

# SAFARI-1 research reactor Ageing Management Programme: A case study : successes and challenges

International Group on Research Reactors (IGORR) Conference  
and  
IAEA Technical Meeting (TM) in Research Reactor Ageing Management,  
Refurbishment and Modernization

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# PRESENTATION OUTLINE

Introduction

SAFARI-1 Ageing Management Programme (AMP)

Ageing Management Projects

Reactor Vessel Assessment

Biological Shield and Plant Health Assessments

Successes and Challenges

Conclusion

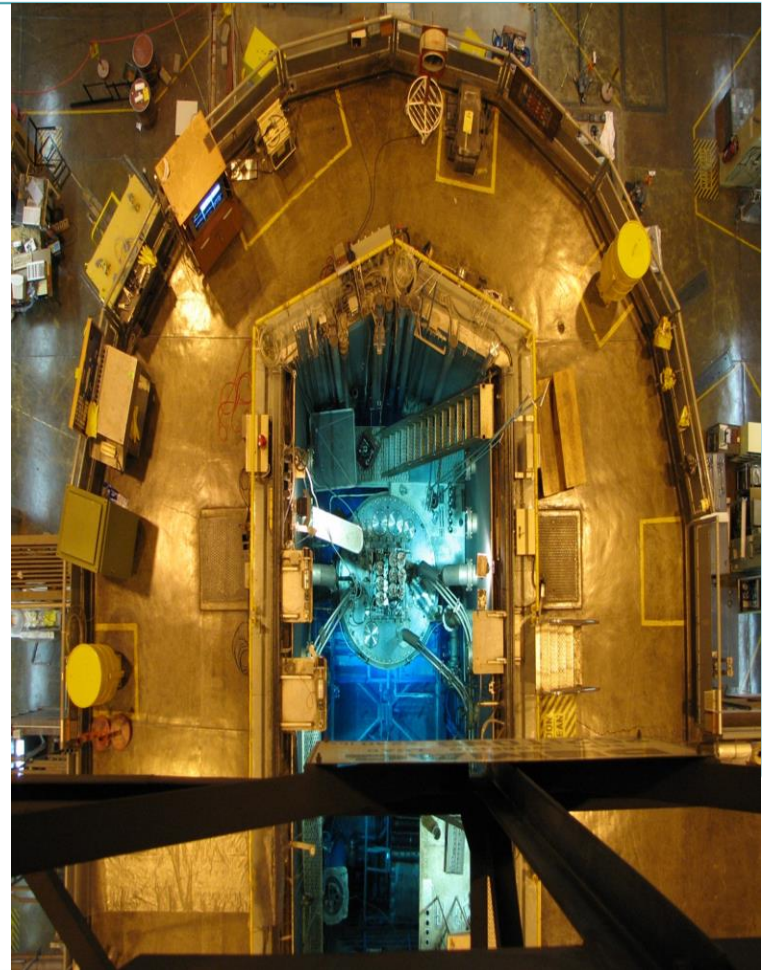
# Introduction

## South African NUCLEAR FACILITIES & LOCATION



# SAFARI-1 Research Reactor

- ❑ 20 MW pool-type research reactor
- ❑ Light water cooled and moderated
- ❑ Beryllium reflected
- ❑ **Operational since 18 March 1965**
- ❑ Impeccable safety and environmental record
- ❑ Recognised for high utilisation
- ❑ **> 300 operational days per year**
- ❑ **Fully converted to LEU silicide fuel**
- ❑ **Utilisation:** *Irradiations for isotope production, neutron activation analysis, neutron beam-line research, silicon doping*
- ❑ Successfully implemented Ageing Management Programme



# SAFARI-1 AGEING MANAGEMENT PROGRAMME

- Ageing Management Programme (AMP)  
at SAFARI-1 is based on IAEA Guideline :  
**SSG-10**

- SAFARI-1 AMP Reference documents
  - ▶ 2009: *Ageing Management Strategy*
  - ▶ 2010: *Ageing Management Plan*
  - ▶ 2011: *AMP Projects List updated and tracked annually*

## IAEA Safety Standards for protecting people and the environment

### Ageing Management for Research Reactors

Specific Safety Guide  
No. SSG-10

# AMP Implementation at SAFARI-1



- 1 • Conduct AMP Workshops
- 2 • Determine Ageing Mechanisms
- 3 • Develop Assessment Matrix
- 4 • Provide Remedial Actions (RA)
- 5 • Classification of RA
- 6 • Prioritisation of RA
- 7 • AMP Projects listing
- 8 • Update / Track Status

Systems, Structures and Components relevant to safety and sustainability.	SAFARI-1 RESEARCH REACTOR AGEING MANAGEMENT ASSESSMENT												
	Radiation - Change of Properties	Temperature - Change of Properties	Creep due to Stress/Pressure	Mechanical Fatigue/Wear from Vibration, Cyclic Loads	Material Deposition (e.g. Oxid)	Flow Induced Erosion	Corrosion due to water, steam, chemical attack, humidity	Damage due to Power Excursions	Operational Events	Flooding, Chemical Contamination	Fire - effect of heat, Shock, Resonance, Seismic	Obsolescence, Technology Change	Changes in Requirements or Acceptable Standards
	A	B	C	D	E	F	G	H	I	J	K	L	M
<b>1. Reactor block, fuel and internals</b>													
1.1 Fuel Assemblies (incl. Control rod followers)												1a/b	1a/b
1.2 Fuel Storage													
1.3 Core components - removable (other than reflector and fuel)	1c			1c, j			1c	1c					
1.4 Reflector	1d			1d					1d				
1.5 Reactor tank/vessel (including feed core structure and components)	1e, j			1e, j		1i	1i					1i	
1.6 Pool Liner, Pool gates and jambs etc.	1g												
1.7 Pool structure (Concrete structure excluding Biological Shield)						1f	1f		1f				1f
1.8 Beam tubes													
1.9 Control rods, shut down rods, drive mechanisms	1e												
1.10 Biological shield						1f	1f		1f				1f
1.11 Thermal Shield													
1.12 Start-up Source													1h

RA Ref	Remedial Action	Addresses Ageing Issue(s) on Matrix	Project Break Down Or Status Or Title	Overall Priority	1-Complete 2: Progress 3: Delayed 4: On Hold
1	<b>Reactor Block, Fuel and Internals</b>				
1a	Convert to LEU Fuel	1.1 (K, L)	Complete	0	1
1b	Convert to LEU Targets	1.1 (K, L)	Complete	0	1
1c1	Replace core support grid and CR bearings	1.3 (A, D, G, H)	Grid Plate Manufacture, including inserts	100	2
1c2			Bearing and bearing plate manufacture	70	2
1c3			Develop equipment and approach for grid plate removal	100	2
1c4			Grid plate and bearing plate removal/replacement	70	2
1d	Replace Be Reflector Elements	1.4 (A, C, D, H)	Replacement complete. (Disposal considered to be non-AM)	0	1

No	RA No	Remedial Action or Project Description	Priority	Status	Classification
1	1c1	Grid Plate Manufacture, including inserts	100	In Progress	Mission
2	3d	Implement Standard Charcoal Filter Measurement Capability	100	In Progress	Safety
3	4g2	Stack PLC	70	In Progress	Compliance
4	4l	Rehabilitate N-16 channels	70	Delayed	Maintenance
5	1e	Assess Reactor Vessel Lifetime (may lead to recommendation to replace the RV)	40	In Progress	Lifetime
6	2g2	Manufacture and Install New Heat exchanger	70	On Hold	Lifetime
6	4e	Refurbish Control Room	60	On Hold	Infrastructure
7	4b2	Replace Automatic Flux Controller	100	In Progress	Mission
8	4b4	Replace Rod Drop Monitor	100	In Progress	Mission
9	4b1	Refurbish Neutron Control Channel (WR/MRL)	100	In Progress	Mission

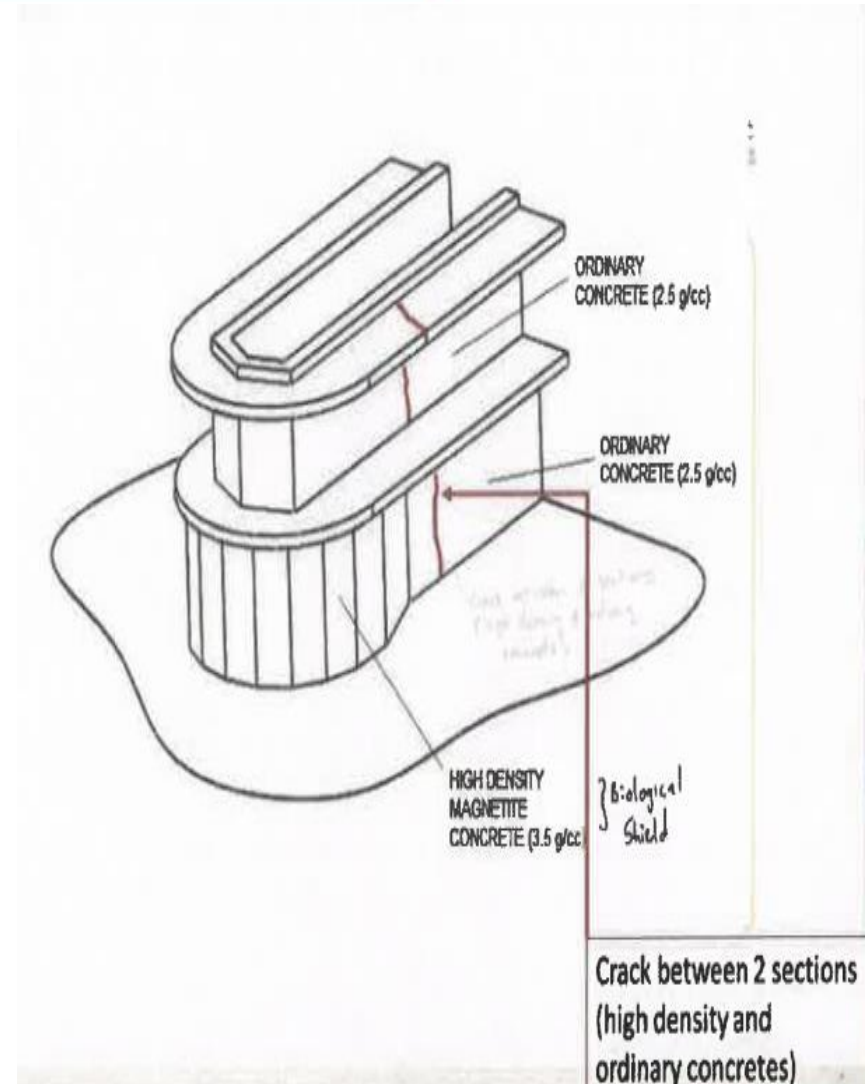
Table 3. A sample List of SAFARI-1 Projects

# SAFARI-1 AMP PRIORITY PROJECTS

- Nuclear Safety Channels ----  
Completed
- Area Monitoring System Upgrade---  
Completed
- Gamma Safety Channels Upgrade ----  
Installation in progress
- Neutron Control Channel ----  
installation in progress
- Automatic Flux Controller ---  
Completed
- Rod Drop Monitor Upgrade ---  
Completed
- Ventilation System refurbishment –  
Completed
- Stack Monitoring System upgrade ----  
Completed
- R1 and R2 Liquid effluent Tanks  
upgrade ---- in progress
- Beam lines upgrades ---- in progress
- Silicon Roller Service Station –  
in progress ??
- Charcoal Ventilation Filter  
Efficiency Measurement Capability-  
-- Completed
- Fresh Fuel Vault Upgrade ---- in  
progress
- Primary Heat Exchanger  
replacement --- in progress
- Reactor Vessel Assessment –  
Completed
- Biological Shield Assessment –  
Completed
- Plant Health Safety Assessment –  
in progress
- Portable External Plug-in Power  
Supply ----- On hold
- Emergency Water Return----- in  
progress

# Biological Shield Assessment

- ❖ It provides the **structural support for the pools, radiation shielding** in the vicinity of the reactor vessel, active equipment in the pools and active piping embedded in the concrete
- ❖ The Biological Shield assessment aimed at **assessing the structural soundness of the reinforced concrete members**



## Conclusion:

*The Strength or durability of the reinforced concrete biological shield was found to be still intact - did not reveal any corrosion staining or cracking*

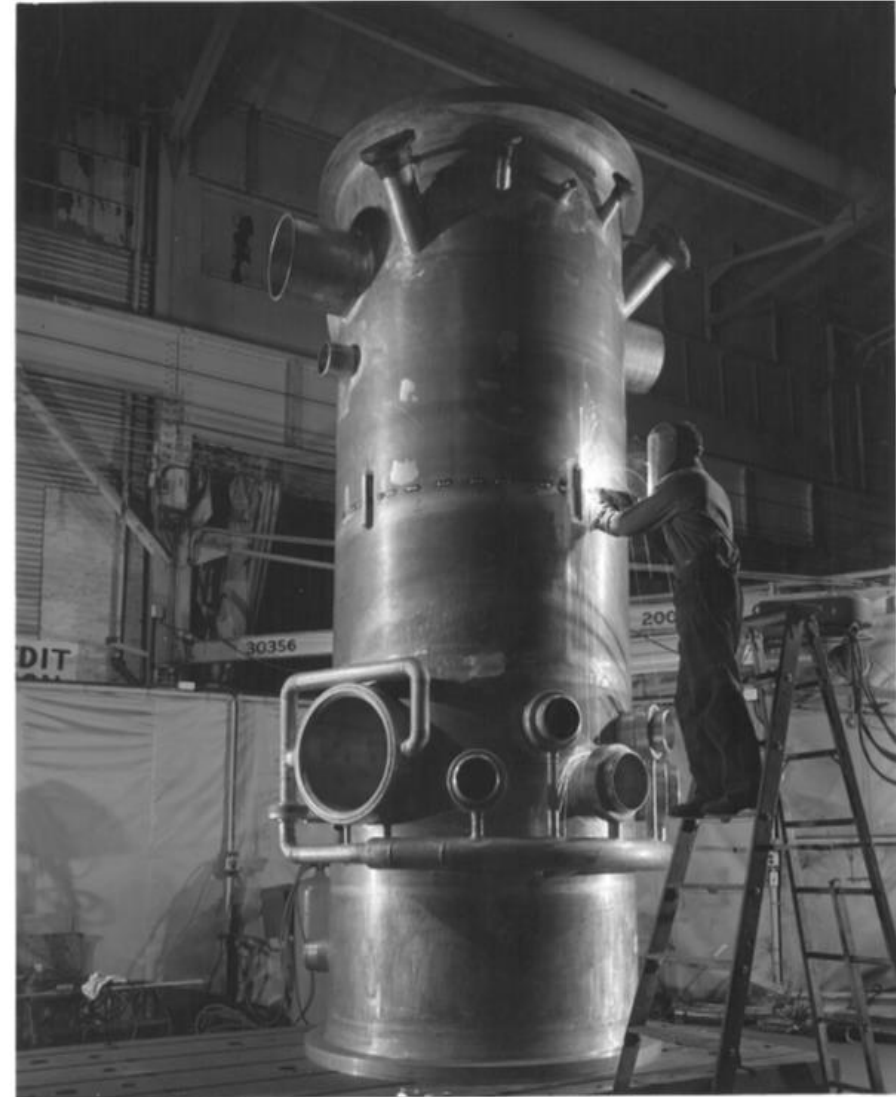


# Plant SSCs Health Assessment

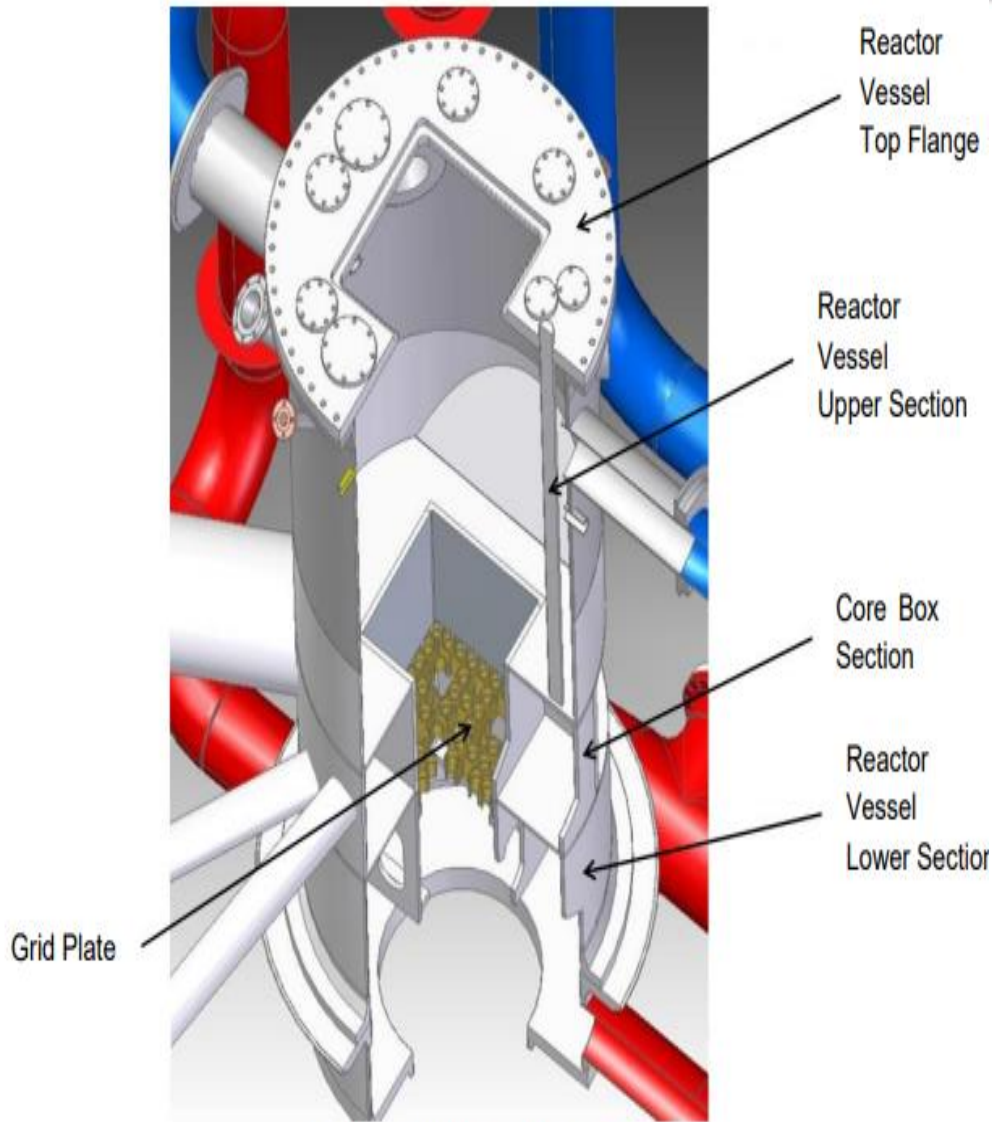
- ❖ SAFARI-1 Plant **SSC Functional Status Assessment** focused on the maintenance performed on SSCs
- ❖ Calculations on reliability and availability were carried out
- ❖ A criterion was developed to carry out maintainability
- ❖ The assessment focused on the status of Ageing Management (AM) initiatives associated with SSCs and provides feedback on whether the activities implemented were effective.

## □ **Conclusion:**

- *Current Ageing Management and In-Service Inspections are functioning effectively*
- *SAFARI-1 Plant SSCs functional /health status preliminary indications most SSCs are safe for continuous operation due to effective maintenance, ISI and AM*



# Reactor Vessel Assessment



Source: (NECSA, 2017a, p. 7)

- **Reactor Vessel and Support structures - aluminium alloy 5052-0 ASTM designation**
- ***Due to the absence of surveillance programme a model to determine the mechanical integrity of the vessel was proposed***
- **A computational fluid dynamics analysis was carried out**
- ***A structural integrity assessment of the SAFARI-1 reactor was carried out for the purpose of determining the fitness-for-purpose period of the reactor.***
- ❖ **to determine the remaining safe operating life of the vessel and**
- ❖ **the required inspection intervals.**
- **Conclusion:**  
*A fatigue life for a given number of reactor cycles was calculated and presented*
- ☐ **Recommendations:**  
*Ultrasonic inspections / non-destructive examinations every ten (10) years to detect and monitor any abnormalities that can initiate in the location of highest stress.*

# Successes and Challenges

## Instrumentation and Maintenance projects

- ❖ Successfully implemented instrumentation projects as part of the AMP
- ❖ Improved plant instrumentation instruments reliability and performance

## Reactor Vessel Assessment

- ❖ Provided a justification to the Nuclear Regulator for revised accumulated power limit (Assessing Neutron irradiation effects)
- ❖ However, a re-assessment need to be done prior to 2030 to justify fluence limit safety for continuous operation beyond 2030
- ❖ Update SAR (Safety Analysis Report) to motivate continuous operation up to 2030 and beyond.

## Biological Shield Assessment

- ❖ Results from the assessment show that the biological shield is fit for continuous operation up to 2030 and beyond.

## Plant SSC Health Safety Assessment - 80 % complete

- ❖ It is a challenge to confirm health status of selected critical SSCs
- ❖ The health assessment initiative is bearing results and still under internal review

# Conclusion

- *In Integrating ageing management and maintenance requirements with other programmes – careful management is required to avoid **duplication of effort** and **wastage of scarce resources***
- ***Ageing management of inaccessible equipment is vital** since replacement and repair is not usually an economically feasible option*
- ***Sharing of operational experiences** by tracking generic failures and monitoring effectiveness of ageing management activities is vital of ageing management programme success*
- *In SAFARI-1 Proposed **modifications to SSCs** as well as modifications to the operation, maintenance and/or utilisation of the reactor, where such modifications **have significant impact on the safety of the reactor and its facilities** are presented for review to the RSC – Reactor Safety Committee – *This have assisted considerably in facility safety assurance and adherence!**
- *The **regulator / reactor operator technical discussion** on regulatory review process of AM projects **facilitated projects delivery timelines***



# Questions?