SAND2014-16083D

Modeling and Analysis of the ACRRF Transient Rod Pneumatic System

Sandia National Laboratories

Exceptional service in the national interest

Student Information

Name: Brandon Fehr
School: Georgia Institute of Technology
Degree Pursued: B.S.
Discipline: Nuclear Engineering
Graduation Date: Fall 2014
Mentor: Michael Black
Manager: Dave Wheeler
Org Name: Nuclear Quality and Requirements
Org Number: 1382
Sandia National Laboratories, NM
U.S. Department of Energy

Abstract

The Annular Core Research Reactor Facility (ACRRF) relies heavily upon 3 transient rods for reactor pulse operations. As this system is aging, the ACRRF Transient Rod (TR) Pneumatic System has experienced degradation and failures that may be prevented by implementing proposed modifications. However, in order to assess whether the modifications largely impact system performance, a thorough understanding of the current system must be established. Through the use of previous drawings and pictures, a model of the current TR system and all of its components has been assembled. Drawings were created from the model such that a complete system rebuild could be done if it were ever necessary. With the current system modeled, the model was modified to document the movement of many components from under the ACRR bridge. Drawings have also been created from this model in order to provide further documentation for the system. With the models compiled and documented, the system can be referenced studied further to determine weaknesses that eventually lead to breaks.

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 desperate 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.

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. In fact, the dashpot rod fails so often that numerous spares 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.

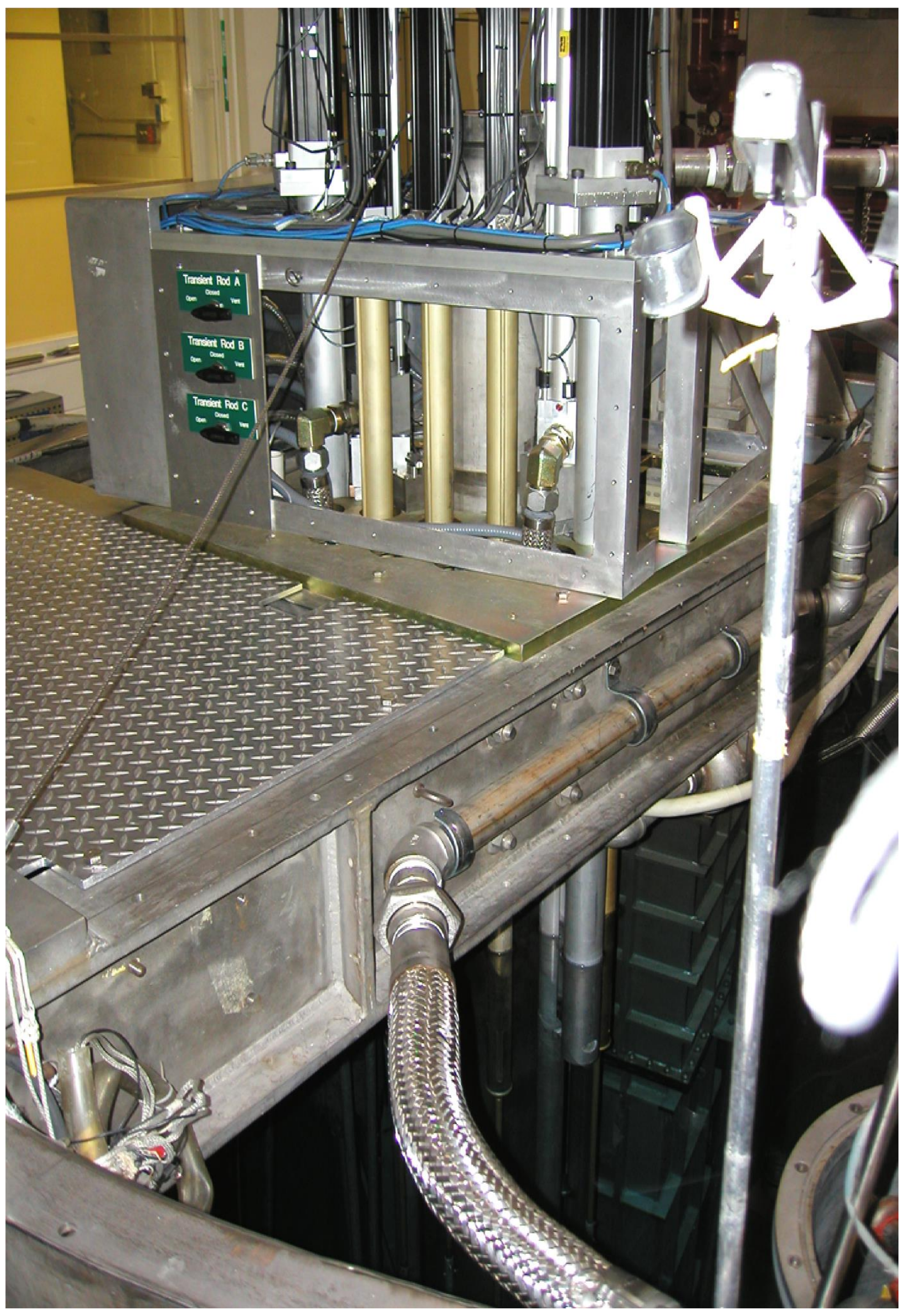

Figure 1: View from the South of the ACRRF Bridge

Figure 2: Outside of accumulator cabinet. Note that this part was built specifically for the proposed modification.

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

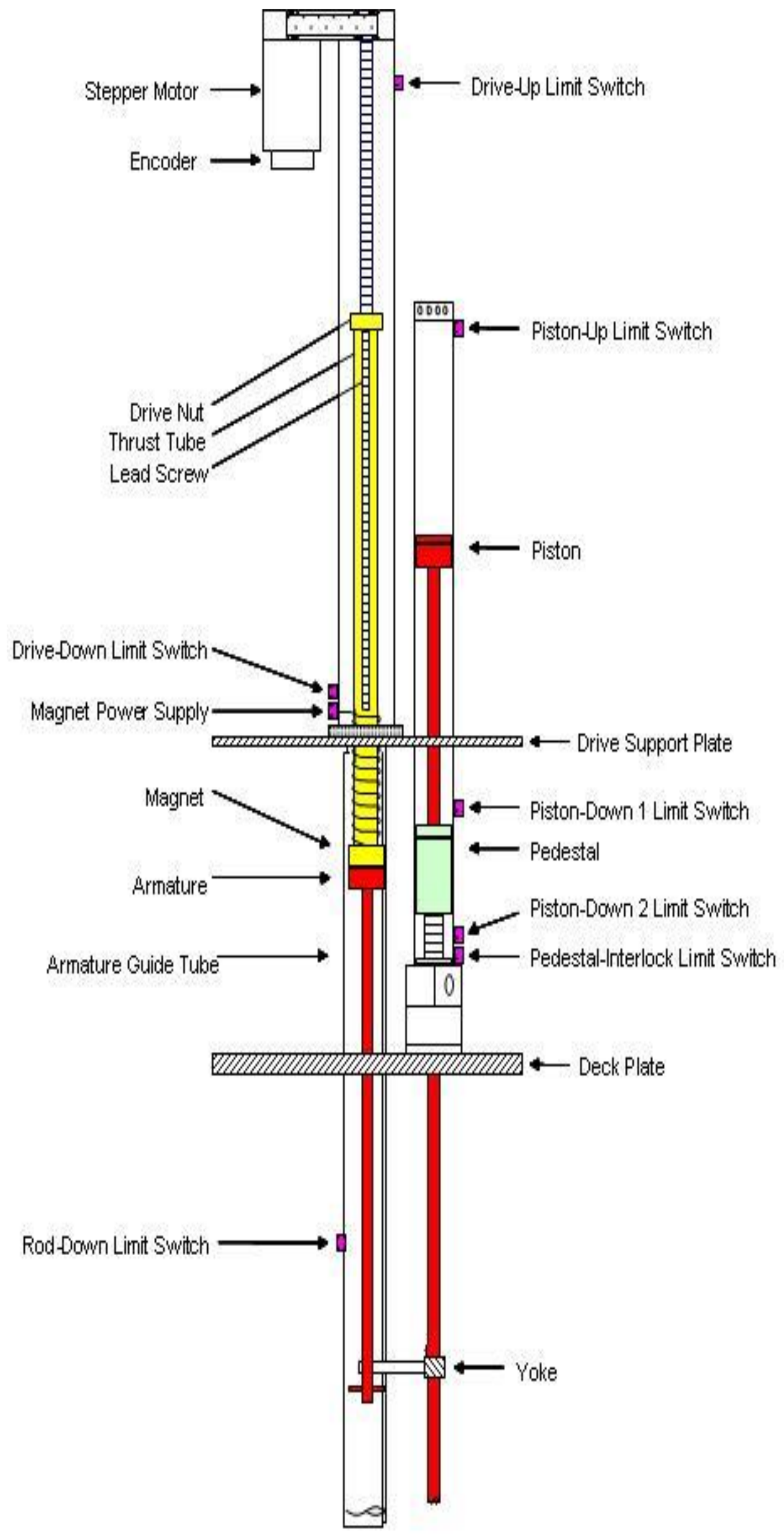

Figure 4: Representation of the connection between the transient rod pneumatic system and the transient rod assembly.

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.
SAND No. 2011-XXXXP

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.

Current System Model

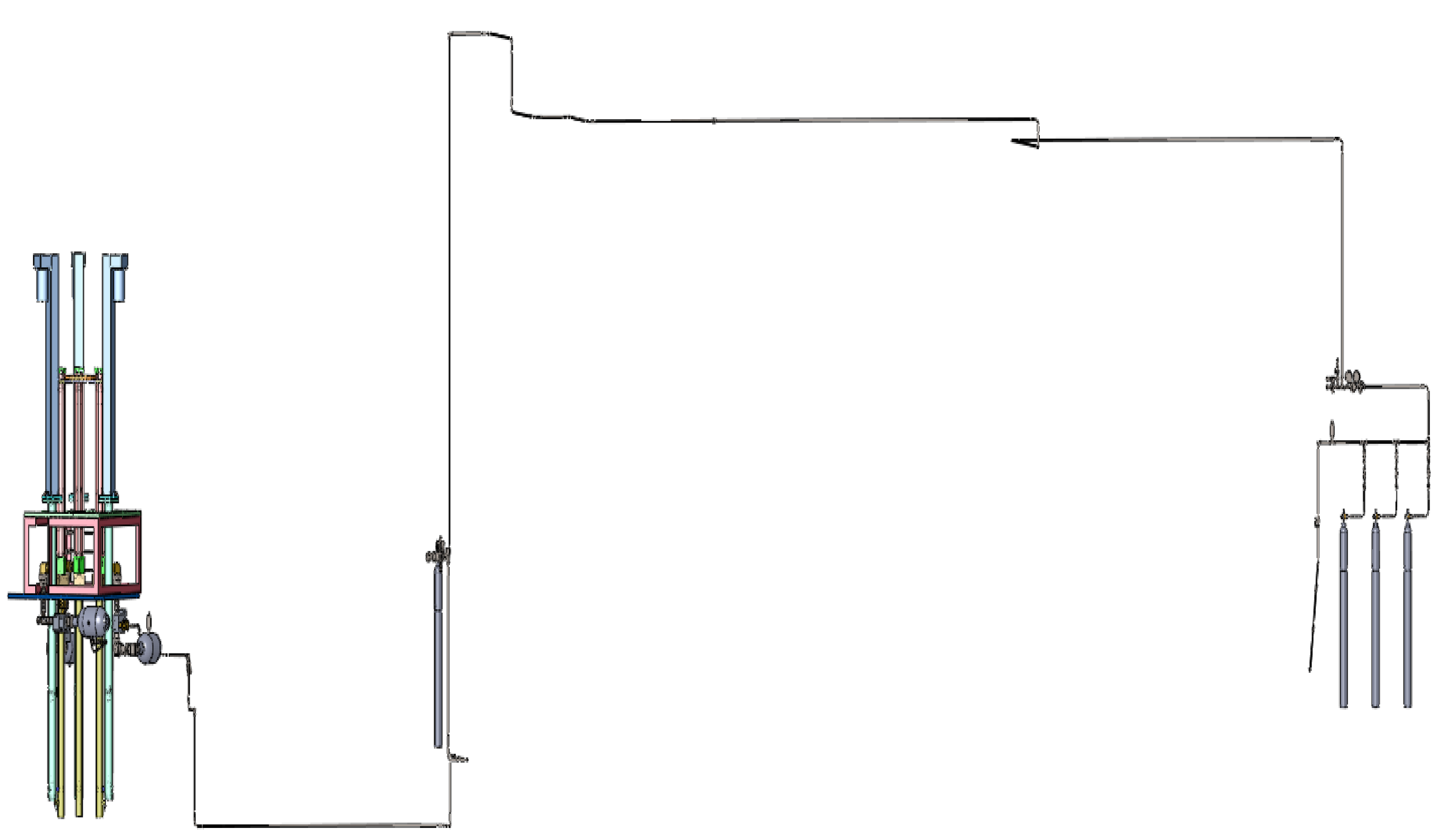

Figure 5: View from North of complete system as it sits. Note that this system does not show any surrounding structures on which most of the piping lies.

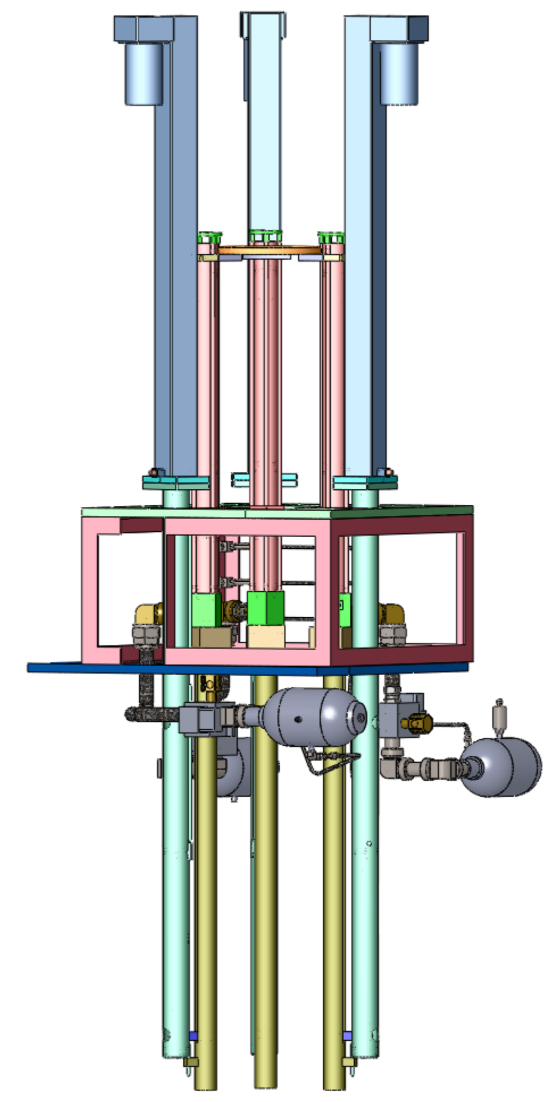

Figure 6: Close up view of the ACRR bridge with the pneumatic system component connections. Note that most of the vital pneumatic components are located under ACRR deck (blue plate) causing concern if those components were to ever fail.

Proposed Modification Model

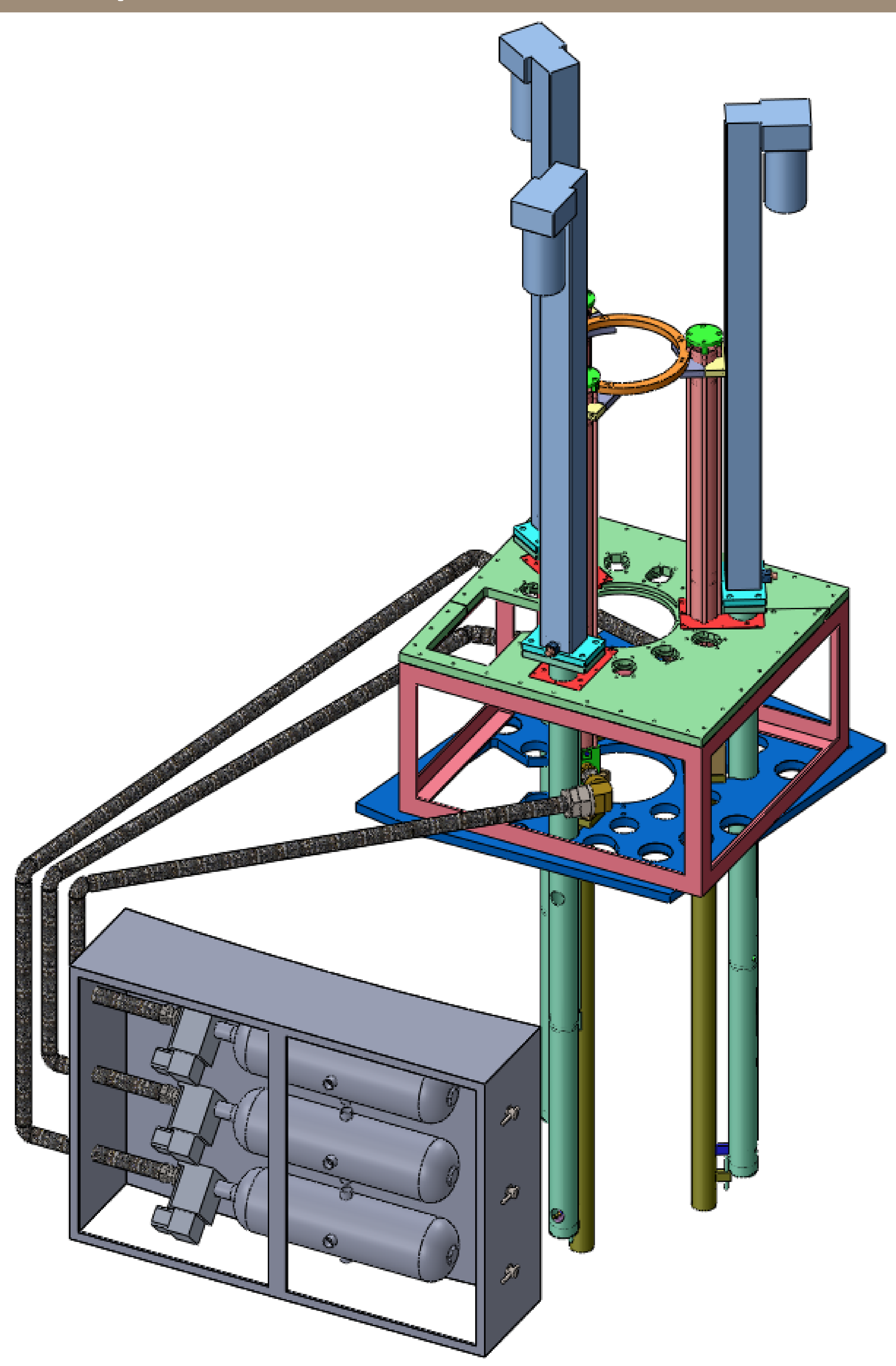

Figure 7: Proposed ACRR bridge from north with view of accumulators and solenoid valves inside of the accumulator cabinet, specifically designed for this modification.

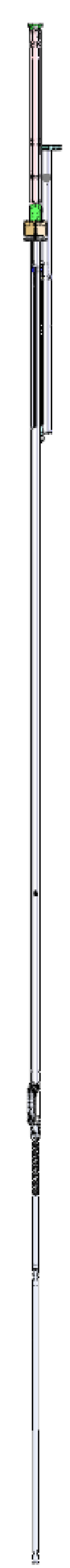

Figure 8: View of the transient rod assembly

Differences in the Two Models

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.

Future Work

A flow analysis of each system will be completed using SolidWorks© Flow Simulation in order to determine the velocity profiles of the fluid entering the piston within the transient rod assembly. With the velocity profile, a vibrational analysis can be utilized to find any weak points in the transient rod assembly. A successful analysis will be able to provide the data needed to show that both the proposed modification will not have a significant effect on the operating parameters of the ACRRF TR system, and would hopefully provide information as to where and why the transient rods break and what needs to be done to prevent the breaks from occurring as often.

Acknowledgements

I would like to thank my mentor Michael Black, James Arnold, Dave Samuel, and Brent Melville for their support during this project. I would like to thank my manager Dave Wheeler for giving me the opportunity to work at Sandia. I would also like to thank the interns in 1380 for accepting me into their awesome group.

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.
SAND No. 2011-XXXXP