

Document number	RR-SPE-0053(TCE No: 211547)
Revision number	00
Date	JUNE 2023
Title	Specification for SAFARI-1 Reactor Pool, and Primary Heat Exchangers Cleaning and In-service Inspection - 2023

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DOCUMENT:	RR-SPE-0053 (TCE No: 211547)	REVISION No. 00	PAGE 2 of 11
TITLE:	Specification for SAFARI-1 Reactor Pool, and Primary Heat Exchangers Cleaning and In-service Inspection - 2023		

INDEX

1.	PURPOSE	4
2.	SCOPE	4
3.	REFERENCES	4
3.1	Referenced Documents	4
4.	ABBREVIATIONS	5
5.	DEFINITIONS	5
6.	HEAT EXCHANGER DESCRIPTION	5
6.1	Safari-1 Pool Heat Exchanger	5
6.2	Safari-1 Pool Heat Exchanger Specifications	6
6.3	SAFARI -1 Primary Heat Exchangers	6
6.4	PRIMARY HEAT EXCHANGER TUBE SPECIFICATIONS	7
7.	STATEMENT OF REQUIREMENTS	7
7.1.1	Pool Heat Exchanger	8
7.1.2	Primary Heat Exchangers:	8
7.2	PRELIMINARY REQUIREMENTS	8
7.2.1	Inspection Approach	8
7.2.2	Inspection Timeframe	8
8.	CLEANING REQUIREMENTS	9
8.1	HEAT Exchangers Cleaning.....	9
9.	IN-SERVICE INSPECTION (ISI)	9
9.1	ISI item description and requirements	9
9.1.1	Tube Visual Inspection	9
9.1.2	Eddy Current Inspection of Tube Thickness	9
10.	CLEANING AND ISI METHODS	10
11.	COMPLIANCE	10
12.	REPORTING.....	10
13.	QUALITY ASSURANCE	10
14.	SAFETY REQUIREMENTS	10

FIGURES

Figure 1 Safari-1 Research Reactor Pool Cooling System	6
Figure 2 Safari-1 Research Reactor Primary Cooling System	7

TABLE

Table 1 ISI Plan of listed equipment to be inspected	8
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SAFARI-1

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DOCUMENT:	RR-SPE-0053 (TCE No: 211547)	REVISION No. 00	PAGE 3 of 11
TITLE:	Specification for SAFARI-1 Reactor Pool, and Primary Heat Exchangers Cleaning and In-service Inspection - 2023		

REVISIONS

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

Rev. No.	Date approved	Nature of Revision	Prepared
0	See title page	First Issue	N.A. Lukoto

SAFARI-1

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DOCUMENT:	RR-SPE-0053 (TCE No: 211547)	REVISION No. 00	PAGE 4 of 11
TITLE:	Specification for SAFARI-1 Reactor Pool, and Primary Heat Exchangers Cleaning and In-service Inspection - 2023		

1. PURPOSE

This document is intended to outline the requirements for high-pressure cleaning and In-Service Inspection (ISI) of the secondary side of the heat exchangers in the SAFARI-1 reactor pool and primary heat exchangers. These requirements are specified as per the directives in the SAFARI-1 management systems.

The cleaning and in-service inspection (ISI) of the SAFARI-1 research reactor pool, and primary heat exchangers should ensure optimal performance and comply with IAEA research reactor safety standards. This specification details the requirements, methods, and standards for these tasks.

2. SCOPE

This document specifies the scope of tasks, including high-pressure cleaning and In-Service Inspections, for tubes and associated parts on the secondary side of the heat exchanger. The conduct of these tasks must align with the guidelines set forth in RR-MPR-0003 and RR-ISP-2300. The outlined tasks encompass cleaning, inspection, maintenance, and report preparation for the following:

Reactor pool & primary heat exchangers

Further, it details the regulations governing inspection authorities.

3. REFERENCES

This report is based on the requirements and guidelines supplied in the following references:

Specific revisions are preferably listed in the last column. Where all role players agreed to take full responsibility, the specific revision was replaced with 'Latest approved' revision.

3.1 REFERENCED DOCUMENTS

Ref. No.	Doc. No.	CMS ID	Document Title	Revision
[1]	RR-SPE-0030		Specification for the Reactor Pool & Primary Heat Exchangers Cleaning and ISI	00
[2]	RR-ISP-2300		In-Service Inspection Plan (ISP): SAFARI-1	08
[3]	RR-MPR-0003		Mechanical Maintenance Schedules	

SAFARI-1

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DOCUMENT: RR-SPE-0053 (TCE No: 211547)

REVISION No. 00

PAGE 5 of 11

TITLE: Specification for SAFARI-1 Reactor Pool, and Primary Heat Exchangers Cleaning and In-service Inspection - 2023

4. ABBREVIATIONS

The following abbreviations are referenced in this report:

EC	Eddy current inspection
DP	Die penetrant inspection
ISI	In Service Inspection
NDE	Non-Destructive Evaluation
TVC	Control Valve
TVC054	Control Valve number 054 that regulates the flow of the secondary coolant through the heat exchanger tubes
Vis	Visual inspection

5. DEFINITIONS

The following definitions are referenced in this report:

Sulphamic acid	Also known as amidosulfonic acid Sulphamic acid (H_3NSO_3) is used as an acidic cleaning agent, sometimes in household products, for removing rust and limescale deposits

6. HEAT EXCHANGER DESCRIPTION

6.1 SAFARI-1 POOL HEAT EXCHANGER

The temperature of the pool water is reduced to around 30°C using a shell and tube heat exchanger, which is designed similarly to the primary heat exchangers. However, this heat exchanger has a smaller capacity of only 820 kW. To regulate the temperature of the primary coolant in the pool, the flow of the secondary coolant through the heat exchanger tubes, control valve (TCV054) is controlled. This ensures that there are no fluctuations in flow or pressure within the Pool Primary Coolant System.

SAFARI-1

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DOCUMENT: RR-SPE-0053 (TCE No: 211547)

REVISION No. 00

PAGE 6 of 11

TITLE: Specification for SAFARI-1 Reactor Pool, and Primary Heat Exchangers Cleaning and In-service Inspection - 2023

6.2 SAFARI-1 POOL HEAT EXCHANGER SPECIFICATIONS

- Tube Material: Stainless Steel 304
- Tube Diameter: $\frac{3}{4}$ " OD and 16.4mm ID
- Tube Length: 6m
- Tube Configuration: Straight/Horizontal
- Total number of tubes: 342

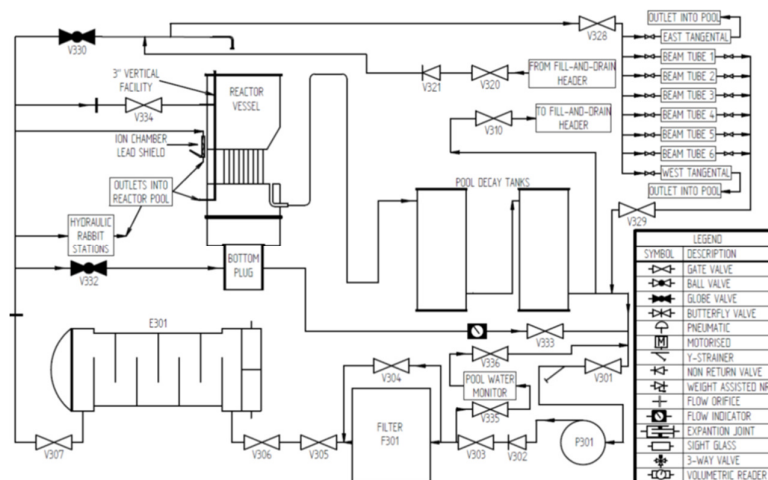


Figure 1 Safari-1 Research Reactor Pool Cooling System [1]

6.3 SAFARI -1 PRIMARY HEAT EXCHANGERS

The primary coolant piping, originating from the reactor primary pumps, extends towards the east and then divides into four separate 7.5 MW heat exchangers: E101, E102, E103, and E104. The outlets of these heat exchangers are subsequently reconnected using a 508 mm pipe. These heat exchangers are of the shell and tube type, constructed with stainless steel shells, tube plates, and tubes, along with carbon steel end covers [1].

To maintain the purity of the primary coolant water the reactor primary coolant circulates through the shell side of the heat exchangers. This ensures that the secondary side, which is more challenging to clean can be kept clean. Furthermore, the shell side, being a sealed unit, minimizes the risk of leakage to the outside.

The tubes of the heat exchangers accommodate the secondary cooling water, with the tubes being expanded and seal welded to the tube plates. Typically, all four heat exchangers operate simultaneously, with E103 and E104 sharing a common inlet valve on the primary side.

For structural integrity reasons, it is important to maintain a maximum operational differential pressure of 70 kPa across the primary side of the heat exchangers.

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DOCUMENT: RR-SPE-0053 (TCE No: 211547)

REVISION No. 00

PAGE 7 of 11

TITLE: Specification for SAFARI-1 Reactor Pool, and Primary Heat Exchangers Cleaning and In-service Inspection - 2023

6.4 PRIMARY HEAT EXCHANGER TUBE SPECIFICATIONS

- Tube Material: Stainless Steel 304
- Tube Diameter: 25.4mm
- Tube Wall Thickness: 1.65mm
- Tube Length: 6m
- Tube Configuration: Straight/Horizontal
- Total number of tubes: 484/unit

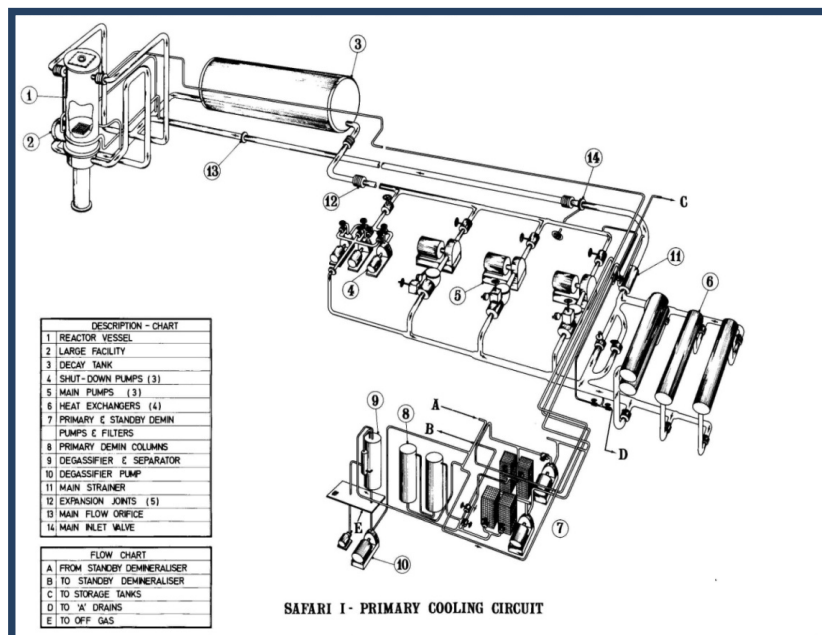


Figure 2 Safari-1 Research Reactor Primary Cooling System [1]

7. STATEMENT OF REQUIREMENTS

The SAFARI-1 In-Service Inspection Program (ISIP) establishes a critical set of obligations to ensure safe and efficient operation of the facility. Among the central components of this program is the required inspection of the reactor pool and the primary heat exchangers. This is an imperative process to detect any potential issues or areas of concern that could impact operational integrity or safety.

The In-Service Inspection Plan RR-ISP-2300, provides a breakdown of components/items that are designated for inspection. Each component is listed in this plan, indicating its relevance and the nature of its inspection. This plan serves as a blueprint, guiding the operational team through the required procedures to guarantee the continued safety and functionality of the facility [2]. These items are specifically listed in Table 1.

This specification comprehensively outlines the inspection requirements and components to be inspected, all of which are crucial for maintaining the operational standards and safety of the SAFARI-1 facility.

SAFARI-1

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DOCUMENT: RR-SPE-0053 (TCE No: 211547)

REVISION No. 00

PAGE 8 of 11

TITLE: Specification for SAFARI-1 Reactor Pool, and Primary Heat Exchangers Cleaning and In-service Inspection - 2023

Table 1 ISI Plan of listed equipment to be inspected

Item	Sample freq *	Technique / Reference	Frequency (Yearly)
7.1.1 Pool Heat Exchanger			
1. Vessel welds	100%	Vis	4
2. Tube surface conditions (Internal Secondary side)	All	Vis	4
3. Tube thickness	100%	EC / Go, No-go Gauge	4
7.1.2 Primary Heat Exchangers: E101, E102, E103 & E104			
1. Vessel welds	100%	Vis	4
2. Tube surface conditions (Internal Secondary side)	All	Vis	4
3. Tube thickness	100%	EC / Go, No-go Gauge	4

The table lays out the sample inspection frequency, inspection method, and the interval between inspections. The listed frequency or inspection coverage represents the bare minimum requirement.

7.2 PRELIMINARY REQUIREMENTS**7.2.1 Inspection Approach**

The ISI provider must detail the methodology that will be used in preparing for, implementing, and documenting the ISI program.

7.2.2 Inspection Timeframe

The ISI provider must ensure they are prepared to perform the inspection within the agreed time period, with the actual inspection not exceeding 2 days. This timeframe does not include potential on-site preparations and equipment setup which can be completed prior to shutdown.

Similarly, the high-pressure cleaning provider must confirm their preparedness to carry out the cleaning within the agreed timeframe, with the actual task not lasting more than 3 days. This does not include potential on-site preparations and equipment setup which can be accomplished prior to shutdown.

SAFARI-1

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DOCUMENT:	RR-SPE-0053 (TCE No: 211547)	REVISION No. 00	PAGE 9 of 11
TITLE:	Specification for SAFARI-1 Reactor Pool, and Primary Heat Exchangers Cleaning and In-service Inspection - 2023		

8. CLEANING REQUIREMENTS

8.1 HEAT EXCHANGERS CLEANING

The primary heat exchangers shall be cleaned to ensure optimal thermal efficiency, ensuring the removal of any deposits and obstructions.

Objective: The task's aim is to thoroughly clean all heat exchanger tubes in compliance with RR-MPR-0003. The pool heat exchanger is to be cleaned annually, while primary heat exchangers require cleaning every two years.

The cleaning procedure comprises:

- Unsealing, cleaning, and conducting a visual inspection.
- Treating with a 5% - 10% solution of inhibited Sulphamic acid, followed by high-pressure water tube cleaning.
- Cleaning and inspecting lids & end shields for any signs of rust.

The supplier is tasked with safely discarding all Sulphamic effluent from the site, an obligation encompassed in their pricing structure.

9. IN-SERVICE INSPECTION (ISI)

ISI for heat exchangers should assess the performance of tubes, seals, and joints, and overall structural integrity.

9.1 ISI ITEM DESCRIPTION AND REQUIREMENTS

The goal of the inspection process is to visually inspect and measure the thickness of the secondary side heat exchanger tubes.

9.1.1 Tube Visual Inspection

Objective:

The inspection aims to visually scrutinize the heat exchanger tubes to detect any irregularities like cracks, visible corrosion, or deformations implying corrosion, especially at welds on the tubes.

9.1.2 Eddy Current Inspection of Tube Thickness

Objective:

The inspection's purpose is to assess the tube integrity through an Eddy Current (EC) inspection of all (100%) internal heat exchanger tubes.

The following shall be verified by Necsa and copies obtained as applicable:

- Personnel Qualification Records (qualified NDE person)
- Calibration of test equipment.
- All inspection and test reports.
- Inspection and test instructions (detailed the codes and standards used for the NDE).

SAFARI-1

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DOCUMENT:	RR-SPE-0053 (TCE No: 211547)	REVISION No. 00	PAGE 10 of 11
TITLE:	Specification for SAFARI-1 Reactor Pool, and Primary Heat Exchangers Cleaning and In-service Inspection - 2023		

10. CLEANING AND ISI METHODS

Methods used should be based on international best practices, with an emphasis on non-intrusive, remote techniques to minimize exposure to personnel.

11. COMPLIANCE

All activities should comply with relevant regulations and safety procedures, including radiation protection measures, environmental protection guidelines, and waste disposal practices.

12. REPORTING

Detailed documentation of all cleaning and ISI activities should be provided. This includes a description of the process, findings, any issues, and corrective actions taken.

Cleaning and In-Service Inspection (ISI) of the heat exchangers are crucial for maintaining operational efficiency and safety standards. Detailed documentation of these procedures is essential for quality control and future reference.

The documentation of the cleaning process should cover the techniques and methods used, along with the outcomes, noting any anomalies observed during the process. Similarly, the ISI reports should detail the inspection methodology, findings, and any concerns identified during the procedure.

Both these reports should comprehensively discuss any issues encountered. These could include equipment malfunctions, unforeseen conditions, or any other incidents that may have hindered the process or potentially affect the performance of the heat exchangers.

Lastly, the documentation must also include the corrective actions undertaken to resolve any detected issues. These may include immediate repairs, changes in maintenance protocols, or upgrades in equipment based on the findings.

13. QUALITY ASSURANCE

The supplier shall implement a quality assurance program, ensuring that all activities are carried out in line with the industry's best practices and regulatory requirements.

14. SAFETY REQUIREMENTS

The supplier is obligated to rigidly comply with all nuclear and occupational safety norms and guidelines, including provisions for emergency situations, worker protection, and reduction of radiation exposure.

Given that the facility operates at its maximum power level and only accommodates brief monthly and annual shutdowns, these short intervals will be capitalized upon for carrying out this task as dictated by RR-MPR-0003.

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DOCUMENT:	RR-SPE-0053 (TCE No: 211547)	REVISION No. 00	PAGE 11 of 11
TITLE:	Specification for SAFARI-1 Reactor Pool, and Primary Heat Exchangers Cleaning and In-service Inspection - 2023		

During any shutdown phase, it is mandatory to completely drain the water level in the secondary system before embarking on this task.

Steps will be taken to regulate exposure to workers near the heat exchangers as well as to the supplier's equipment. It is anticipated that the supplier will align with all safety mandates set forth by SAFARI-1. To ensure this, a safety induction conducted by Necsa will be arranged prior to the commencement of work. This induction is not expected to exceed a 4-hour duration.