Oklo Reactor Engineering

Technical Mini-Project

The purpose of the mini-project is to showcase your reactor engineering skills and your creative thought process during the interview. We want to know more about

- how you think through reactor design process
- how you handle working with a limited set of information
- your ability to research new topics
- your ability to conduct analysis to understand system behavior

The final deliverables should be (1) a presentation detailing your responses to the questions, the assumptions you made, and the analysis you conducted; and (2) code used for the analysis (please use Jupyter notebook). Once you're done with this mini-project, you'll be asked to present and discuss your responses with the Oklo team.

Have fun with this mini-project – we are very excited to learn more about you through your work!

Additional notes:

None of the mini-project questions require extensive analysis using tools beyond hand calculations (i.e., you should not need to create neutronics or CFD models); however, if you have access to these tools and you wish to use them, please feel free.

We expect that you should spend a **maximum of 8 hours** on the project. If you think you are going to take much longer than that, please reach out.

Use all resources available to you! If you are unfamiliar with a concept – Google it! This mini-project is open book, open internet.

Mini-Project Question 6 (Thermal-Hydraulics)

EBR-II's demonstration of safety through passive design features and functions is an example of the simple safety case for sodium fast reactors (SFRs) and advanced reactors as a whole. As part of its safety case, EBR-II used multiple systems for decay heat removal. The primary pathway for decay heat removal was through continued circulation of the primary sodium, either pumped or through natural convection, and transfer to the secondary sodium loop. The secondary pathway was through passive NaK loops, called "shutdown coolers." Finally, some heat was rejected through the shield and thimble cooling systems, either through forced air flow or through passive means.

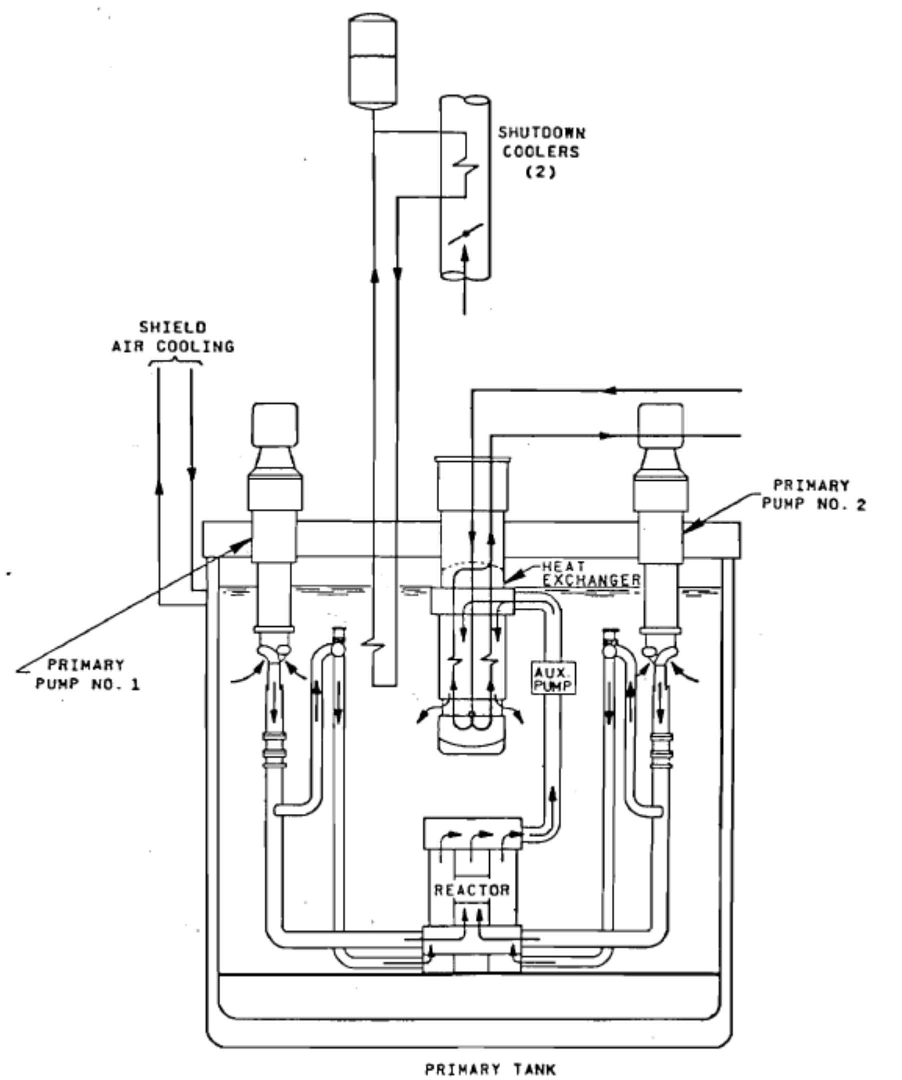

Figure 1: EBR-II Primary Tank Sodium Flow Paths [1]

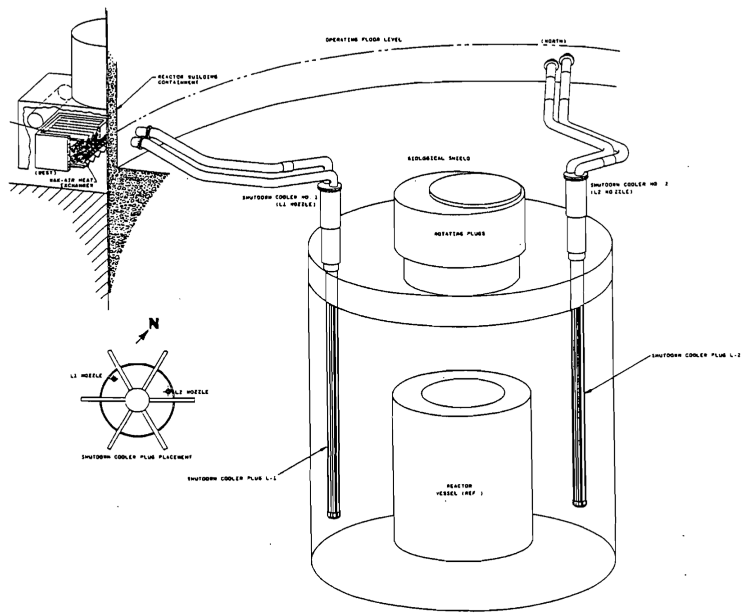

Figure 2: Shutdown cooling system design [2]

There were two shutdown coolers: each was an independent NaK loop with a NaK-air heat exchanger. When the louvers on the natural draft NaK-air heat exchangers were closed, each shutdown cooler would remove 30 kW (total of 60 kW). When the louvers were open, each shutdown cooler would remove 180 kW (total of 360 kW). The louvers were designed to open automatically at a bulk sodium temperature of 377 C and close at 371 C. When the primary heat transfer pathway failed and active systems failed to actuate (i.e., louvers remain closed and shield and thimble system forced airflow failed), shutdown coolers would provide the majority of heat removal capabilities (60 kW out of 85 kW) [2].

A reactor designer is looking to re-construct EBR-II with minor tweaks to the design intended to improve the reliability of the system – consider it EBR-III. Due to concern of common cause failures of the two shutdown coolers, the reactor designer wants to add a third independent NaK loop while maintaining the total open and closed heat removal capacities of 360 kW and 60 kW, respectively.

1. Is the reactor designer justified in their common cause failure concern? Why or why not?
2. How much does the size of the NaK loops change? Sizing should include heat exchanger dimensions, overall height of each NaK loop, and area occupied within the primary system (from above).
3. Instead of using NaK, the reactor designer has decided to use nitrogen as the working fluid of the third loop with the goal of equal heat removal capacity in all three systems. How does the design of the nitrogen loop differ from the NaK loops?
4. Why was NaK chosen as the working fluid of the shutdown cooler system? Should other fluids (including nitrogen) be considered as a working fluid?

Mini-Project Question 8 (Thermal Hydraulics)

The radial power distribution of the Argonne National Laboratory ABR1000 design is shown in the figure below [3]. Inspecting the batch-averaged assembly power (left portion of image), a strong radial dependence on assembly power can be observed. Typically, this power distribution is compensated for by creating several “flow zones” in the core where flow is appropriately matched to assembly power.

1. Why is there a radial power distribution in the core?
2. Which phenomena/phenomenon is/are flow zoning attempting to mitigate?
3. What factors need to be considered when flow zoning the core and how could these factors change over core life?
4. How could flow zoning be accomplished and what are the pros and cons of each approach?
5. Would your answer from Question 4 change if the assemblies were to be shuffled during core life? Why or why not?
6. OPTIONAL – using the core below, create an algorithm to zone the flow for this design.

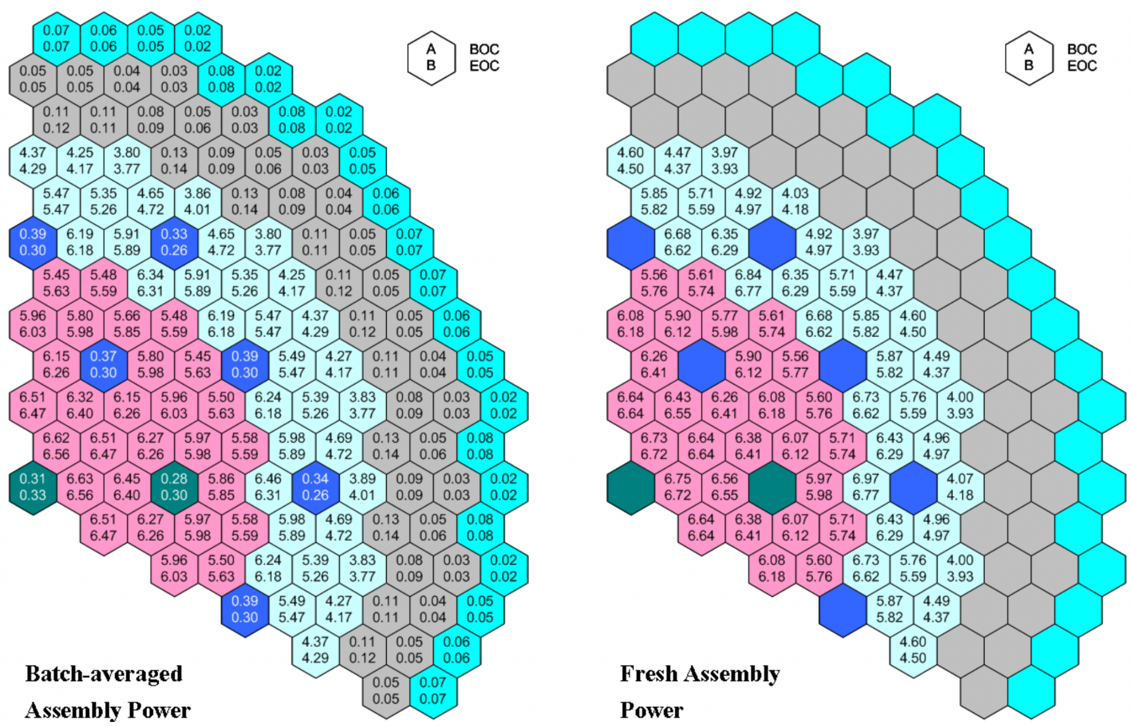

Figure II.1-6 Assembly Power Distributions of Recycled Metal Core (MWt)

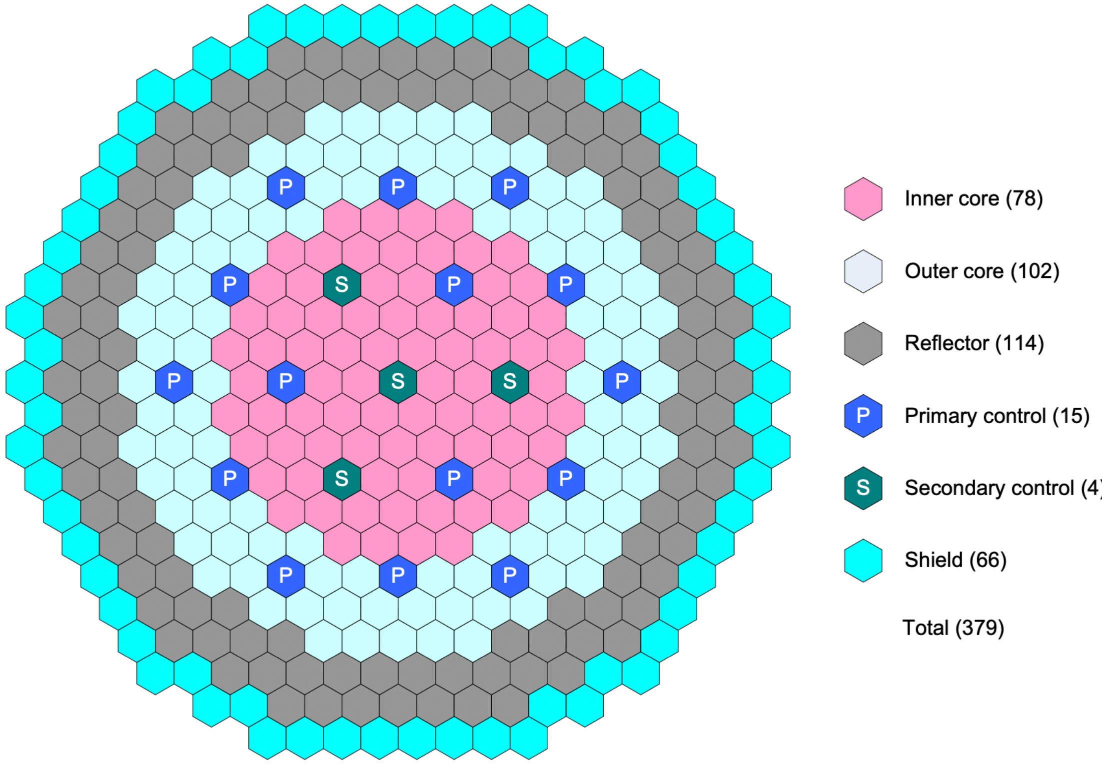

Figure II.1-1 Radial Core Layout of Reference 1000 MWt ABR Concept

References

[1] T. Sumner and T. Y. C. Wei, “Benchmark Specifications and Data Requirements for EBR-II Shutdown Heat Removal Tests SHRT-17 and SHRT-45R,” Argonne National Laboratory, ANL-ARC-226 Rev.1, 2012.

[2] Y. Chang, D. J. Hill, W. A. Ragland, and J. Roglans-Ribas, “Experimental Breeder Reactor II (EBR-II) Level 1 Probabilistic Risk Assessment,” ANL-NSE--2, 1483951, Oct. 2018. doi: 10.2172/1483951.

[3] C. Grandy and R. Seidensticker, “Advanced Burner Reactor 1000MWth Reference Concept,”, Argonne National Laboratory, ANL-ABR-4, 2007.