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Modeling and Analysis of the ACRRF Transient Rod Pneumatic System

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INTRODUCTION

In order to produce a pulse in the ACRRF, three TRs are simultaneously ejected from the core using a nitrogen-based pneumatic system. To trigger a pulse, the first step is to pressurize the accumulators to the system pressure. Once the accumulators are pressurized, the reactor operator sends an electrical signal to the solenoid valve telling it to actuate, letting the pressurized nitrogen flow all the way to the piston. The piston is then shot upward from the adjustable-height pedestal, ejecting the poison from the core, allowing for the reactivity insertion to occur. The pressure of the pneumatic system is set in order to not exceed reactivity insertion rates into the core, which are largely influenced by the time it takes to eject the rods. Many of the operations of the ACRRF depend on being able to produce a pulse leading to repeatability of the TR system being an important requirement. Ideally, ACCRF should be able to pulse hundreds, if not thousands, of times before the TR system encounters a failure; however, this is not the case at the moment. Throughout the 40+ years of operating experience, numerous failures have occurred within the TR system. Most failures can be attributed to the mechanical linkages connecting the neutron poison section of the TR to the pneumatically-driven piston which initiates the motion of the TR. Of all components, the dashpot rod, which connects the upper and lower aluminum connecting rods, fails most often. Numerous spares of the dashpot rod are kept on hand for such cases. Using a meticulous study of the TR pneumatic system, the main failure modes of the components within the TR itself should be more easily understood, possibly leading to prevention.

OBJECTIVE

A model of the ACRR transient rod pneumatic system is needed in order to better document and understand the vital system for ACRR operation. The mechanical linkages connecting the transient rod assembly to the pneumatic system are especially prone to failure and in need of analysis in order to pinpoint the weakest components. Modifying the system to move important components outside the bridge is being attempted, but needs further study in order to determine the effect on system performance.

Fig. 1. Outside of accumulator cabinet. Note that this part was built specifically for the proposed modification.

Fig. 2. View from the South of the ACRRF Bridge

Fig. 3. Inside of the accumulator cabinet. By moving critical parts out from under the bridge, maintenance is much more easily managed.

METHODOLOGY

The software package being used to create models and drawings consists of the SolidWorks™ Premium suite. The first task of assembling the system consisted of gathering all of the current system components. Of the 50+ system components, many came directly from the manufacturer's website; the others being modeled from manufacturer's spec sheets. The model was assembled with the help of measurements and previously documented photos. Once the 3-D model was completed, drawings were created in accordance with the models. Modeling the proposed modification involved the same process as before with a few small differences such as having to build custom-built parts and not having to gather near as many parts. However, since this modification is only proposed, some components, such as the piping, are still yet to be determined.

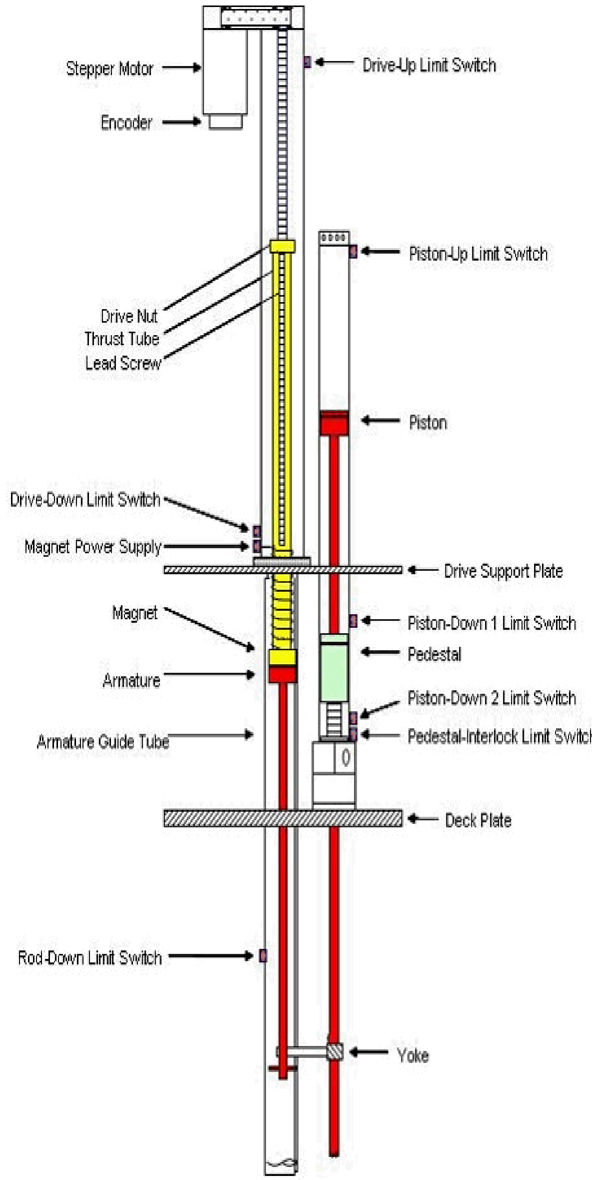

Fig. 4. Representation of the connection between the transient rod pneumatic system and the transient rod assembly.

CURRENT SYSTEM MODEL

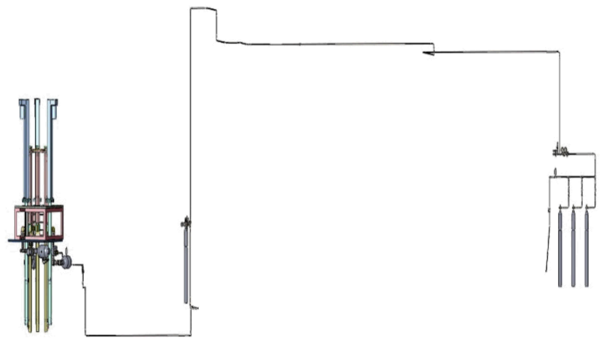

Fig. 5. View from North of complete system as it sits. Note that this system does not show any surrounding structures on which most of the piping lies.

In SolidWorks, the current system model takes over 50 single components and combines them into multiple sub-assemblies. Most of the models for the components came from the Swagelok website, while a few others were modeled in accordance with the manufacturers' spec sheets. The sub-assemblies include the nitrogen tanks for the pneumatic-driven system, piping from the tanks to the ACRR bridge, the accumulators which act as mechanical switches to rapidly release the pressure into the system, and the TR components and mechanical linkages, which are connected to the accumulators with piping under the ACRR bridge. These sub-assemblies combine to form the whole assembly shown in Fig. 5. The ACRR bridge and mechanical linkages of the TR itself were modeled by Dave Samuels, and were included in this model to depict the complete system.

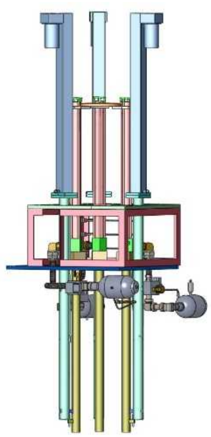

Fig. 6. Close up view of the ACRR Bridge with the pneumatic system component connections. Note that most of the vital pneumatic components are located under ACRR deck (blue plate) causing concern if those components were to ever fail.

PROPOSED SYSTEM MODEL

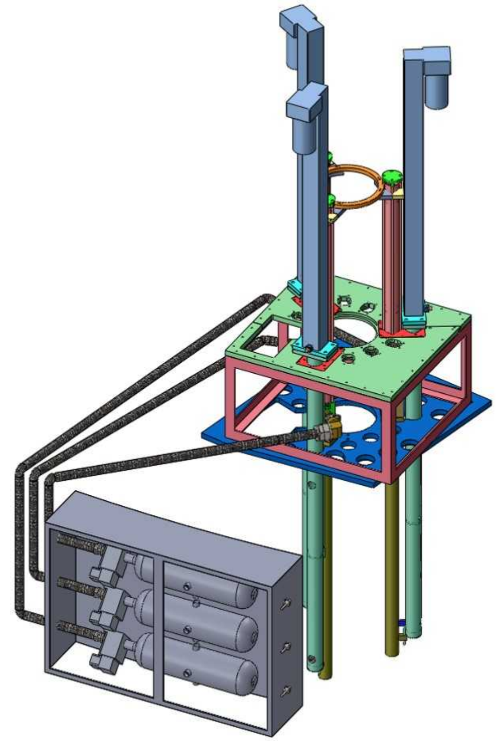

Fig. 7. Proposed ACRR Bridge from north with view of accumulators and solenoid valves inside of the accumulator cabinet, specifically designed for this modification.

The proposed system model intends to move vital components (accumulators, check valves) above the bridge such that maintenance becomes easier to conduct. In terms of the model, it is very similar to the current system with the exception of a few important changes. A custom-built cabinet to house the accumulators and solenoid valves has been constructed and is attached at the north end of the bridge. This leads to an increased length of piping between the solenoid valve and the pneumatic manifold which has been shown to increase pulse time slightly. The check valves have also been relocated from the south side of the bridge to the west side of the accumulator cabinet; however, the piping from the nitrogen bottles to the cabinet is still yet to be determined.

CONCLUSION

The models turned out well with the help of SolidWorks. There were a few small kinks that caused trouble, such as old and incomplete data sheets, and discontinued parts. In terms of modeling, some of the piping was difficult to accurately model and will be improved upon for further studies. There were a couple of analyses run on the TR itself calculating stress and strain, however, these results will be presented with a more complete analysis. The last model that will be included at a later date depicts the TR system completing a pulse from start to finish. Since this is a moving model, it cannot be accurately portrayed on a poster. The modeling completed in this poster provides an excellent base for continuation and optimization of the TR system as it sits.

FUTURE WORK

Due in part to several recent failures of the TR mechanical linkage components, there is an effort to look into a re-design of the whole TR pneumatic system. The research shown here sets the baseline to understand the feel of how the TR system is designed and operates. For the re-design, design concepts and preliminary designs will be generated using 3-D CAD models and simulations. Overall system response and behavior will be analyzed in response to static and dynamic loading in a coupled fashion for both the ejection and stopping of the TR. The mechanical analyses will provide a significant baseline to input into a nuclear pulse model to determine the reactivity addition rates as a function of time. With successful models, the re-designed TR system will be tested using a mock-up to validate and verify design concepts. The last aspects of the project include preparing design review presentations and reports, final detailed designs, system specifications, and fabrication drawings. Once these have been generated and the final designs have been approved, the re-designed system will be fabricated, assembled, installed and tested.

NOMENCLATURE

ACCRF: ANNULAR CORE RESEARCH REACTOR FACILITY
TR: TRANSIENT ROD

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