Modelling and characterization of Beryllium reflectors under irradiation conditions

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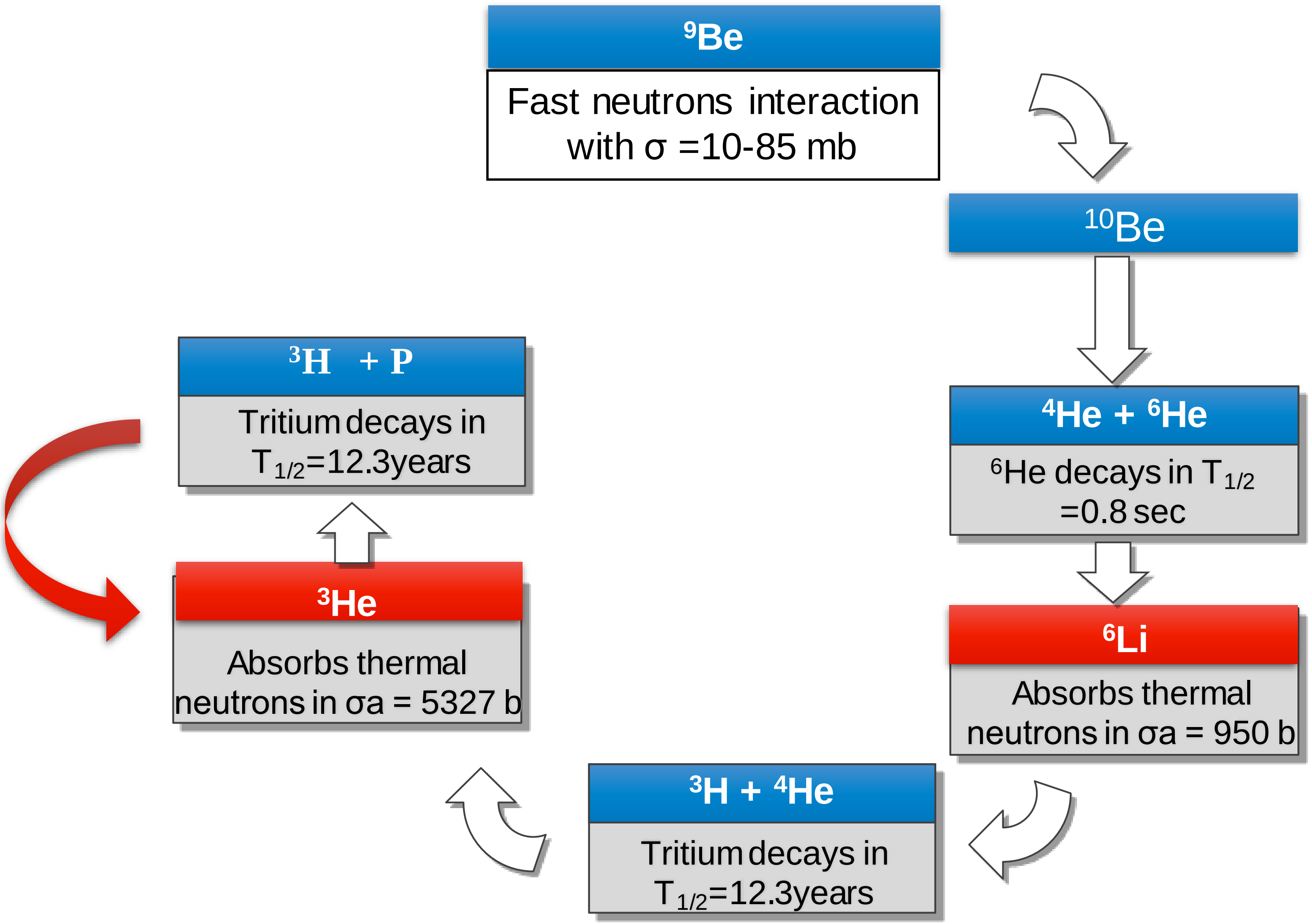
CONTENTS

INTRODUCTION

- Many research reactor are using beryllium reflectors (Such as ETRR-2, MARIA, and SAFARI-1)
- Neutron interactions with beryllium lead to the problem of accumulation of ^{6}Li, ^{3}H and ^{3}He isotopes within the beryllium matrix.
- The ^{6}Li and ^{3}He are neutron poisons (strong absorbers have large thermal neutron absorption cross sections of about 940 barns and 5327 barns respectively) inducing changes in properties of the beryllium reflector elements and are considered as ageing degradation.
- The large densities of ^{6}Li and ^{3}He poisons can impact the worth of beryllium reflector and core parameters (such as core excess reactivity and cycle length) .
- Modeling of accumulation of the poisons are provided for various scenarios and irradiation conditions and calculation of the impact of beryllium poisoning on the core parameters are also provided.
- The proposed solutions/approaches to manage the beryllium poisoning and compensate for the impact on core parameters are compared and discussed.

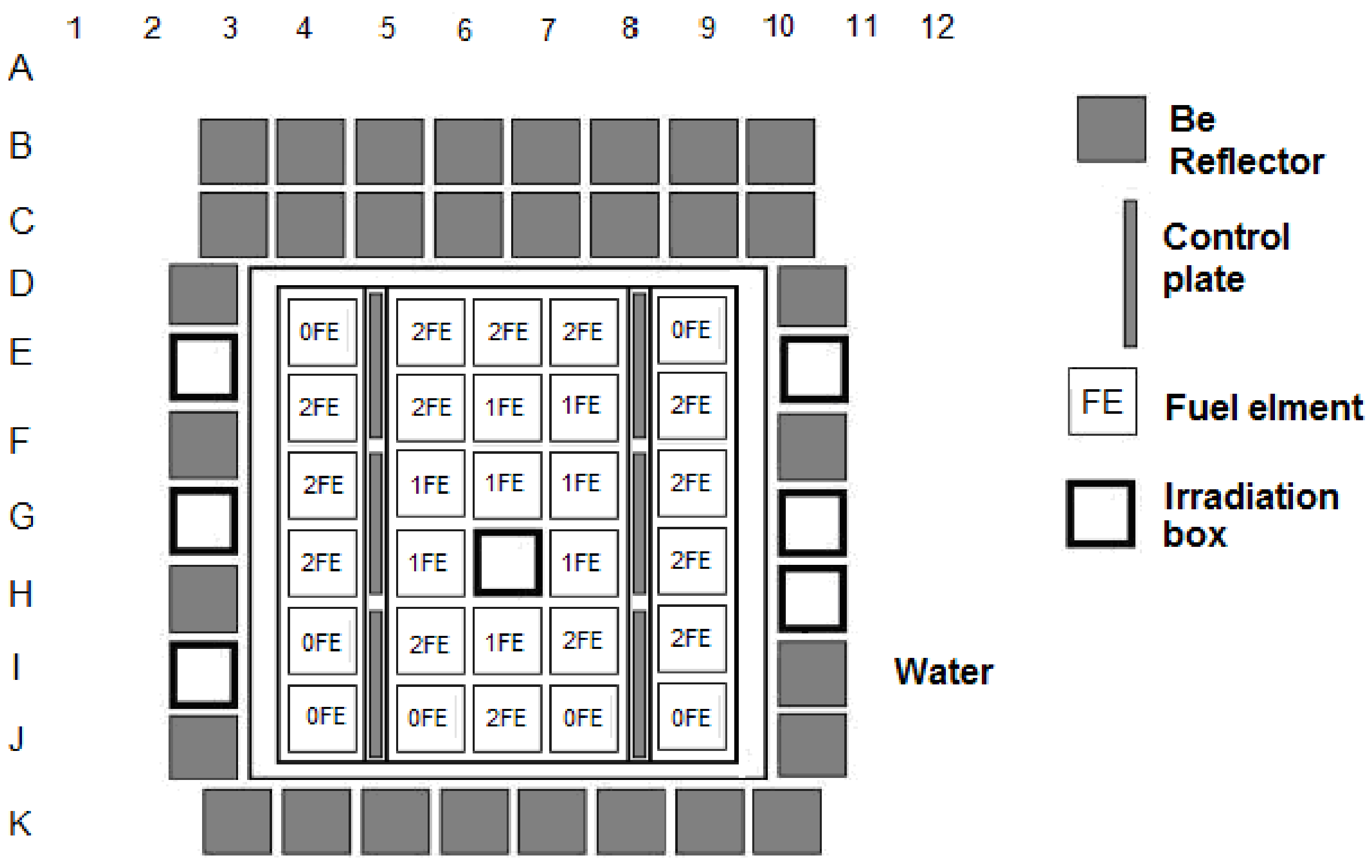
INTODUCTION

Beryllium Poisoning



BENCHMARK CORE

- The bench mark core consists of 29 fuel elements and one in core irradiation device.
- The core active length of the fuel element in (z-direction) is 80 cm.
- Three Fuel Element (FE) types with different ^{235}U content (0FE, 1FE, and 2FE) are loaded in the core.
- The core reflected by beryllium elements.
- The benchmark core specifications are based on ETRR-2 reactor specifications and results of commissioning [IAEA TECDOC 1879].



METHODOLOGY (1/2)

1. Verification of Validating BERY program and CITVAP code used in modelling and calculation of impact on core parameters by comparing the results with the benchmark core design calculation and measured values.

   Verifying that that it has been understood how to use the calculation tools properly

2. Calculation the neutron flux values in 7 energy groups in each Beryllium element using CITVAP with 7 energy groups macroscopic cross-sections library.

3. Dividing of Beryllium elements into zones according to the neutron flux values (the average flux) for each zone and the reactions rates between fast neutrons and Be, 3He, 6Li and Tritium.

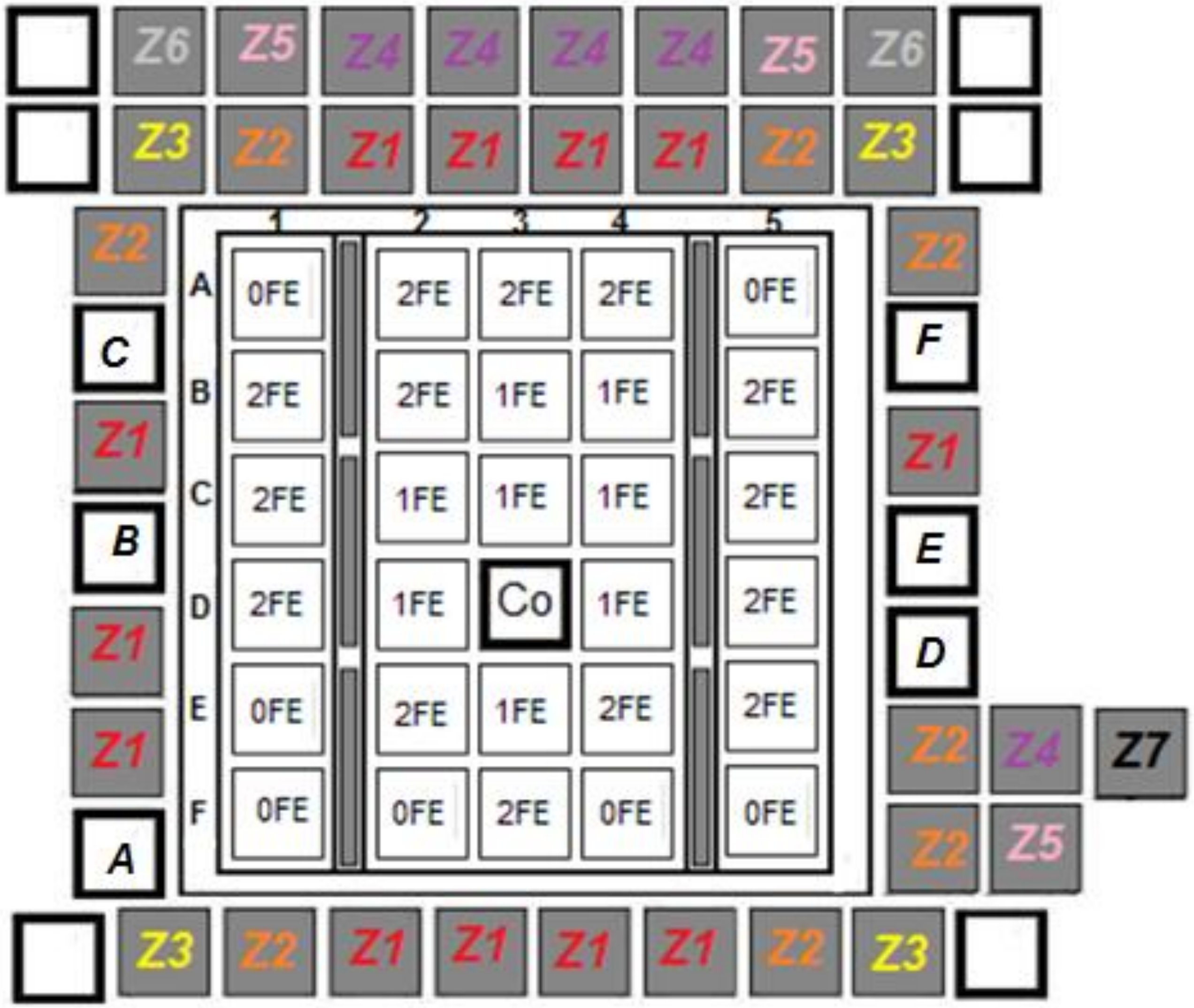
METHODOLOGY (2/2)

5. Calculation of the atomic density of different poisons (^{3}He, ^{6}Li, ^{3}H) accumulated inside the Beryllium reflector matrix under the reactor operational scenario conditions using BERY program.

6. Assessment of the impact on core parameters for verius operational scenarios on the build-up of beryllium poisons.

7. Propose and compare base on calculation solutions to minimize and compensate for the impact of beryllium poisoning on the reactor core parameters for the worst conditions.

Zones of core reflector base on Av. Flux (7 zones)



ρ_x = 3185.1 pcm.

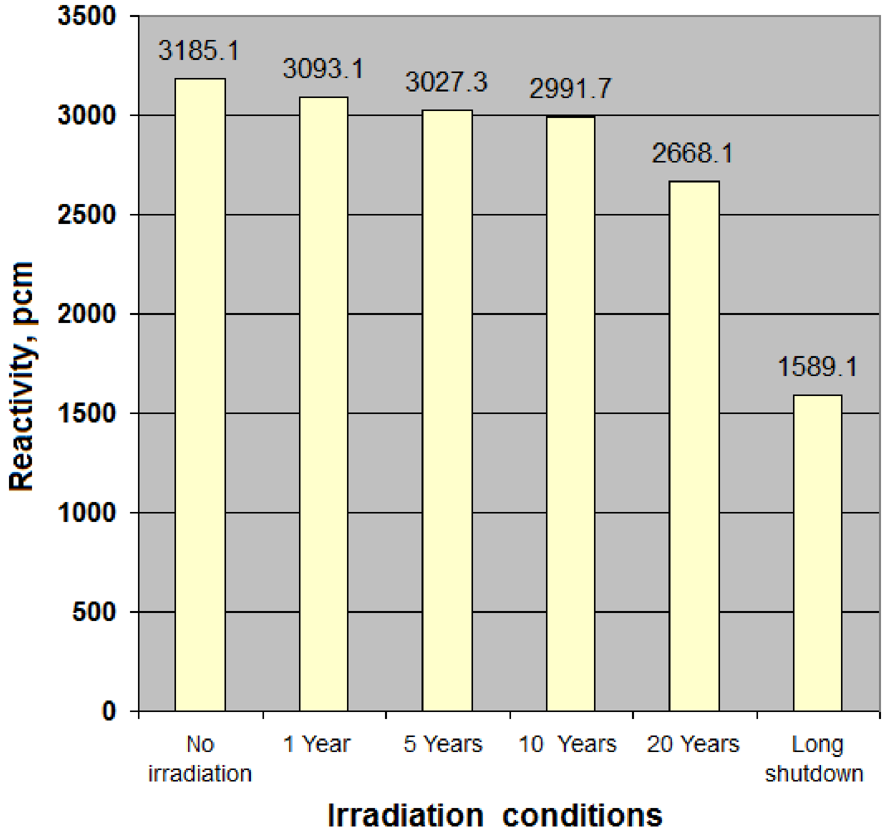
Cycle length = 15.10 FP days.

Core parameters with no irradiation

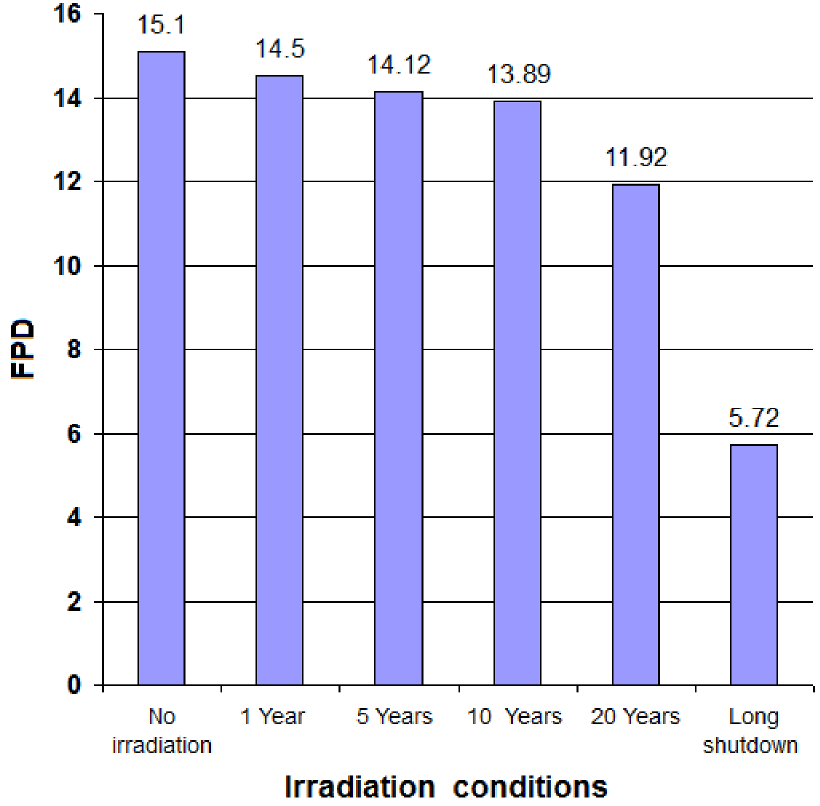
OPERATION SCENARIOS AND CONDITIONS

Operation scenario	Description
Scenario (1)	Regular operation for each month **5 days power + 2 days shutdown] for 3 weeks + shutdown for 1 week**
Condition (1Y)	Irradiation for 1 years under scenario (1)
Condition (5Y)	Irradiation for 5 years under scenario (1)
Condition (10Y)	Irradiation for 10 years under scenario (1)
Condition (20Y)	Irradiation for 20 years under scenario (1)
Long-term shutdown	Irradiation for 10 years under scenario (1) + 10 years of shutdown
Comparison with actual Scenario (2)	MARIA research reactor actual scenario (93-94).
Long term operation (3)	SAFARI-1 research reactor actual scenario (1965 – 2011)

Comparison of Scenario 1 conditions



(a) Excess reactivity (pcm)



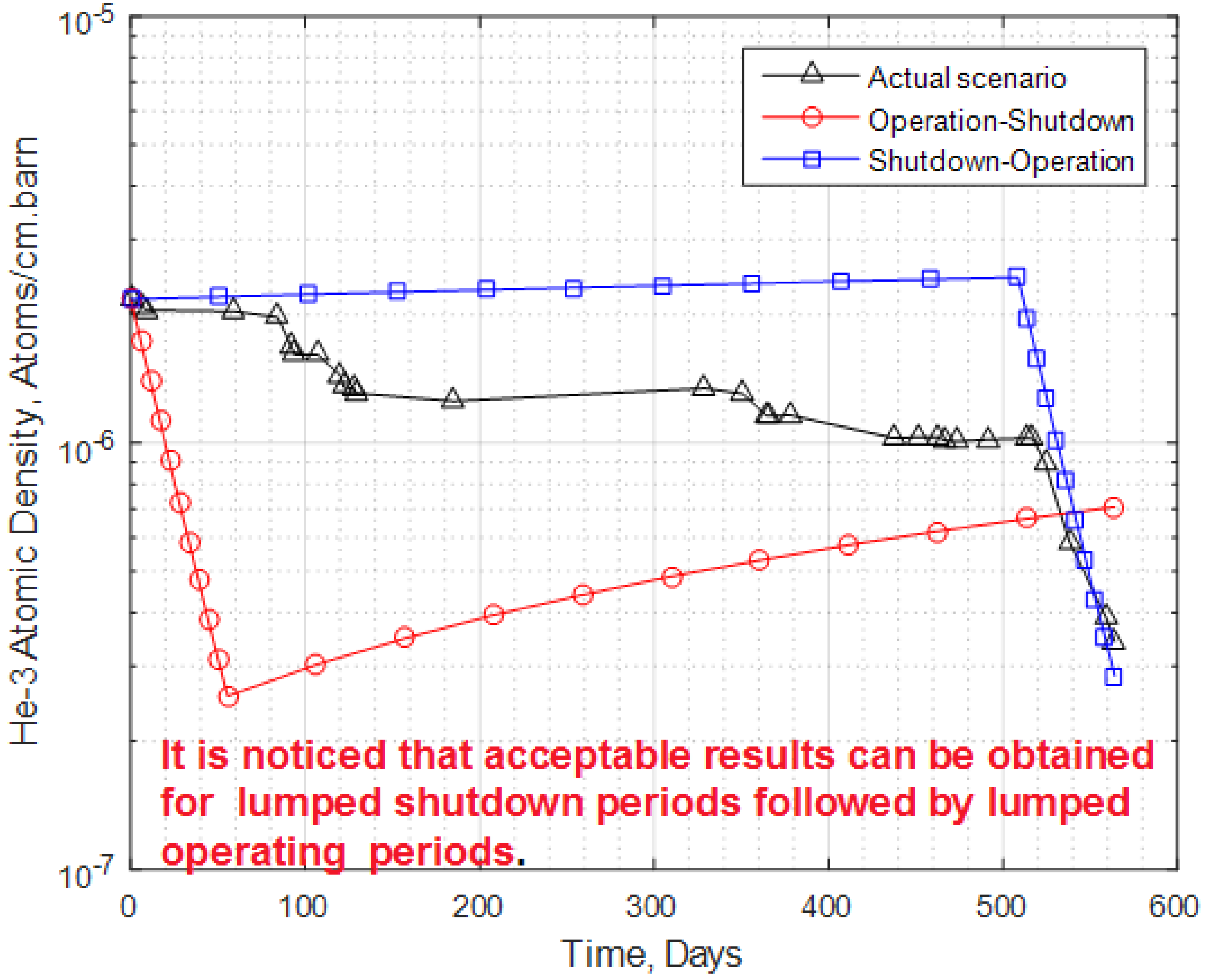
(b) Cycle length (FPD)

Impact of Be poisoning on excess reactivity and cycle length under irradiation conditions of scenario (1) the worst conditions is the long shutdown

Comparison with reactor actual Scenario 2

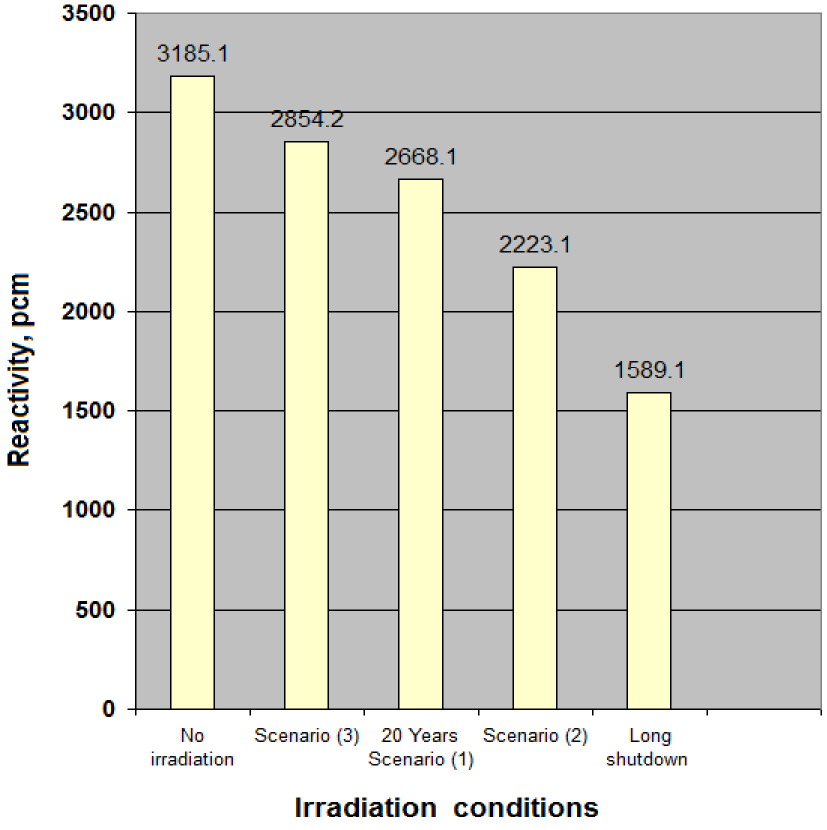
- Additional calculation using the period 93-94 of MARIA reactor actual scenario has been carried out using the neutron flux values in zone (1) for the benchmark reactor core in 3 approximations:

1. The detailed description of actual reactor operational history.
2. The lumped total hours of operation followed by the lumped shutdown period.
3. The lumped shutdown period followed by the lumped operating time.

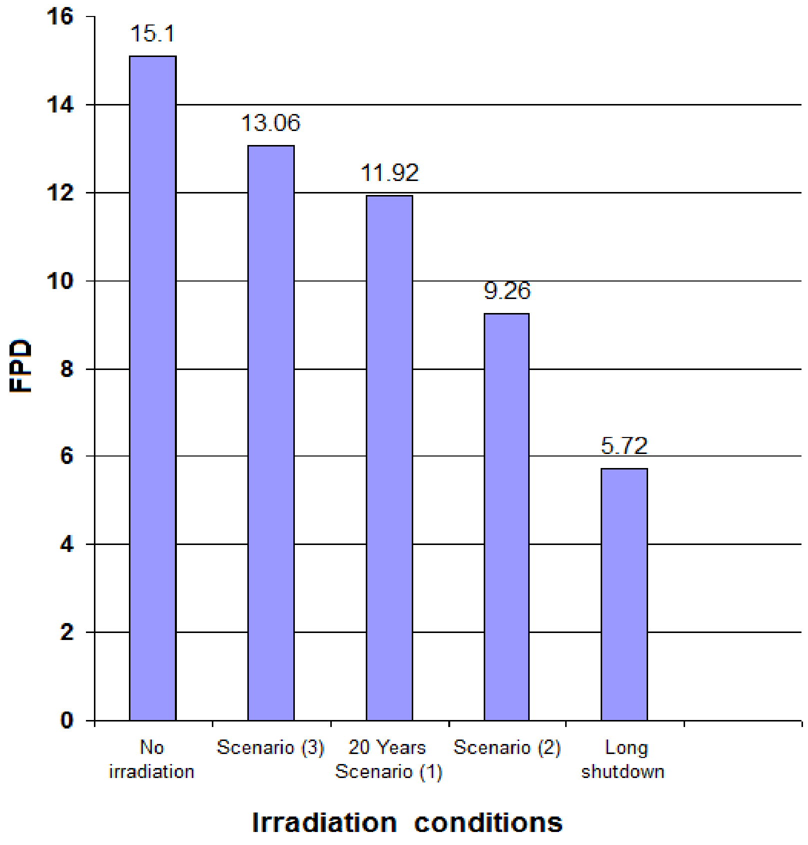


Comparison with long term operation Scenario 3

- This scenario has the longest history between all simulated scenarios but its negative impact on beryllium reflector elements and core parameters is almost the least one because the limited changes in power history and **no long periods of shutdown**.

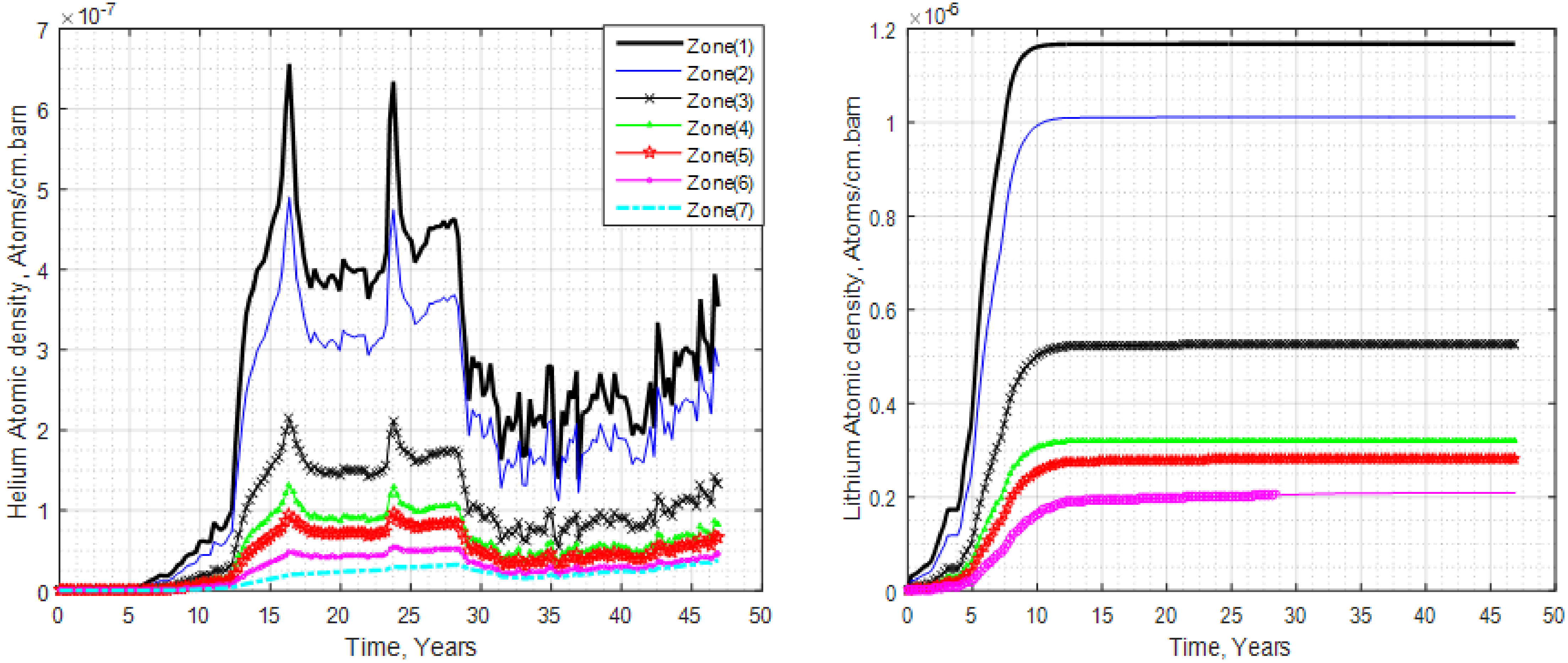


(a) Excess reactivity (pcm)



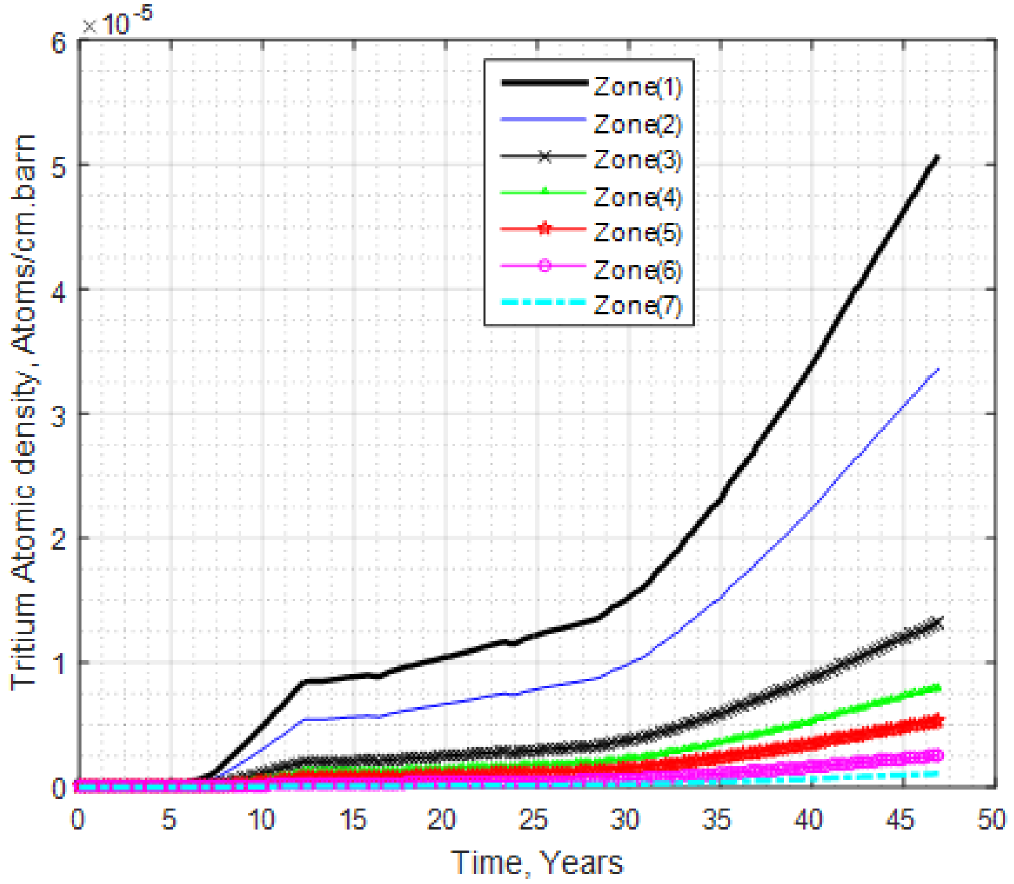
(b) Cycle length (FPD)

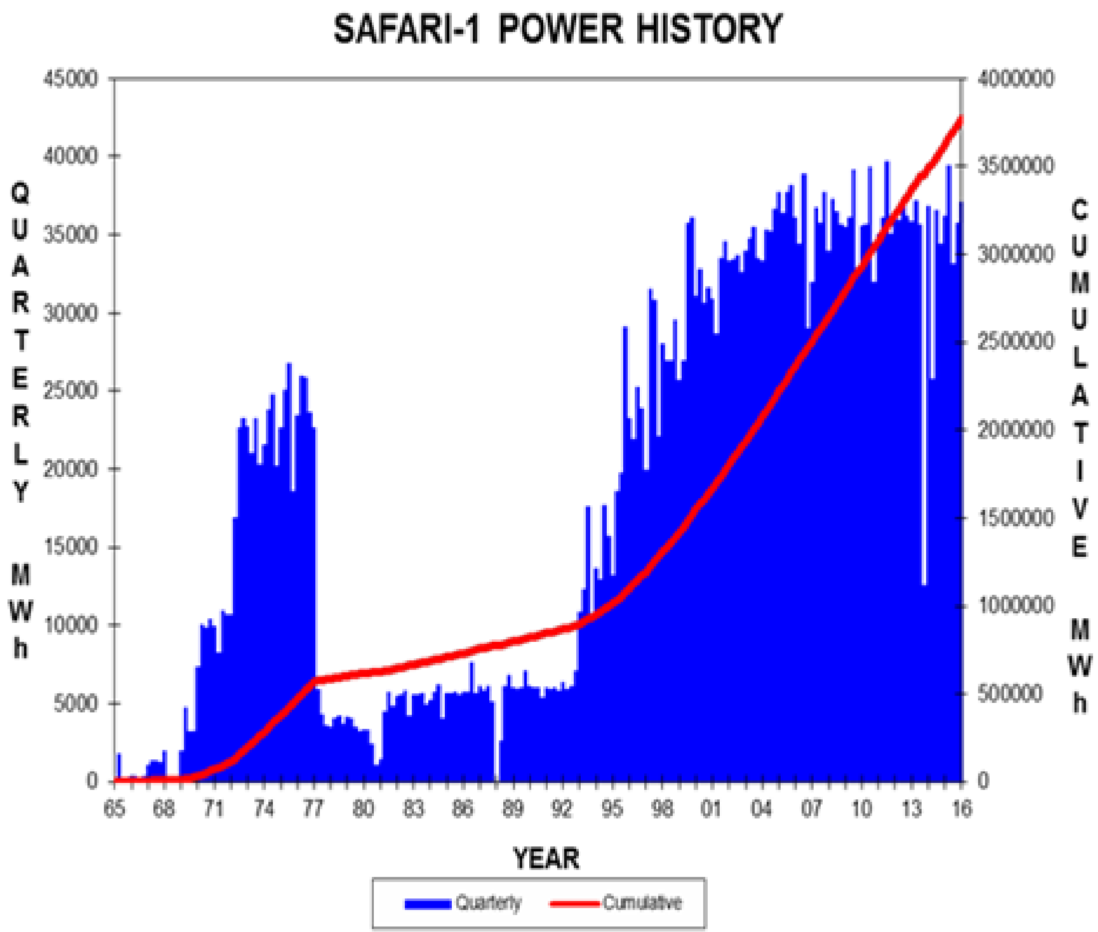
^{3}He and ^{6}Li long term accumulation



Accumulation depends strongly on flux of the reflector zones

^{3}H accumulation compared with cumulative power history





PROPOSED SOLUTIONS (1/3)

Worst condition

- The long-term shutdown scenario with ten years of regular operational history and another ten years of reactor break-out, is the WORST condition on the beryllium reflector elements and on the reactor core parameters.

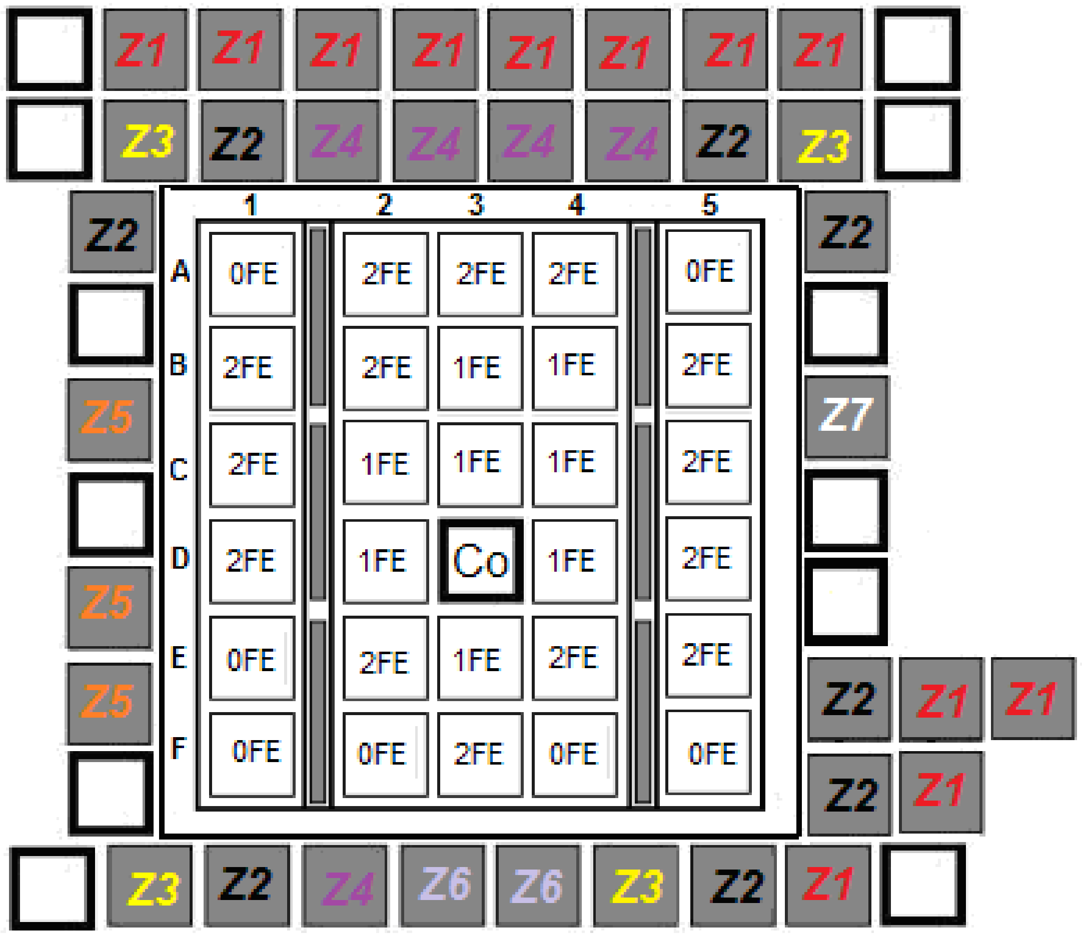
- The seven zones of beryllium elements contain high atomic densities of Helium-3 and Lithium-6 poisons and reactor cycle length **is decreased to almost the third of its initial value of the fresh reflector core**.

PROPOSED SOLUTIONS (2/3)

1. Full extraction of strong negative experiment (cobalt irradiation device) to add more excess reactivity to the reactor core.

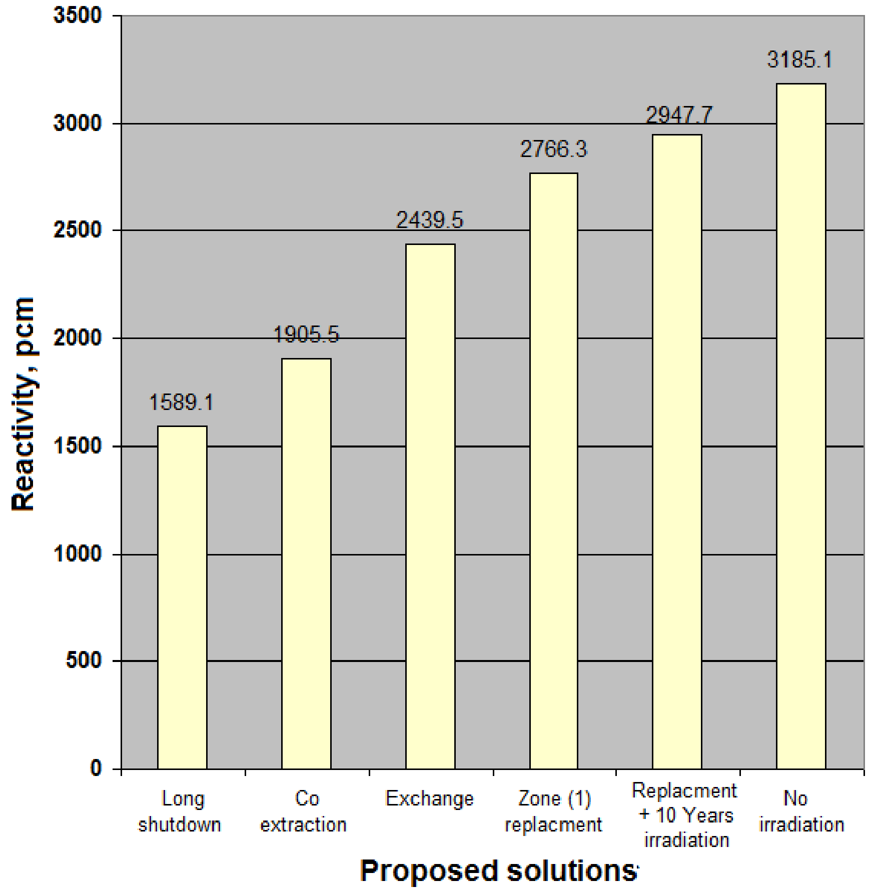
2. Exchanging beryllium zone (1) in the first row with the other zones.

3. Replacement of poisoned beryllium elements of zone (1) with fresh ones.

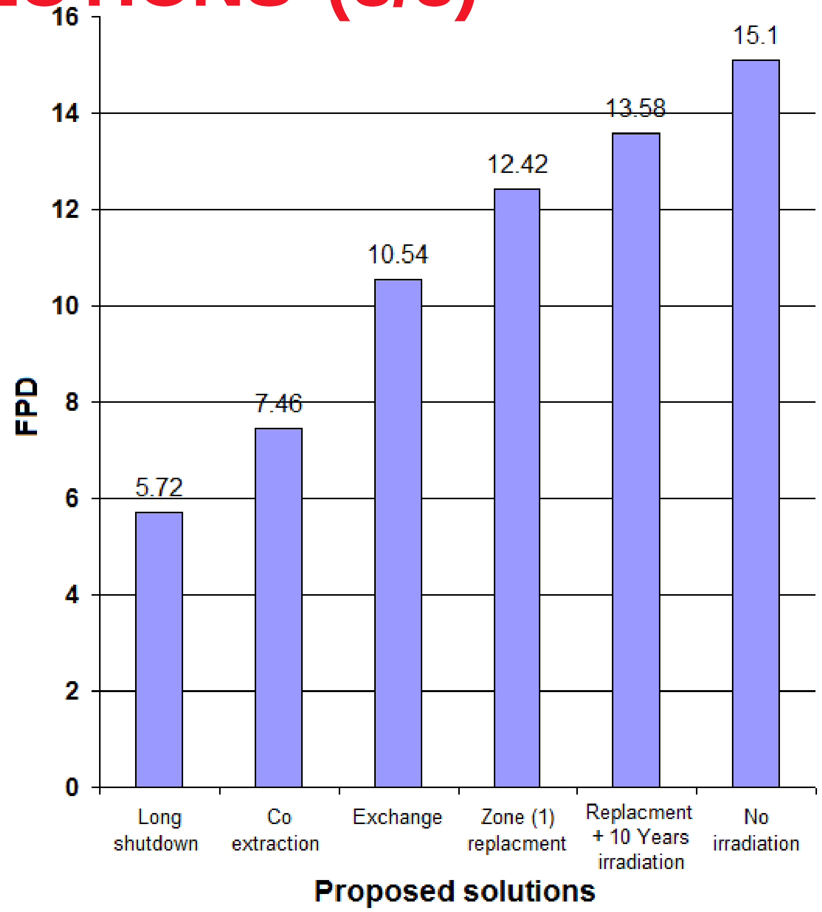


Exchanging the beryllium elements of zone (1) with the other zones

PROPOSED SOLUTIONS (3/3)



(a) Excess reactivity (pcm)



(b) Cycle length (FPD)

Proposed solutions in terms of increasing the excess reactivity and cycle length compared with the worst condition and Be with no irradiation

CONCLUSIONS

1. Comparing the results of all operational scenarios, confirmed that the neutrons poisons ^{3}He and ^{6}Li have a **strong negative Impact on the reactor core operation parameters specially in the case of long-term shutdown**.
2. The accumulation of these poisons inside Beryllium matrix depends strongly on **the values and distribution of neutron flux**, the position of beryllium elments around the reactor core and **the elements should be divided into zones according to their neutron flux values**.
3. Three solutions are supposed and to minimize the impact of beryllium poisoning on the reactor core parameters, these solutions are extraction of cobalt irradiation device from the core for adding more reactivity, replacement of the first row Beryllium zone (1) with fresh Beryllium and exchange between this zone (1) and other Beryllium zones.
4. The solution of **zones exchange** is the best to add more excess reactivity and increase the core operating cycle length without more cost.

Thank you for your attention