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# Pneumatics in Industry

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# PNEUMATICS IN INDUSTRY

## Schematic Design of OSRAM Glass Tractor

**Patric Bracco**

*Mentored By: Dr. Ni Wang*

### **Author Note**

Fluid power research for an industrial example using pneumatics for the design of a schematic in Dr. Ni Wang's Hydraulics and Pneumatics course (AEM 371). Research was presented in Microsoft PowerPoint format. The example used is a Glass Tractor in operation at OSRAM Glass Technologies - Versailles Plant, located in Versailles, KY. The schematic was designed on Automation Studio to replicate the pneumatically operated mechanism of the Glass Tractor.

### Acknowledgements

Special thank you to Dr. Ni Wang for the thorough and well-rounded knowledge obtained in AEM 371 and with pointing me in the right direction when I was stuck on my schematics. Also, through the encouragement of my work which has been inspiring and greatly increased my confidence and understanding of subject matter.

Thank you to everyone at OSRAM for all of their assistance and generosity with gathering the proper information to complete this project, but furthermore, I can't express my gratitude enough for the daily knowledge that I have gained from all of you.

To Isabella, Hudson, and Samantha - Thank you for all your support and for being the best form of motivation anyone could ever have. I love you. I know it is hard putting up with my countless hours in front of my computer or being away at school/work, but hopefully one day it will all be worth it. Dream big.

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Eastern Kentucky University

Applied Engineering and Management Program

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## Abstract

The basis of information obtained through research for this project was to design a pneumatic schematic based on a real life example in an industrial atmosphere. The example had to include the overall intention of the equipment that used pneumatics to operate an entire machine or specific mechanism in which was pneumatically powered. Once the decision was made on what machine was a good fit for the example, it would be necessary to design a schematic for the pneumatic operations. The schematic would be designed using knowledge obtained in Dr. Ni Wang's Hydraulics and Pneumatics course (AEM 371) through course work which covered the components of a fluid power system and operations of these components. Important knowledge to complete fluid power calculations and Automation Studio software to demonstrate a working schematic within a fluid power system was also covered and integral to the project. The final project decision based on the research and knowledge obtained was a Lime Glass Tractor which was currently operating at OSRAM Glass Technologies - Versailles Plant in Versailles, Kentucky. The machine was designed by Engineer Matt Hughes - with the assistance of others - as a "new and improved" version of legacy equipment used on other manufacturing lines in the Versailles, Kentucky plant. Specific to the requirements of the project, the pneumatically operated cylinders which lift and determine the force of pressure emitted on the glass tubing being formed was the choice for schematic design. Knowledge of design, materials, and usage were critical to obtain and understand in order to properly draw a schematic for the pneumatic components of this machine.

*Keywords:* engineering; glass; fluid power; pneumatics; schematic; design; industrial; manufacturing; Automation Studio; CAD; mechanics; research; ATMAE; Applied Engineering & Technology

## Introduction

Fluid power is vital to machines, robots, and all non-living things encountered every single day. It is defined in Introduction to Fluid Power (Johnson, 2002) as “the use of a fluid (liquid or gas) to transmit power from one location to another.” Another way to identify the importance of fluid power’s role and how it pertains to a machine, is to comprehend the synonymous role blood plays in the human circulatory system. The nervous system sends signals to the heart to pump the blood throughout the body to specific locations through atriums and ventricles and filtered through the lungs (Alters & Alters, 2006) in the same sense that a power supply tells the hydraulic pump (liquid) or compressor (air) to pump the fluid to various areas of the machine via supply/return lines which are guided by manifolds and directional control valves (DCVs) which has been filtered through various types of filters. The human heart utilizes an atrioventricular valve which only allows the blood to flow in one direction as a fluid power system has check valves that operate with principles in a machine. The blood pressure is critical to the human circulatory system, as fluid pressure is vital to the working machine.

Doctors and surgeons must understand the importance of the pressure to

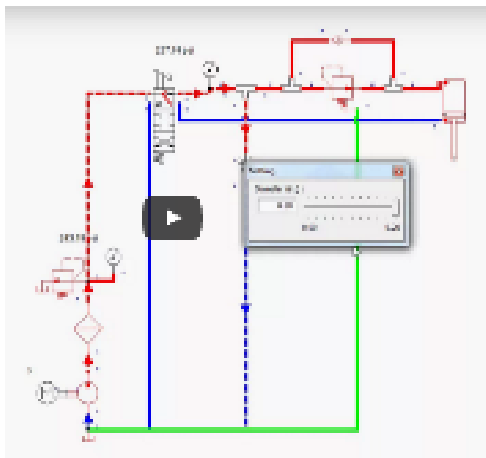


FIGURE 2: PNEUMATIC SCHEMATIC ON AUTOMATION STUDIO

keep human hearts from stopping

when something is not at optimal levels within a person’s

body. Without the blood circulating properly at every

location, the doctors cannot keep the people well or fix them

when they have not maintained themselves. The principle is

identical to mechanics and engineers who must understand the

importance the pressure plays to keep the pumps from stopping

when a machine has a component not operating with prime

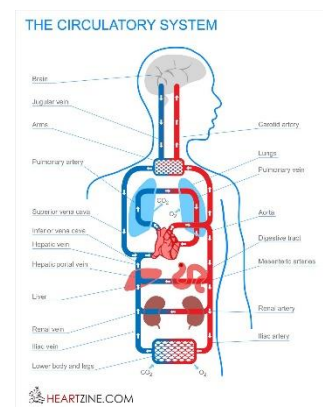


FIGURE 1: HUMAN CIRCULATORY SYSTEM (HEARTZINE.COM, 2011)

efficiency. Without the fluid power being dispersed at the right place/right time, engineers cannot fix or improve areas of a machine that have not been maintained. The circulatory system is as crucial to a surgeon as fluid power and its components are crucial to engineers.

### *Pneumatics at OSRAM*

OSRAM (previously OSRAM Sylvania and soon to be LEDVANCE<sup>1</sup>) in Versailles, Kentucky uses pneumatics throughout the entirety of the manufacturing plant. The applications vary depending on the system it is designed for. In the raw materials section of the industry leading lighting factory, glass is created in tube form to later be assembled into a fluorescent light bulb.

#### *Glass Tractor*

Creating this glass with quality that exceeds expectations and/or requirements has an important device that has been around for many years at OSRAM. This device is called a tractor. The “chain style” tractor (SEE FIGURE 1) allows for a continuous pulling of the glass to (along with a variety of other processes) maintain the features that are important to the structure of the future bulb. The glass product can be formed in a variety of standard sizes and thicknesses.



**FIGURE 3: LEGACY MACHINE, “CHAIN STYLE TRACTOR” – MUST BE ADJUSTED MANUALLY**

A common bulb is the Fluorescent T8 lamp. The majority of these T8 lamps are assembled from glass with very similar technical characteristics. Many products, formed through customer requirements,

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<sup>1</sup> As of July 1, 2016, OSRAM will be officially be changing the name of the OSRAM Lamps business to LEDVANCE (LED + Advance). (OSRAM GmbH, 2016)

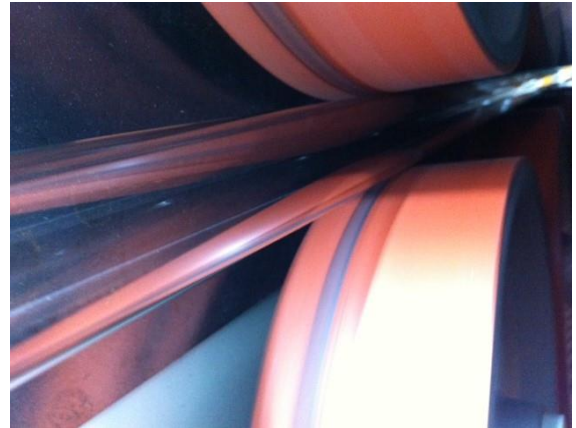
have a wall thickness of 0.028" and outside diameter (O.D.) of 1.01" <sup>2</sup>. Manufacturing glass with these requirements on a daily bases brings a sense of normalization to the profound idea of dragging molten hot glass through a mechanical device that squeezes this thin glass at a constant rate with little to no problems.

Before OSRAM production engineer Matt Hughes designed the new standard tractor for the OSRAM Glass Technologies - Versailles Plant, the tractor was good but had many areas in which it could improve functionality and efficiency (Hughes, 2015). The machine was made up of many similar materials the new one is but a significant issue was when that very thin and small (in terms of O.D.) glass would have a deformation, such as a crack, it would get stuck in the tractor and continuously crush the glass that it was trying to hold in place. Beyond the lost production and wasted materials, this created a state of emergency among operators and anyone would was out on the factory floor. The safety factor was not great as someone would have to get to the tractor at a

brisk pace, then either break the glass before/after the tractor or manually raise the top half of the tractor to prevent the rotating pads from crushing the glass further. This was done directly in



**FIGURE 4: THE NEW & IMPROVED TRACTOR DESIGNED BY OSRAM ENGINEER MATT HUGHES (HUGHES, 2015)**



**FIGURE 5: MATT HUGHES' NEWLY DESIGNED TRACTOR MAINTAINING T12 GLASS WHICH WILL BE MANUFACTURED INTO A T12 FLUORESCENT LAMP**

the area in which the glass was being crushed. When Hughes designed the new tractor, he made sure that this was a focal point of his improvements. Among the numerous improvements that his newly designed tractor came equipped with, one important improvement was the ability to automatically lift and return to the proper

<sup>2</sup> OSRAM fluorescent T8 lamp technical information is provided on the corporate website - inside the products section. (OSRAM GmbH, 2016)



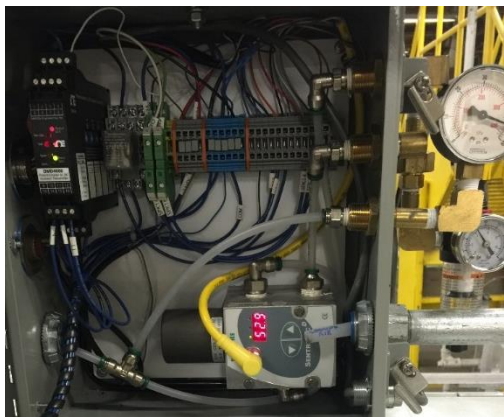
height/pressure ensuring the glass was correctly held when one of these ‘crush-out’ instances occurred.

## Problem Statement

Automatically lifting and returning to a specific position and with a calculated pressure is the perfect job for a pneumatic cylinder. In the case for Hughes’ design, it would take five cylinders. As described by someone who assisted in ideas and assembly of the new tractor, Robert Bicknell, - one of OSRAM’ s Master Craftsman for the Machine Shop - the way the design and functionality of the tractor was intended, a single acting cylinder would be sufficient for the job (Bicknell, 2015). Precision of the cylinder extension is not the most important function of the pneumatic component, but the quickness and pressure control is. To be able to lift when an electronic sensor does not see glass at a speed instantaneous to the quickness required to avoid lengthy crush-out instances, the cylinders would need to be controlled by a DCV that determines the route of flow from the information that the sensor provides.

## *Lifting the Cylinders*

The DCV would have to be specific to the requirements of the newly designed tractor and also tie into the electrical system in place. Mentioned earlier, the DCV can be controlled in various ways. The actuator determining this control is important to the DCV that routes the flow of air in a pneumatic system. These controls can be manual pushbuttons, foot pedals, or levers. A mechanical operation can initialize the actuation of DCV to change flow direction with features such as a cam



**FIGURE 6: INSIDE THE CONTROL BOX THAT HOUSES MAJOR PNEUMATIC / ELECTRICAL COMPONENTS FOR THE GLASS TRACTOR**

on a machine. Automatic or remote control is an option as well. Actuation through solenoids, or pilot-operated solenoids are options for no-touch features of operation. A regulation system will also be necessary to a pneumatic system. The regulator does exactly what the name implies - regulates the air pressure to/from a system. This allows a desired pressure of flow to be consistent and not exceed a given pressure to avoid variation in performance of the

system or section of the system in which it is installed. These are related to pneumatics fluid power sibling, hydraulics, version which is a pressure regulating valve (PRV).<sup>3</sup> The regulators are very efficient both on the system and on the cost of the system. James Johnson says that “Using a lower pressure means using less air, which is always desirable because it reduces the cost of operation. In addition to reducing air consumption, regulators provide a machine with a more consistent supply pressure.” (Johnson, 2002).

<sup>3</sup> Introduction to Fluid Power textbook makes the connection between the two on page 449, in the Pneumatic Component chapter. It also gives the definition by stating “*Pressure Regulators* are used to adjust the supply pressure to an appropriate level for a particular machine.”

The glass tractor would require a DCV and pressure regulator that needed to be researched and well-known. In the design for the improved tractor, Electrical Engineer at OSRAM Shawn Cantrell would have to make this decision (Cantrell, 2015). Cantrell used a variety of tactics to achieve a final decision in the choice of the components he was responsible for integrating into the entire system. Although it was only two components, the rest of the machine depends on these two components to operate suitably. His decisions were a Rexroth (Bosch Rexroth USA, n.d.) 2/2 DCV (2 Positions / 2

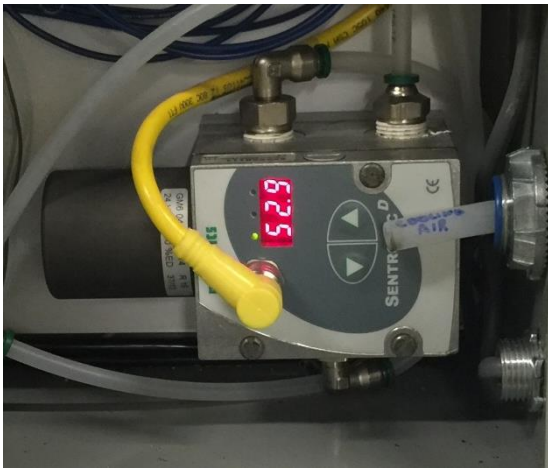


FIGURE 7: NUMATICS SENTRONIC-D PRESSURE REGULATOR  
INSIDE THE CONTROL BOX

Ways to flow) and a Numatics Sentronic<sup>D</sup> (Numatics, Inc., 2009–2012) pressure regulator. Previously working with Rexroth assisted in his immediate knowledge base of the DCV and he paired it with the digital regulator because it fit the Servo programmed electrical system with a voltage rating of 0–10V. This was a good fit for the pressure regulator to be efficient at the intended pressure range of 0–50 psi<sup>4</sup> and another motive for implementing

standardization in fluid power systems. The regulator is controlled by the electronically which receives the information needed through a connected O.D. laser.

## Method

### *Brief Overview of Industrial Pneumatics*

Efficiency is a trait sought after among the majority of any industry and most certainly practiced spanning a range of factories and various manufacturing settings. Becoming “efficient” is a task

<sup>4</sup> Electrical Engineer Shawn Cantrell previously worked for Rexroth which gave him confidence of the product as well as a good background knowledge base and knew that Numatics would match the system without compatibility issues.

that requires a loftier degree of difficulty than the surface of the word efficient presents. A key component to achieving the all-too-elusive efficiency is achieving stability and process improvement<sup>5</sup>. (Association for Operations Management, 2008) This done by achieving a culture and habit, among a barrage of other improvements, that installs a tool called “standard work.”<sup>6</sup> This directly relates to the usage of fluid power in industrial settings, which is “the most effective combination of manpower, materials, and machinery.” The National Fluid Power Association (NFPA) agrees and dedicates an entire section of their webpage and focus to the necessity of standardization. (National Fluid Power Association, 2015). The standardization of pneumatic devices critical to safety and proper operation across devices and manufactured parts. Festo, a worldwide leader in pneumatic components and systems,<sup>7</sup> has a very strong and logical stance on the standardization of its (all) pneumatic devices (Festo, 2007), in which standardization is described as “rationalization.” This makes the consumer of any Festo manufactured good very confident that the operations will be in line with the general standards of all pneumatic devices. In most cases the term ‘psi’ sums up the need for standardization and the firm foundation of its importance as many people who have had a flat tire or inflated a sports ball are familiar enough that the acronym stands for ‘pounds per square inch.’

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<sup>5</sup> Part 4 of the workbooks within the Lean Enterprise Workshop

<sup>6</sup> Standard work as defined in the Lean Enterprise Workshop

<sup>7</sup> According to Pneumaticsonline.com (Pneumatics Online, 2016)

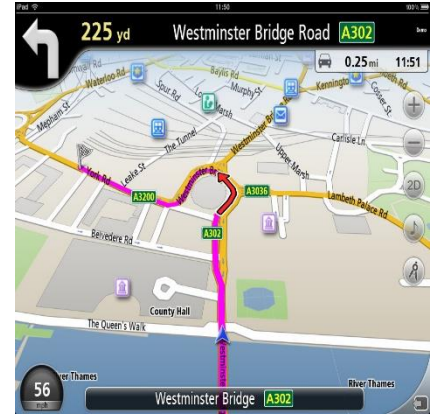
### Components Required for a Schematic

Getting from point A to point B can be done in a multitude of ways depending on where point A and point B are. In a car, this can be done through road maps, memory, or with the use of global positioning systems (GPS). Regardless of the mapping device chosen, there are important steps that need very specific calculations for the result to be achievable or even more important efficient in nature. In a 2012 survey (Zickuhr, 2012), 74% of all smartphone owners use their device to get directions/information. This highlights the importance that is placed on mapping out a route to your destination and the possibility of retracing steps made.

A schematic diagram, in any form (electrical, hydraulic, pneumatic, etc.), is a map for the flow of power just as the GPS on many individual's smartphones are a map for the route they must travel.

Accuracy is critical in a schematic diagram to anyone who needs to understand, fix/alter, or recreate the path of flow through various components. Each component is a road sign for the flow of power and in the case of pneumatics, that power is gas (air). The

air follows the path it is told to travel. Ultimately the path is created on paper, in a schematic, with a designed intention of being the blood that allows the entire device to operate properly. This has a pay it forward effect on many other components, such as machines. Without the meticulously drawn schematic, the air does not properly operate the components within its 'circuit' or flow



**FIGURE 8: GPS IS A COMMONLY USED APPLICATION THAT IS VERY SIMILAR IN THEORY TO SCHEMATIC DIAGRAMS. (GOOGLE IMAGE SEARCH)**

#### Three-quarters of smartphone owners get real-time location-based information, and one in five use geosocial services

% of adults within each group who use their cell phone to get directions, recommendations, or other information related to their present location, and the % who use a geosocial service such as Foursquare or Gowalla to "check in" to certain locations or share their location with friends.

	All adults	All cell owners	Smartphone owners
Get location-based directions/information	41%	46%	74%
Use a geosocial or "check-in" service	10%	11%	18%

Source: Pew Research Center's Internet & American Life Project January 20–February 19, 2012 tracking survey of 2,253 adults, including 901 cell phone interviews. Interviews were conducted in English and Spanish.

path. An inefficiency in the operations of any single component can, and in most cases will, cause the machine to operate with a drastic reduction in efficiency or possibly not operate at all.

### Cylinders

Cylinders are important and widely used components in a pneumatic system. These components vary in configuration depending on the application in which they are required. One example is a double-acting cylinder. Speed is important in pneumatic systems<sup>8</sup> and a double-acting cylinder can operate in

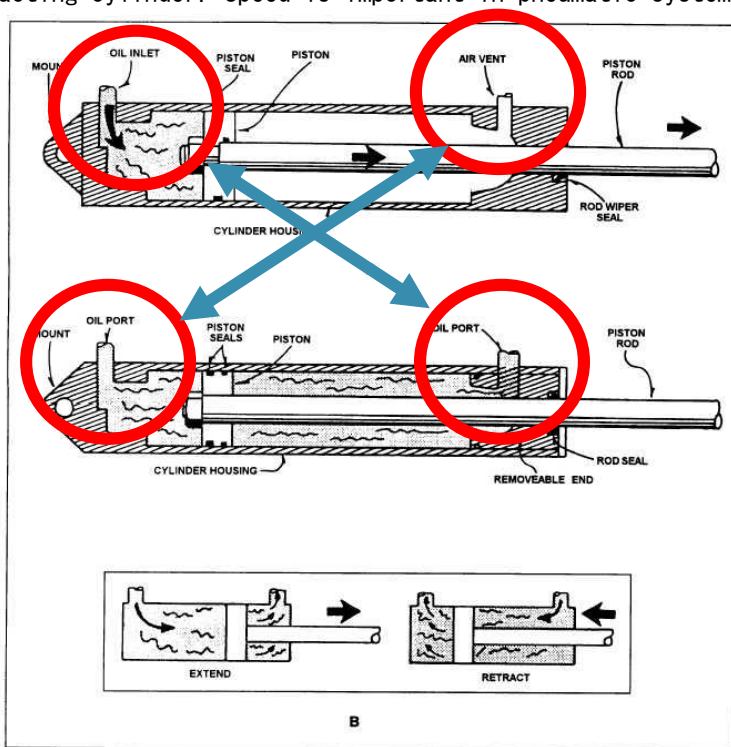


FIGURE 9: GRAPHIC FROM STUDY (ZICKUHR, 2012)

two separate directions with two separate speeds (or force). The cylinder is made up of three key components - the cylinder, the piston rod, and piston head. The rod is attached to the piston head which acts as a seal inside the cylinder. As the rod extends in the direction of the piston head, any substance at all inside the cylinder will be forced out in that same direction. The inverse effect takes place as the rod retracts. The cylinder will fill with a substance due to the seal of

FIGURE 10: THE IMAGE ABOVE DEMONSTRATES THE DIFFERENCE BETWEEN A SINGLE AND DOUBLE-ACTING CYLINDER. NOTICE THE PORTS AND/OR AIR VENTS CIRCLED. (INTEGRATED PUBLISHING)

the piston head and cylinder creating a suction effect. Returning to the circulatory synonymy to

<sup>8</sup> Introduction to Fluid Power describes them as “appropriate applications that require high speed and lower forces and do not require a high degree of precision.”

pneumatics in a machine, the cylinder is an equivalent to a needle which gives or removes blood. In fact, the exact principles apply.

A single acting cylinder also is used in similar applications. With precision not being at the top of the priority list, clamping applications can use a single acting cylinder which uses force in one (single) direction and when the force needs to be released, the pressure is simply removed. This allows more than just the pressure to be released from the cylinder but also the object being clamped by the piston head in a chain reaction.

### *Directional Control Valve (DCV)*

Direction of pressure is routed by a directional control valve, or DCV. The DCV can have a multitude of options in how the air in a pneumatic system is directed. When operating a single cylinder or a group of cylinders that work simultaneously and of the same type (i.e. double-acting or single acting) then a common version of DCV is a three-way. This means that the flow can be can start or stop in one direction, causing the flow to start or stop in the opposing direction, also block or allow flow from the inlet or outlet, *and* allow the flow, if obstructed, to reverse back to the tank - creating *three ways*<sup>9</sup>. The decision needs to be made by engineer designing the system what will signal or determine the operation of the DCV. This can be done in a variety of forms depending on the application of the DCV and the application mechanisms of the system as a whole.



**FIGURE 11: DIRECTIONAL CONTROL VALVE**  
 – ABOVE HAS TWO SOLENOID ACTUATORS  
 (DISTRIBUTOR TO INDUSTRY)

<sup>9</sup> In chapter six of Introduction to Fluid Power, it states that DCVs “two-way valves are used to start and stop fluid flow in a particular line. They can either allow or block flow from a pump to an outlet line, for example. Three-way valves also either block or allow flow from an inlet to an outlet. They also allow the outlet to flow back to the tank when the pump flow is blocked, while a 2-way does not.”

### *Drawing a schematic diagram*

The schematic that would be drawn needed all this vital information to be accurate. The accuracy of the schematic will be critical to how efficiently a failure in the system as a whole or a single component causing the malfunction can be identified and repaired. This is crucial to the manufacturer as it determines the cost of repair and/or replication if need be. Visualizing the flow was important aspect to not only learning the functionality of components but to get to see what these components would do instantaneously. This can be done without having to build the physical machine and connect the components. Automation Studio is a computer aided drawing (CAD) for schematics (Famic Technologies Inc., 2010). It gives an engineer the ability to not only draw up the schematics for a fluid power system, but see if it should work accurately. Not only is the motion of each component visually animated, but real adjustments such as psi, directional control, regulation settings, etc. can be made in real time to give a sense of functionality. If the components do not operate within the manner they are drawn, they can be swapped out in seconds with a new component. At Eastern Kentucky University, in Dr. Ni Wang' s Hydraulics and Pneumatics coarse (Ni Wang, 2015), it was also important to adjust the very many different settings within each component as they are customizable to match precisely any component that would be researched to fit the fluid power system being created or recreated<sup>10</sup>. This would be an excellent engineering tool in any industry that uses fluid power, which is ALL industrial settings.

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<sup>10</sup> Eastern Kentucky University' s Applied Engineering and Technology Building (Whalen Hall) provided the accessibility to Automation Studio and other CAD programs within the computer lab on the third floor.



## Results

### *Components in Example*

The allotment of components necessary varies from application to application. The core components are similar in nature but also may need additional features that provide utilities important to the task it was designed to accomplish. The components in the industrial example of pneumatic usage researched here has stereotypical components along with some specialized variations of commonly recognized pneumatic tools.

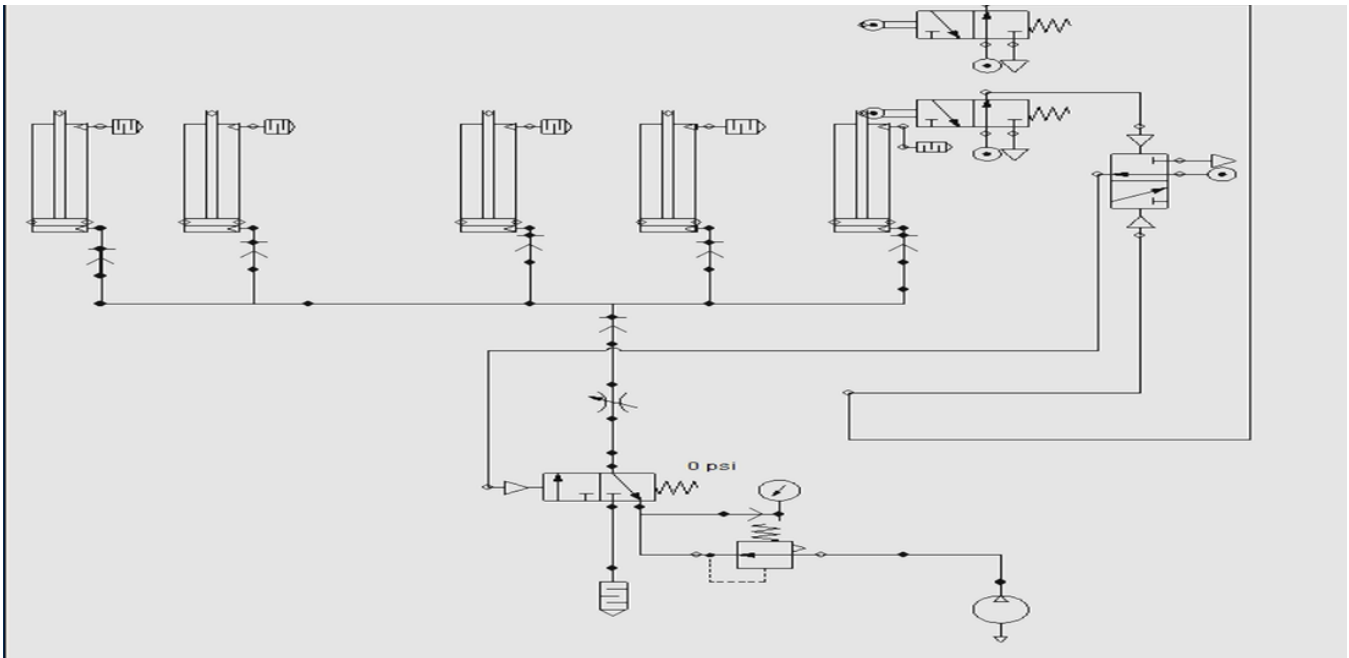
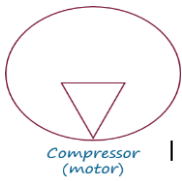


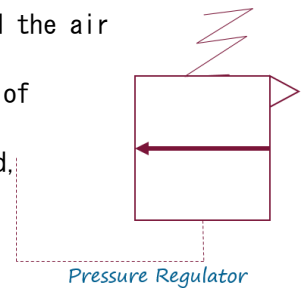
FIGURE 12: THE SCHEMATIC ABOVE MAPS THE FLOW OF PNEUMATIC POWER TO LIFT THE TRACTOR WHEELS DURING A "CRUSH OUT" OR TO ADJUST THE PRESSURE ASSERTED TO THE GLASS FROM THE WHEELS THAT HOLD IT IN PLACE.

The pneumatic fluid (gas) starts at the bottom. The compressor in this case is actually very far away and provides the air flow to all the pneumatic operated machines and devices throughout the manufacturing plant. As long as the shut off valve is open to this line, the air is constantly flowing through the lines. Eventually it reaches a pressure regulator. The pressure regulator is set to 60 psi. This ensures that the pressure is constantly providing the components that use this pressure with enough to fulfill the actions required - but also *not too much pressure*.



### Preparation is important

The pressure regulator falls under the category of preparation. The pressure and the air that initiates the pressure is being prepped and very important to the lifespan of numerous areas of the machine. <sup>11</sup> Once the air pneumatic power has been regulated, it moves to the DCV. Typically (and in this example), a pressure gauge will be placed in between the DCV and any components before-hand. This is important to locating problems and maintaining efficiency as it easily locates a point within the system that the flow of air is not optimal.

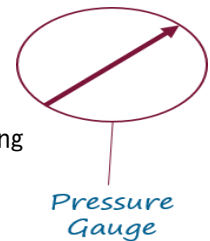


Once the flow reaches the DCV, it needs to be directed towards or away from the cylinders that will lift the wheels and wreaking havoc among the glass plant when a “crush



out” takes place. The DCV must be in the normally closed position. This will annotated

by a ‘NC’ on many schematics because this is an important aspect to note when looking



<sup>11</sup> Introduction to Fluid Power lists the preparation as “filtering out contaminants, controlling the pressure, lubricating the air, and removing moisture.” Many regulators are built to achieve all of the above and are known as Filter Regulator Lubricator units, or FRL for short.

at the system. The wheels do not need to be lifted at this point and the regulator is not allowing the pressure to drop below 9 psi. When the crush out takes place, sensors (which is electronically controlling the DCV) will not see glass. The information is sent to the DCV and the max pressure will be routed to the cylinders to do damage control on the glass.

The pressure is actually increased directly after the DCV when the air is flowing towards the cylinder by restricting the size of the hole that air travels through. This is important and on the surface sounds counter intuitive. However by restricting the flow, it creates an increase in pressure as proven with Pascal' s Law<sup>12</sup>. In mathematical terms Pascal' s Law is: 
$$p = \frac{F}{A}$$

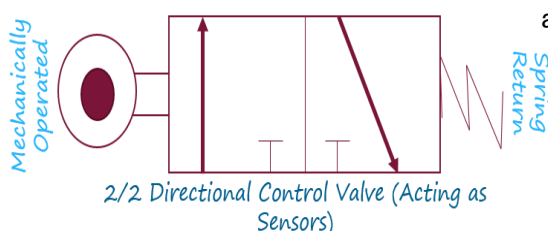
Where: p = pressure

F= force

A= area

This forces the air to the cylinders at an increased rate provides a boost so that the cylinders will be lifted before the glass is completely altered to a point of no return in which it will stop coming up the production line.

The motion within Automation Studio had to be demonstrated in schematic form with mechanical operated DCVs. The mechanical operation allowed the air to be redirected once the wheels reached the maximum height. <sup>13</sup> As the cylinder reaches the top it will create a spring return and send direct the



air in the opposing direction until the sensor electronically sends the signal to lift again.

<sup>12</sup> Pascal' s Law states "The pressure exerted on a confined fluid is transmitted undiminished in all directions and acts at right angles to the containing surfaces." (Johnson, 2002)

<sup>13</sup> Typically in the event of a crush out, the wheels only needed to be lifted to max position. By this time, the glass stops being crushed and continues up the production line. Once the glass is not being crushed, the wheels must return to the glass so it can be pulled and maintain its specifications.

## Discussion of Future Work

Improvement, in any facet of life, must be continuous. This holds true for systems designed in manufacturing and industry. One of the most challenging aspects of engineering is improving something that is in operation when it is decided or thought that an upgrade is necessary. This is also the most fun because using creativity and benchmarking takes an imagination that many associate with Legos and childhood.

## Simulation

Another challenging aspect of improvement while a machine is currently in operation is having the ability or time to implement the scientific method of trial and error with specific devices and components. The creation of the schematic was not the only thing that could be done in a simulated atmosphere, but the improvement as well. Automation Studio is a great tool because it can - in real time - give the designer a reasonable calculated idea of how the system might work with additional or subtraction of components. This can be the difference between continuously providing efficiency in machines and having to create something because of failure and/or legacy (outdated) mechanisms, tools, parts, etc.

## The Tractor improvement was great but....

The improvement of this tractor was fantastic. It was similar to trading in an old beat up model of car for the newer version, complete with the features available in that decade. However, just like cars, new materials and components will become available and hard to ignore in terms of what they can provide for the machine and the bottom line of that company.

Taking the new version of the machine to the test track is necessary and will be done from the seat of a computer chair with CAD software. Any new thought or idea will be tested with tools like Automation Studio. Statistical information can be collected and inputted into the software to better simulate the mannerisms of the machine and how it operates in its current state. This data will be important and help track and quickly identify improvement areas rapidly.

**To be continued...**

The schematic drawn and is presented demonstrates (Bracco, 2015) the pneumatic system of the OSRAM glass tractor with the Automation Studio software. It maps the positioning of system components as they guide the travel of fluid power through the vital system of the machine, ultimately giving (and maintaining) life to Matt Hughes' version of Frankenstein. It' s alive!

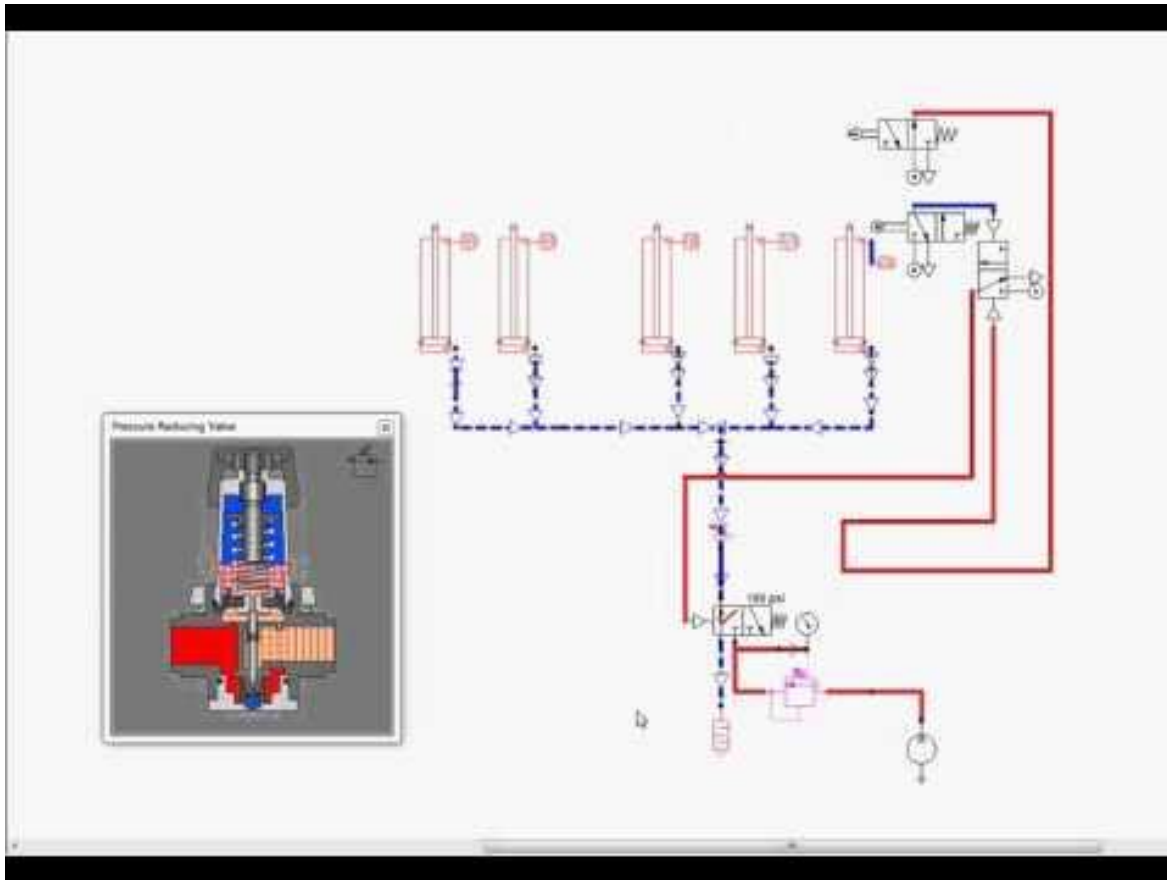


FIGURE 13: AUTOMATION STUDIO DEMONSTRATION OF THE SIMULATED SCHEMATIC OF THE OSRAM GLASS TRACTOR

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