

DENSO Automatic Box Unloader

A Senior Design Project

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Executive Summary:

It was the beginning of September, 2006 when what was to be our senior design project was first conceptually explained. A “flow rail,” a device used to carry boxes to and away from a worker on the line, was to be automated. The box was to be automatically put into position, and then, at the push of a button, the box was to be conveyed away and another one put in its place. The deliverables were to be a working prototype and a report defining the steps taken in the production of the prototype.

The report and the prototype are both complete. The structure of the frame was first designed. Because it was necessary that the storage rack hold six boxes, the decision was made to go with two storage racks. However, by doing so, the working height was increased in order to meet the clearances necessary for the box to pass onto the bottom storage rack.

Onto the frame were placed the motion sensors and the cylinders that control the motion of the components. Mounting brackets were constructed and the optimum positions for the motion actuators were experimentally determined.

Lastly, everything was tied together with the PLC. A code, written by an SMC representative, controls the movement of the boxes. At the push of a button, the box is transferred to the proper storage rack—the one with available space—and the tray is returned to the loading position. Any errors are indicated by a red light, and the system has been designed for easy lockout and shutdown.

This project has given us the first opportunity during our undergraduate studies to work on a hands on design project from concept to completion, and for that we are very grateful to DENSO. We would also like to specifically thank Reeve Rummel and Kevin Kelly for their support throughout the process as we would not have been able to do it without them. Thanks is also due to SMC associates Mark Blair and Dan Schroeder who provided us with much assistance throughout the design and building phases of the project.

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Background

As the largest manufacturer of automotive parts, DENSO is a model of efficiency. The Maryville, TN branch of this international corporation is no different. Here in Maryville, DENSO is responsible for the production of instrument clusters. Producing instrument clusters is, without doubt, a very tedious and complex process involving plastic molding, assembly, and a number of other manufacturing operations. Currently, DENSO is in the process of streamlining this operation by eliminating non-value added tasks from its process.

At present, there exists a step in the assembly process which involves the repetitive movement of boxes by an operator. Boxes are placed on a gravity feed roller-conveyor which conveys them in stacks to an operator who then must reach up, take hold of a box, and place it in a position from which she can withdrawal a piece of the pieces of instrument clusters within. Once the pieces have been removed, the operator is responsible for lifting the box and putting it on another roller-conveyor which conveys the box to its pickup location. Three different operators perform this task approximately 30 times each every day, accounting for a substantial amount of non-value added time.

The goal of our project is to automate the unloading of the box from the unloading position. The operator will still be required to load the box.

An outline of the design methodology we are using is presented first, followed by the official problem statement, the design specifications, and the three concepts that were brainstormed for the initial meeting.

Design Methodology

As seniors in Mechanical Engineering we have yet to be exposed to the world of design and know very little about the methodology of design. The paragraphs below briefly outline the broad approach that we are taking in this, our first, design project and will continue to take when on the job.

When developing a product idea, there are certain basic steps that must be taken in order to ensure that the idea will become a profitable venture. These steps are illustrated in Figure 1. The first few boxes indicate the importance of market analysis and customer input to confirm the need for the product in the current market. They also help define and refine the attributes of the product.

At this point, engineers begin to develop design specifications based on the initial market feedback and further discussions with the potential customers. These specifications represent the engineering baseline for generating design concepts and for future engineering calculations. It is important that they be established accurately and in concert with users of the future product.

Design alternatives are typically generated by a team of professionals through an activity called concurrent engineering. In this process, the team considers every aspect of the product from technical feasibility to product life cycle to manufacturing and market strategy. Once viable designs have been generated, the next step is to evaluate each alternative and choose the preferred concept, which will be advanced to the next stage of the development process.

At this point in the process, a preliminary design of the preferred concept is generated. A preliminary design represents an up-date of the engineering baseline and more detailed design specifications. Computer-aided-design, numerical analysis and other analytical tools may be required to develop a preliminary design. The product configuration is again evaluated in the market place for customer feedback and approval. At this point a prototype of the design must be built and tested.

The next step is to interface the computer-aided design codes with manufacturing and this requires a conversion of the design software into machine tool codes. Various methods of machining are considered to optimize machining and accuracy of machining. Computer Integrated Manufacturing is also an issue. Depending on the product and the market, the ability to reconfigure the machining and handling process quickly may be important for “just in time” delivery.

In both large and small environments, designers must extend their creative skills through the use of a number of design and analytical tools which may not yet exist. By satisfying the requirements of this senior design experience, we will have the opportunity to both exercise and test our creative skills.

(This design methodology is an abbreviated version of one written by Dr. Dareing and is included with his permission)

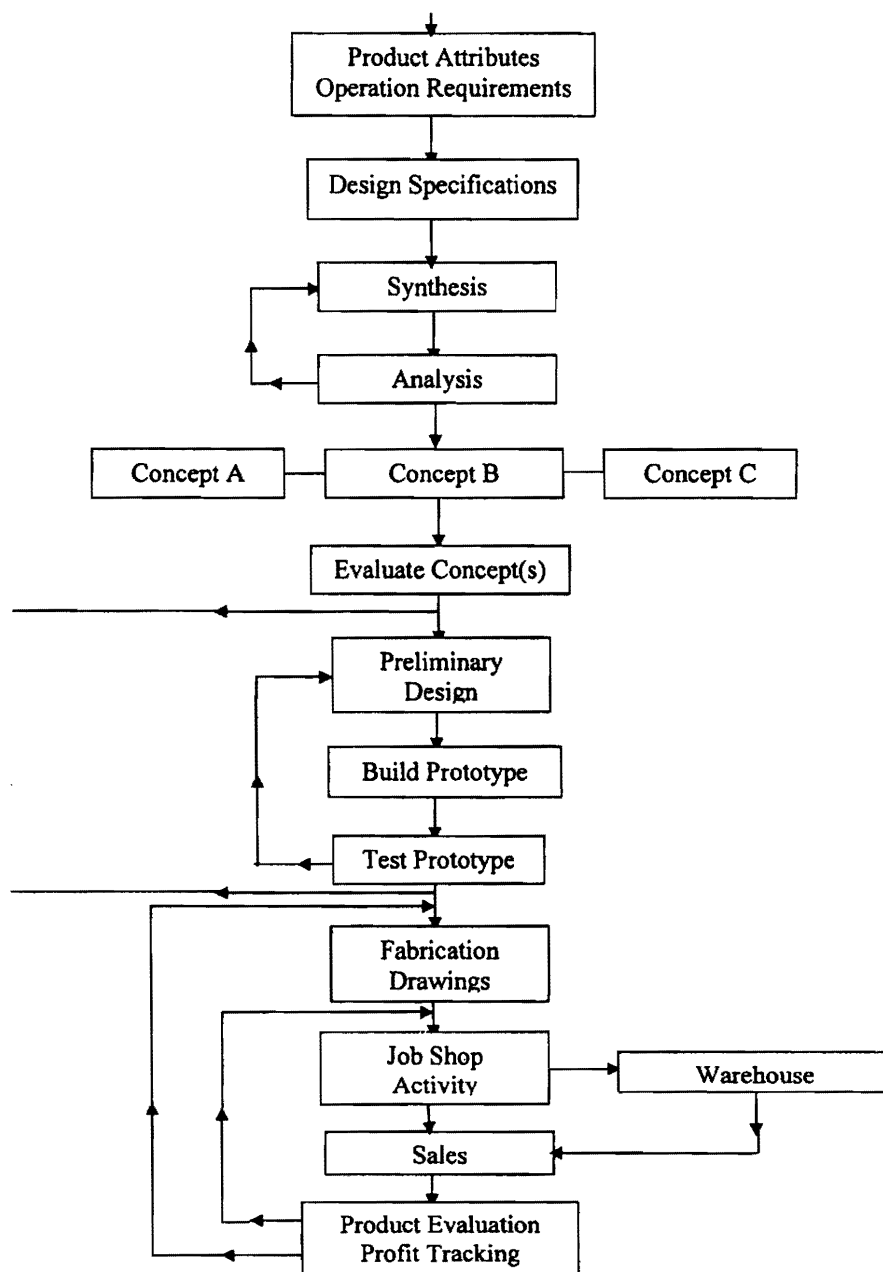


Figure 1 – The Project Development Process

Problem Statement

The objective of our project is to design an automatic box positioning system. The unloading of the box, after the operator has removed all the parts from it, will be the part of the process that will be automated. Converting the existing manual process to an automatic one will eliminate redundant work performed by the operator. The end result of this capstone project should be a life size assembly capable of replacing the existing one.

Design Specifications

Engineering is a profession ultimately guided by the specific requirements of that which is being engineered. Even the most open ended design problem has, at the least, some distant goal that is channeling thinking in a certain direction. The design specifications are these guidelines. They are the engineering baseline which must be satisfied before any decision is made.

The guidelines for this project include:

- Eliminate the non-value added task
- Be able to accommodate different box sizes with similar weights
- Have a top rack height of 38 inches
- Box in working position at 38 degrees from horizontal
- Have an empty box capacity of 6 boxes
- Have a box change time of approximately 30 seconds
- Occupy only currently available space

Initial Design Concepts:

With the above design specifications in mind, the following concepts, were brainstormed:

- Concept A – Four Bar Mechanism
- Concept B – Paddle Wheel
- Concept C –Pneumatic Piston Device
- Concept D – Telescoping Cylinder

Concept A - Four-bar Mechanism

This concept relies on a four-bar, motor driven mechanism to reposition the box. The box moves down the upper conveyor until its weight forces it to tip and slide into the “working” position. The operator will unload the box and then press a button activating a stepping motor. As the stepping motor rotates the box will move down to the lower conveyor and once in position a motion sensor will shut the motor off while the box unloads. When unloaded, the box will trip another motion sensor which will set the tray back in motion and return it to its original position. This process is shown schematically in Figure 2.

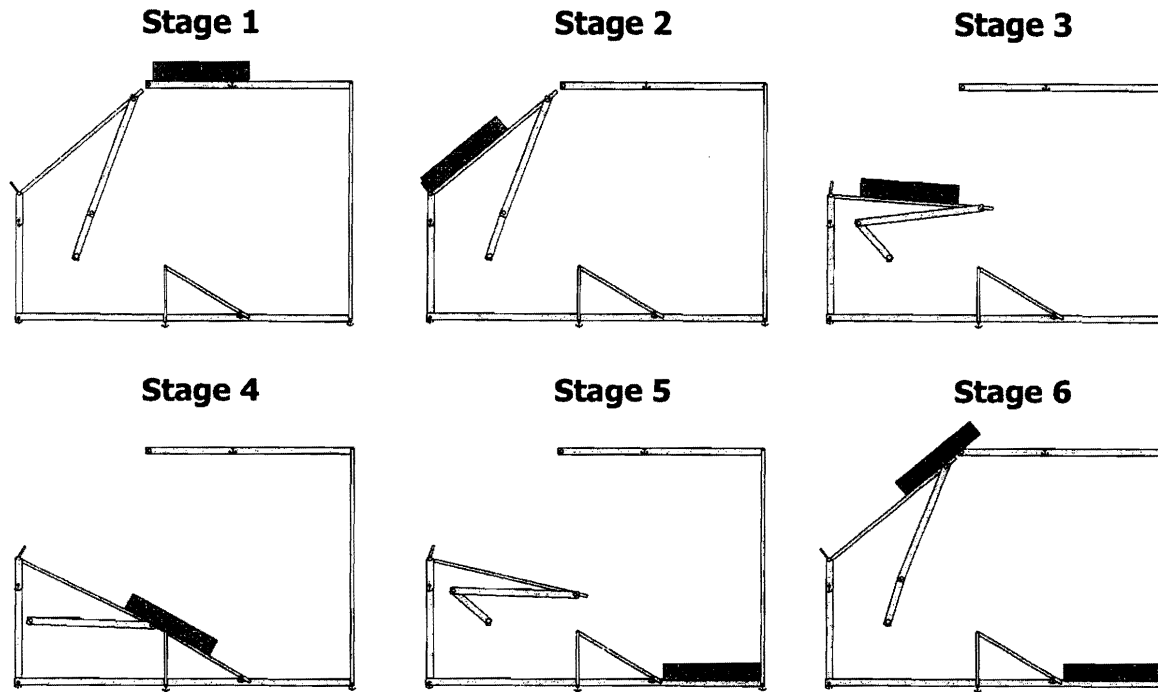


Figure 2 - Various stages in the Four-Bar Mechanism unloading process

Concept B - Paddle Wheel

This concept involves the use of a paddle wheel type device to drop the box from the upright "working" position down to the lower conveyor. Similar to Concept A, the box will move down the upper conveyor until tipped by its weight and consequently sliding it into the "working" position. A four-pronged paddle wheel type device will be used to hold the box in this position for the associate to work. A gate stop will be used to hold the paddle wheel in the stationary position. Once finished with the box, the associate will press a button, releasing the gate and therefore allowing the paddle wheel to rotate. This allows the box to then drop vertically down to the lower conveyor. Once on the lower conveyor, the box can then either be stored vertically or rotated into the horizontal position. In the process of releasing the box, the paddle wheel rotates 90 degrees which sets a new prong in its place. The gate holds the paddle wheel in

position ready for the next box. Figure 3 shows a sketch of the overall paddle wheel design as well as individual stages taking place in the paddle wheel process.

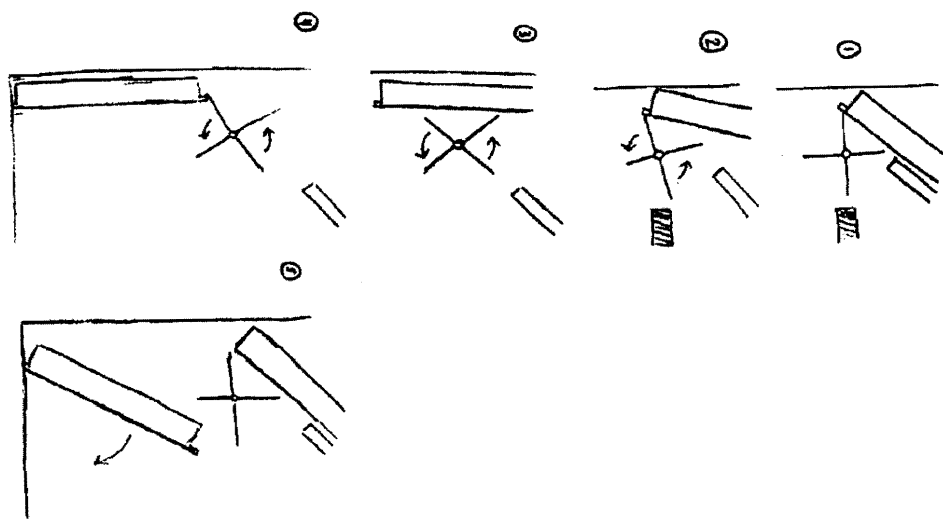
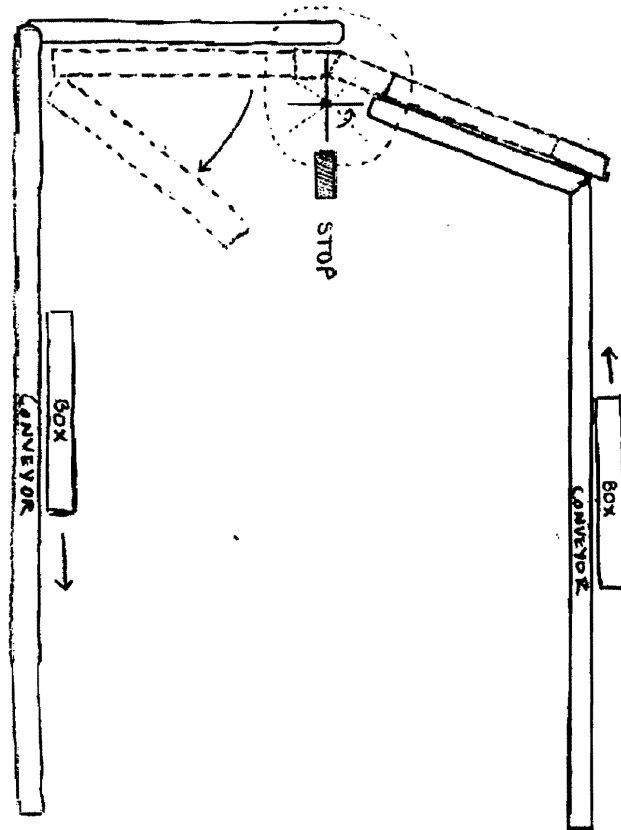


Figure 3 - Sketch of the Paddle Wheel unloading design

Concept C - Pneumatic Piston Device

A pneumatic piston will be used to reposition the box. The box will be conveyed to the tray with the use of a motorized conveyor and will tip and slide down into the “working” position. The operator will unload the box and will then press a button actuating a valve and opening the pneumatic cylinder to atmosphere. The cylinder will compress fully (the rate of descent will be controlled by the orifice size of the cylinder), lowering the box to the bottom conveyor. Once unloaded, the box will trip a motion sensor, switching the valve and forcing air into the cylinder. The cylinder will raise the tray back into the loading position and the process will begin again. If air pressure is inadequate to support the weight of the box during unloading, a gate will be used to support the tray during this process. Figure 4 shows a schematic of this process.

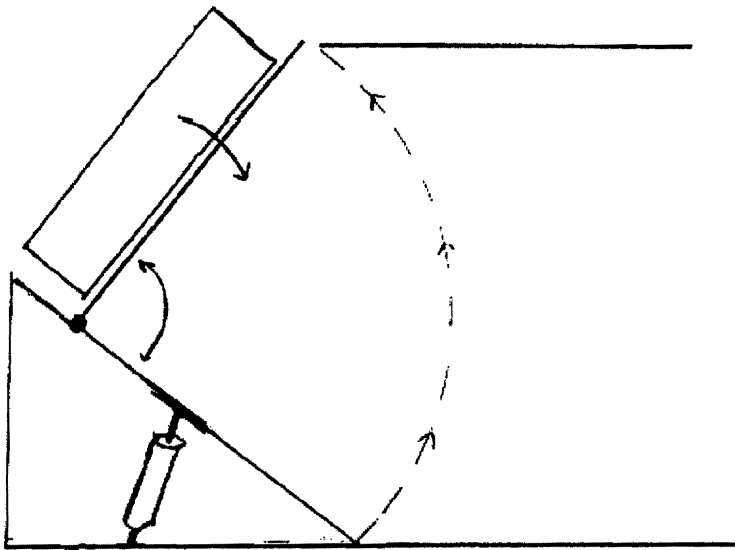


Figure 4 - Sketch of Pneumatic Piston Device

Concept D - Telescoping Cylinder

Two telescoping air cylinders will be used to move the box tray through a range of three positions. As seen in the figure below, the tray will start flush with the upper conveyor in order to eliminate the unpredictable “teeter.” The box will be pushed directly onto the tray and will trip a motion sensor opening a valve and compressing cylinder 1. This will lower the box into the “working” position. After the operator has finished working with the box she will push a button and cylinder 2 will compress, lowering the tray and placing the box onto the lower conveyor. Cylinder 1 will be stationary while cylinder 2 will be allowed to rotate and follow the movement of the tray. The box will trip a motion sensor and actuate both cylinders replacing the tray in its original position. See Figure 5 for a schematic of the overall Telescoping Cylinders design and Figure 6 for a more detailed view of the process.

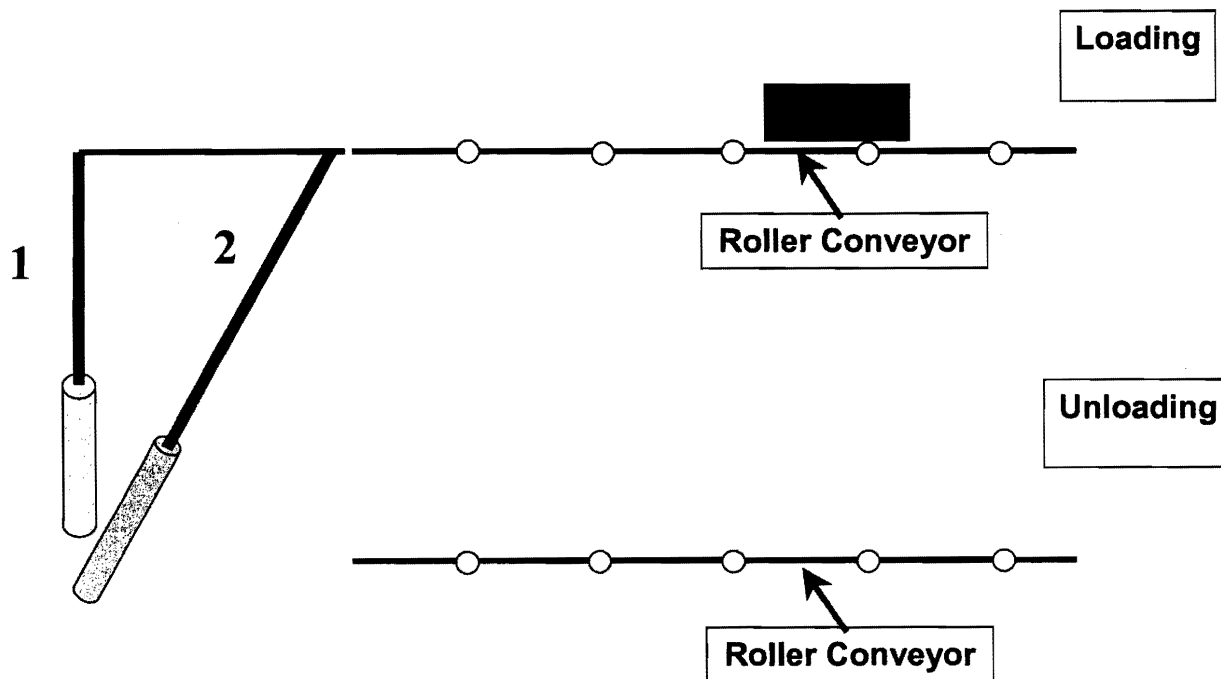


Figure 5 - Overview schematic of Telescoping Cylinders Design

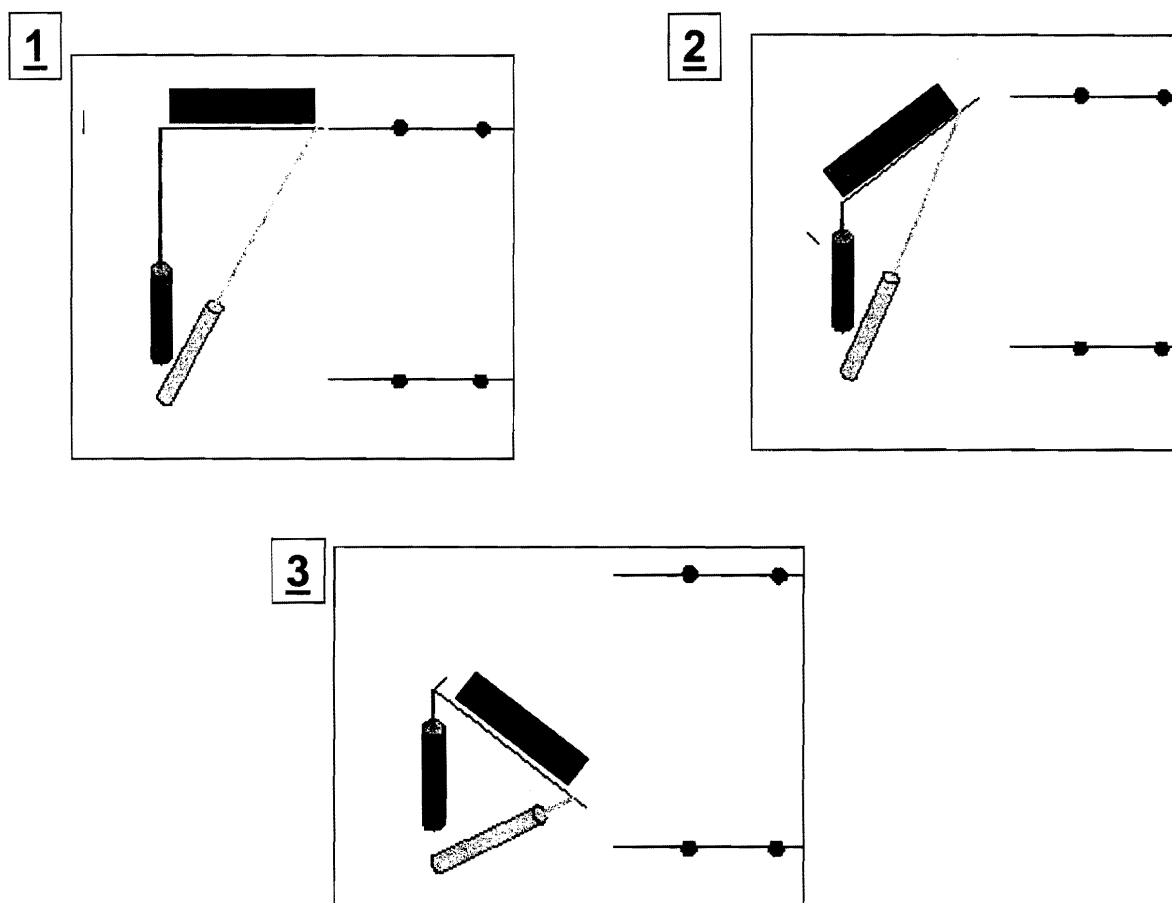


Figure 6 - Schematic of specific stages in the Telescoping Cylinders design

Concept Evaluation Summary

The four concepts described above are all viable options capable of improving the current system.

They each have their own strengths and their own weaknesses. The metric below has been chosen and has been used to rank the concepts based on these guidelines:

Performance: The capability to achieve needed operational characteristic, plus reliability

Cost: The estimated cost of the design, including development and manufacturing costs

Risk: The possibility that performance may not be met because of the design approach, absence of testing, or some specific technical consideration

Schedule: The time it will take to complete the design and prototype and train personal on the process

	WEIGHTING (%)	A	B	C	D
PERFORMANCE					
Reliability	10	5	7	6	9
Maintenance	15	10	14	14	13
Safety	15	12	12	12	14
Motion Control	<u>10</u>	7	5	7	9
	45				
COST					
Manufacturing	10	5	10	8	7
Impact on Production	<u>10</u>	11	14	13	12
	25				
RISK					
New Technology	10	5	8	9	8
Skill Level	<u>5</u>	5	5	5	5
	15				
SCHEDULE					
Personnel Training	5	5	5	5	5
May 2007	<u>10</u>	8	10	10	10
	15				
TOTAL SCORE	100	73	90	89	92

A= Four Bar Mechanism, B= Paddle Wheel, C=Pneumatic Piston, D= Telescoping Cylinder

Initial Concept Recommendation

Design D, the telescoping cylinder, is the recommended design due to its safety, motion control, and reliability. Designs B and C, the paddle wheel and the pneumatic piston, respectively, were given high marks because of their ability to satisfy the design specifications but were scored below Design D because they were considered less reliable and provided less motion control. Design A, the four bar mechanism, is ruled out because of low reliability and indeterminable technological complications.

Concept Design Presentation – Notes/Outcomes

The four concepts and the overall design objective were presented to DENSO. The engineers present were most interested in two of the design ideas: the telescoping cylinder and the paddlewheel designs, the two that had scored highest. The drawbacks and the workability of both concepts were discussed and some excellent feedback was given. Our advisors were worried that telescoping pneumatic cylinders capable of satisfying our specifications would be hard to come by. They also cautioned us to concern ourselves with the working noise of the paddlewheel design. Dropping a box could potentially be obtrusively noisy and would not fit the working conditions of the area. Thus, a new specification has been added: a noise constraint. The two other design concepts, the motor and the simple pneumatic cylinder, were not discussed thoroughly, leading us to discard the motor idea, a design overly complicated by the need to stop and restart.

At the conclusion of the meeting the scope of the project was reconsidered. Originally, the entire three mechanism process—loading, repositioning, and unloading—had been within the range of the project. Later, only the repositioning mechanism was targeted, this was the case for the concept design presentation. Now, after speaking with the DENSO representatives, the necessity to focus once again on the unloading mechanism as well as the repositioning system has been stressed. The final, built and polished product will include a repositioning and unloading mechanism.

The meeting held at UTK early Tuesday morning was the first time design objectives had truly been analyzed. DENSO's engineers brought up the possibility that the designs presented might be overly complicated and that a spring design might be the way to go. However, pictures of a

similar machine built and designed in Japan revealed a structure controlled by pneumatics and not springs. Also, the specifications of the unloading mechanism were set. The device must be capable of stacking or storing at least two rows of boxes.

After the meeting, the project focus was finally narrowed down to one concept and the engineering baseline was moved forward once again. The decision was made to use pneumatics, but to simplify motion and minimize pinch points. A single telescoping cylinder will be used to position the box and then lower it to two bottom conveyors for storage. The most significant complications we see with this design include how to actuate the piston after the box has been unloaded as well as how to trigger the mechanism to stop at the second storage conveyor once the first one is full.

Engineering Design

Due to the complexity and the number of components which comprise the automatic box unloading design, the process was separated into four different distinctive design segments in order to clarify the process. These segments include the frame design, motion actuators, pivoting tray, and the PLC. Each segment will be explained in detail, followed by circuit and process flow descriptions that explain how each distinctive part is incorporated into the final design. The components include:

- The Frame
- The Pivoting Tray
- The Motion Actuators
- The PLC

The Frame

The frame design consists of the structure that the motion actuators and pivoting tray will be mounted to, as well as the storage location for both full and empty boxes. The frame must include one flow rack to deliver stacked boxes full of parts for the associate to assemble. It must also be capable of storing single layered empty boxes, which requires the use of two more flow racks. The design specifications limit the height of the loaded flow rack, as well as the angle for which the box must sit, which introduces complications into the frame design. Multiple design sketches were created and evaluated in order to find the best possible frame design. The frame design concepts that were not used are located in the appendix.

The frame design we decided to use is seen below in Figure X. This design involves the tray hinged at its edge, with Storage Rack #2 having varying angles of descent. The first angle is steeper, which allows the box enough clearance to slide under Storage Rack #1 while also minimizing the angle of transition between the Tray and Storage Rack #2. This allows the box a smoother transition from the Tray onto Storage Rack #2. Once the box has cleared Storage Rack #1, the angle of Storage Rack #2 becomes more gradual. This design allows for an ideal working angle and working height, at 38 degrees and 38 inches, respectively. One other point to note is that with this design, Storage Rack #2 will extend lower to the ground than in the other designs.

We chose this design because it allows for the ideal working angle and working height while avoiding the safety issues associated with an overhanging tray.

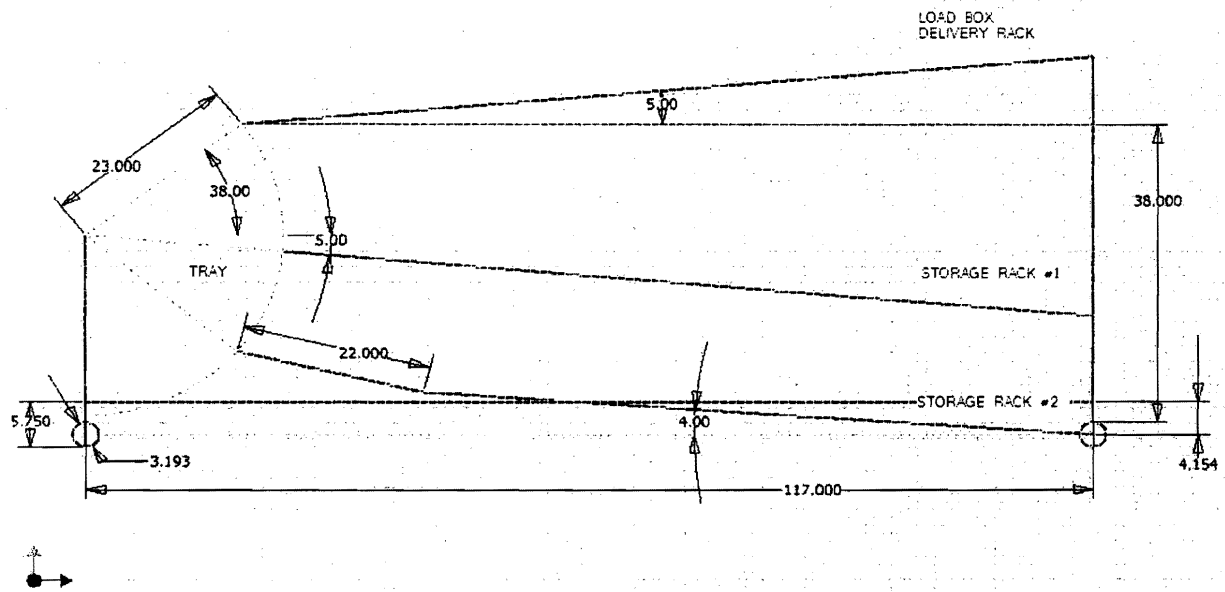


Figure 7 - Multi-Angled Storage Rack Frame Design

The Pivoting Tray

The Tray has evolved from a one piece to a two piece design. With the previous one piece design, a motion detector, control valve, and actuator were required to keep the box from sliding off the tray until the tray was in position. However, with a two piece design the box release mechanism is no longer needed.

The two sections of the new tray are the outer tray and the inner tray (See Figure 10). The bottom tray supports the top tray and is the one connected to the motion control cylinder. The top tray sits on the bottom tray and directly supports the box. The box is in contact with only the top tray.

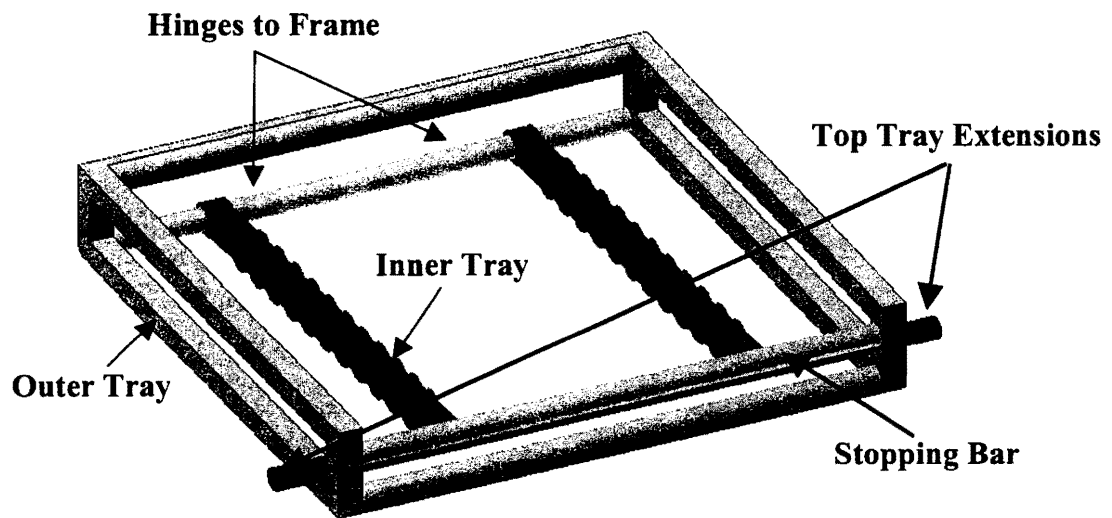


Figure 8 – Isometric view of the Tray

How it works:

While in the upright position the top tray is resting on the bottom tray (See Figure 11). When the tray is lowered to rack 1 the top tray extensions are caught by stopping cylinders—as long as the top rack is not full and the cylinders are extended—and the top tray is held steady while the bottom tray continues to descend. The top tray is held steady while the bottom tray continues to descend. Once the extensions catch on the bottom tray all motion is halted (See Figure 12), and the bottom edge of the box is above the level of the stopping bar.

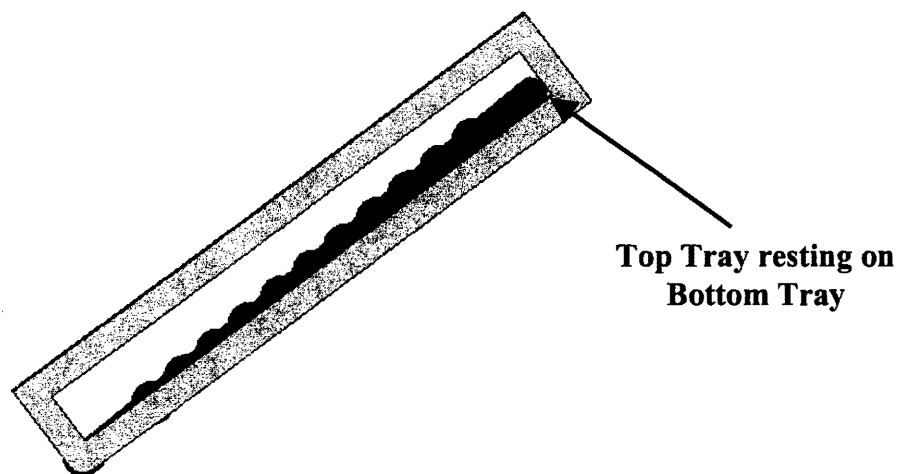


Figure 9 – The tray is up in the box-loaded position and the top tray is in the down position. The box will not roll out.

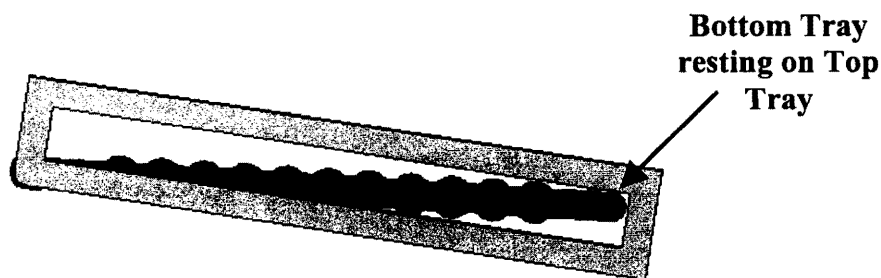


Figure 10 – The tray is in the box-unload position and the top tray is in the up position. The box will roll out.

The Motion Actuators

The motion actuators segment of the design consists of those mechanisms that are used to bring motion to the box unloading process. There are two different processes within the design that will utilize motion actuators: the two tray positioning cylinders and two cylinders that stop the tray at Storage Rack 1.

In order to position the tray, which holds the box at the necessary locations--Loaded Box Delivery Rack, Storage Rack 1 and Storage Rack 2--a Rod-less Cylinder is used. This cylinder can be seen below in Figure 13. The tray positioning cylinder, also referred to as the vertical cylinder, is triggered by one of two optical thru-beam motion sensors located on storage rack 1 and storage rack 2 which control a three-position valve. The three-position valve controls the position of the cylinder by either sending air to the top of the cylinder (down), sending air to the bottom of the cylinder (up), or sending equal amounts of air to the bottom and top of the cylinder (stop).

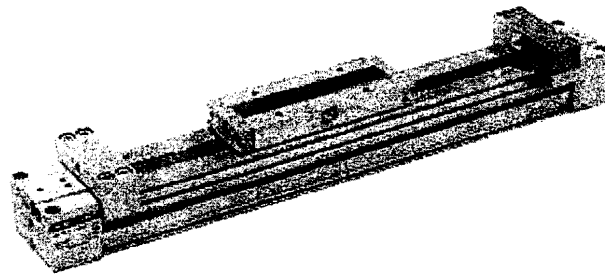


Figure 11 - The Mechanically Coupled Rod-less Cylinder used to position the tray

A stopper cylinder, like the one depicted in Figure 14, located at the edge of Storage Rack 1, is used to stop the tray at the rack when there is available box storage space. This stopper cylinder is triggered by the optical motion sensor located on Storage Rack 1. The motion sensor controls a

2-position valve. The valve either sends air to the back of the cylinder (extended) or to the front of the cylinder (withdrawn). Normally, the valve sends air to the back of the cylinder and extends the piston.

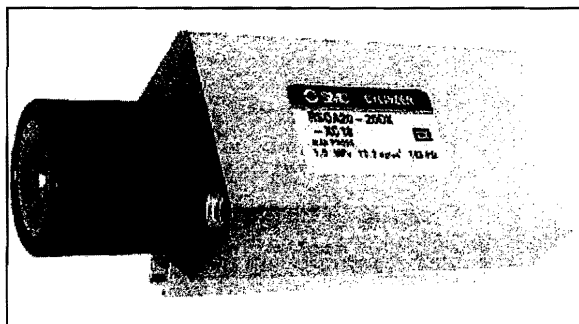


Figure 12- The stopper cylinder used to stop the tray at Storage Rack 1

The PLC

The PLC is the brain of the process. We've chosen a Mitsubishi PLC with 8 inputs and 6 outputs.

For more detailed information on the PLC please see the programming and wiring manuals

which have been included on a CD. An electrical schematic of the PLC has been included as well as has the code (See Appendix). The inputs and outputs to the PLC are:

Input:

1. Pushbutton
2. Top Storage Rack motion sensor
3. Bottom Storage Rack motion sensor
4. Top position sensor on the vertical cylinder
5. Middle position sensor on the vertical cylinder
6. Bottom position sensor on the vertical cylinder

Output:

1. Stopper Cylinder control valve
2. Vertical Cylinder control valve (Lower)
3. Vertical Cylinder control valve (Raise)
4. Indicator Light

The process that the PLC goes through is described in detail below in the circuit description.

Circuit Description provided to SMC for PLC programming:

This is a description of the signals we think the PLC should be receiving and sending. Both storage racks begin empty.

1. The three Auto switches are placed on the vertical cylinder so that one is at the top of the cylinder, one is at the first storage rack, and the other is at the bottom storage rack.
2. Button sends a signal to the PLC telling the valve to lower the vertical cylinder.
 - a. The tray must be at the top position.
3. The cylinder stops at the first storage rack and the auto position sensor on the vertical cylinder senses the tray.

4. When the box has completely offloaded from the tray it passes through the motion sensor on the top storage rack. This tells the tray to return to the top position.

This goes on until the top storage rack is full. Then...

1. Within the PLC, the motion sensor on the top storage rack is programmed with a timer so that once a box has been in front of it for more than 10 seconds the valve controlling the stopper cylinders pulls them back.
2. The same thing that happened above with storage rack 1 will happen with storage rack 2. Except here the motion sensor on the bottom storage rack will tell the tray when to return to the top position.

We appreciate the support of SMC, and specifically, Dan Schroeder, in developing the PLC program.

The Complete Process

Below, the process of getting the box from the operator to the storage rack is explained in two steps. The vertical tray positioning cylinder is described first, and the description of the tray stopping cylinders follows.

Physical Flow Description for Vertical Cylinder:

This is a flow description for the box repositioning system. This description assumes both racks and the tray are empty. In parentheses () the position of the tray is noted for each step. *Home* is denoted as the top position. The cylinder referred to is the main vertical tray positioning cylinder.

*Process starts with storage rack 1 not full, air flow into the vertical cylinder

1. (tray at home) The Box is loaded onto the tray by the operator.
2. (tray at home) The parts are all removed from the box.
3. (tray at home) The button is pushed by the operator. The tray descends to rack 1, the top rack.
4. (tray at rack 1) The box flows off the tray. Once the box is completely off the tray, the cylinder returns to the home position.
5. (tray at home) Another box is loaded onto the tray.

Steps 1-5 will be repeated until rack 1 is full

Once rack 1 is full, the tray stopping gate is retracted and the tray descends until it reaches rack 2 (the stopping gate process is described below). The same steps described above will pertain to

rack 2 with the only difference being that the tray will be moving between rack 2 and home, rather than between rack 1 and home.

As soon as there is space on rack 1 (as soon as some of the boxes have been removed) the boxes will again be unloaded on rack 1. Rack 1 is the default position.

The Rack Selector Flow Description:

This is a flow description for the rack selector switch and gate. This description assumes that at the beginning both storage racks are empty. There are two racks, one on top of the other, running parallel, and each rack holds 3 boxes. With this design it is imperative that we distinguish onto which rack each box should be placed. To do this we have designed a system with a “stopping gate” controlled by a motion sensor. The “stopping gate” is constructed using two RSQ stopper cylinders and is built onto the top rack. It defaults to the stopping position when there are no boxes in the top rack. In the stopping position the gate will stop the tray at the top rack and the box will unload onto the top rack. The items in parenthesis () describe the action of the tray and/or the box that are taking place at each step.

Process starts with both storage racks empty

1. (tray stops at rack 1) The motion detector which controls the stopping gate is positioned so that only when the rack is full will the switch put the gate in the passing position. When the gate is in the passing position the tray will descend to rack 2.
2. (box 1 flows onto rack 1) The box flows past the motion detector, actuating it for a moment, and then moving past. A PLC timer will be used to keep the gate from attempting to retract while the box slides past. Unless the box remains in the motion sensor beam for more than 5 seconds the stopping gate will remain in the stopping position.
3. (tray moves to home) The motion sensor tells the tray to return to the top position once the box is completely on the storage rack..
4. (tray stops at rack 1) Repeat step 1 with box 2 on tray

5. (box 2 flows onto rack 1) The box will flow past the motion detector, actuating it for a moment, and then move on until it contacts Box 1.
6. (tray moves to home) Repeat step 3
7. (tray stops at rack 1) Repeat step 1 with Box 3 on tray
8. (box 3 flows onto rack 1) Part of the box will flow past the motion detector, but will be stopped by contact with Box 2 before moving far enough down the rack to get past the motion detector beam. Once the box has broken the motion sensor beam for 5 seconds, a VQ series valve switches the “stopping gate” into the passing position.

Rack 1 is now full (As long as rack 1 is full the valve control switch will remain activated and the “stopping gate” will remain in the passing position.)

9. (tray moves to home) Repeat step 3
10. (tray stops at rack 2) The tray stops at storage rack 2 and the box is unloaded.
11. (box 4 flows onto Rack 2)
12. (tray moves to home) Repeat step 3
13. Steps 10-12 are repeated for boxes 5 and 6

Racks 1 and 2 are now both full

14. (tray moves to home) Trays are occupying all the available positions and the system is saturated. Not until a box is removed from either rack will the cylinder be allowed to descend with a tray.

Safety Features

Safety has been a priority since the initiation of this project. The PLC code has been designed to precisely control the entire process. Nothing is allowed to happen unless a number of predetermined conditions are first satisfied

1. The tray must be at the top position before the process can be initiated. Only when the tray is in this position will the button do anything. Otherwise, pushing the button does nothing.
2. The tray must be at the top position before the stopper cylinders can either retract or push out. This ensures the tray cannot get stuck under the stopper cylinders.
3. The tray can not come back up from storage rack 1 until both the motion sensor on storage rack 1 has detected the box and the middle position sensor on the vertical sensor has detected the tray. The tray can not come back up from storage rack 2 until both the motion sensor on storage rack 2 has detected the box and the bottom position sensor on the vertical sensor has detected the tray.
4. A red warning light is placed at the front of the flow rail next to the operator. The light will indicate to the operator any fault in the system. During normal conditions the light will be unlit. However, if something happens and the tray gets stuck for some reason the light will turn red, indicating to the operator that something is wrong.
5. A Hoffman Type 1 enclosure houses the PLC, the 24V power supply, and the two valves, as well as a 10 amp breaker for the electrical circuit. The exhaust from the valves is tubed out of the enclosure to keep moisture and oil away from the electrical components.

Future Design Recommendations

As with all projects that are done within a constrained time frame, this project is not quite where we'd ideally like to see it. This part of the report lists and explains the improvements we think would benefit our delivered product. Though we think the changes listed would ultimately improve the reliability of the flow rail, we do not feel that they are necessary prior to the institution of the product into the assembly line.

The Tray Stopping Mechanism:

Currently the tray is stopped by two 1 inch wide metal brackets that are secured to the creform pipe of the tray. If the stopper cylinders are out, the brackets land on the stopper cylinders when the tray descends. However, after experimenting with the tray mechanism, we have found that its form is not as permanent as we would like it to be. Over time, the tray and the brackets could potentially shift and cause the brackets and the stopper cylinders to lose alignment.

The Lower Storage Rack:

Because the flow rack was required to store six empty boxes we decided to go with a dual storage rack design. The design works great, but one problem with it is the angle at which boxes leave the tray at the lower rack. In order to clear the top storage rack boxes must load onto the lower storage rack at a steep angle which results in high velocity unloading. Though this poses no threat to the operator of the device, the noise during unloading can be discomforting. Another beneficial addition would be a metal guide located on the sides of the bottom storage rack to help assist the box onto the lower storage rack in a slightly more controlled manor.

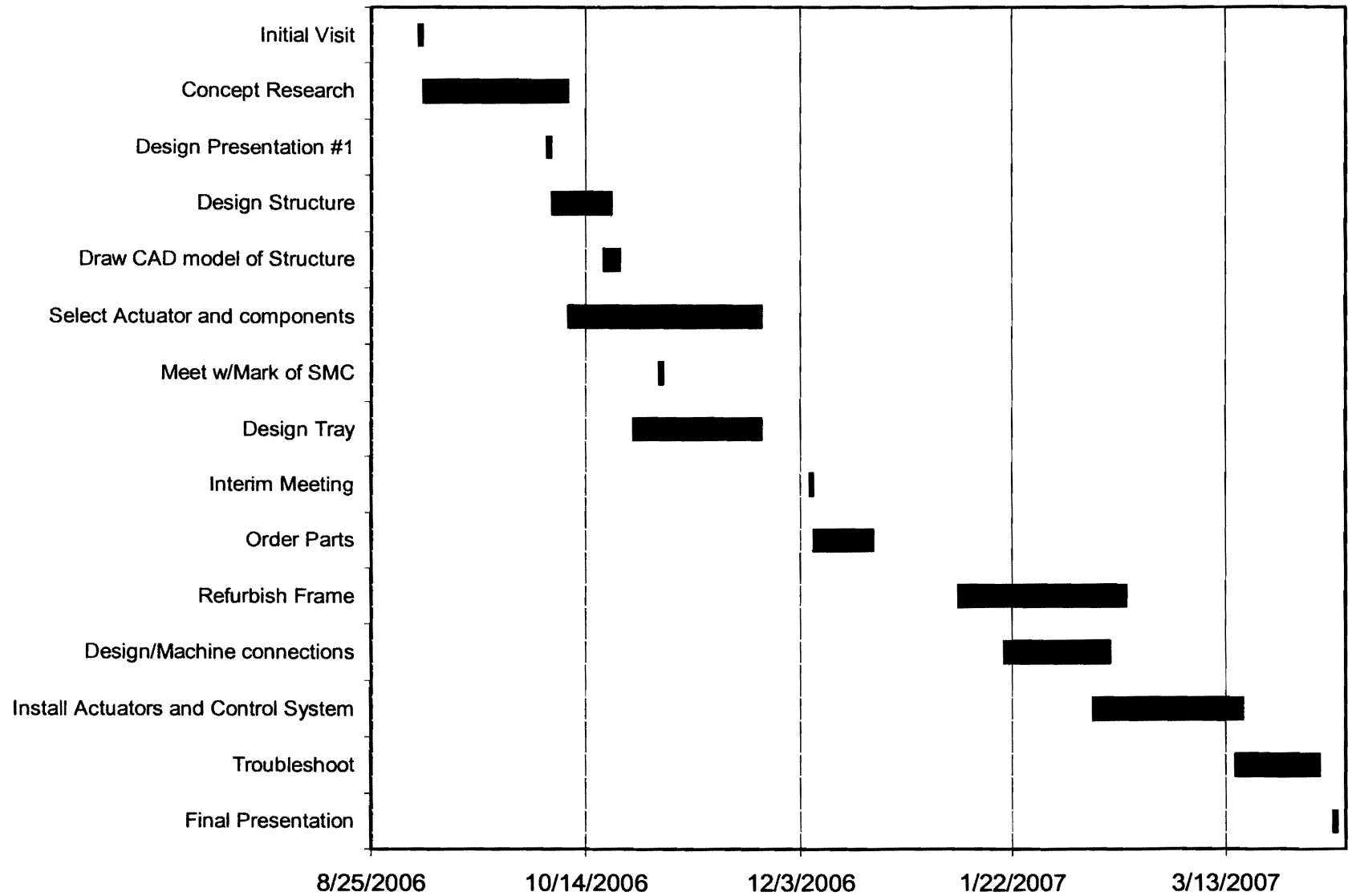
The Reset Function:

Currently, the PLC triggers the red light to turn on if the system faults and a box does not leave the tray properly. However, in order to reset the PLC and get the tray back to the home position, the “OK” button on the PLC as well as the green button on the solenoid must be pressed. This process could be improved by altering the code such that the tray would return to the home position simply by pressing the main button. This change is a very simple one, however due to external circumstances, we were unable to get the code altered.

Appendix

The following sections are contained within the Appendix

- Gantt Chart
- Frame Parts List
- Motion Components and PLC Parts List
- Frame Design Concepts



Gantt Chart

Frame Parts List

Part Number	Part Description	Quantity	Unit Cost	Total Cost
EF-1000	Casters	6	\$26.72	\$160.32
EF-2044-2500	Conveyor, Plastic Wheel ø34mm	5	\$29.81	\$149.05
EF-2044J	Conveyor Track Union, Flex	2	\$4.61	\$9.22
EF-2044C	Conveyor Mount	8	\$3.34	\$26.72
EF-2044D	Conveyor Track Mt.w/ Stop	4	\$3.54	\$14.16
EF-2044-DW	Conveyor end piece	2	\$3.54	\$7.08
EF-2048P	Conveyor Clip	18	\$0.18	\$3.24
EF-2044P	Conveyor Stabilizer	6	\$1.78	\$10.68
EF-4018L	Metal Pipe Clamp, Flat	18	\$2.46	\$44.28
HJ-1	Metal Joint Component – 28mm	56	\$2.38	\$133.28
HJ-2	Metal Joint Component – 28mm	14	\$4.53	\$63.42
HJ-4	Metal Joint Component – 28mm	6	\$3.70	\$22.20
HJ-6	Metal Joint Component – 28mm	14	\$2.33	\$32.62
HJ-8	Metal Joint Component – 28mm	4	\$4.71	\$18.84
HJ-11	Metal Joint Component – 28mm	2	\$2.42	\$4.83
H-4000-02	Standard Pipe Ivory	11	\$11.40	\$125.40
J-110	Pipe End Cap	14	\$0.11	\$1.54
LYK-1005	Rail Caster Fixed	2	\$26.72	\$53.44

**Total
Cost: \$720.00**

Motion Components Parts List

Assembly	Control	Part #	Explanation	Quantity	Cost
Tray Positioning Mechanism	Magnetically Coupled Rodless Cylinder	MY1B25G-500	Tray positioning cylinder	2	\$674.10
	Speed Controller, One Touch Fitting	AS2051F-06-3	Controls the speed at which the cylinder descends	2	\$16.09
	3-port Solenoid Position Valve	VQ4200-5-02	Valve responsible for controlling the position of the vertical cylinder	1	\$121.37
	Auto Position Sensor	D-Z73L	Position Sensor for vertical cylinder	3	\$69.39
Gate Positioning Mechanism	Stopper Cylinder	RSQB20-20D	The cylinders act as the gate	2	\$144.08
	2 Port Solenoid Valve, Compact, Direct Operated	VQ4100-5-02	Controls the flow of air to the stopper cylinder	1	\$83.62
	Visual Sensor Transmitter	(Telco) SMT3000A 5	Tells the gate when Rack 1 is full	2	\$152.92
	Visual Sensor receiver	(Telco) SMT3006A 5	Tells the gate when Rack 1 is full	2	\$215.54
	Sensor Mounting Brackets	(Telco) TR10S		4	\$44.88
PLC	Controller	ECC-PNAL2-14MR-D	This is the actual PLC Controller	1	\$489.23
	Memory Cassette	ECC-PNAL2-EEPROM-2	Memory Cassette for PLC	1	\$57.85
	Software	ECC-PNAL-CDROM-3	PLC Software	1	\$214.00
	Cable	ECC-PNAL-232CAB	Upload Cable for PLC	1	\$5.15
Electrical	24V Power Supply	(IDEC) PS5R-E24	Power Supply for motion sensor	1	\$183.21
	Electrical Enclosure	(Hoffman) A2016AT1PP	20" x 16" electrical enclosure	1	\$174.00
	Wire Strain Reliefs	CGB193	1/2" threaded	5	\$38.8
	Wire		Two Conductor 18 Gauge	12 ft	\$3.36
	Switch	(IDEC) ABW110-BGR	22 mm Push Button	1	\$11.38
	Fuse/Fitting	Buss AGC-10	Five 10 Amp Fuses with in line mount	1	\$5.72
	Pilot Light	(ASI) 8LP2TILB4	Red Light	1	\$14.08
Tubing/Fittings	Tubing	TU0604C-20	6 mm Tubing	20 ft	\$16.53
	Fittings	KQ2L06-01S	6 mm x 1/8 Fitting	6	\$12.00
	Fittings	KQ2H06-02S	5 mm x 1/4 Straight Fitting	6	\$7.50
	Fittings	KQ2L06-02S	6 mm x 1/4 Fitting	8	\$13.44
	Reducer union	KQ2UD06-08	4 to 1 reducer for 6 mm tubing	1	\$6.16

	Plug in Reducer	KQ2R06-08	8 mm to 6 mm reducer	1	\$1.13
	Bulkhead Connector	KQ2E06-02	Connects fitting to Hoffman enclosure	1	\$3.69
	Flow Controls	AS2201F-01-06S	6 mm x 1/4 Fitting	4	\$34.80
	Tees	KQ2T06-00	6 mm Tee Fitting	6	\$14.64
Miscellaneous	Pressure Regulator	AW20-02BG-C	145 psi max. Regulator	1	\$33.14
	Cutoff Valve	VHS20-02	Pressure Release Valve w/bracket	1	\$30.15
	Exhaust Silencer	AN200-02	Silencer for 1/4 inch port	1	\$3.83
	Mounting Supplies		Bolts, Screws and Mounting Pieces		\$28.05
					\$2,923.83

Design #2: Tray with Overhang

This design includes an ideal “working” angle of 38 degrees, but in order to achieve that the tray must be hinged approximately 5 inches from its edge (See Figure 8). This mildly complicates the design and we also feel that it could introduce some safety issues.

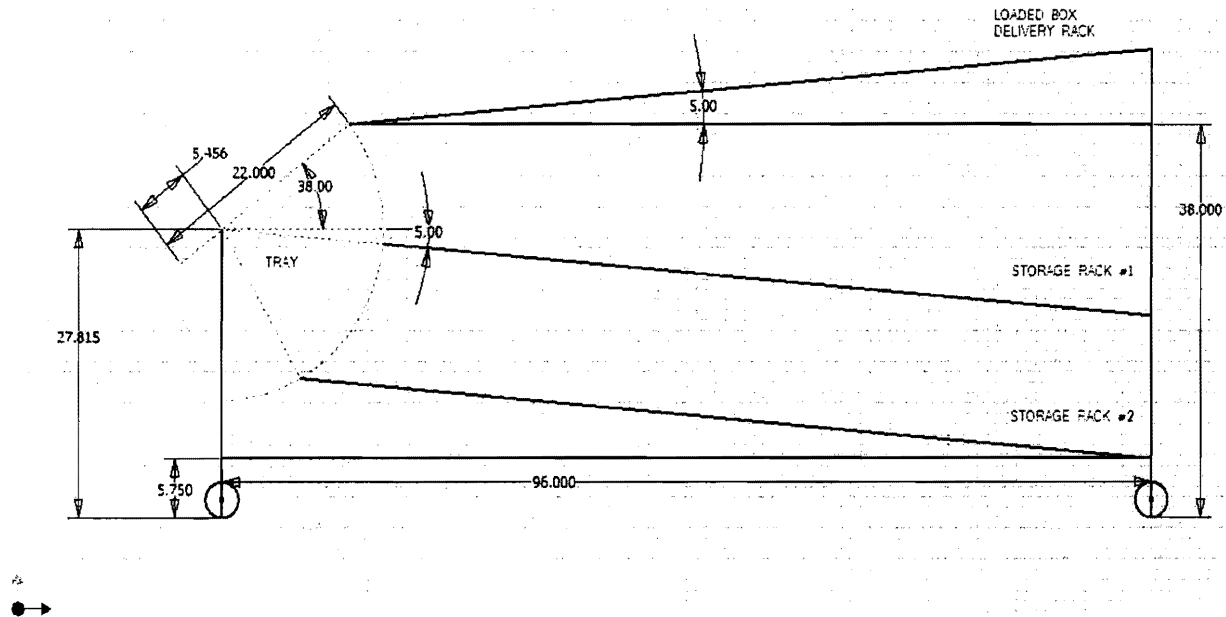


Figure 14 - Tray with Overhang Frame Design