Vertical Packaging Accumulator

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Abstract — *The beverage manufacturing process is based on filling a product with a defined structure or flexible structure. If that product is pasteurized, there are different considerations that must be met, such as the filling temperature and cooling time. This cycle of filling and cooling must be fulfilled without affecting the manufacturing operation. It is common in the industry to have accumulators that help us meet the filling cycle, as well as to absorb time lost by micro stops in the production line. Unfortunately for products with flexible structures (such as flexible packaging), there are no practical systems that can be used in any environment. This project is to design a mechanical device to ensure that this cycle of filling and cooling will be completed without any negative effects on the manufacturing line. In addition, not only allows to meet the cycle, but, avoid quality issues on the flexible packaging material.*

Key Terms — *Absorb time lost by micro stops, Product accumulator, Flexible packaging, Quality issues.*

PROBLEM STATEMENT

In the process of manufacturing beverages in aluminum Pouches, a series of parameters must be met to ensure Quality and Efficiency in the operation. Currently every time the packaging area is stopped, a jam of Pouches is created in the packaging area conveyor. A requirement of the manufacturing line is that the line cannot be stopped at the same time the packing area stops. This is because once the drink is deposited inside the Pouch, it must be some time eliminating the bacteria inside the Pouch, and then it must be cooled to preserve the color and flavor of the drink. This is caused because there is no accumulation system to store the Pouches while solving why the packing area was stopped. Another situation is that once the packing area stops, also when stopping the filler after the time that must be fulfilled, it also causes low efficiency for lost time. Another situation is that, when stopping the packing area, the Pouches are placed in baskets, this creates a defect in the product, which is caused by the collisions between Pouches, drilling each other. Also due to the jam, operators run to stop the conveyor to avoid further problems, as well as to reprocess the entire jammed product. This adds more tasks to the packaging operators, making the jobs in the area more tedious.

Packaging Material

To have a better understanding of what is being solved, it is important to know concepts applicable to the design of the mechanical system. The packaging material is a material composed of metal and polymers. In the industry it is called Aluminum Stand Up Pouch, which belongs to the category of flexible packaging. These flexible containers are manufactured from a film made of the materials I mentioned before.

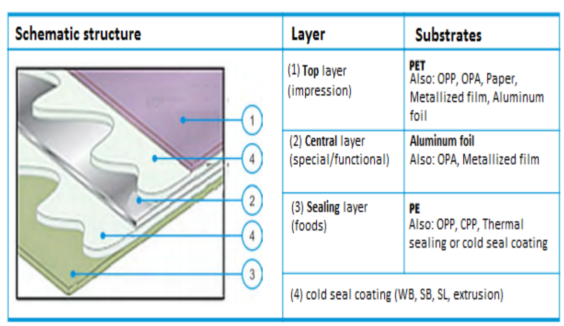

Figure 1
Layers of Substrate of the Basic Laminate

As shown in the Figure 1, there are different kind of substrates and layers [1]. These are rolls of films manufactured by extrusion of two or more layers, to create as a sandwich with clearly identifiable individual layers. The term "film" is generally used to describe a thin and continuous plastic material, while "laminate" refers to a product manufactured by joining two or more layers of material, be it plastic, paper or sheet.

The tests of strength to the packaging were realized. These tests were carried out to know one of the mechanical properties of the packaging, which is the force that the packaging can withstand until there is a failure in the material, be it fracture, delamination or failures in the seal. The packaging withstood up to 1500N of force, but in the worst case, it resisted up to 1,000N. Already with this information we have our first limit, I cannot place a quantity of Pouches stored at the equivalent of 1,000N.

Type of Packaging

The packaging is a "Stand Up Pouch" type. Which offers the advantage that it can be consumed while it is upright. This is due to the geometry of the bottom of the pouch.

Figure 2
Pouch with K-type bottom

The type of Pouch we work with is type k, which is shown in Figure 2. The design should work with any type of background, which are type k, rounded and type "plow". The difference between them is the geometry of the "gusset". The “gusset” consists of having more material in the area, to reinforce the Pouch so that it stays upright. In the Figure 2 shows the pouch and the area where has more material to make the pouch strong enough to keep stand up.

Adaptability and Capacity

The system must adapt to other Pouches handling circumstances. Not all manufacturing areas are the same, but they are not very different either. In addition to its adaptability, you must also have the ability to add more storage space. The importance of the system would be the height, since it is focused on occupying less space than conventional accumulators. From my experience in manufacturing, I can say that in food, the conveyors have an approximate height of 2ft to 2.5ft. This means that I can take that as a limit on the design.

Beverage Manufacturing and Packaging Process

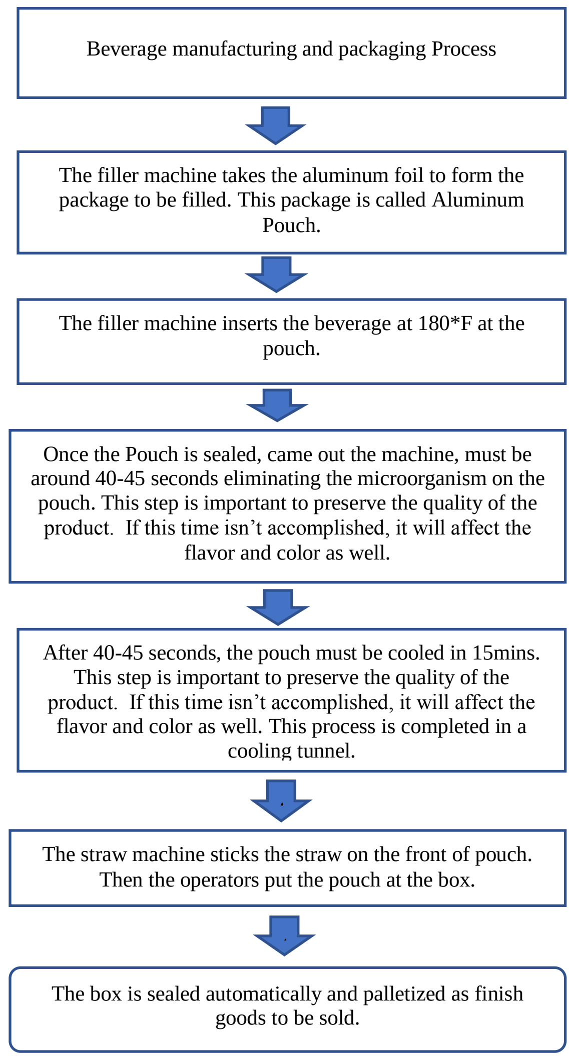

Figure 3
Redirecting the Product

METHODOLOGY

The project will be divided into three phases;

- Dividing of the product: First we must control the way and where I will take the pouches. Currently the packaging area allows me to do it. The conveyor is 24 " wide, while each pouch has only 4 "with a pouch to pouch separation of 2". As shown in the Figure 3, I need to re directing the way of the pouch when the packaging area stopped. Since the cycles are every 1.2 seconds, it means that I have enough time to change the trajectory of the Pouch. This I will do with a divider at the entrance of the conveyor, taking advantage of the distance from Pouch to Pouch. This divider will be activated once the packaging area stops. Once the Pouches go through the area that I need, the second phase of the project gets in.
- Storage in the accumulator: The area does not allow to have a robust or very volumetric accumulator. Therefore, you can no longer think about the horizontal, but about the vertical. This is why the height of the conveyor is used. The height of the conveyor is 28".

  This height allows me to store 84 pouches per loader (using 21 inches of the 28" that has the conveyor height). Each column has for every 1.5" two pouches, the system would have two accumulators, one for each side of the conveyor. This allow to store 168 pouches, the equivalent of 100.8 seconds. Storage time may seem small, but it should be noted that most of the stops in packaging are resolved in less than 60 seconds, like change straw package, clear a jam in the straw machine, clear a jam in the other 5 machines in the packaging area. Therefore, it can be considered that the system is useful for micro stops. In addition, the system will be one that can be expanded and placed more storage loaders, thus allowing more time to accumulate. In the Figure 4 shown below, is the height of one cycle of pouch (where are two pouches per cycle), one pouch in one direction and the other in the opposite direction.

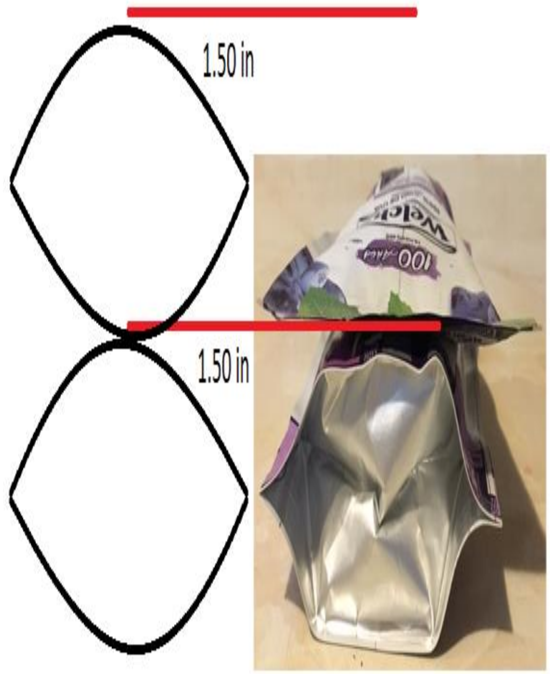

Figure 4
Height of Staking Pouch

- The Pouch recovery. Since the Pouches are stored, they need to be recovered while the line is in Production to absorb the stoppage time, and not have downtime. That station will be called "The Pouch Recovery station". This station will be responsible for recovering the Pouches. This will be a robotic system that will deposit the Pouches one by one on the packaging conveyor's entrance conveyor.

  The system needs a control unit that integrates all the stations interacting. Also needs a logic to work in synchrony. Below in Figure 5 is the flow chart showing how the system interacts to activate the divider, store the pouch and recover it to absorb the downtime.

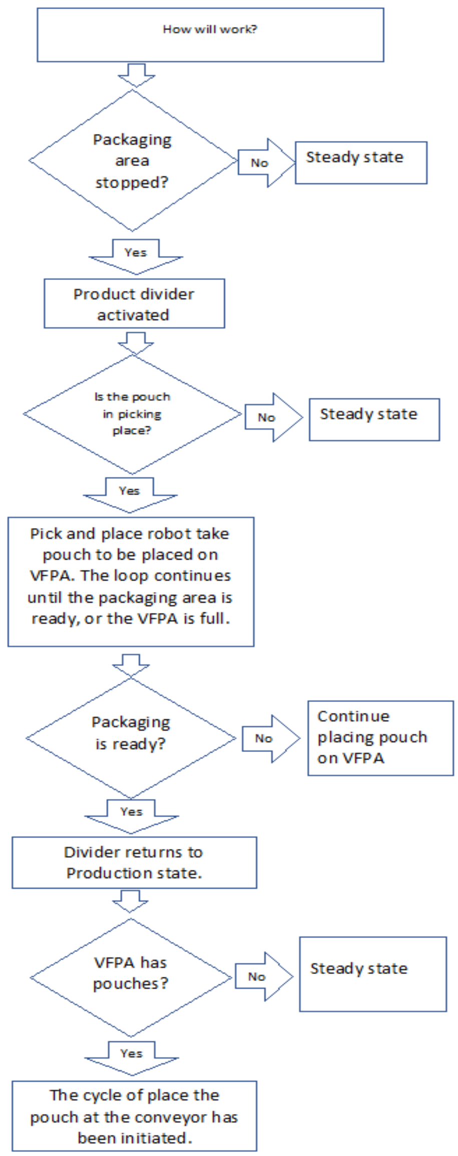

Figure 5
Flow Chart of the Control Logic used in the System

Results and Discussion

This project has the singularity that I developed a new way to accumulate product on a manufacturing line. I not only work on the accumulator, but I also go further with the divider and the recovery station.

Divider station: I took advantage on the gap between pouches to design a mechanical guide that will be fixed in the gap between pouches. Once it needs to be activated, it opens the guides and diverts the pouches in to the fixed place in the accumulator station. The Figure 6 shows the configuration of Production mode, where the pouch is taking its normal way to packaging area.

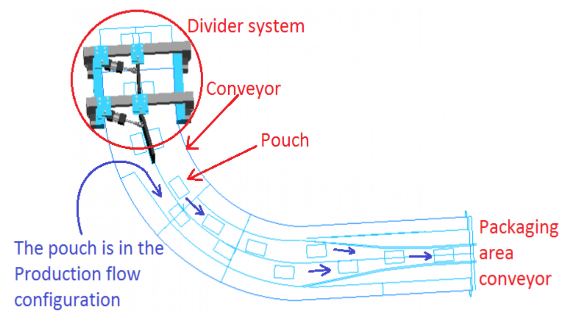

Figure 6
Divider System in Production Configuration

Once the divider is in accumulator mode, it will displacement the pouches to the border of the conveyor. The pouches are going now to the fixed location at the VPA area. Once the pouch is there, the second stage will be activated to take the pouch and place it on the VPA. The design will have two gates, one in front of the other, like serial mount between the pouches, with its respective air cylinders.

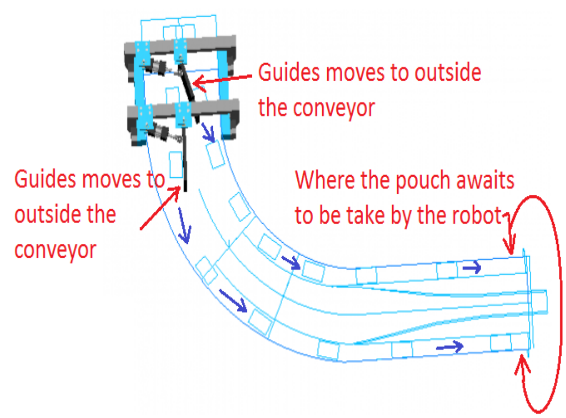

Figure 7
Conveyor in Accumulator Configuration

As watched on the Figure 7, the pouches have a new way to go trough the conveyor. This way is to the accumulator area, where the robot will pick it to store it in the VPA. I used two Teflon guides, ¾" shafts, two pistons, bushings and couplings to finish the design. In the Figure 8 below shows the divider isometric view to have a better understanding of how it works.

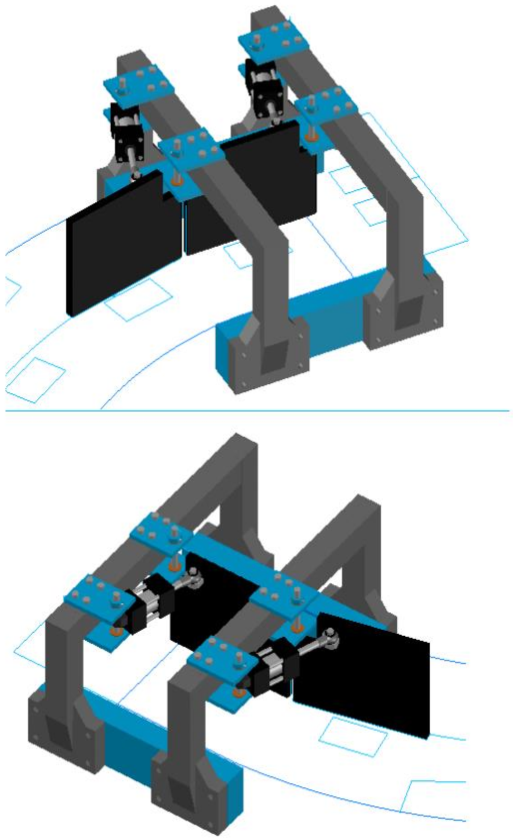

Figure 8
Divider Design, Both Sides Isometric View

Vertical Packaging Accumulator: This is the main development of the project. First of all, I need to determine if the pouch can hold the weight in the column of 28 pouches. I took 10 pouches and applied a force until the pouch break. The force gauge indicates the pouch can still at an average force of 1,500 N. The lower force registered was a 1,000 N. That force is extremely superior that the column will have, approximately;

$$F_p = m_p a * 27 \quad (1)$$

$$F_p = 0.21kg * \frac{9.81m}{s^2} * 27$$

$$F_p = 57.62 \text{ N}$$

Where:
F_p = Force acting on first pouch on the column
m_p = Weight of the pouch in kg
a = gravity acceleration in m/s^2

This is the force of the 27 pouches acting on the first pouch of the column as calculated with the equation 1. With that number I can continue designing the VPA. Once I have all the measures, I can to conceptualize in AutoCad 3d. in the following Figure 9, it's the side view of the VPA, where its visually the geometry of the VPA.

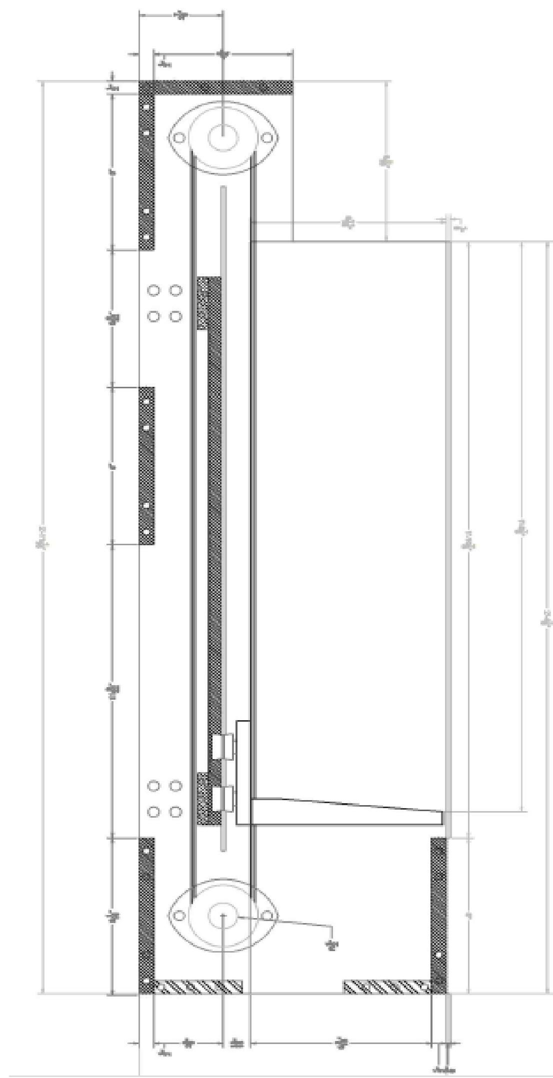

Figure 9
Side View of VPA

Due to the advantage of 3d imaging, I first do the VPA in 2d format. In this format I can do all the measures to watch any error that might complicated the design. In addition, in 2d I can see in a better way the reactions of the bearings supporting the shaft of the VPA. With those dimensions, like we watch in Figure 10, I can do the free body diagram to calculate the torque and the moment of all forces acting on the shaft.

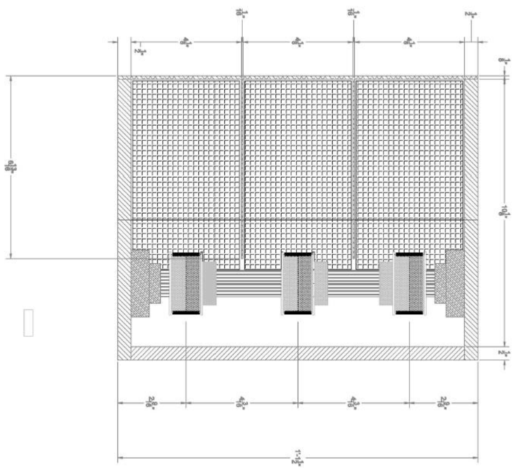

Figure 10
Top View of VPA

Now I can calculate the forces acting in the shaft. Considering the approximate weight of the two sprockets, belt, base of column of pouches, bearings with the base of them, the sum of all with the pouches weight are 15.02 lbs of force acting on each length of shaft. First, I need to draw the FBD like in the Figure 11, where show all the forces acting on the shaft.

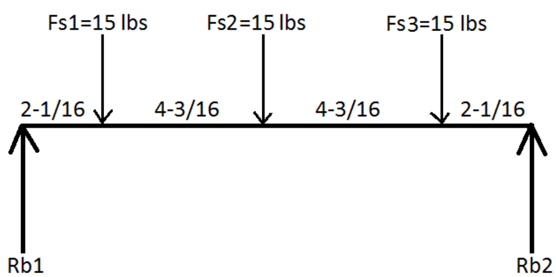

Figure 11
Free Body Diagram of Forces Acting on the Shaft

$$\sum M = 0$$
$$= -(15.1)(2.0625) - (15.1)(6.4375) - (15.1)(10.8125) + (12.875)(Rb2)$$
$$Rb2 = 22.5\ lbs \quad (2)$$

$$\sum F_y = 0 = Rb1 - 45\ lbs + 22.5\ lbs = Rb1 = 22.5\ lbs \quad (3)$$

With all the reactions calculated in the equations 2 and 3, I can show the diagram of Moment.

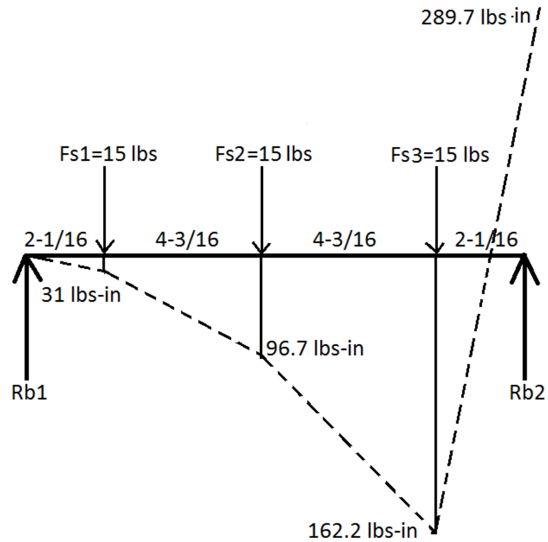

Figure 12
Moment of Torsion

Also, I need to know the torque on the sprocket to have a better idea on all forces acting on the shaft.

$$T_S = r * F_s \quad (4)$$
$$T_S = \left(\frac{2.375\ in}{2}\right) * (15\ lbs)$$
$$T_S = 18\ lbs - in$$
$$T_S = r * F_s$$
$$T_S = Sprocket\ torque$$
$$F_s = Force\ in\ the\ sprocket$$

With this data provided by the equation 4 used to calculated the torque, I will have an idea of what torque on the motor it will needs to move the shaft. In this case the VPA will have a motor with high torque because I don't know all the inertia forces on all the VPA. Also, the shaft of the VPA will be 1.00 in of diameter, more than enough for this kind of application. Now other variable important in this design is the RPM needed to up and down the column of pouches. The cycle time is 1.2 s every two pouches coming and the radio of the sprocket is 1.1875 in, thus the circumference of the sprocket is 7.46 in. It means that in one revolution the distance reflected in the column will be 7.42 in. the VPA needs 1.5 in per cycle, hence;
Maximum velocity of cycle: 1.50 in at 0.50 secs.

Velocity= 1.50in/0.50secs=3in/secs (5)

Velocity=180in/min
Diameter of sprocket: 2.375in
Circumference(C): 2πr (6)

C=2*π*1.1875in=7.46in/revolution of sprocket
So, using the following formula I can get the RPM to the accumulator.

RPM=(3in/s)*(1rev/7.46in)*(60s/min)=RPM (7)
=24.13RPM

As the data analysis showed, the RPM of the sprockets must be 25RPM. With this number I can select a motor and transmission necessary, so the accumulator works perfectly. I selected a stepper motor with transmission with a maximum torque of 90N.m. The motor is a NEMA 34, part number 34HS59-5004D-B400 with a transmission ATO-TA-PR-ZBR on different store.

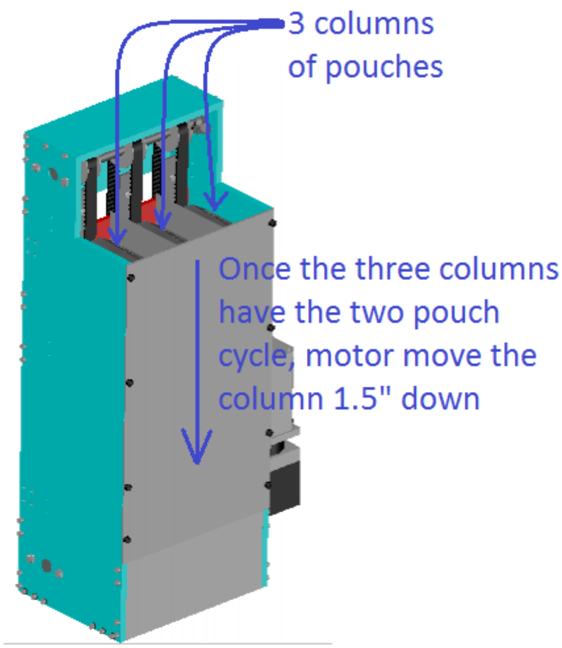

Figure 13
Final Design of the VPA, Front Isometric View

As the Figure 13 describes, the VPA is communicating with the robot who is stacking pouches in the VPA, by that manner when the robot counts the first 6 pouches, sends a signal to the VPA to move 1.5 inches (one cycle). In that cycle are two pouches per column. So, when the robot counts 84 pouches, he will stop until the line is ready to pop out the pouches to the conveyor. All of this communication is through the PLC. Also, in the Figure 14 shows the back of the VPA to have a better understanding of the geometry of the VPA.

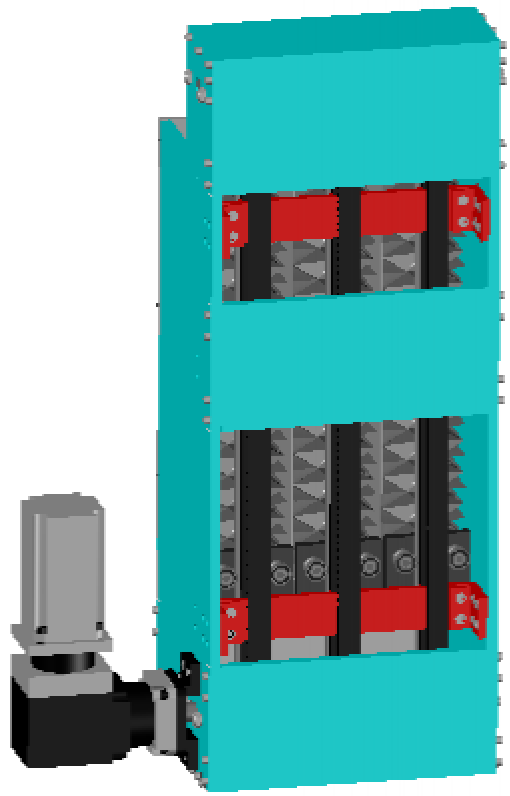

Figure 14
Final Design of the VPA, Back Isometric View

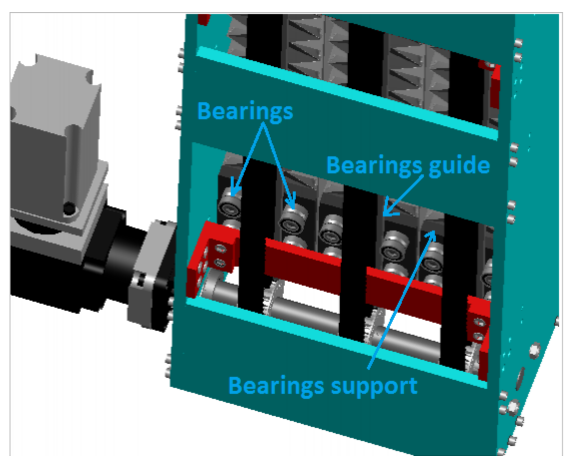

Figure 15
Bearings, Support and Guide of VPA

Al the components on the VPA has a part number who identifies it. All the mechanical parts were bought at McMaster, the PLC parts at Automation direct online, the motor and transmission in separate directions on the web that will be in the references, and the aluminum and Stainless Steel will be acquired local in P.R. all the parts we need are shown in the Figure 15 to Figure 16. They have a visually manner to identified all the parts used in the design of the VPA.

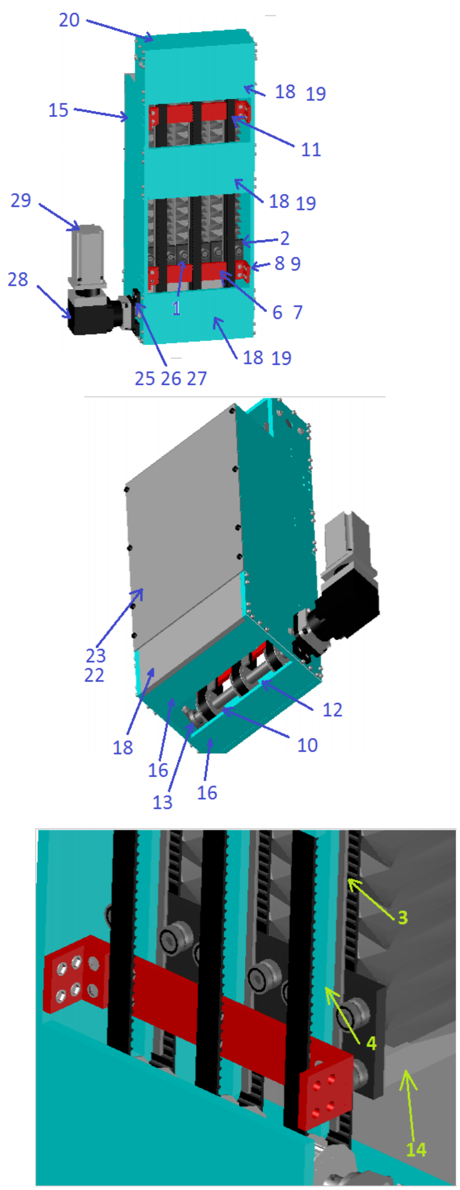

Figure 16
Identification of All Parts on VPA

With all parts correctly identified is easier to assembly the VPA. These parts will be found on the Bill of Materials table. On the table we will find not only the mechanical parts, but the other electric and control elements added to the ones I have in the plant. On the next image, Figure 17, I will show the table.

Bill of Materials VPA		
Item number	Description	Qty.
1	Bearings of the transport support	12
2	Transport support	3
3	Hepco Guide	3
4	Guide support bar (2'-1"x1 3/16"x7/16")	3
5	Screws for item 4	12
6	Support bar(12 1/2"x1/2"x2")	2
7	Screws for item 6	12
8	Support angular (2"x2"x3/8")	4
9	Screws for item 8	24
10	Timing belt pulley 1304N31	6
11	Timing belt L shape 7959K28	3
12	Shaft 1"x13" 5947K29	2
13	Two-Bolt Flange, for 1" Shaft 5913K74	4
14	Stacking pouch base 1"x4 1/8"x6 9/16"	3
15	Principal frame support (3'x1'x1/2")	2
16	Bottom base support (3"x12 1/2"x1/2")	2
17	Screws for item 16	12
18	Lateral support (6"x12 1/2"x1/2")	4
19	Screws for item 8	16
20	Superior support (4 3/4"x12 1/2"x1/2")	1
21	Screws for item 21	4
22	Stainless Steel divider (6 11/16"x1'-10 7/8x1/8")	2
23	Stainless Steel support (13 1/2"x22 7/8"x1/4")	1
24	Screws for item 24	8
25	transmission support (2"x1"x1/2")	4
26	Screws for item 26	8
27	transmission support base (4"x4"x1/2")	1
28	Transmision ATO-TA-PR-ZBR	1
29	Stepper motor 34HS59-5004D-B400	1
30	Stepper driver H2-CTRIO2	1
31	Input module D2-16ND3-2	1
32	Output module D2-12TR	1
33	H2 CPU H2-DM1E	1
34	DL205 I/O base	1

Figure 17
Bill of Materials Table

Pouch Recovery Station

This is the area where the pouch returns to the packaging conveyor. Once the manufacturing line is ready to start, and the VPA has pouches, this station takes the pouches and put them in the conveyor again. The system I will use is a group of two robots. The kind of robots I will use are the Scara type. Is a low cost robot that complies with our application in all aspects. They have a 400mm range, cycle time of 0.54 secs., payload of 1kg, and 150mm of elevation taking the pouch. The Scara robot model is the EPSON T3-401.

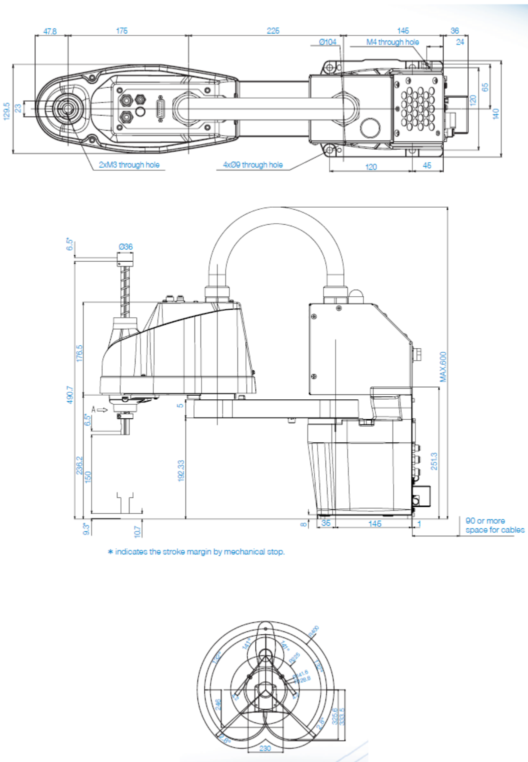

Figure 18
Layout and Elevations of EPSON T3-401 [2]

As watched on the previous Figure 18, there are all the important measurements to be take into consideration when I want to be aware of all the aspects of the design area. With these in mind I will be able to complete the design.

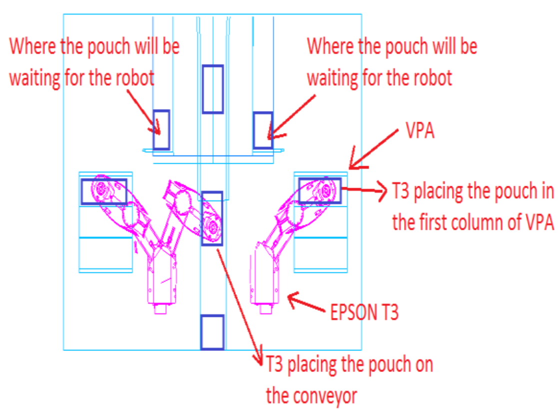

Figure 19
Illustration of Layout with the EPSON T3-401

In the Figure 19 is shown the interaction of the EPSON T3's with the packaging conveyor and the VPA. This layout help me out to have a better understanding with the dimensions of what I need to do with the position of the robots and VPAs.

CONCLUSIONS

In the time I spend looking for product accumulators for flexible packaging, I watched buffers at most. That make me think what happens if I work on other form to do the same, that's is the main idea of how the VPA was developed. This accumulator has better use of space than any other in the industry. Where the others accumulator store one pouch, the VPA can store 28 pouches (depending on the height of the conventional accumulator conveyor). This happens because the VPA use volume to accumulate, the others use areas where the space occupied would not be used for other purposes. Also, the project not only contemplate the development of the VPA, but the efficient way to divide the way of the product before get store on the VPA. This project also takes in to considerations the downtime absorbed by the VPA, and the quality issues created by the lack of this accumulator. Every time the VPA is working, it store100.8 seconds until full. This means that the system is functional for micro stops also than to comply with the filling and cooling cycle I spoke before in the abstract. The quality issues found were the perforations in the package created by the other packages when the operator toss them to a Basket when the line is stopped.

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[2] Epson Scara Robots. (2017). *Robots Specifications Catalog* [Online]. Available: https://epson.com/Support/Robots/SCARA-Robots/SCARA-T-Series/Epson-T3-SCARA-Robots/s/SPT_RT3-401SS#manuals.