider shall use equipment that that are able to detect minimum of 1.5mm surface defect size and 2mm internal defect size.


9.5. ISI QUALIFICATION

- a) The service provider shall compile an ISI qualification to show that a systematic assessment of the inspection method and equipment was followed to ensure it is capable of achieving the required performance under realistic inspection conditions.
- b) The inspection system is qualified for In-service Inspections such that it reliably detects, characterizes and/or sizes defects that are relevant to the structural integrity and nuclear safety of the components being examined.
- c) The inspection procedures, equipment, personnel and testing of pieces as well as the technical justification or demonstration is considered the key elements of the inspection qualification process.

9.6. INSPECTION REQUIREMENTS

9.6.1. Stability of inspection equipment

The ISI procedure shall make provision that the inspection equipment be installed where necessary in a manner such that it is mechanically stable for the purpose of accuracy in measurements, and such that it does not fall or damage the RVA or internals.

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9.6.2. Manufactured components/equipments

No wetted component shall be manufactured of Mercury, Lead, Copper or any alloy containing these elements. If equipment or components do contain these elements, it shall be appropriately sealed to prevent contact with the water

9.6.3. Mobility of inspection equipment

In case of practically inaccessible areas the ISI procedures and techniques shall make provision for equipment access. In certain instances it may be possible to move, assemble or disassemble certain components within the vicinity of the RVA, this will need to be further discussed with SAFARI-1.

9.6.4. Contaminated Inspection equipment

Due to the nature of the work and environment in which the ISI is conducted, there is possibility that some component/s used for the ISI may get radiologically contaminated. The ISI process shall make provision for safely storing the contaminated inspection equipment within SAFARI-1 until such a time they are decontaminated.

9.7. ENVIRONMENTAL CONDITIONS DURING NORMAL OPERATION

9.7.1. Temperature

The ISI process is undertaken as per this specification, over ISI items required life, during and after exposure to temperatures between 10°C and 50°C as indicated in [8].


9.7.2. Humidity

Non-submerged components and /or equipment used during the execution of this ISI process, will be subject to a humidity of 7% to 90% (non-condensing) during use and storage. [8]

9.7.3. Water quality

The reactor primary and pool water are both maintained at a pH value of between 5.2 and 6.5 for normal operation.

The reactor primary and pool water conductivity is maintained at less than or equal to 1.2 µS/cm for normal operation.

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9.8. VERIFICATION METHODS

The following verification methods as applicable and specified in the table above apply:

Inspection:

Visual examination and cursory test of the item and/or documentation.

9.8.1. Demonstration:

Performed by operating the item and observing its performance without the use of instrumentation or test equipment.

9.8.2. Analysis:

Compare the item's design with generally accepted scientific and technical principles, procedures and practices. This may include mathematical modelling and simulation. As analysis represents theoretical conformance only, it is imperative that the level of confidence in the validity of the analysis be high enough to mitigate the possible risk involved.

9.8.3. Similarity:

Review a similar item's prior verification results, and confirm that its verification status can be regarded as representative of the present item. Note that similarity of the items as well as the intended use and environment need to be proven.

9.9. DELIVERABLES

Upon completion of ISI, ISI report shall be submitted to SAFARI-1 Senior Manager. The report shall provide findings, results and recommendations based on the outcomes of the ISI.

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APPENDIX A: IMPORTANT DRAWINGS

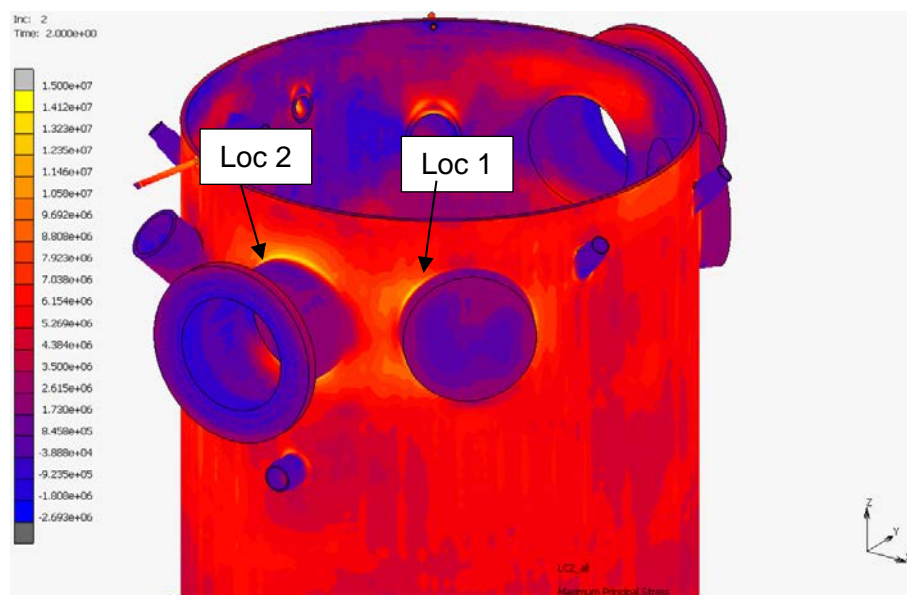


Figure 9: FEA model of high stress location on reactor vessel

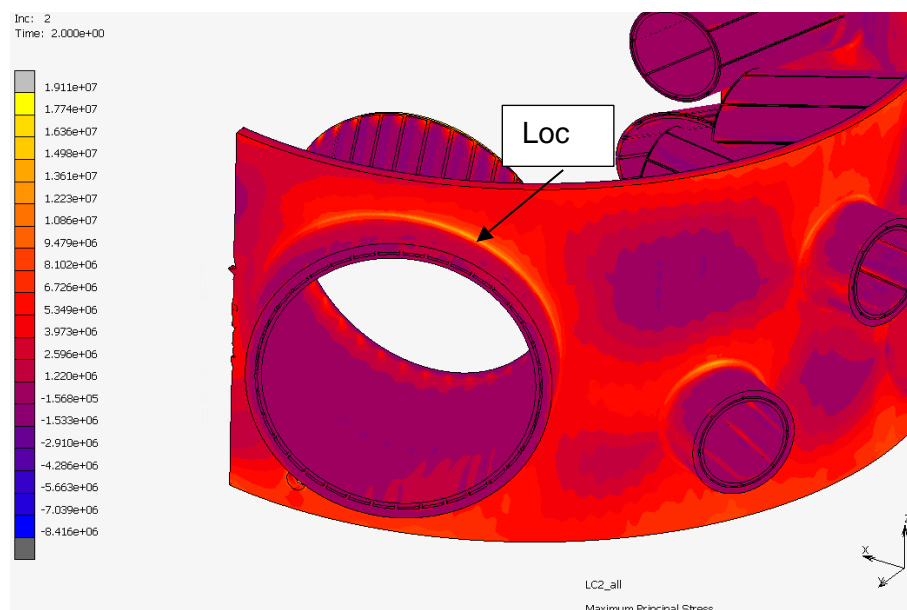


Figure 10 High stress location 3 on the beam tube area

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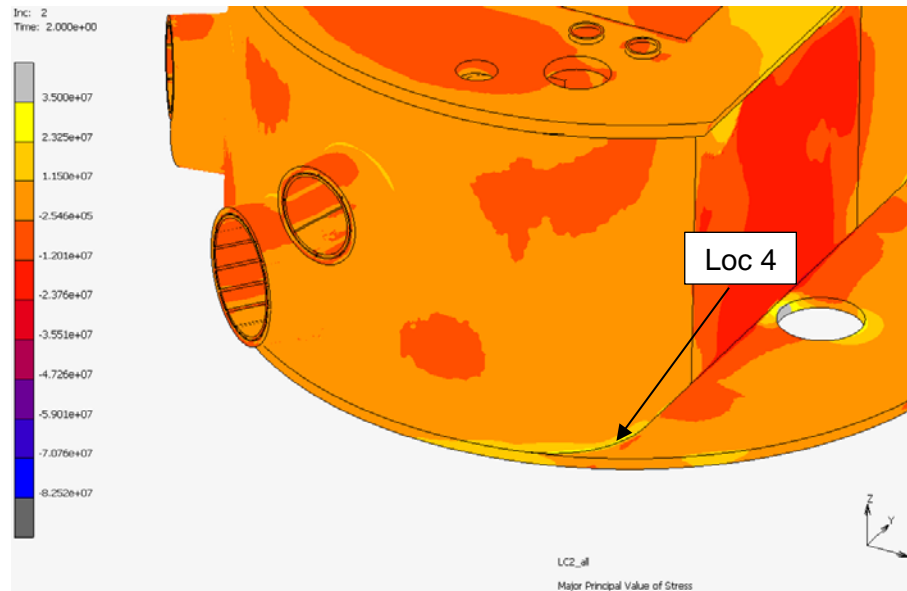


Figure 11: FEA model of high stress location 4 on the bottom weld toe of reactor shell

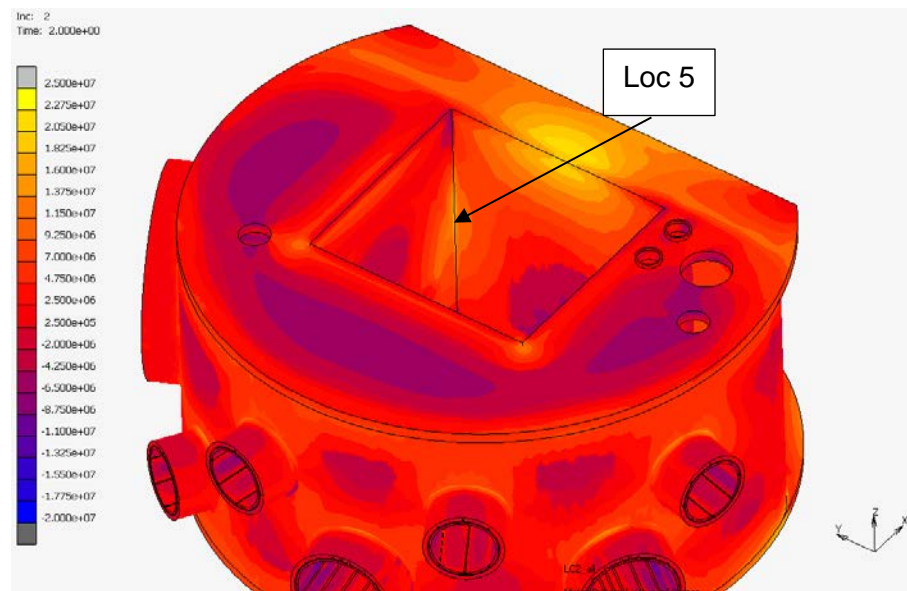


Figure 12 High stress location 5 on the core box

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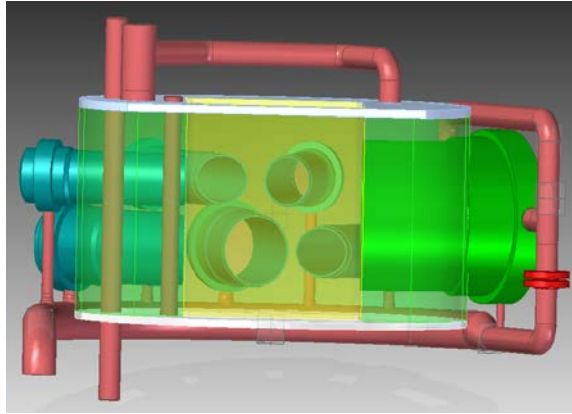


Figure 13: Core Box Section Northern View

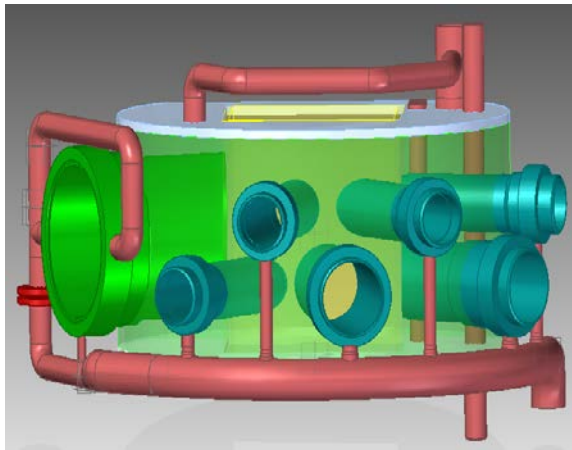


Figure 14: Core Box Section Southern View

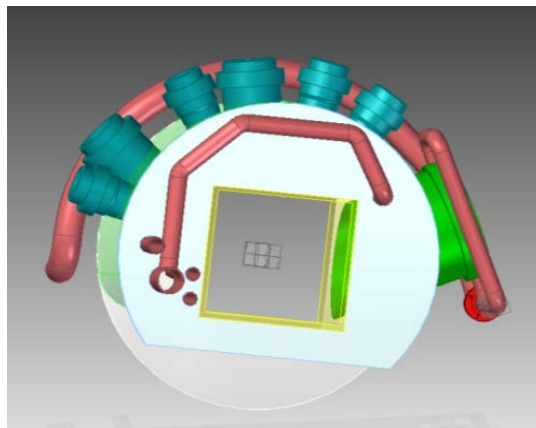


Figure 15: Core Box Section Top View

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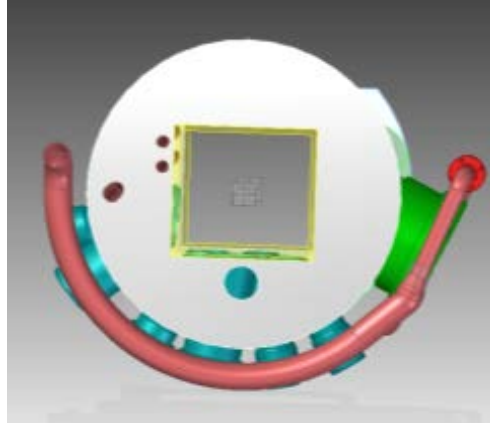


Figure 16: Core Box Section Bottom View

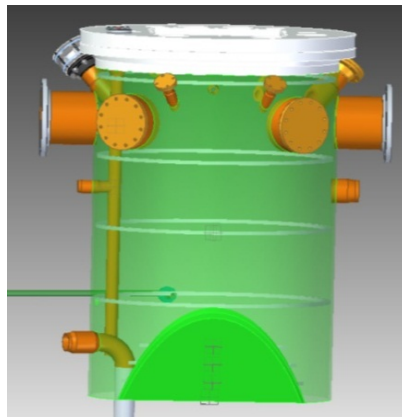


Figure 17: Upper Vessel Section Northern View

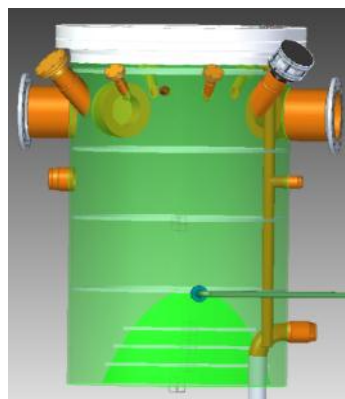


Figure 18: Upper Vessel Section Southern View

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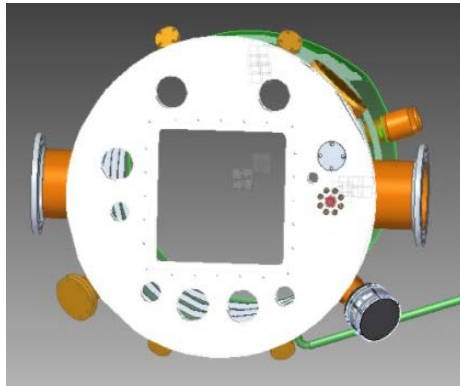


Figure 19: Upper Vessel Section Top View

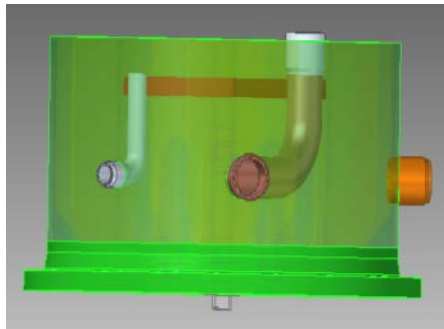


Figure 20: Lower Vessel Section Northern View

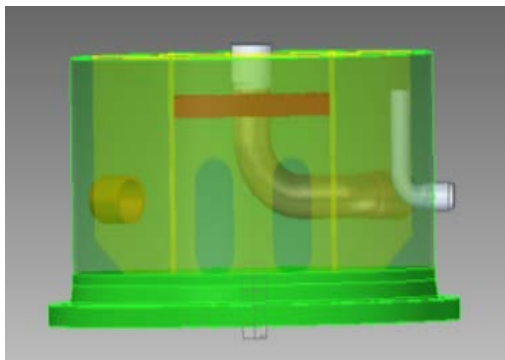


Figure 21: Lower Vessel Section Southern View

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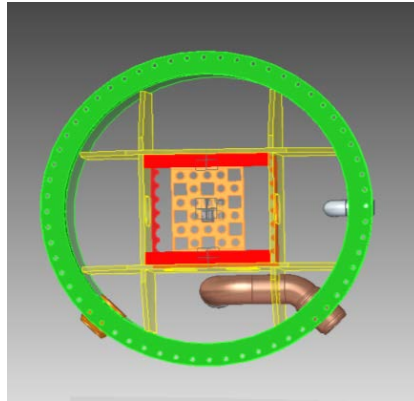


Figure 22: Lower Vessel Section Bottom View

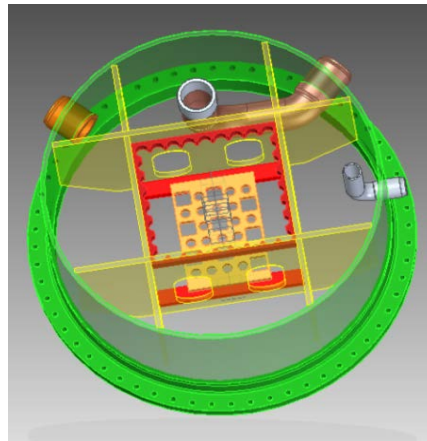


Figure 23: Lower Vessel Section Top View

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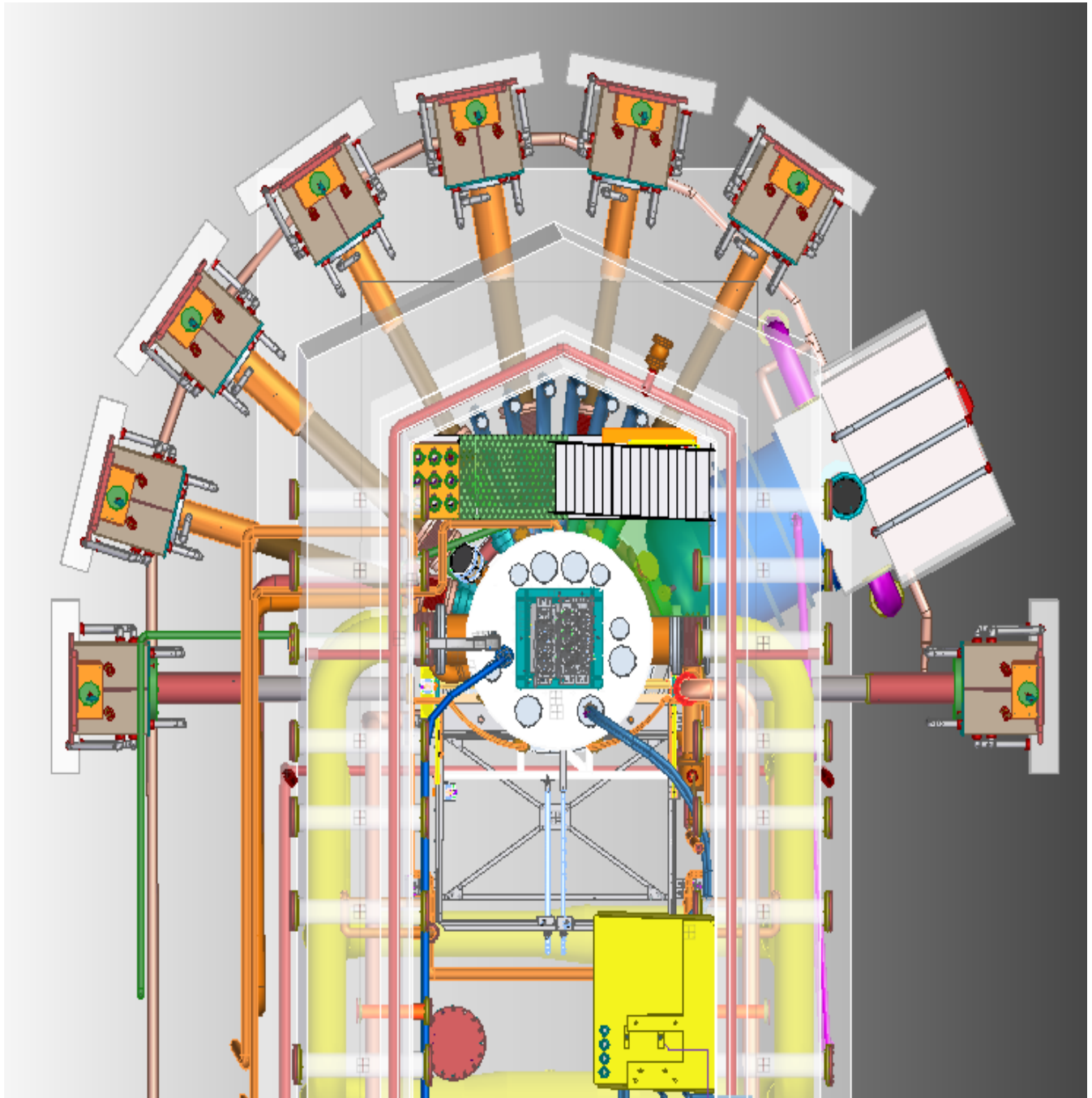


Figure 24: Reactor Pool Top View

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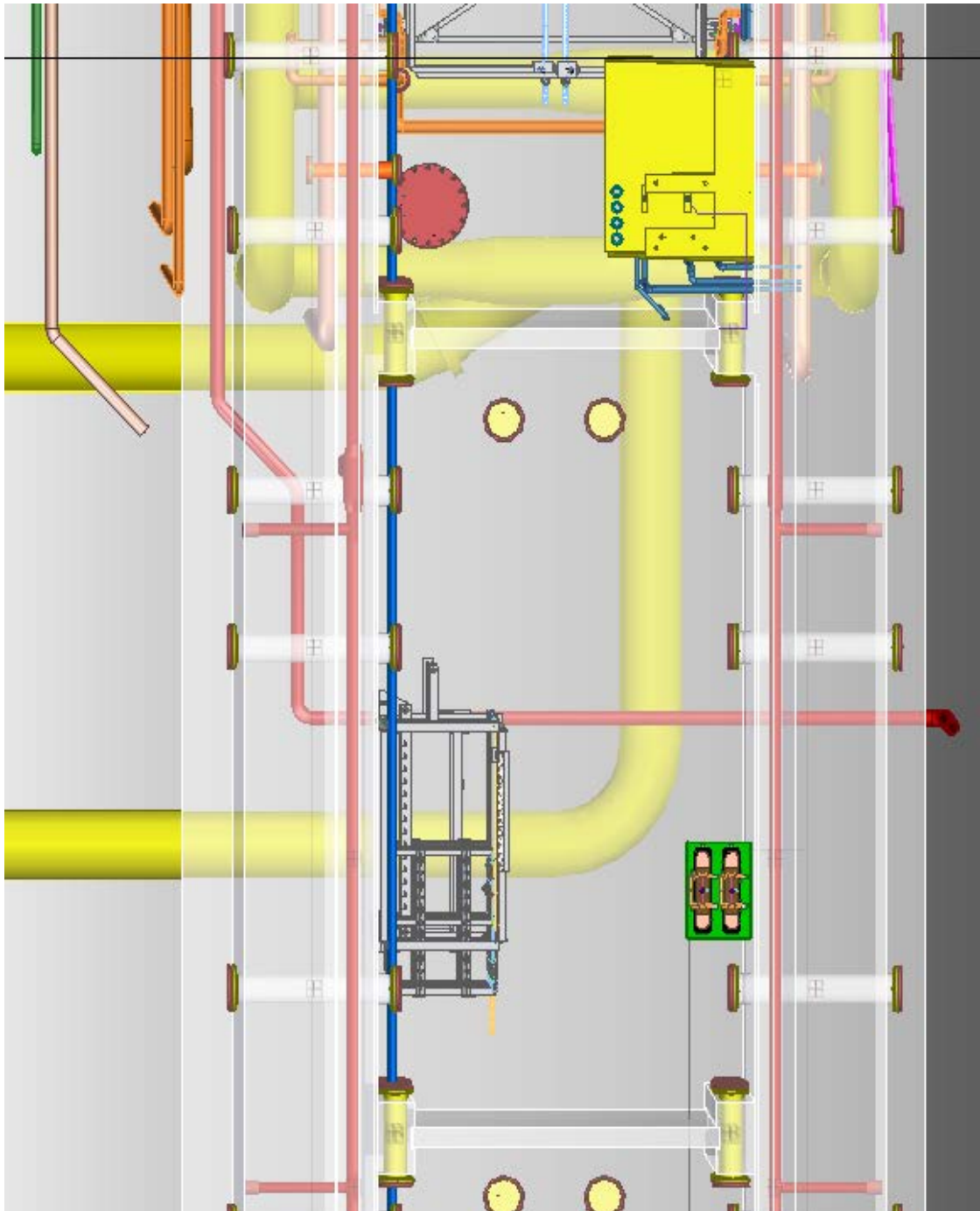


Figure 25: Storage Pool Top View