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Development of Automated Control Systems for Pilot-scale Combustors in the New BYU Engineering Building Annex

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Introduction

The purpose of this MEG grant was to train 3 undergraduate students from either Chemical or Mechanical Engineering on the use of OPTO 22 control system and then to direct them, along with the input from engineers at OPTO 22, as they build and install a control system and logic for the Burner Flow Reactor (BFR), Multi Fuel Reactor (MFR) and the Pressurized Oxy Coal (POC) reactors in the new Engineering Research Laboratory (ERL). This program is comprised of 6 tasks as follows:

• Task 1 – OPTO 22 Training

• Task 2 – Criteria for the Control System

• Task 3 – Supplemental Training for Wiring and Configuration

• Task 4 – Development of Control Logic and HAZOP Review

• Task 5 – Shakedown of the Control System

• Task 6 – Publication and Presentation

The completion of the ERL was substantially behind schedule. The building was opened to my group for modifications and installations in January of 2018, which was 6 months later than anticipated. In addition, the completion of the BFR and the MFR are indefinitely on hold pending solution of safety concerns. Therefore the execution of this program was modified to adapt to the circumstances and to provide the maximum benefit to students.

Despite the delays in executing this program and the modification of the tasks, the impact of the program on students has been greater than expected. More students were impacted through training and hands on-experience than was proposed and the magnitude of the impact was greater than expected. The following sections of the report provide information on the work that has been completed on each task of the program, the current state of the budget and the impact that the program has had on students.

Project Tasks

Task 1 – OPTO 22 Training

Task 1 was to send a group of students to Temecula, CA for OPTO 22 training. OPTO 22 is a company that produces industrial automation hardware and software. As I discussed the details of this training with my contact at OPTO 22, Bruce Campbell, we determined that it would provide much more value to more students if the training were to be performed at BYU instead of at their office in Temecula, CA. The arrangements were made and the training occurred in the Fletcher building on May 16 – 17, 2017. The hardware necessary for the training was shipped from OPTO 22 to BYU and was set up by the students before the training occurred. Bruce Campbell visited BYU on those dates and administered the training supported by myself. OPTO 22 covered the cost of sipping the hardware and Bruce's travel. Figure 1 and Figure 2 are pictures of the training as it occurred.

Figure 1. OPTO 22 Training that occurred on BYU Campus in the Fletcher Building on May 16-18, 2017

Figure 2. OPTO 22 Training that occurred on BYU Campus in the Fletcher Building on May 16-18, 2017

Following the training the hardware was sent back to OPTO 22. All of those who participated in the training received a certificate of completion for the course. The list of those who received these certificates are:

Kevin Cole

Derek Holmstead

Dallin Keesling

Jacob Tuia

Landon Nuttall

Cody Carpenter

Aaron Skousen

Justin Harwell

Diehl Mutamba

Jens Griffin

Craig Schoenberger

Nathan Van Katwyk

Ammon Eaton

Dave Krug

Several of the students who participated were from John Hedengren's and Dale Tree's research groups. Therefore, this training benefitted students of more professors than just myself. Bruce Campbell commented several times following the training on how impressed he was with the quality of our students and their capabilities. Following the training I purchased two of the training hardware packages (Learning Centers) from OPTO 22 in order to train new student in the future.

Task 2 – Criteria for the Control System

I worked with students in my group from the time of the Training in May 2017 until the completion of Winter Semester 2018 concerning the design of the control system for the POC reactor. Updating and small modifications to the system are ongoing. However the substantial portion of this task was completed by the end of April 2018. As a deliverable from this task, the students produced Piping and Instrumentation Diagrams (P&IDs) of the POC Reactor. The P&IDs represent the POC Reactor and all of the subsystems with all of the instrument and control hardware necessary for operation and safety detailed. These diagrams represent the blue print for construction of the POC reactor control system. The P&ID for the POC reactor system and all of its sub-systems are presented in Figure 3 through Figure 8.

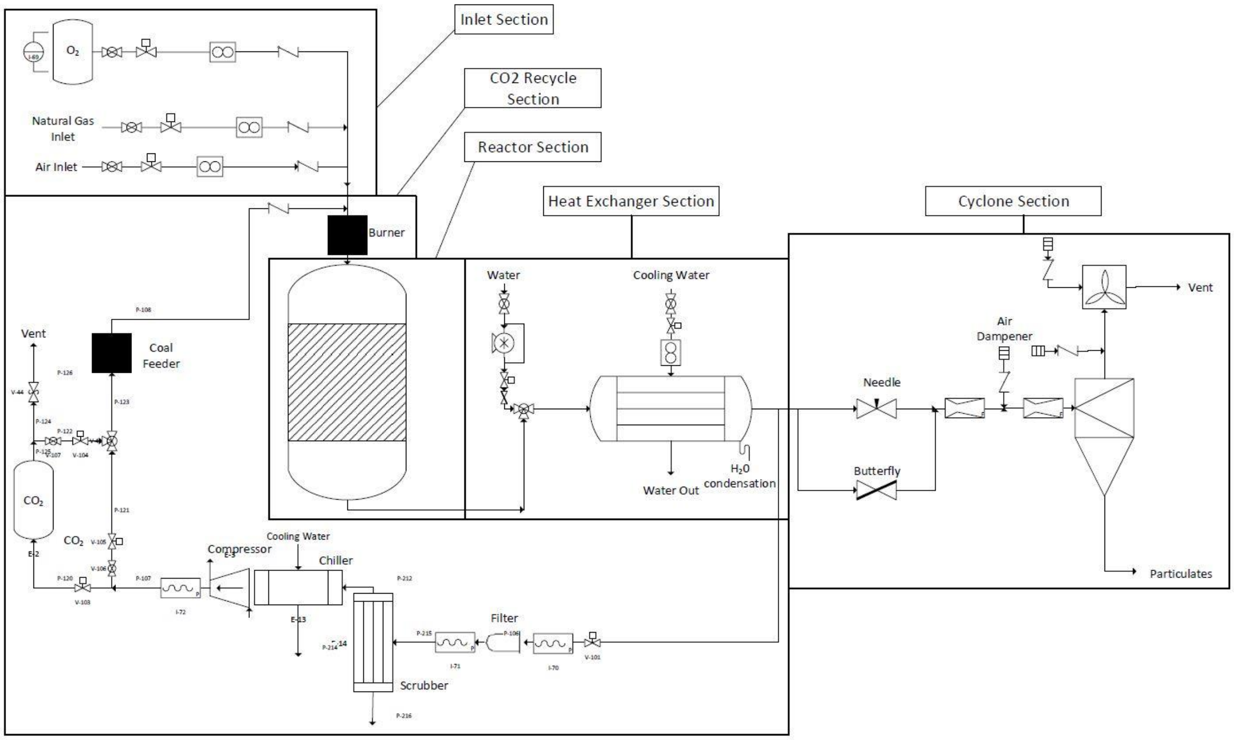

Figure 3. P&ID Overview

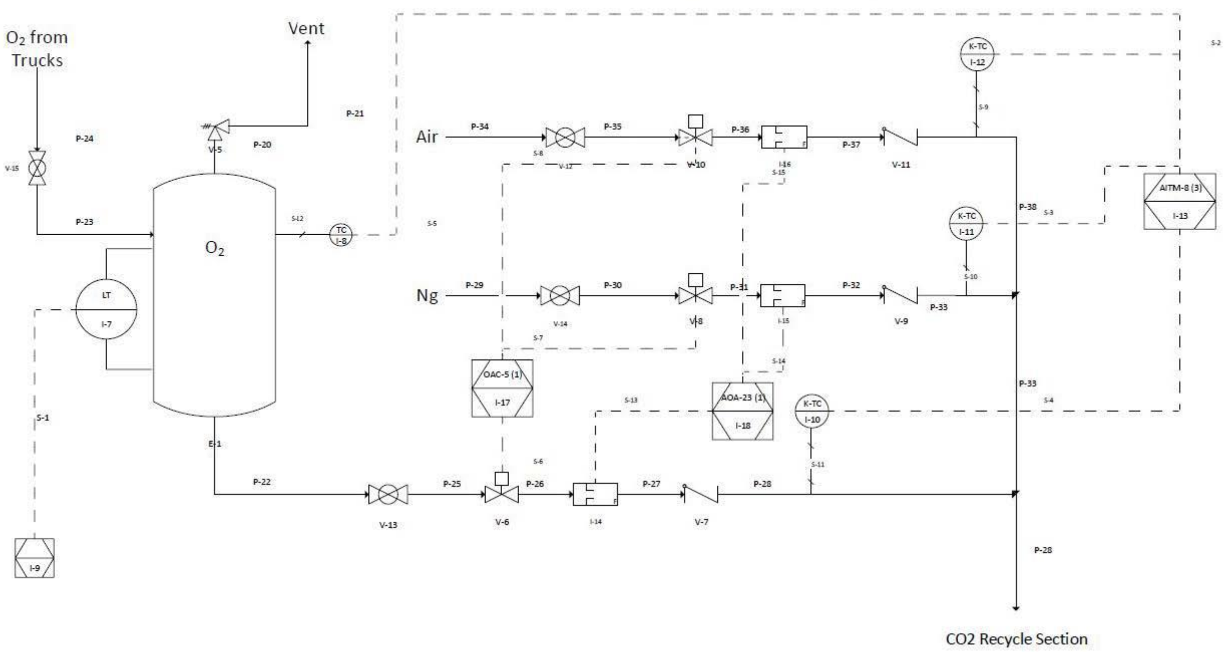

Figure 4. P&ID for the gas supply which forms the reactor Inlet Section

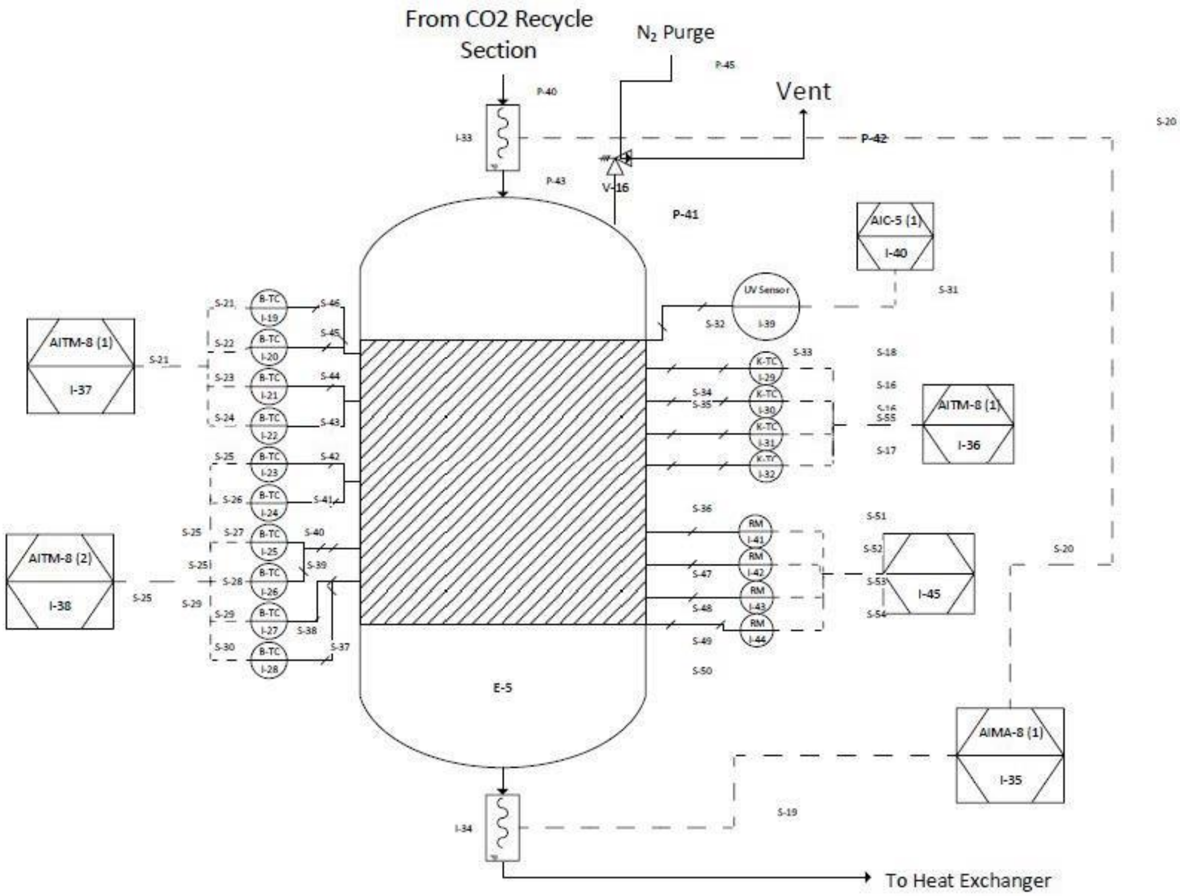

Figure 5. P&ID for the POC Reactor

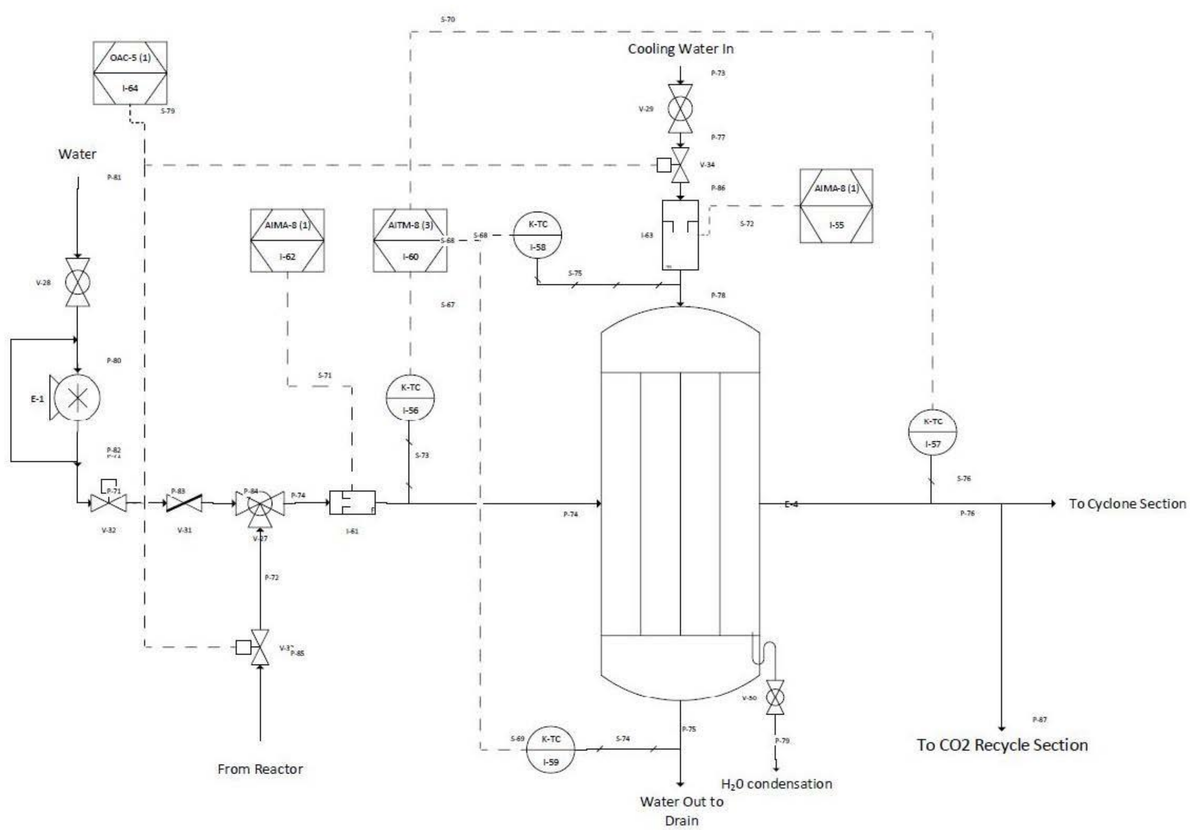

Figure 6. P&ID for the Heat Exchanger Section

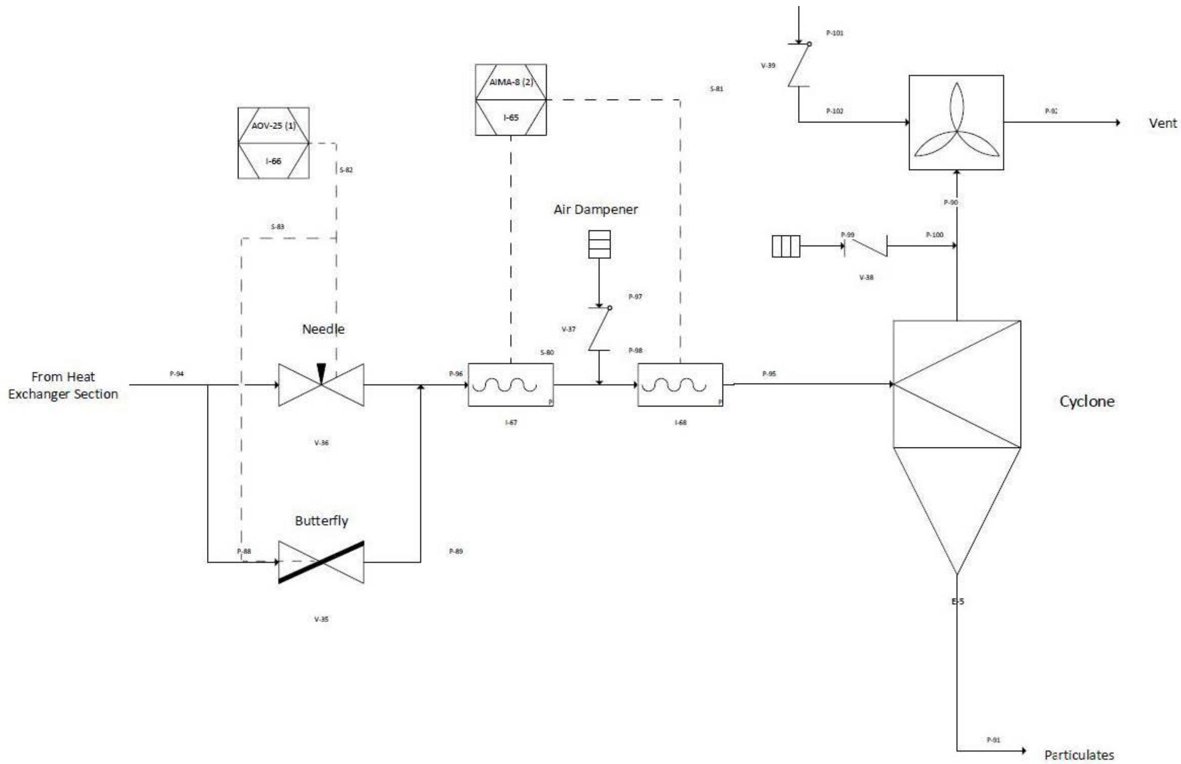

Figure 7. P&ID for the Cyclone Section

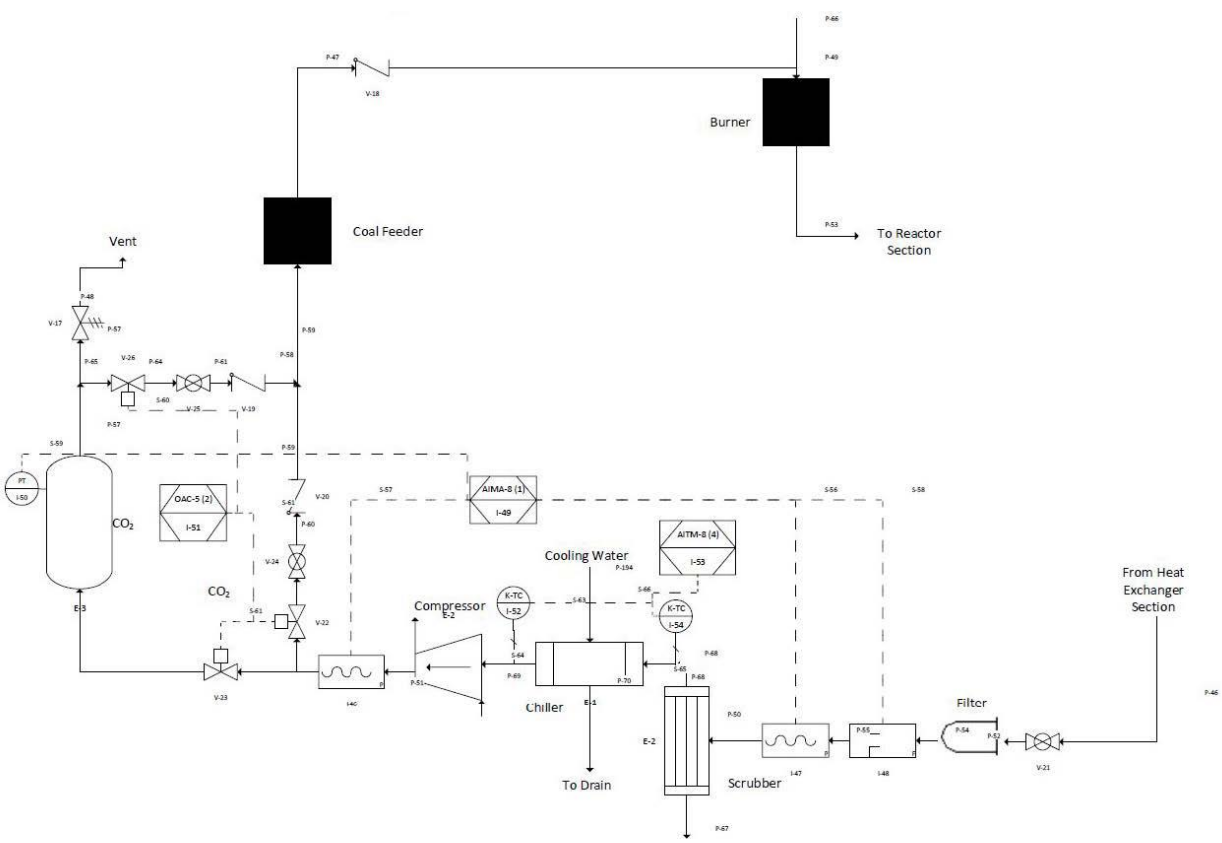

Figure 8. P&ID for the CO2 Recycle Section

Task 3 – Supplemental Training for Wiring and Configuration

The students were provided control hardware purchased form OPTO 22 using funding from my US DOE program. They iterated several times on the layout of the hardware within the control box and the ductwork, wiremold and conduit structure outside of the box until the design was optimized. I then instructed the students on the proper use of the tools and wiring techniques for installation. They then proceeded to put together the control box, install the box in the POC reactor room and install all of the necessary ductwork, wiremold and conduit. Figure 9 is a picture of the control box with mounted hardware after installation in the ERL.

Figure 9. POC Reactor Control Box following installation in the ERL

Task 4 – Development of Control Logic and HAZOP Review

All of the components of this task have not yet been completed because of the delays in building completion. A portion of the control logic has been constructed and implemented in order to perform burner shakedown testing. The logic was formulated through OPTO 22's Groov system and can be operated using any web browser or using your smart phone. A screenshot of the burner control system using Groov on an Android phone is provided in Figure 10.

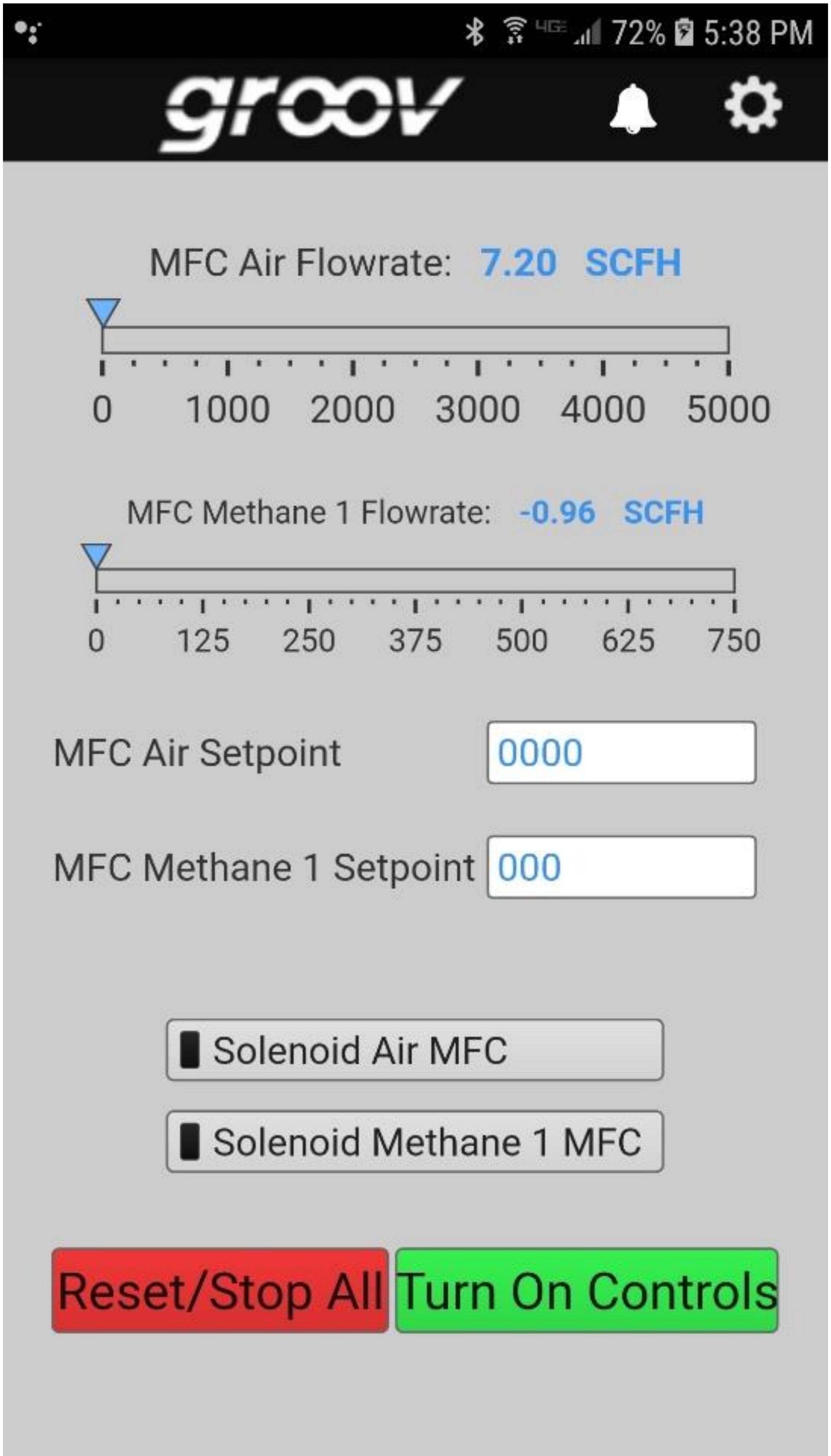

Figure 10. Screen shot of the Groov burner controls on an Android phone.

Further development of the control logic will progress and new hardware for the POC reactor is installed. The software for the HAZOP review has been purchased using funds from the US DOE program. The review has tentatively been scheduled for March 2019. The graduate student, Justin Harwell is in charge of this task and he will be supported by Undergraduates Marcus Reynolds and Brett Siddoway.

Task 5 – Shakedown of the Control System

This task is underway, but has not yet been completed due to the delays in building construction. The POC reactor has been installed and is currently configured for combustion at atmospheric conditions. This system is detailed in Figure 11. Approximately 80% of the control hardware has been installed that will allow atmospheric combustion and these systems have been shaken down and they perform as desired. A significant amount of additional hardware is planned in order for the reactor to be operated at pressurized conditions. As it is installed over the next six months these systems will be shaken down by undergraduate students, supervised by the graduate student, Justin Harwell.

Figure 11. POC Reactor configured for atmospheric combustion.

Task 6 – Publication and Presentation

This task has not yet been addressed. After completion of the high pressure safety and control system, the graduate student, Justin Harwell will publish a paper. Undergraduate students will participate in that endeavor.

Program Budget

Due to the building delays, the undergraduate students working on this project were instructed to work in more detail on the earlier tasks, expending budget disproportionately on the earlier tasks in the program.

The budget for this program is nearly spent with the expenditures summarized in Table 1 totaling $19,405.06.

Table 1. Program expenditures

Description	Expense
OPTO 22 Learning Center Hardware	$1,702.19
Food for Training	$75.99
Shipping of Hardware	$50.82
Brent Dorff (Undergraduate Research)	$2,745.72
Derek Holmstead (Undergraduate Research)	$3,822.89
Diehl Mutamba (Undergraduate Research)	$1,160.04
Josh Nguyen (Undergraduate Research)	$916.96
Andrew Powley (Undergraduate Research)	$246.24
Annie Reed (Undergraduate Research)	$590.81
Derek Sutton (Undergraduate Research)	$8,093.40

The tasks in this program will continue until their completion. After the budget for this program is spent the activities will be financially supported by the DOE Project.

Student Impacts and Outcomes

The travel portion of this program was eliminated making it possible for more undergraduate students to participate. Twelve students were trained to use the OPTO 22 control hardware and software. These students are in the process of training others. So far an additional 6 student have been trained. Originally the program was intended to provide an opportunity for only 3 undergraduate students to be paid to work on the project. Instead 7 students participated in this way. I have interviewed several of these students, some of them still here and some of them who have gone to industry, about their experiences on the program. These are responses that I was able to get in writing. Other responses were similar.

This project "has allowed me to develop skills unique in an academic world which are more commonly found in industry. These skills and experiences are the main factor that enabled me to find and receive multiple offers and even now, still receive requests for more interviews. These skills and experiences are multiple disciplinary and hits at the core of all engineering: Problem Solving. For example, in one day I can breach many disciplines by updating a 3D CAD drawing of the electrical box (mechanical and civil), determine contact issues in a signal (electrical), size and order structural steel for valve support (mechanical), determine corrosive effects and expected pressure drops in the piping structure (mechanical and chemical), and purchase parts, delegate responsibilities, and determine timeline of next project (business, leadership, product development). Also, while classes have prepared us for the engineering equations, the problems addressed are nothing like traditional homework problems and force us to use out-of-the-box problem solving. This research has been as valuable/more valuable than an internship and it has paid off in mine and others personal career"

-Justin Harwell (Current Graduate Student)

“Working on this project had incredible impact on my development as a student and on my future. This project helped me develop a sense of what chemical engineers actually did and exposed me to a side of industry that I would not otherwise have seen. I was able to present my research at workshop held in Germany, which empowered me and gave me an understanding that the work I was doing is actually relevant to the world and other people’s work. Additionally, the experiences I had and skills that I gained with this project ultimately led me to gaining full-time employment with a reputable company, where I now am using those skills”

-Lara Houghton (Former Undergraduate Student, currently at Exxon)

“Working on the project helped me connect what was taught in the classroom to real life scenarios and find out the similarities and differences. Helping install the electrical components into the electrical box taught me how different the actual components can be than how they are designed or specified out on a design. I learned that there may be some minor adjustments that would need to take place to take into account unforeseen differences with actual equipment and how to be flexible with that matter.”

-Derek Holmstead (Former Undergraduate Student, currently at Safety Management Services)

“Working in the Pressurized Oxy-coal combustion group gave me experience in handling engineering challenges that would not normally be a part of getting a degree in Chemical Engineering. I learned how to work with vendors and design equipment needed to complete necessary (but not overly technical) tasks. This experience propelled me into my first job where both formal chemical engineering training and the ability to work with vendors and mechanical designers is required. My work in this group gave me skills that have been very useful in industry.”

-Luke Houghton (Former Undergraduate Student, currently at Exxon)

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