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Replacement of Legacy Analytical Codes at the Advanced Test Reactor

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Idaho National Laboratory

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INTRODUCTION

For each operating cycle of the Advanced Test Reactor (ATR) at Idaho National Laboratory, a Core Safety Assurance Package (CSAP) is necessary to demonstrate compliance with the safety basis approved by the United State Department of Energy (DOE). Certain computer codes are used in CSAP development, most of them developed in-house. This work describes replacement of a large set of these codes and updates previous work [1]. Replacement of legacy codes is necessary due to computer hardware failure but also has generally improved user-friendliness.

The ATR core (see Figure 1) consists of forty (40) plate-type fuel elements of aluminum-clad highly enriched uranium. Pressurized water is both the moderator and the primary coolant and flows downward through the fuel element channels. The forty elements are organized around nine (9) flux traps and often conceptualized as five (5) power-producing lobes, named for the ordinal directions (NW, NE, SW, and SE) and the Center (C). Power is shifted from one lobe to another by means of control elements such as Outer Shim Control Cylinders (OSCCs), to obtain desired powers for irradiation of flux trap experiments. The purpose of localized power control is to simultaneously irradiate multiple experiments in the various flux traps, at programmable power levels. Most of the flux traps include the additional advantage of an in-pile tube, isolated from the reactor primary coolant system, which allows a given experiment to be irradiated at temperature, pressure, and chemistry conditions selected by the sponsor.

As indicated in Figure 1, OSCCs are withdrawn by rotating such that the hafnium plate is moved closer to or further from the fuel. In addition to providing localized control for each corner lobe, the axial shape of the neutron flux is largely unperturbed. Safety Rods are installed in many flux traps, where their reactivity worth is maximized.

Driver Fuel Reactivity

The RHODOL code was used for two purposes: one of two predictions of critical shim position and calculation of the impact of localized power variations on safety rod worths. It was previously shown that at least two databases can be used as input data for these calculations [1]. The prediction of critical shim position was shown to improve slightly, although it cannot be shown to make a definite improvement with the alternative input data. The use of RHODOL for information regarding safety rod worths can be circumvented with other conservatisms.

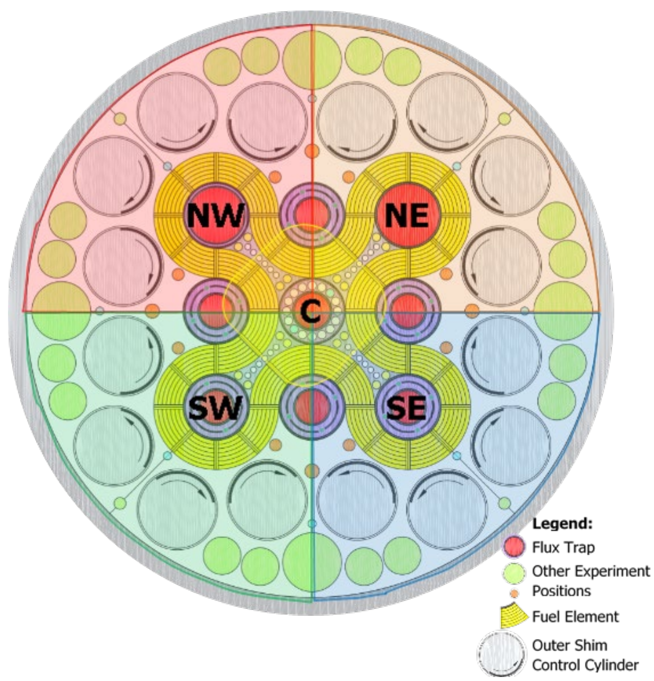

Fig. 1. Plan View of ATR Core.

Cycle Surveillance Codes

Various codes were used to display and edit reactor plant parameter data, including shim positions, lobe powers, nuclear instrument signals, and cumulative exposure in megawatt-days.

This data was displayed as text only, but in recent years the text has generally been parsed into meaningful values and plotted for quick visual reference. Figure 2 shows excess reactivity, computed from surveillance data. It includes comparisons with predictions "…in CPA" in Figure 2.

Legacy tools provided hourly or daily data, but millisecond-scale data has been leveraged more recently. This increased functionality as particularly valuable during 2022 nuclear testing [2-3]. Processing such a large amount of data requires new tools. The legacy computer system is no longer used as a definitive repository of data. As a result, associated tools to edit the various data streams are no longer needed.

The legacy codes also included some predictive tools, such as prediction of xenon transients in the event of an unexpected shutdown. A restart prior to xenon preclusion has not been attempted in several years at ATR, and the theoretical basis for the legacy toolset is not documented. Therefore, the replacement tools include prediction of only the xenon decay transient [1].

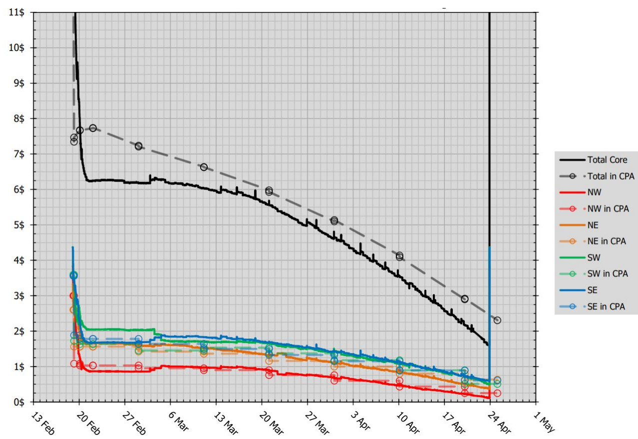

Fig. 2. Sample ATR Operating Data.

Impact of Operating Power Division

SUPRMAX

Predicting worth of safety rods and certain other control elements is a CSAP requirement. The SUPRMAX code predicts worth of reactivity control elements, given an input of requested lobe powers. A reactivity change such as safety rod insertion has higher importance to core reactivity where local power is higher, because the higher local power essentially means that the given fuel positions are stronger neutron sources for the rest of the core [4]. SUPRMAX also takes an input of driver fuel reactivity from RHODOL output, which requires an array of outdated tools to maintain a meaningful database. The use of RHODOL has been circumvented with conservative assumptions about fuel reactivity. Figure 3 compares 3 options for computing safety rod worths from SUPRMAX. In every case, it is possible to predict a conservatively low safety rod worth without using RHODOL.

SUPRMAX functionality was retained by transcribing and re-compiling the source code as a Windows executable. RHODOL is no longer used. SUPRMAX is still used in CSAP development.

MAXVOID

Predicting the reactivity worth of losing water from an experiment in-pile tube is also a CSAP requirement. The MAXVOID code predicts that worth. The analysis is usually coupled with prediction of the reactivity input of experiment failure, which is generally expected to result in absorbing nuclides' falling from near core centerline to the lower neutron flux near the bottom of the core.

Like SUPRMAX, MAXVOID functionality was retained by transcribing and re-compiling the source code as a Windows executable.

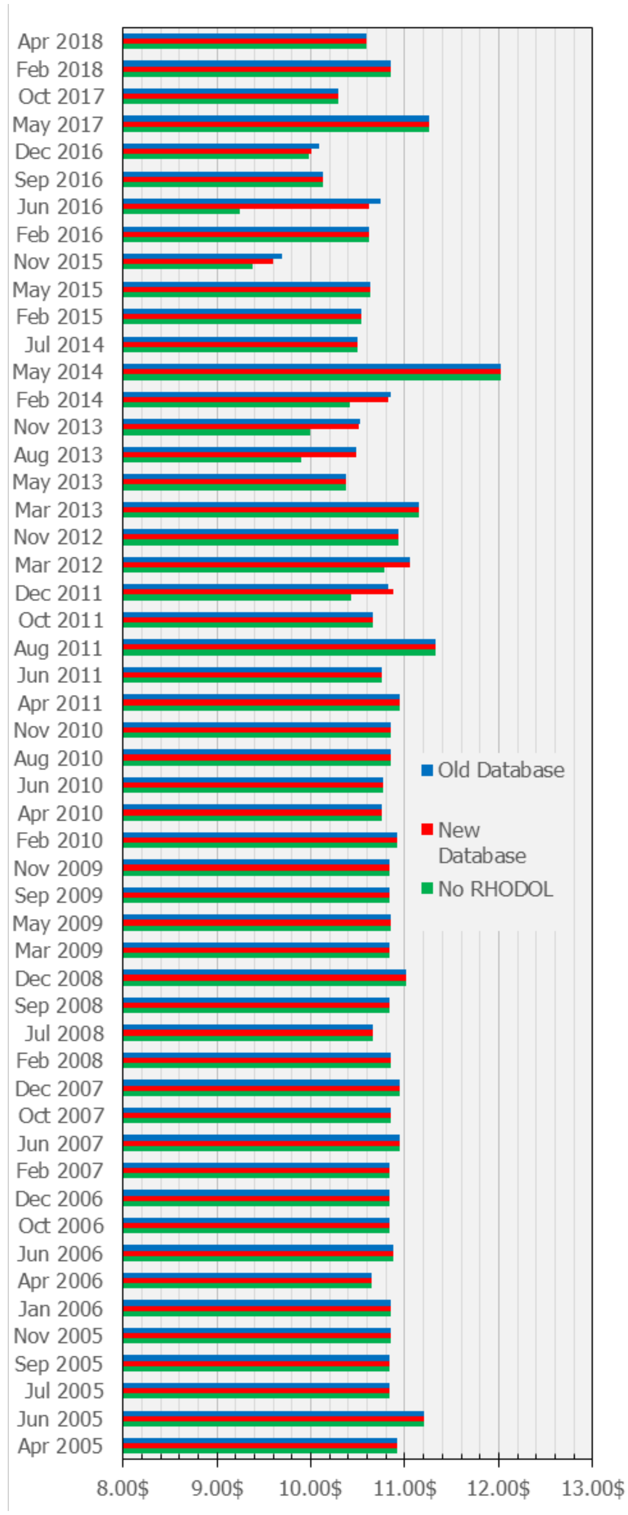

Fig. 3. Comparison of safety rod worths for reactor shutdown, as computed at beginning of cycle.

CONCLUSION

Many legacy computer codes useful for ATR CSAPs have been retired without like-for-like replacement, their functionality essentially provided by conservative assumptions or by more powerful tools with additional functionality. Two have been replaced like-for-like but made more user-friendly.

Individual codes are summarized in Table 1.

TABLE I. Legacy Codes

Code	Use	Replacement
RHODOL	Estimate reactivity worth of a fuel loading	Explicit modeling of core loading with Helios
FEIUD	Update database for RHODOL	None
DAIMONH	Collect operating data	Various Visual Basic and Python scripts
RHOXS	Compute excess reactivity and compare to predictions	Equivalent calculation in Microsoft Excel
HFBURN	Estimate reactivity worth changes for hafnium elements	Explicit modeling of core depletion with Helios
CORRDAT	Correct files produced by DAIMONH	Directly editing text and csv files produced by scripts replacing DAIMONH
SUPRMAX	Estimate reactivity impact of safety rods, as a function of power division	Equivalent calculation in a Windows executable
MAXVOID	Estimate reactivity worth of loss of experiment coolant	Equivalent calculation in a Windows executable

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