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Pneumatic Trainer
Senior Design Project Report

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TECH 471 - Senior Project
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ACKNOWLEDGEMENTS

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ABSTRACT

The purpose of this project is to design a pneumatic trainer that will serve as a hands-on learning tool for any pneumatic section being taught. This device will allow students to apply what they have learned in class on physical equipment to better grasp air logic controls. This will also be done through labs that our team will create to highlight the trainer and help students better learn the class material.

Designing the trainer required varied tasks to be completed. Initially, research had to be done to look at trainers on the market and for understanding of pneumatic logic. Components were then decided on based on client specification. After this, a completed computer aid design model was created. This model would help determine how the official trainer would be designed and how components would be placed. The trainer was then assembled according to the layout of the computer model and tested for quality before it was given to the client.

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1 INTRODUCTION

The University of Southern Indiana currently has a need for more learning tools and devices that can better help students get hands-on experience with pneumatics. The devices chosen to help solve this issue are pneumatic trainers. These trainers can complement labs and help students see in real-time how pneumatic circuits can be connected and operated. Our team was tasked with researching, designing, and building a pneumatic trainer prototype based on requirements provided by our client. Our client wanted to prove that that a pneumatic trainer could be custom made for a reduced cost compared to trainers that are currently on the market.

2 DELIVERABLES AND REQUIREMENTS

For this senior design project to be considered complete there are certain deliverables that were required and certain constraints that had to be followed.

2.1 DELIVERABLES

The items that had to be completed are as follows:

- A completed pneumatic trainer prototype
- A complete computer aided design model of the trainer
- A bill of materials with sources of supply
- Detailed instructions to aid in replication of the trainer
- Minimum of two example lab exercises that can display what the trainer is capable of

2.2 REQUIREMENTS

There were needs and expectations supplied by the client, that had to be addressed and always followed while designing the trainer.

- Base plate with minimum dimensions of 30 inches length x 30 inches height x 1/4 inches thickness
- Minimum of one Single-Acting Cylinder
- Minimum of three Double-Acting Cylinders
- Minimum of four Normally Open Limit Switches
- Minimum of four Normally Closed Limit Switches
- Must use 1/8-inch NPT ports when possible
- No electronics on first iteration of board
- Minimum of two selector switches
- Minimum of two push buttons
- Four 3/2 valves for selector switches and push buttons
- Minimum of five 5/2 Pilot Valves
- Must have some form of containing frame for easy mounting
- Two accumulators

3 RESEARCH

One of the first steps in this project was to conduct research concerning pneumatic trainers. This research included two main parts: research into different pneumatic trainers on the market and on how pneumatics works both in a practical and theoretical sense.

3.1 MARKET RESEARCH

3.1.1 Trainer Research

Our team knew very little about pneumatic trainers, so some initial investigation was required. This investigation was to gain inspiration as well as checking to see if there was an industry standard that the team would benefit from following. We decided to look at the most successful companies that offer pneumatic parts and trainers (Figure 1). The companies that have the biggest market share in the United States and the ones we gathered information from: SMC, Festo, Amatrol, and TECH-LABS (Pneumatic Components Market Size…). Each of these companies offer the buyer different levels of trainers with some having components that are fixed and some that offer complete customization in terms component placement and different component options. Some of these customizable options can have interchangeable parts and were closely related to what we wanted for our own trainer. This research also helped us evaluate market prices. This was an important aspect for us to check because if there were cost-effective options available on the market, then there would be no need for our team to take on this project.

Searching through different company catalogs for trainers quickly proved, however, that pneumatic trainers being sold in 2021 are quite expensive. Current pneumatic trainers can range anywhere from $6,000 to $30,000. The less expensive ones were seen in the SMC catalog while more expensive models from TECH-Labs (PNEUTRAINER-400; Hydraulics/Pneumatic Trainers). We are in no way saying that the less expensive ones are of less quality; the more expensive ones found just had larger bundles and packages, increasing their costs. Once we found that SMC provides a good entry level trainer that is a little cheaper when compared to other companies; we decided to make the entry level our benchmark for comparison. This was chosen because our team wanted to make sure we could make a trainer that costs less than one of the lower end models of a large manufacturer. This trainer is the PNEUTRAINER-200, seen in Figure 1 (SMC International…), which offers different levels and packages of this version of trainer.

We decided to look at a package that offered most of the same components that were desired by our client. This made the cost of the trainer to be around $6,000. After finding this trainer, we decided to see how much it would cost to order each component from that trainer separately to see the price difference. Buying each part separately and finding vendors for other third-party components made the price total to be around $4,200. This proved to us that we could put a trainer together and do it at a lower price than just buying a premade trainer from a pneumatics focused company.

Figure 1: Example of SMC Beginner Trainer (SMC International…)

3.1.2 Component Research

After researching different vendors to buy our parts from, we decided on the company AutomationDirect. This decision was made for a couple of reasons. Firstly, they offered every component that was wanted by the client. This helped reduce our research time and made ordering easy through the USI (University of Southern Indiana) student ordering process. Secondly, they offered quick shipping and on average had more cost-effective prices when compared to other companies (Pneumatic Components and Systems). For example, they offer a 5/2 valve for around $18 and other companies will charge anywhere from $40 to $55 even though they offer the same function (MSC 5/2 Way Valve).

While quick shipping may sound trivial, because this project only spanned a couple of months, being able to order parts and get them the same week allowed us to make great progress and order more parts for either corrections or additions without falling behind. It should be noted that AutomationDirect was not our only site used for parts as BIMBA was also used. BIMBA was used exclusively for the accumulators which will be explained later. Accumulators were more difficult to find than anticipated and took a great deal of research to decide on. Many companies offer different forms of accumulators but very few allow custom sized ones both in terms of length but also bore size and other options. It also helped that BIMBA was a large supplier of accumulators in the United States (Non-Repairable Reservoir).

3.2 PNEUMATICS RESEARCH

Although our team has basic knowledge of pneumatics from previous courses, we wanted to make sure we were well versed in pneumatic logic. Helping with this was a company called Camozzi Automation. They have a great online booklet that explains pneumatic principles and components (Pneumatic automation…). They show graphs and pictures of pneumatic logic as well as how basic circuits can be setup. It was of great help from beginning to end. Some of the most important diagrams for us to understand were on how to use 5/2 and 3/2 valves.

These two components were the two parts that confused us the most so looking at diagrams on how they functioned helped greatly. The two diagrams that assisted us the most and were referenced back to can be seen in Figure 2 and Figure 3 for the 3/2 valve operations and Figure 4 for the 5/2 valve operations (Pneumatic automation). Using these figures deepened our understanding of the valves as we could visually tell how the valves would operate under certain conditions. Increasing our understanding also allowed us to make more confident component choices for the trainer. We also used a simulation software at USI called AUTOSIM (Autosim Premium). This program allowed us to test different circuits without having to physically set them up. An example of these circuits can be seen in Figure31 and Figure 32 down below in the "Example Labs" section.

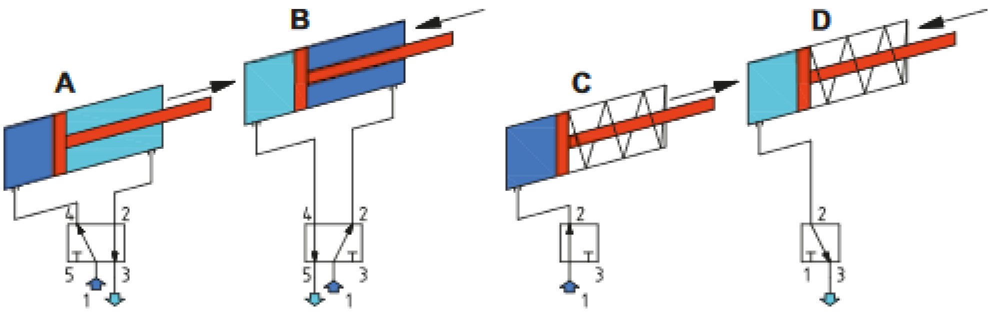

Figure 2: 3/2 Valve Operations from Camozzi (Pneumatic automation…)

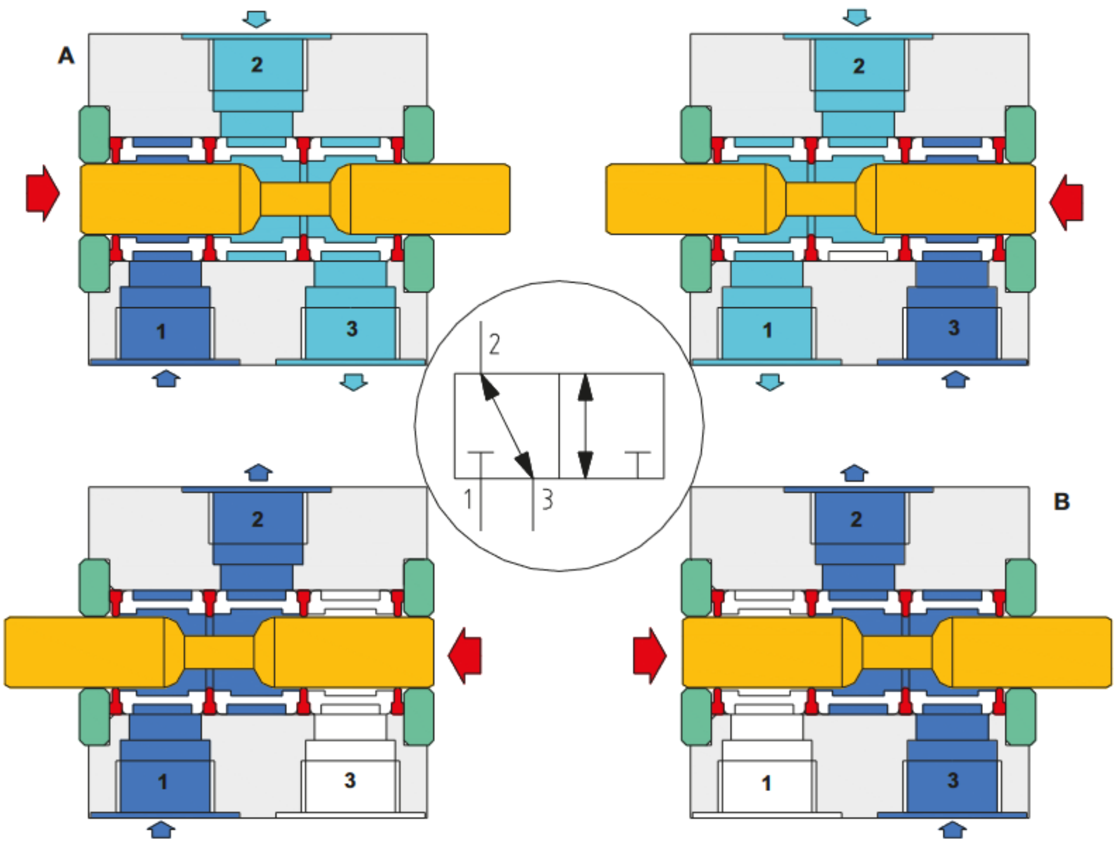

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Figure 3: 3/2 Valve Operations from Camozzi (Pneumatic automation…)

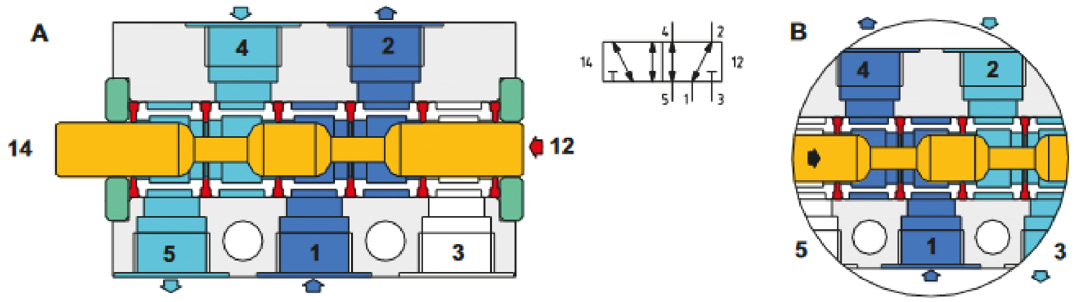

Figure 4: 5/2 Valve Operation from Camozzi (Pneumatic automation…)

4 COMPONENTS

After extensive research, our team decided upon different components that satisfied the client's wants and needs as well as choosing parts that would be compatible together. The parts chosen will be shown in the following sections.

4.1 Supply Section

4.1.1 Regulator

One of the first component selections had to be the regulator. The regulator that was chosen is the AFR2-2133 (Figure 5) from AutomationDirect. The main reason this component was chosen is because it provided an adjustable range of 20 psi to 130 psi and has 1/8-inch female NPT ports which allowed us to stay in line with the given constraints. A bonus is that this part comes with an attached filter. The filter is important because it keeps the system clean and allows every other part to last longer, reducing how often parts will need to be replaced.

Figure 5: AFR2-2133 Air Regulator with Filter

4.1.2 Shut-off Valve

The second component that had to be selected was the shut-off valve. The specific part chosen is the ARV-21 (Figure 6) from AutomationDirect. This part was chosen second because of how important it is to the user's safety. In case something goes wrong with the system, this shut-off can be activated and all air going into the system will immediately be stopped and all processes ceased. The ARV-21 also allows for a lockout tagout system as it comes with a lock that can be applied. It also followed the constraints as it comes equipped with 1/8-inch female NPT ports.

Figure 6: ARV-21 Shut-off Valve

4.2 MANIFOLD

The manifold for this system is a sort of hub. This is where most hose lines will be connected as the regulator feeds directly into the manifold. This in turn will supply regulated pressure to all manner of components. The manifold chosen for this system is the MRA-8CB-W (Figure 7) from AutomationDirect. This manifold also follows the constraints as it comes with eight 1/8-inch female NPT ports. The ports are also spaced far from each other to provide the user with an easier time when managing the air hoses.

Figure 7: MRA-8CB-W Aluminum Manifold

4.3 VALVES

There were two main types of valves that were chosen for the pneumatic trainer. The two types are 5/2 valves and 3/2 valves. These valves operate similarly but are harnessed to produce different functions.

4.3.1 3/2 Valves

The 3/2 valves that were chosen were the EVP-AA-PL model (Figure 8) from AutomationDirect. These valves did not follow the 1/8-inch port constraint but instead have 5/32-inch tubing inlets and outlets. These parts cannot be seen from the front of the board as they are attached to the push buttons and selector switches near the bottom of the board and will be mentioned later. The reason this valve was chosen is because it has a metal plunger, so it is optimal when used with the previously mentioned push button and selector switch.

Figure 8: EVP-AA-PL

4.3.2 5/2 Valves

There are two different forms of 5/2 valves used on the pneumatic trainer. Both can be seen on the front right of the board. The two types used are AVS-5241 (Figure 9) and AVS-5251 (Figure 10) from AutomationDirect. An important distinction between the two is that one is a double air pilot (AVS-5251), and the other is a spring return (AVS-5241). This matters because it provides the user a slightly different way to configure a pneumatic circuit. There are three AVS-5251 models and two of the AVS-5241 models. These valves follow the direct requirements of the client by having 1/8-inch female NPT ports, so it conforms to the standard, and the minimum quantity of 5/2 valves needed.

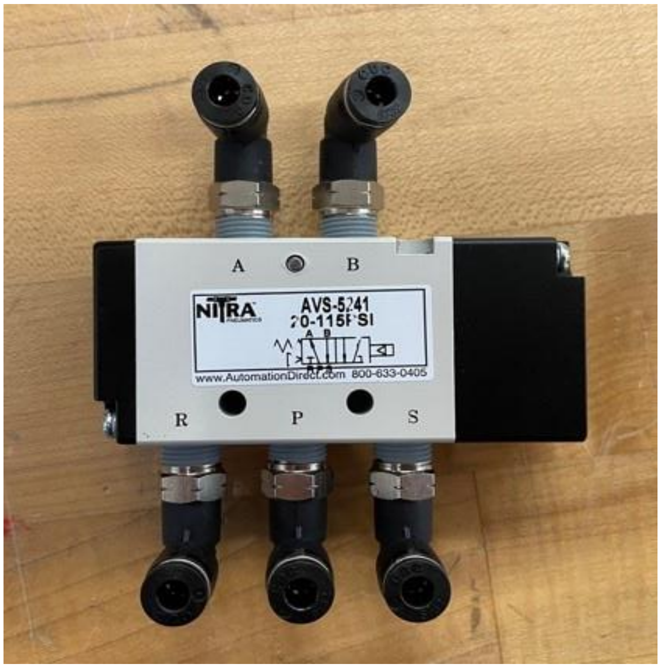

Figure 9: AVS-5241 with Spring Return

Figure 10: AVS-5251 with Double-Air Pilot

4.4 Actuators

Actuators are also called cylinders. These devices add mechanical motion with a rod, specifically linear motion. Based on the type of actuator, they can be double-acting or single acting. Double acting actuators use air to both retract/extend the rod. Single-acting actuators use air to only extend the rod. Usually single-acting actuators are included with a spring-return to “reset” the component after air has been shut off to the system.

By the client’s request, three double-acting actuators (Figure 11) and one single-acting actuators (Figure 12) are to be implemented in this project.

Figure 11: Double-acting Actuator

Figure 12: Single-acting Actuator

4.5 *LIMIT SWITCHES*

These devices act as 3/2 valves with a lever controlling the flow of air. It adds a bit of 1/0 logic to a pneumatic system. 1/0 logic means yes/no, exist/non-existent, or on/off. For this system, limit switches will be used to confirm whether an actuator is retracted/extended. These components can make a pneumatic system more advanced as it can be used to transmit a signal pneumatically to another device. This would then allow the system to automatically change itself or a specific component (such as an actuator).

The client wanted two limit switches per cylinder. He also wanted two types of limit switches. The two types of limit switches used for this project: normally open and normally closed. Normally open limit switches (in Figure 13) are switches that have open air flow while in its normal state (non-contact). When this limit switch is in its active state, no air flows through the component. Normally closed limit switches (in Figure 14) are switches that have no air flow while in its normal state (non-contact). When this limit switch is in its active state, open air flows through the component. Normally open switches will only be used with the double-acting actuators, and normally closed switches will only be used with the double-acting actuator.

Figure 13: Normally open limit switch NITRA EVP-AS-R

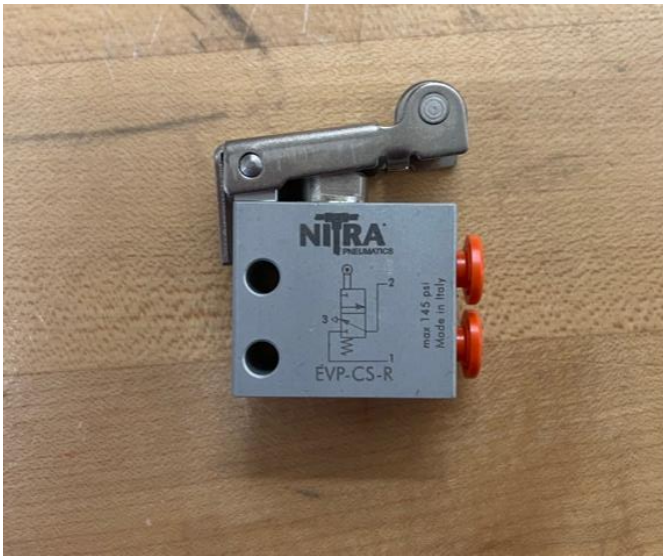

Figure 14: Normally closed limit switch NITRA EVP-CS-R

4.6 ACCUMULATORS

An interesting device that was added to the list of components requested by the client were two different accumulators. An accumulator acts as a capacitor in terms of pneumatic circuitry. It is an empty cylinder that can be filled up with regulated air and used for distinct functions. In terms of this training board, the client wanted accumulators so that they can activate cylinders at separate times and will require the students to consider the differing fill rates. It should also be mentioned that having accumulators on a pneumatic trainer is certainly not the current norm making this addition special. The accumulators that were chosen were from a company called BIMBA. They were chosen because BIMBA offered a great deal of customization options. The options we chose to go with were 1/8-inch NPT ports to match the standard and two differing cylinder lengths. The lengths chosen were two inches and four inches. While other parts of the cylinder can be modified, these were the only two options that needed to be changed. The two accumulators can be seen in Figure 15.

Figure 15: BIMBA Accumulators (four-inch length on left and two-inch length rod on right)

4.7 Selector Switches and Push Buttons

The client wanted two selector switches (Figure 16) and two push buttons (Figure 17) for the trainer. These can be seen at the bottom of the base plate in Figure 30. These two devices are held in by a plastic bracket that comes with the part. They are then inserted into their appropriate cutout spots. The selector switches and push buttons will then have an aluminum plate placed on top of the bracket so only the top cylindrical portion are seen. This plate can be better seen in Figure 28. They will then have a 3/2 valve connected to the back of the bracket so the valves will not be seen by the students. There will be two holes cut out slightly above the brackets that will house push-to-connect fittings that can have hoses plugged into them. The hoses that connect from the valves will be permanently fixed into one end of the fitting while the front board side will remain empty as different labs will have different fittings used.

Figure 16: Selector Switch

Figure 17: Push Button

4.8 BASE PLATE

While it may be surprising, choosing the appropriate board material took longer than selecting all other parts. The top three choices for material type were aluminum, acrylic, and polycarbonate. Originally, the customer wanted an acrylic board but allowed our team to do further research on other options. We initially decided against aluminum due to the difficulty of finding a supplier who could provide an aluminum panel with a thickness of 1/4 inches and still be cost-effective. We then decided to try acrylic as it provided easy machinability, a good durability quality, and was a more cost-effective option compared to aluminum. We did not want to rule out polycarbonate though and decided to shop around. We knew polycarbonate would provide similar qualities to acrylic but would be a bit more durable but not providing quite the level of machinability.

We found suppliers for all three materials but quickly deduced that acrylic was the better priced option for the qualities that were needed for this project. It was then decided to use a company called 80/20 to buy the board from. They offered fair prices while also offering cut-to-order options. The final board size was also to be 3 feet by 3 feet but keep it 1/4 inch thick. Three feet were chosen for the length and width as it provided enough room to comfortably fit all components as well as leaving enough room for future additions. The client also originally wanted the board to be a blue or solid color. This however could not be accomplished due to a conflict between the project timetable and supply chain difficulties within the United States at the time, so a clear option had to be chosen.

4.9 Mounting Frame

As per client request, a mounting frame was to be made that could hold the board in place while in use. The product decided upon was aluminum extruded bar stock. This was an easy choice as aluminum bar stock offers a great deal of customization and can be undone and changed to fit the user's needs. The company this bar stock was ordered from is 80/20 as they specialize in this type of product. Again, they offered fair prices and could cut the bar stock to our specified sizes just like with the board. The U-shaped design for the mount can be seen in Figure 18. A "U" shape was chosen because it would allow the board to be placed into the frame from the top and then be removed in the same fashion. The bottom bar of the shape was 38 inches long while the two side bars were 35.677 inches long. This size difference is because the two side bars are resting on the bottom bar and the board will settle in a slot located on the bottom aluminum stock. The pieces of extruded aluminum were connected using two L-plates and ten sets of bolt assemblies. A bolt assembly in this case one socket cap screw and one slide-in economy T-nut.

Figure 18: U-Shaped Mounting Frame

4.10 FITTINGS & HOSES

Different forms of fittings were needed to accomplish the goal of having a fully functional board. Ideally, the board would consist of one type of fitting to reduce the confusion about what parts are needed and where they should be placed within the system. This could not be the case, however, as some components require a different fitting size and the supply portion of the board proved difficult in conforming to the desired standard.

4.10.1 Push-to-Connect Fittings

The main fittings used were the MS18-18N push-to-connect 1/8-inch NPT fitting (Figure 19). They were chosen because they followed the system standard of 1/8 inch NPT and allowed hose of 1/8 inch to be used in other standard ports. They are also easy to use because of their push-to-connect functionality which will provide a better experience for the students using the trainer. There were other push-to-connects used but they were reducers that had one side consisting of 1/8-inch hose ports and 1/4-inch NPT male screw sides.

Figure 19: MS18-18N Push-to-Connect Fitting

4.10.2 Hoses

Since all fittings were 1/8-inch NPT, tubing of 1/8 inch (Figure 20) was also mainly used for this system. This tubing was used with the “Supply Section,” the manifold, with the 5/2 valves, 3/2 valves and the cylinders as well. It should be mentioned that some ports were 5/32 inch and would not be compatible with 1/8-inch hose. Plug-in reducers were used in these instances so that only 1/8-inch hose would be needed. These reducers will be placed on the board in attachment clips once the board has been built and appropriate placement has been decided with the client.

Figure 20: 1/8-inch hose

5 COMPUTER-AIDED DESIGN MODEL

Before the physical build of the trainer was made, a computer-aided design (CAD) model was created. The design software used, SOLIDWORKS, was chosen due to its different features that assisted our group in putting components together. The model played a couple of roles for our team. Firstly, this was a required deliverable that had to be made for the client. Secondly, it allowed our team to be flexible, make appropriate design choices, and make modifications as component choices were changed throughout the project duration.

5.1 Completed Build

Figure 21 depicts the completed computer design of the pneumatic trainer. This current design shows all the final parts that will be used for the board. This model will be provided to the client so it can be followed in the future for replication. There appears to be a lot of blank space, especially at the top of the board. This was done purposefully to show the room for future additions. The client made it known that future parts may be wanted so apt room was provided. It should also be noted that there are no hoses present within the CAD model. The board is supposed to be seen as providing customizable labs with various parts hooked-up for different logic. Having hoses placed in would make the model look cluttered, could add confusion to the person using the model to replicate the board, and may give the wrong impression that the board is always hooked-up in one fashion.

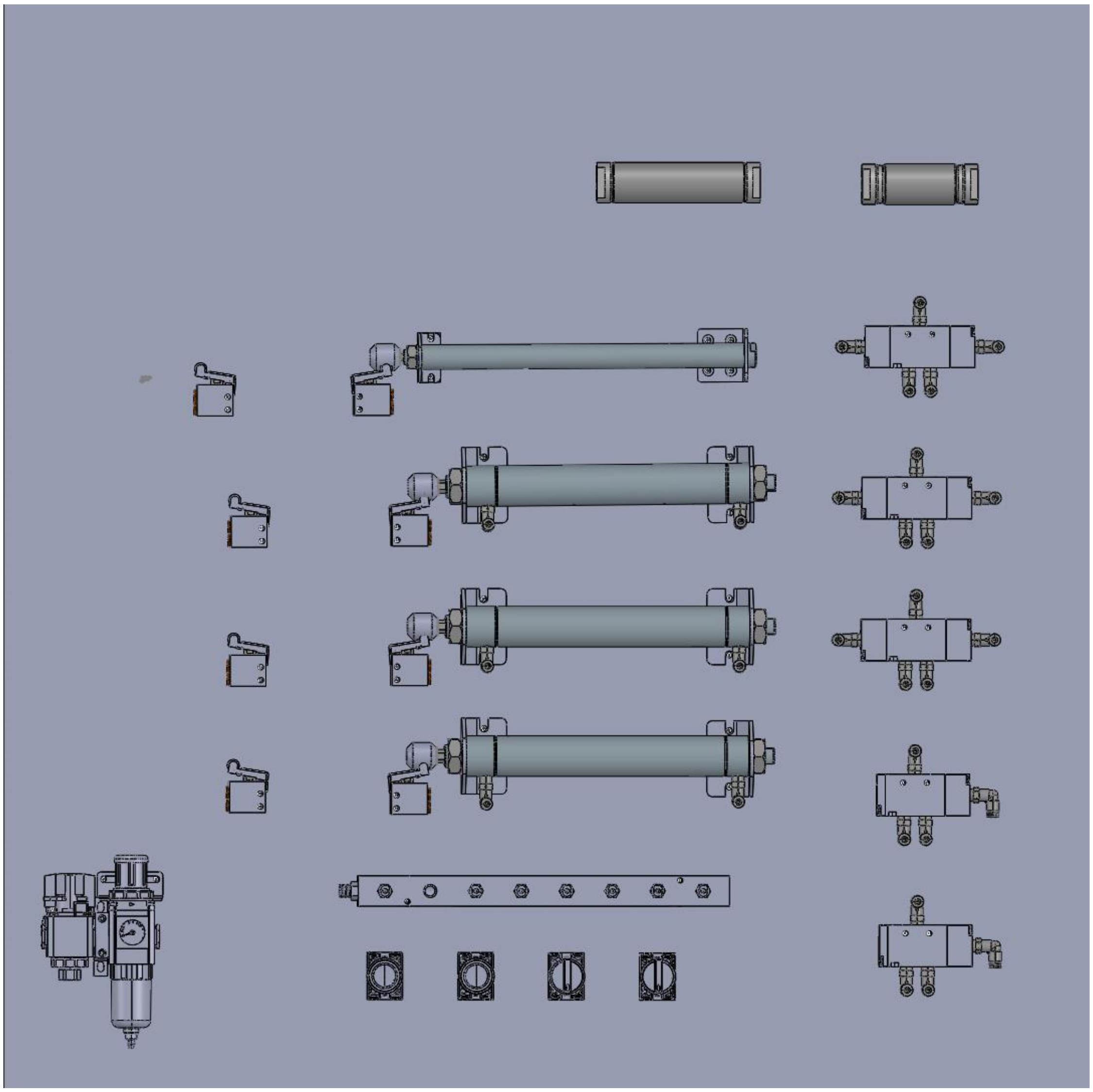

Figure 21: Completed CAD Model

6 TESTING

After the final design was finished for the pneumatic trainer, parts could be ordered, and testing could begin. Testing was first done on a side bench before any parts were officially fixed on the trainer. This would help avoid any unnecessary dismounting and future trouble. We tested the cylinders, the limit switches, 5/2 valves, 3/2 valves, push buttons, and selector switches.

6.1 TESTING ACTUATORS

Testing was done on all components for quality assurance. These tests were completed in different circuit setups that will be talked about in the following sections 6.1.1 and 6.1.2.

6.1.1 Single-Acting Actuator Setup

The testing done for the single acting cylinder also included a normally closed limit switch and the supply portion of the trainer. This was done so a real circuit (seen in Figure 22) could be tested and shown in both picture and video forms. The regulator was set to 35 psi and 1/8-inch push-to-connect fittings were used in the regulator and single acting cylinder. The normally closed limit switch has 5/32-inch NPT female ports so it would be incompatible with the 1/8-inch hose that was desired. Fixing this issue required reducer plug-ins that would allow a 1/8-inch hose to be plugged into the 5/32-inch NPT ports. This allowed the circuit to be completed. The circuit was then tested by having air supplied to the system the limit switch pressed down so the actuator could be extended and then retracted with the release of that same limit switch. Testing of this circuit was done multiple times with the components mentioned above as well as every normally closed limit switch. This allowed our team to confirm that all normally closed limit switches were void of defects and would work on the trainer.

Figure 22: Testing Single-Acting Cylinder

6.1.2 Double-Acting Actuator Setup

The testing done for the double acting cylinders was also like the previous testing mentioned in section 6.1.1. The supply section held a 1/8-inch NPT push-to-connect fitting, and a 1/8-inch hose was connected from that fitting to the supply port of the manifold. This supply port had a reducer fitting with one side being a 1/8-inch hose port and the other side being a male 1/4-inch NPT. The other ports of the manifold all contained 1/8-inch NPT push-to-connecting fittings. One of these ports would connect via 1/8-inch hose to a normally closed limit the switch. This limit switch also contained plug-in reducers as mentioned in 6.1.1. The other port of the limit switch would then feed into the inlet port of a 5/2 spring return valve. This 5/2 valve would also be connected to the manifold from the "P" port (supply port). The other ports of the 5/2 valve, ports "A" and "B", would be connected to the double acting cylinder. Air could then be fed into the Supply Section and the system pressure would be set to 35 psi via the regulator. The actuator could then extend and retract when the limit switch was pressed down and released. The completed circuit can be seen in Figure 23 for better understanding. This test was done with every double acting cylinder to confirm that they would work and could be attached to the trainer. The limit switch was also swapped out with push buttons and selector switches in different tests to confirm their function.

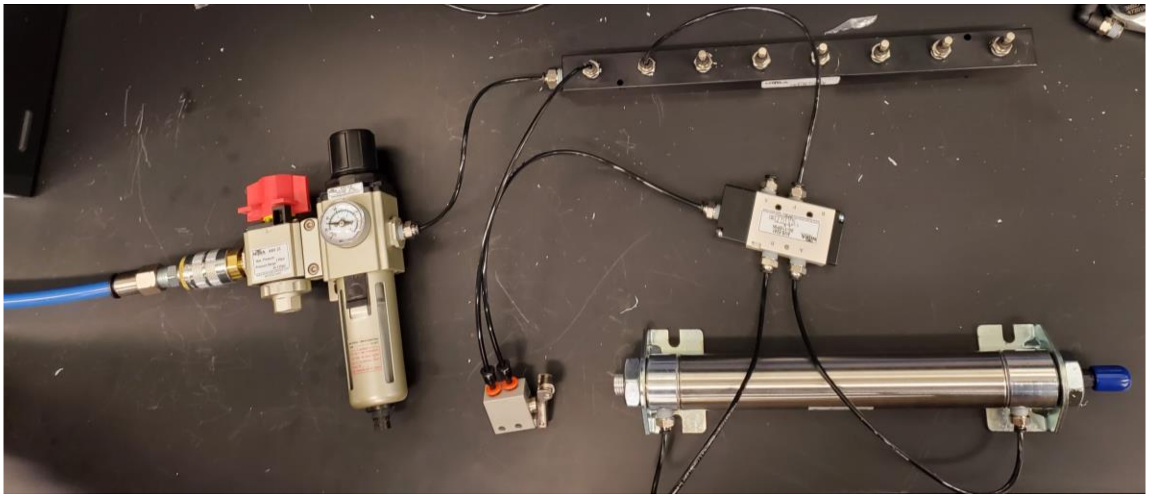

Figure 23: Testing Double-Acting Cylinder

7 CUSTOM FABRICATION

Not all parts needed to complete the board could be ordered from an online store and some had to be custom made. The following sections will highlight the parts that were made for this board.

It should also be noted that CAD models were created for these parts and will be given to those who will replicate the board so it can be easily remade.

7.1 RISERS FOR LIMIT SWITCHES

If the limit switches were laid flat on the board, the actuator heads would simply pass over them due to height differences and no work or action would occur. To counteract this problem, blocks of aluminum were fashioned and cut out using a waterjet cutting device. These blocks were then placed under the limit switches so they could be raised up and activated from the cylinder's heads. The waterjet machine was important because it can take CAD models and cut along given cutting paths. There were two sizes for the blocks with six of them having a depth of 0.72 inches and two of them having a depth of 0.59 inches. The blocks were all 1.18 inches in length and 1.02 inches in height. The differing sizes can be seen in Figure 24.

Figure 24: Limit Switch Risers

7.2 RISER FOR SINGLE-ACTING ACTUATOR BRACKET

Another riser had to be made. This riser was placed under the bought single acting cylinder bracket to make sure there was room for the rod attachment. The riser (as seen in Figure 25) was designed to fit flush with the bracket design so it would not look too noticeable and not stick out anywhere and get in the way. Without this riser, the rod attachment would catch on the base plate. The riser was made from aluminum and the waterjet cutter was again harnessed for this part. The final dimensions of the riser were a width of 0.75 inches, a length of 1.62 inches, and a depth of 0.19 inches.

Figure 25: Bracket Riser

7.3 BRACKET FOR SINGLE-ACTING ACTUATOR

One problem that we solved is that the single acting cylinder only had the design for one mounting bracket leaving the other end with no support. This might not have been an issue for others, but the client wanted every piece securely fashioned to the board. This meant a custom bracket (Figure 26) was to be made that could attach and secure the other end. This bracket was made out of aluminum and was cut out using CNC water jet and mini-drill mill. It was then welded together for completion.

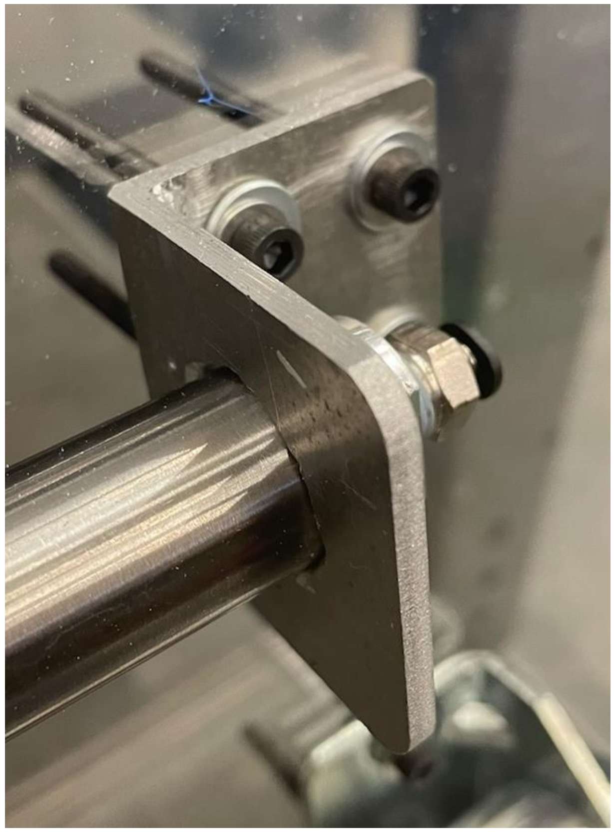

Figure 26: Custom Single Acting Cylinder Bracket

7.4 *Actuator End Rod Attachment*

The single acting and double acting cylinders that were used for this trainer did not come with any rod attachment so one had to be made. The main purpose of the rod attachment was to activate the limit switches that were placed in its path as the rod extended and retracted. The first step was to make a model in SOLIDWORKS that could fit around the model rod ends. Once the piece was designed, four real pieces had to be made. Accomplishing this meant using a lathe and carefully cutting all the angles and eventually tapping one end so it could be screwed onto the rods. The following figure, Figure 27, displays the rod attachments.

Figure 27: Cylinder End Rod Attachments

7.5 *FRONT PLATE FOR SWITCHES AND BUTTONS*

Due to an error in communication and a lack of experience on our team's end, there was an error in designing the section that would house the pushbuttons and selector switches. We did not know that only the top portion of the button and switches should be showing so we left the entire bracket out in the open at the front. After learning of our mistake, a front plate (Figure 28) was designed that covers the brackets and allows the buttons and switches to be fed through the plate and still connect to their respective brackets. The plate was designed in SOLIDWORKS, cut out first in the waterjet cutter, and then cut down to the needed thickness in a milling machine as seen in Figure 29.

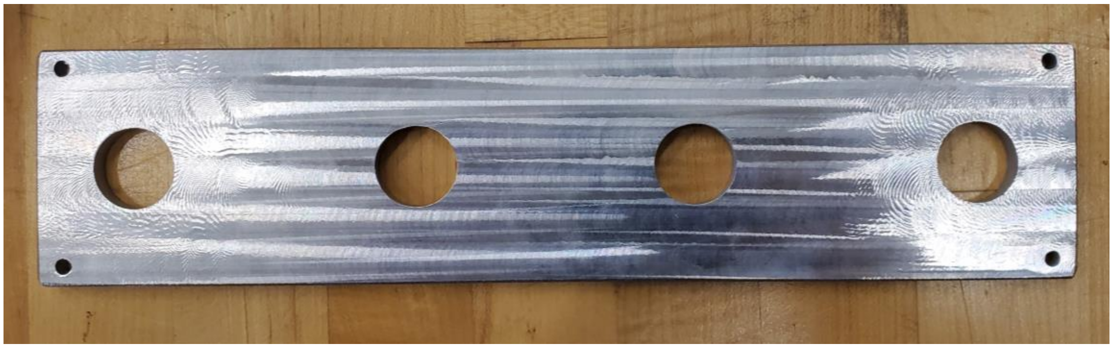

Figure 28: Aluminum Front Plate

Figure 29: Front Plate in Milling Machine

8 BUILDING THE BOARD AND FINAL PRODUCT

8.1 BUILDING

Building the board took very little time and consisted of lining up parts and attaching them to the base plate. The parts were attached using steel socket head screws (thread size 8-32), 18-8 stainless steel hex nuts that would fit the thread size, and general-purpose washers to go between the nuts and screws. This build process was completed quickly as no machining was required.

8.2 FINAL PRODUCT

The final product can be seen below in Figure 30. This is a top-down view of the board as it is difficult to see all other components otherwise. As seen from the picture, there is still plenty of empty base plate space that can be occupied by future components meaning it can be customized even further depending on what the professor requires.

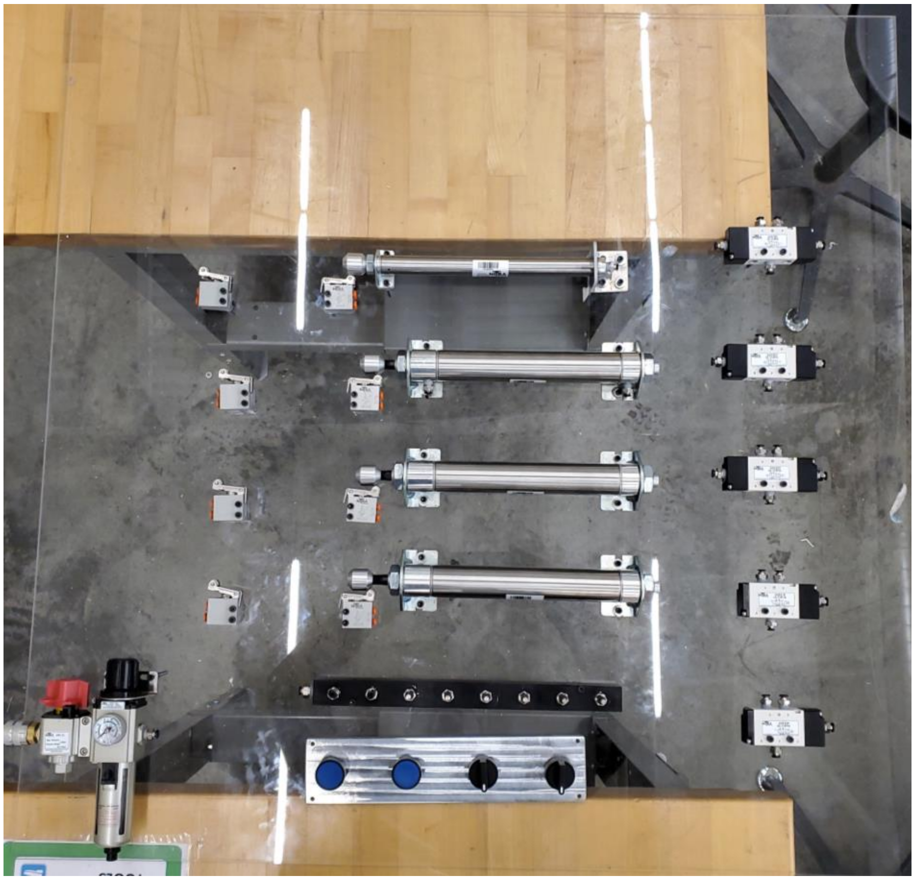

Figure 30: Final Trainer Build

9 EXAMPLE LABS

As mentioned in the "Deliverables and Requirements" section, the client wanted at minimum two example labs. These labs could be used directly in the class, could be used as a template for the professor to modify, or just act as proof-of-concept.

9.1 EXAMPLE LAB 1

The first example lab would act as an introduction to pneumatics and the trainer itself. The lab would require students to design a pneumatic circuit using either paper or a computer program provided by the university. This circuit would connect a supply to a pushbutton (3/2 valve) and then that push button would need to be connected to a single-acting actuator. The actuator would then need to extend whenever the button is pressed and retract when the button is released. This is a very simple circuit, as seen in Figure 31. The students would then test their designs on the trainer. This would allow them to get hands-on experience with pneumatic components and see how their circuits move and react in real life.

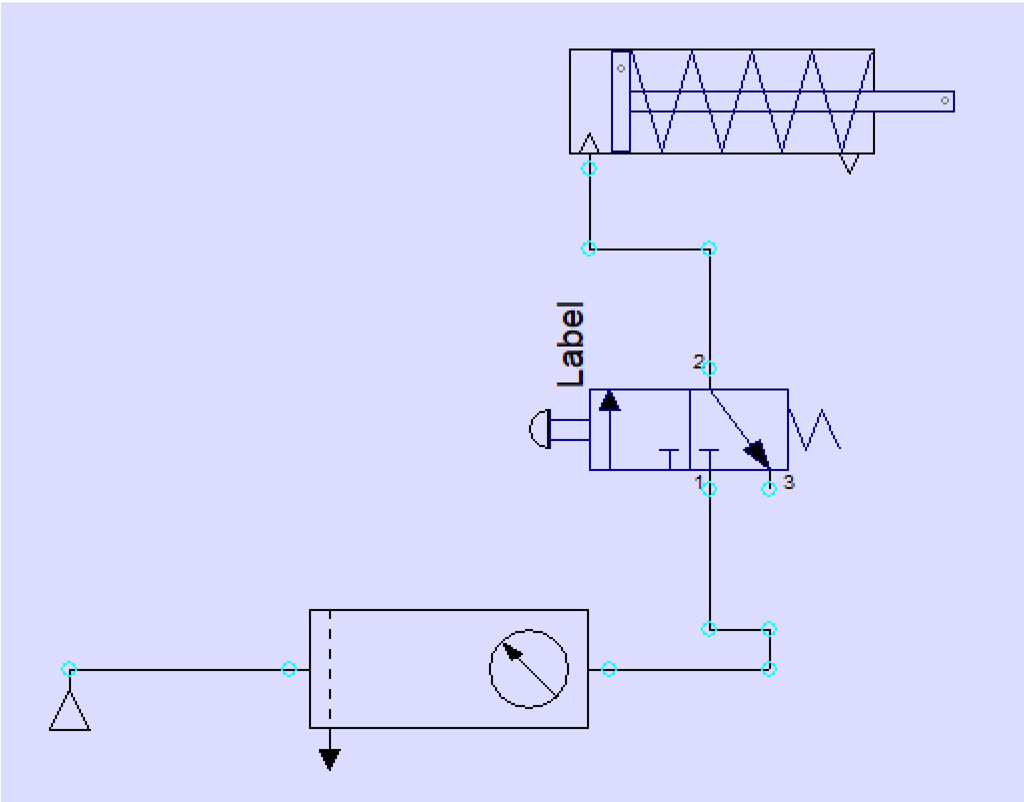

Figure 31: Lab 1 Circuit Diagram

9.2 EXAMPLE LAB 2

Like the first example lab, the purpose of the second lab is the same. The difference is the second lab is intended to be more complex. This time, the circuit will include a pushbutton (3/2 valve), a 5/2 spring return valve, and additional tubing to operate a double-acting actuator. This is shown in Figure 32.

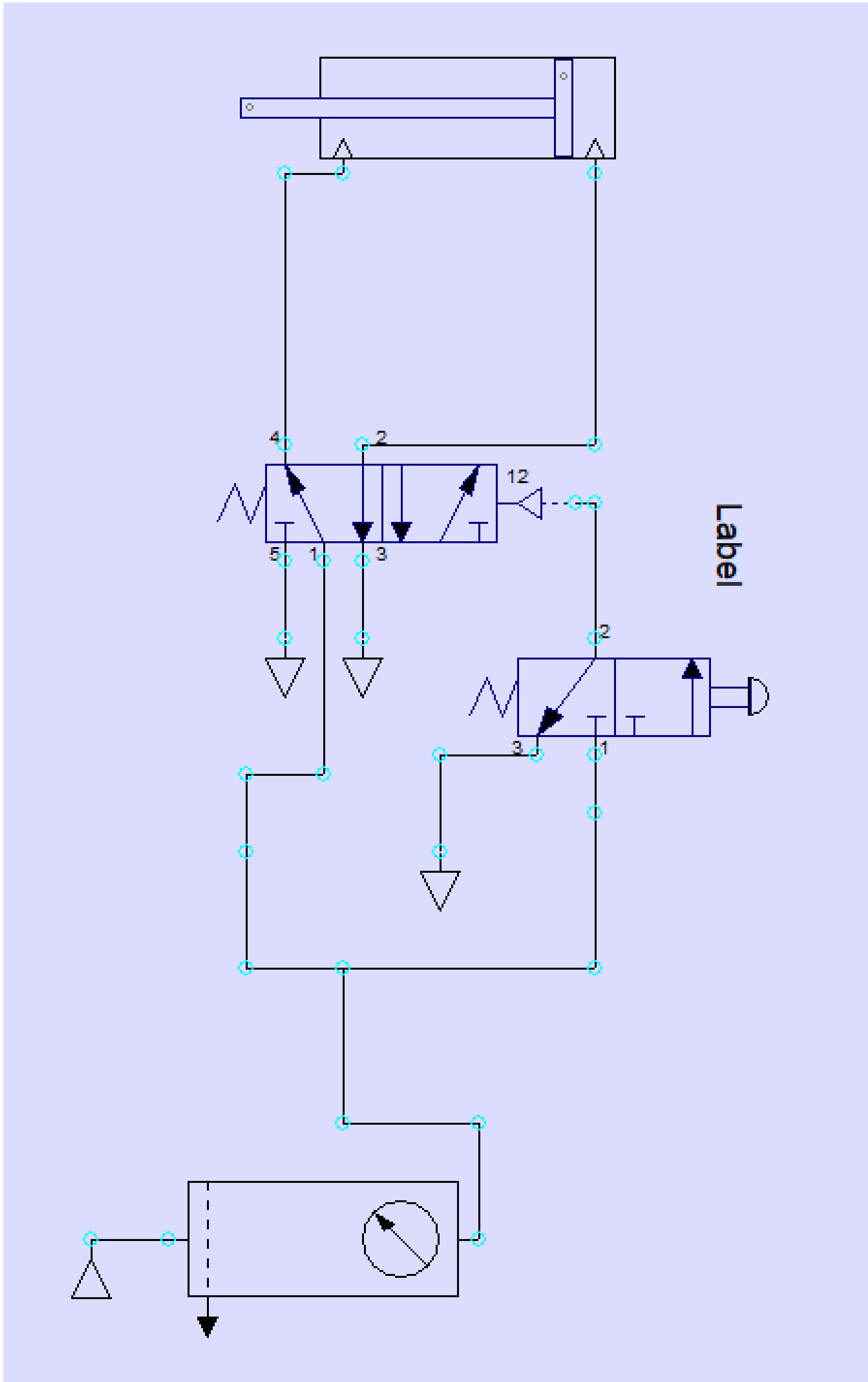

Figure 32: Lab 2 Circuit Diagram

10 DESIGN FACTORS

As requested from the University of Southern Indiana, seven different design factors had to be considered. While not all apply to the project, it is worth mentioning some of them. The design factors are as follows: Public Health, Global, Cultural, Social, Environmental, Economic, and Professional Standards.

10.1 PUBLIC HEALTH, SAFETY, AND WELFARE

The health and safety of the user was of paramount concern. We did not want to design something that would harm students or faculty. The first step in implementing safety was to have a shut-off valve at the beginning of the system so if anything went wrong, it could be activated and stopped at the source. The shut-off valve also comes with a lock so the system can be kept shut off when not under professor supervision. We are also using a lower pressure setting (around 30 psi to 40 psi) so nothing will activate too aggressively or quickly (Control of Hazardous…). There are also no sharp ends on the board or other components so people will not accidentally cut themselves when either walking by it or by operating it.

10.2 GLOBAL

Designing this product while taking into consideration global factors did not occur because we did not think it was necessary. This trainer will be made and stored at the university and not sold to any overseas markets.

10.3 CULTURAL & SOCIAL

This project should not have any foreseeable cultural or social impacts or design factor considerations. The pneumatic trainer is a learning tool that should have no impact on the culture of USI or the social construct of the school

10.4 ENVIRONMENTAL

Due to the nature of the project, there should not be too many environmental concerns. With any kind of fabrication and ordering parts from across the country, there will be an environmental impact. While using the board though, only pressurized air is being used and should not be emitting any harmful gases nor producing any harmful byproducts.

10.5 ECONOMIC CONSIDERATIONS

This design factor is one of the core-factor considerations for this project. One of our team's main goals was to build a board that would be cost-effective and not so expensive that the university would no longer see it as feasible to build more boards. Taking this into account, we chose parts carefully and custom-built others to reduce costs to the university. We also proved it was possible to not have to spend upwards of $6,000 on just one board but would only need to spend around $1,127. Although $1,127 may sound expensive, compared to other trainers on the market that usually range from $6,000 to $30,000, it was a huge success and proved it could be done at a lower cost. A full costed bill of materials can be seen in Appendix B.

10.6 PROFESSIONAL STANDARDS

Due to the nature of the project, there are not too many professional standards that cover the pneumatic trainer. One of the most important standards we decided to follow is having a lockout/tagout system that was part of the shut-off valve. This follows the Occupational Safety and Health Administration standard 1910.147. This standard ensures that the energy being fed into the system does not get out of control. The official standard of 29CFR CHXVII PARAGRAPH 1926.302(b)(7) STATES: "All hoses exceeding 1/2-inch inside diameter shall have a safety device at the source of supply or branch line to reduce pressure in case of hose failure" (Control of Hazardous…) While most of our system only 1/8-inch hose, the air being fed into the system harnesses a ½ inch hose, so the safety standard had to be followed.

11 TEAMWORK

Working as a team was an essential aspect of making this project work. It took clear communication and understanding to bring a design together of both of our ideas to meet the needs and expectations of the client.

11.1 COMMUNICATION

There was constant communication between the team members. The most common form was through texting. There would be constant updates on either research, part selection, CAD design choices, and general meeting times that were formed through texting. Another important communication tool was using Discord. This allowed for remote meetings and to show progress made simultaneously. We would share screens to give input into each other's sections. We could also work on SOLIDWORKS in this fashion by having one member control the program and the other could provide parts that would be loaded into the overall assembly. While this may not sound like the most efficient form of working in terms of CAD design, using Discord to add in creative input was the most logical choice as we could not meet in person every time we worked on the model.

11.2 Task Assignments

Having each member know exactly which sections they needed to complete was important to make sure there were clear objectives for each person and there was no accidental overlap in terms of work done. The way we assigned tasks was simple. Early on we decided at random who would research different components and whoever was researching those components would oversee those parts for all other sections of the project (Decided Components in Table 1). We would find our corresponding parts for the CAD model or make them if needed. When it came to the senior design report, we also wrote the sections that corresponded with the ones we were assigned at the beginning. With the presentation and poster, we also split the slides and portions according to Table 1 if possible. The example labs were also split so each group member each did one. It should be mentioned that even though we had assigned components, we would always help each other when needed and confirmed each other's work before submission or before a final decision was made on any section.

Table 1: Component Task Assignments

Evan's Components	William's Components
1. All 5/2 Valves 2. All 3/2 Valves 3. Shut-off Valve 4. Regulator 5. Manifold 6. Push-to-Connect Fittings 7. Hoses 8. Push Buttons 9. Selector Switches 10. Front Mount Plate 11. Fasteners 12. Acrylic Base Plate	1. All Actuators 2. Actuator Rod Attachments 3. All Limit Switches 4. Risers for Limit Switches 5. Brackets for Actuators 6. Accumulators

11.3 CONFLICT/PROBLEM RESOLUTION

Luckily within our group there were a few disagreements. This could be attributed to the fact that we got along quite well and had past work experience with each other. It also helped that all parts were decided on from the beginning so there were no problems in the future with who should work which sections. When it came to which components to buy, we already had requirements set and approval from the client was sought after early in the decision process. This kept us from having much difficulty or even chances of becoming upset with the other person. The only problem we would have would usually be scheduling. Our schedules would not always line up how we would want due to other classes and work. We would have to find different solutions such as using Discord or coming into the AEC earlier or later in the day.

12 CONCLUSIONS AND RECOMMENDATIONS

Coming to the end of the project, we have accomplished the following goals:

- A completed pneumatic trainer prototype that is fully functional

- A complete CAD model of the trainer
- A bill of materials that shows prices, quantities, and source of supply
- Detailed instructions on how to build the trainer
- Two example labs that will help introduce the different components to students
- Completing the project with a total cost of $1,127

12.1 FUTURE RECOMMENDATIONS AND CHANGES

While the board is complete, there is always room for improvement. This means that future students could potentially find different aspects they would like to change. Some potential changes and improvements are as follows:

- As per the constraints from *Section 3.2*, there are no electronics on the board whatsoever. This could be changed in the future though, and the extra open space on the board would prove useful for those additions. Adding electronics would add further options in terms of pneumatic logic and circuit design.

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APPENDIX

Appendix A: Bill of Materials

Appendix B: Preliminary Project Schedule

APPENDIX A

Costed Bill of Materials			
Name	Quantity	Price	Total Components Price
1. NITRA pneumatic air cylinder (Single-Acting)	1	$ 25.50	$ 25.50
2. NITRA pneumatic air cylinder (Double-Acting)	3	$ 47.50	$ 142.50
3. NITRA manual valve (N.O. Limit Switch)	4	$ 23.50	$ 94.00
4. NITRA manual valve (N.C. Limit Switch)	4	$ 21.00	$ 84.00
7. NITRA pilot valve (Single-Pilot)	2	$ 18.50	$ 37.00
5. NITRA pilot valve (Double-Pilot)	3	$ 24.00	$ 72.00
6. NITRA pneumatic push-to-connect fitting (Flow Control)	5	$ 12.50	$ 62.50
15. NITRA pneumatic push-to-connect fitting	16	$ 9.50	$ 152.00
14. NITRA pneumatic push-to-connect fitting (Elbow)	22	$ 7.25	$ 159.50
12. NiTRA pneumatic selector switch	2	$ 4.50	$ 9.00
8. NITRA pneumatic push button	2	$ 2.75	$ 5.50
9. NITRA pneumatic filter-regulator	1	$ 36.50	$ 36.50
10. NITRA pneumatic manual shut-off pressure relief valve	1	$ 25.50	$ 25.50
11. NITRA pneumatic valve manifold (8 holes)	1	$ 18.00	$ 18.00
18. Brackets (Double-Acting)	2	$ 5.00	$ 10.00
17. Brackets (Single-Acting)	1	$ 2.75	$ 2.75
NITRA Pneumatic Tubing 5/32in (4mm)	1	$ 12.50	$ 12.50
NITRA Pneumatic Tubing 1/8in	1	$ 16.50	$ 16.50
Plug-in Reducer 5/32in to 1/8in	4	$ 16.50	$ 66.00
20. NITRA modular T-bracket	1	$ 9.75	$ 9.75
NITRA Manual Valve Metal Plunger Spring Return	4	$ 21.50	$ 86.00
13. Non-Repairable Reservoir (Accumulator) (1-1/4 in. bore, 2 in long)	1	$ 28.30	$ 28.30
19. Non-Repairable Reservoir (Accumulator) (1-1/4 in. bore, 4 in long)	1	$ 32.95	$ 32.95
1.00” X 1.00” T-Slotted Profile - Four Open T-Slots (35.677 Length)	2	$ 12.25	$ 24.50
1.00” X 1.00” T-Slotted Profile - Four Open T-Slots (38 Length)	1	$ 12.90	$ 12.90
10 Series 5 Hole - "L" Flat Plate	4	$ 7.79	$ 31.16
Bolt Assembly: 1/4-20 x .500" Black FBHSCS and Slide-In Economy T-Nut - Centered Thread - Black Zinc	20	$ 0.60	$ 12.00
1. Acrylic Panel 6mm Thick (914.4 mm x 914.4 mm)	2	$81.87	$ 163.74
2. General Purpose 316 Stainless Steel Washers	1	$ 3.45	$ 3.45
3. 18-8 Stainless Steel Hex Nuts	1	$ 5.97	$ 5.97
4. Alloy Steel Socket Head Screws	4	$ 12.55	$ 50.20
		Total Cost:	$ 1,127.00

APPENDIX B

Week	What Is Due:	Project Goals for that Week:
1		• Complete first meeting with advisor and set plan for project
2		• Preliminary market research • Client Meeting for requirements and constraints
3		• Form final parts list and get parts approved by client • Finish Introduction • Write Synopsis and Scope • Work on CAD Model
4		• Get actual parts approved and ordered • Work on paper and presentation while waiting for parts o Complete intro and synopsis • Work on CAD Model
5		• Work on paper and presentation o Work on different impact sections (Public Safety, Global, etc.) • Finish CAD Model (all details finished and implemented) (excluding hoses) • Decide on board material and size • Figure out how to attach each piece to board

6		• Assuming parts are in; begin building trainer
		    o Confirm part placement on board (place without attaching)
		    o Place pilot holes
		        ▪ May needed CNC machine or other equipment
		        ▪ May need to be trained
		    o Place valves, manifold, regulator
		        ▪ Make sure brackets are correct
		• Test each part (valves, switches, cylinders especially) before board placement
		• Work on Presentation
		    o Put in slides and current pictures
		• Begin looking at lab exercises from Pete Vree
		    o Early labs recommended

7		• Work on trainer
		    o Get cylinders, accumulator, and switches setup correctly
		    o Work on getting trainer board matched with 80/20 pieces
		• Work on Presentation
		• Work on Paper
		• Work on lab exercises
		    o Complete Lab 1

8		• Finish trainer o Make sure every piece is attached correctly

		○ Make sure 80/20 and board are attached correctly ○ Check spacing of cart to see if the current cart will work ○ Look into holding bin for different smaller parts and hoses • Work on Presentation • Work on Paper • Work on lab exercises ○ Complete Lab 2
9		• Work on paper, presentation, and poster ○ Need to make sure presentation is mainly completed by this time ○ Invite another professor to DPR
10		• Work on paper, presentation, and poster ○ Make any final changes to presentation ○ Continue working on paper
11	• Put program info into shared drive • Invite list into drive	• Make sure DPR is complete • Work on draft report ○ Complete conclusion ○ Maybe add a section about where it will go next after this semester
12	• DPR complete	• Make changes to presentation based on DPR comments • Work on Draft Report ○ Make any final changes
13	• Draft Report due	• Work on poster and presentation • Practice the presentation • Make changes to senior design report based on feedback
14		• Make final preparations for presentation • Practice presentation • Work on poster session material • Make sure all slides and potential videos work in the presentation room
15	• Final Presentation Day	• Finish poster and final draft of report
16	• Poster Session and Final Draft	• Turn in final report - **must not be late**
17	• Final Report for SOAR	• Turn in final senior design report to library SOAR system