DESIGN, CONSTRUCTION, AND ANALYSIS OF A CONVEYOR SYSTEM FOR DRYING SEASONED SNACK ALMONDS

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ABSTRACT

The senior project discusses the design, construction, and analysis of a conveyor system for drying seasoned snack almonds. The report will follow the project through the initial design, construction and testing of the conveyor. The current oven drying method used at Nunes Farms is inefficient and in need of a replacement solution. The conveyor was designed to be capable of continuous operation which keeps the steel belt, which holds the small quantities of almonds, constantly moving through the system. There is not a conveyor system of this scale and size commercially available, so the report will elaborate on overall cost and feasibility of the conveyor. The purpose of building this type of conveyor is to reduce almond drying time, labor costs and reduce worker injury occurrences at Nunes Farms Almonds Inc.

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INTRODUCTION

The California almond industry is very prosperous with an overall annual harvest of over 1.5 billion pounds. California – grown almonds account for 100% of the U.S. crop and 80% of world production. Around 70% of these almonds are exported overseas in bulk and the other 30% is sold within the United States. Around half of the almonds that stay within the U.S. are processed into retail products (Almond Board of California, 2014).

Nunes Farms Almonds Inc. is a food processing company located on the Nunes family almond farm in Gustine, CA. The company has a processing facility which specializes in producing almond snack foods and candies. Due to the small scale of the facilities, their food products are made in small batches due to limited space and small-scale machinery.

Nunes Farms has been recently looking into increasing production for their most popular product, seasoned snack almonds. Their current practices of producing the seasoned almonds is time consuming and inefficient. In a nutshell, they first start off by roasting the almonds. When the nuts are cooled off, they are run through a tumbler where a liquid bonding agent is applied followed by the seasoning. Before the nuts go to the bagging assembly, the wet bonding agent and seasoning cure must be dried to prevent mold or mildew once they are bagged. A large industrial oven is currently being used for the drying process. A dolly equipped with racks and baking sheets is used to hold the nuts and is capable of rolling into and out of the oven. This current method is very labor intensive for the workers due to the constant loading and unloading of almonds on the baking sheets.

To further help mechanize Nunes Farms Almonds, the owners decided they were in need of a conveyor system for the process of drying the almonds before they are bagged. The conveyor system must be able to continuously run a batch size of 150 pounds of seasoned almonds. It must also be as fast, if not faster than their current practices without compromising the quality of the finished product. Due to limited space in the warehouse, the conveyor system must be relatively small and capable of being moved.

LITERATURE REVIEW

Research was done on the several aspects that Nunes Farms requested to be incorporated into their custom conveyor system. Due to the fact that there aren't many small business almond manufacturing companies with public information, it took some careful research to find what new technologies the larger corporate snack food companies are using on their large scale equipment. According to Jihong Yang, an Engineer for a large food processing equipment manufacturer in Japan, infrared heat is the new up and coming energy source for drying and roasting nuts, especially almonds. Infrared heat is starting to gain popularity in the food processing industry because of its high, efficient heat output and low maintenance features. The traditional propane roasters and dryers are becoming obsolete because they are expensive, inefficient and require significant maintenance when compared to infrared heating elements (Yang, 2010).

As mentioned earlier, there is not much information on a drying conveyor of the size and application that Nunes Farms is requesting. Since this is the case, excessive research had to be done on temperatures and times a conveyor would have to be set at to cure the seasoning coat on the almonds. George Maidof, a food scientist from Germany, wrote an article on the process of seasoning and processing nuts into snack foods. The heating process and temperatures of exposure he mentions is very similar to that of Nunes Farms practices in that Maidof confirms almonds need to be exposed to 250 – 300 degree Fahrenheit heat to have a good bond of the spice to the nuts (Maidof, 1978).

The process used by Nunes Farms to process their seasoned almonds consists of putting the nuts in a large tumbler and adding a liquid bonding agent, tapioca syrup, to the nuts as they tumble. The last step is to apply a seasoning blend to the tumbling nuts which will evenly coat and stick to the almonds due to the tapioca syrup.

A physical property that needed consideration is the physical properties and drying times of the bonding agent used by Nunes Farms, tapioca syrup. The conveyor system that Nunes Farms needs is much smaller than the larger industrial standard. There are many calculations that need to be made before a conveyor system can start to be designed. An article by a Food Scientist of Pennsylvania, J. Kelly, notes the various coatings and edible substrates placed on different foods. He mentions how tapioca syrup is thicker than other bonding agents and needs a longer drying time dependent on the application and heat source (Grillo, 1999).

Figure 1. Berndorf Belt Technology Single Belt Conveyor System (Courtesy of Berndorf Belt Technology USA Company, Gilberts, Illinois, 2013).

One small scale drying conveyor system found was built by a custom manufacturing company, Berndorf. The conveyor is equipped with a hopper for loading product, an almost fully enclosed heat box and a discharge outlet as seen in Figure 1. The single belt conveyor is driven by an electric motor in the rear of the conveyor which drives the rear roller through a roller chain and sprocket attachment. This conveyor system is used for a wide variety of material including food, chemical, rubber and plastic products (Berndorf, 2013).

Figure 2. Ranar Redstar Infrared Conveyor Dryer (Courtesy of Ranar Manufacturing Company, El Segundo, California, 2013).

Another conveyor system on the market is built by a small, custom manufacturing company named Ranar. The continuous infrared conveyor system features a front loading end, an almost fully enclosed heat box with adjustable infrared heating elements and a discharge end as shown in Figure 2. This conveyor has a very simple, efficient design made for small scale production. Although not built primarily for food processing, it is capable of drying and curing products such as glass, plastic, metal and ceramic (Ranar, 2013).

PROCEDURES AND METHODS

Design Procedure

After the initial design ideas were drawn on paper, AUTOCAD 2014 was used to draw the conveyor system in an electronic format because of its versatility, dimensional preciseness and editing capabilities. The overall design of the conveyor is shown below in Figure 4.

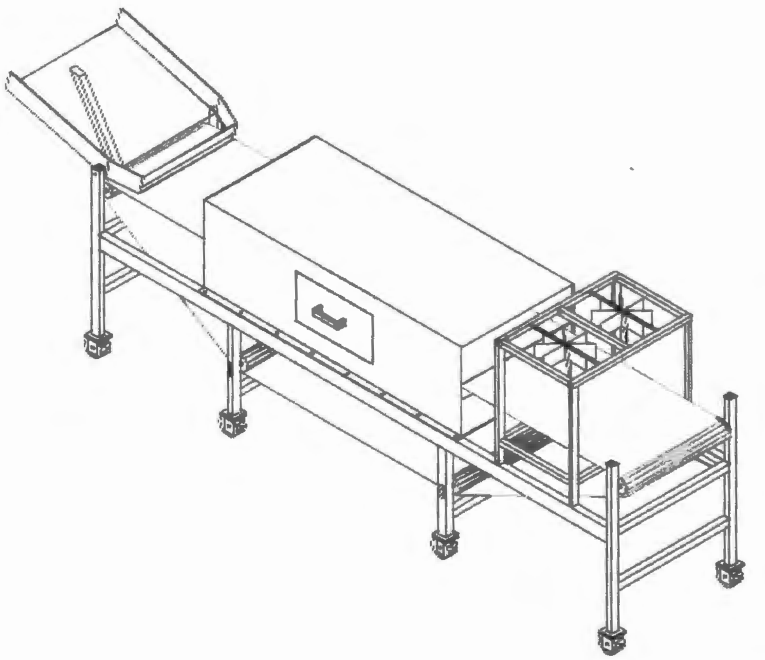

Figure 4. AUTOCAD Drawing of the Conveyor System (Southeast Isometric View)

Frame

The design began by following the parameters that were given by Nunes Farms. The first and most important part of the assembly was that the unit needed to be portable because of the limited space in the warehouse.

Figure 3. Caster Wheels Used For the Transportation of the Assembly

The initial conveyer system was planned to be on caster wheels so that it could be easily transported throughout the warehouse. Scattered and non-stationary equipment in the warehouse also meant the conveyor would most likely need to be moved every so often and be able to fit in tight spaces. The swivel caster wheel with a locking brake, (as seen above in Figure 1), would be the ideal fit because of its ability to make tight turns and keep the system stationary when locked. The maximum batch load for the conveyer system will be 150 pounds of almonds, so structural strength of the frame was designed using $1\frac{1}{2}$" mild steel square tubing and 3" mild steel channel. From the point load calculations in Appendix B, it can be determined that the steel chosen for the frame is more than adequate to support the load at any point on the frame. The frame design was constructed to be simple and cost efficient, while maintaining structural strength.

Due to the 10-foot span of the conveyer system it was necessary to design the frame with 8 legs (4 per side) to keep the frame rigid and structurally sound as seen on the previous page in Figure 4. The side rails on the frame were constructed of 3-inch mild steel channel; this enabled the oven box to be bolted through the side flange of the channel easily. On the end legs of the conveyer assembly, it was critical to put cross-braces to support the downward force of the chain belt turning around the sprockets on the shaft. In order to accommodate the 24 inch wide chain belt that was ordered, the width of the frame was designed to be 26 inches wide to give a 1 inch buffer for support the rails in the oven box on either side and to prevent rubbing of the chain on any external components.

Oven Box

The oven box was designed based on the strength requirements, cost and food safety requirements. The best material decision based on these constraints was to use 16 GA. stainless steel sheet metal. The largest size of stainless steel sheet available for purchase was 5-foot by 10 foot. The maximum size of the sheet metal that was available for purchase was a critical part in the design of the oven box. It helped to determine how large the oven box could be formed into a box shape using a single sheet of 16 GA stainless steel sheet metal. As shown in Figure 4, there were numerous bends that needed

to be made on the heat box in order to obtain the box shape. Due to the width that was needed for the bends of the oven box, it was crucial that there was a 64 and a half inch span across the width of the stainless steel sheet. Considerations for the oven box were based on the infrared heating elements that needed to be purchased to heat the box. The optimum heating range for the heating elements is 9 inches from element to product surface; therefore, the height of the box needed to be 18 inches tall to provide 9 inches from the top elements to the almond surface as well as 9 inches from the bottom elements to the bottom surface. Other design aspects that needed consideration were the maximum thickness of almonds on the belt and the cook time of the almonds. Nunes Farms current drying practices involve loading the almonds on the baking sheets until they are stacked at a height of 1 inch. The product thickness of 1 inch will be used for the conveyor system as it has proven to be an adequate product height for even drying of the nuts.

An important aspect of drying the nuts evenly in a conveyor system is the belt speed as it enters and exits the oven box. As seen in Appendix B of this report, calculations show that the belt needs to be running at a speed of 3"/min. to attain proper drying of the seasoned almonds.

Ventilation inside the box was also of concern due to the evaporation of the bonding agent from the almonds as they travel through the oven box. A vent hole on the top, middle portion of the box was critical in order to provide an area for a power venter attachment for ventilation of the oven box.

Hopper

In order to accommodate the 150-pound batch of almonds, the hopper was sized to have an overall width of 25 and 5/16 inches. This size was determined by the space between the front legs on the frame (26") so that it could easily be bolted on the inside of the front legs of the square tube of the frame assembly. In order to be able to adjust the hoppers angle, a turnbuckle attachment was mounted to the underside of the hopper. This attachment point was designed to hold one end of the turnbuckle to the hopper. A piece of 1-1/2 inch square tube protruding from the cross brace on the frame was designed to hold the other end of the turnbuckle. The reason for this design was to be able to adjust the hopper for the optimum angle of repose, so that the almonds can be fed uniformly onto the belt chain. The hopper threshold was designed with a 1-1/2 inch tall by 23 inch wide space in order to feed the almonds onto the belt chain in an evenly fashion. The side walls were designed to be 5 inches tall to provide a significant amount of surface area for the almond holding capacity.

Analysis Procedure

The conveyor system was analyzed based on the feasibility of implementing a continuous conveyor drying system into the Nunes Farms operation and the cost of production.

Cost of Production

An initial cost analysis was performed by developing a bill of materials. The bill of materials includes all raw materials, electrical components and hardware used for the construction of the conveyor. All of the stainless and mild steel was purchased from two local steel retail stores: McCarthy Steel in San Luis Obispo, CA and B&B Steel Supply in Santa Maria, CA. When the steel orders were placed, an excess of each type of material was purchased. This was in part due to the nominal lengths and sizes of steel available and to have an extra supply in the case that the original design needed to be modified. All of the electrical components and custom ordered parts (i.e. the belt) were ordered online because of the lack of availability from local retailers. The hardware was all purchased from the local hardware store ACE in San Luis Obispo, CA. The final cost listed on the bill of materials, Consumables, refers to all of the small additional items used in the construction and fabrication process. This includes items such as MIG welding wire, inert gas, CNC plasma cuts, cutting oil, grinding wheels etc. These items are difficult to calculate in small portions so a general rule for estimating consumables cost is to price it at 10% of the materials cost.

The bill of materials table is shown in the *Results* section.

Feasibility

To do a full feasibility analysis of the conveyor system, all of the associated costs with the conveyor system had to be looked at and compared to the traditional drying practices that are being currently used. The first cost recognized was the cost of production which is displayed below in Table 1. The operational cost of running the conveyor system for almond drying had to be calculated given the current energy costs in the location of the Nunes Farms Inc. operation (Gustine, CA). The operational costs of the conveyor system were compared to the operational costs of the traditional oven drying method in order to determine if the conveyor system is in fact a more economical method of drying seasoned almonds. The other associated operational cost is the cost of labor to dry a 150 lb. batch of seasoned almonds. As stated previously in this report, the reason for the construction of the conveyor system was not only to provide a less labor intensive method to drying the seasoned almonds, but to have a system that will do this in an economically feasible way.

The operational cost comparison calculations and the labor comparison tables of the two drying methods can be found in the sub-section, *Feasibility*, under the *Results* section of this report.

Construction Procedure

The Frame

The initial idea for the overall construction of the conveyor was to build from the ground on up. Cutting the base plates for the casters was the first step of the construction process. Eight square pieces identical to the caster plate were cut from ¼" hot rolled mild steel plate. In order to increase efficiency and time, all eight base plates were tack welded into one solid piece. This made it easier to drill the all of the holes necessary to bolt the casters to the base plate. The Carlton Drill Press was used in order to carry out the drilling. After the holes were drilled, the tack welds were ground off to separate the base plates into eight individual pieces again. As seen below in Figure 5, a base plate was welded to each of the eight legs.

Figure 5. Caster Base Plate Attachment Welded to Frame Leg

The support legs on the conveyer system were fabricated individually in sets of two. A MIG (Metal Inert Gas) welder was used through the entirety of the frame fabrication. Each set of legs was fabricated with the cross braces in order to aid in a simple welding environment. This enabled the square tube to be clamped to the table to prevent distortion or movement when welding as can be seen below in Figure 6.

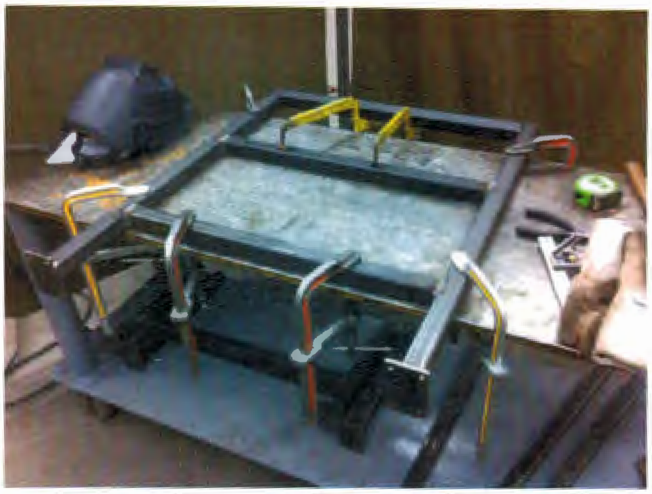

Figure 6. One Set of End Legs Complete with Cross Braces

Figure 7. Both Completed Sets of the Middle Legs

Once all four sets of legs were completed with the cross braces, the bearing plates were fabricated to the associated frame leg. This made fabrication of the frame easier to weld, because each set of legs were capable of being welded on the welding table with a jig assembly to prevent distortion. When welding parts that extrude out from an attachment point, distortion will occur unless there is backing support from clamps and/or other material. Figure 8 shows how the bearing plate was clamped on an improvised jig to prevent distortion. The bearing plates are an attachment plate in which the flange mount bearings are attached to.

Figure 8. Bearing Plate Fabricated to the Square Tube Leg

Figure 9. Completed Set of End Legs with Bearing Plates

Once all the legs were fabricated with the cross braces, both pieces of channel were placed lengthwise on either end which was then clamped and prepared for the fabrication of the legs to it. Once the frame was set up in the proper way for fabrication, half inch steel plates were placed between the channel and all of the leg assemblies to keep the legs and channel pieces connected for preparation to fabricate the assembly. Figure 10 shows the clamped assembly ready for fabrication.

Figure 10. The Frame Assembly Ready to Be Welded

The shafts which hold the sprockets for the chain belt needed to be precisely machined in order for the sprockets to have a snug fit to the shaft. The bore for the shaft to fit in on the bearings was 5/8" Diameter. Stainless steel solid round with a diameter of 5/8" was ordered to use as shaft material. The shaft was not able to fit into the bearings because they both had the same diameter, so the shafts had to be placed in the lathe and filed down as shown below in Figure 11.

Figure 11. Filing Down the Axles on the Shaft

Keyways had to be machined out of the 5/8-inch shaft to accommodate the 4-inch OD stainless steel sprockets. The stainless steel sprockets that were ordered had a 3/16-inch keyway and a setscrew. The keyway was milled out using the milling machine with a 3/16" End Mill Bit. As shown below in Figure 12, the shaft had to be clamped down with a collet, within a block, within the vise. This was to prevent any movement of the shaft when milling the keyway.

Figure 12. Milling the Shaft Keyways with a 3/16" End Mill Bit

The fan frame was constructed around the 12 inch cooling fans that were available for purchase at Global Industrial. As shown below in Figure 13, the frame was constructed of 1-inch mild steel square tube that provided easy access to bolting the fans to the fan frame.

Figure 13. The Fan Frame Attached to the Steel Channel of the Main Frame

The Oven Box

The oven box was constructed of 16 GA stainless steel sheet metal. Precise cuts with the CNC (Computer Numerical Control) plasma cutter had to be made to compliment the infrared heating elements, exhaust fan, door and bolt holes. Figure 14 shows the pieces that were cut out with the CNC plasma cutter to make up the oven box.

Figure 14. 16 GA. Stainless Steel Plasma Cut-Outs

The first sheet of 16GA stainless steel measured to be 6 feet by 5 feet. This had to be sheared from a 10 foot by 5 foot piece that was purchased. The maximum width of 5 feet determined the length of the box because the width of the box had to be larger due to the body of the box and necessary bends to form the box shape. The top and bottom part of the box were the first to be placed to the frame, as they are the basis which makes up the body of the oven box. After the top and bottom were cut out by the CNC plasma cutter, the side caps had to be measured and cut. A 3-inch gap was to be left in the middle of the sides of the oven box so that the belt chain would have easy access while the box could be enclosed with a space for the belt to travel through the middle of the box. A door, on the operator side needed to be cut out with the CNC plasma cutter in the case that an internal part needed to be fixed or replaced inside the oven box. The main body of the oven box can be seen below in Figure 15.

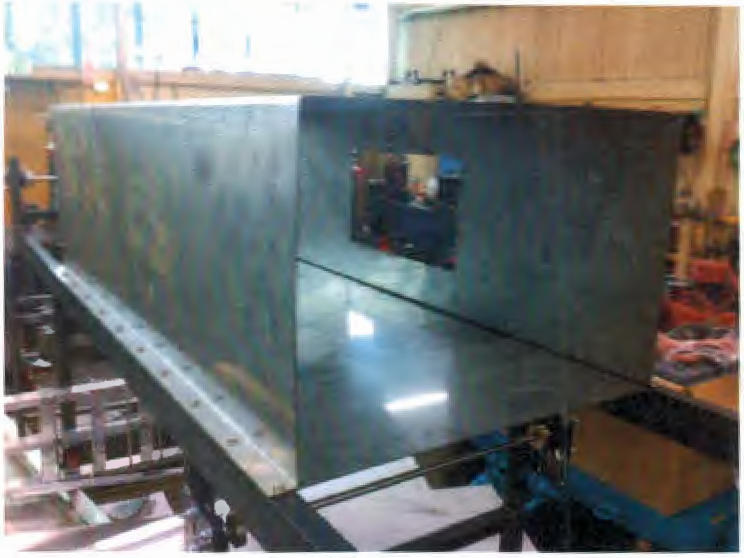

Figure 15. The Main Body of the Heat Box

Guide rails to support the belt in the oven box were cut and welded inside using a TIG (Tungsten Inert Gas) welder as shown in Figure 16. The TIG welder was used to weld all of the stainless steel components of the conveyor because of the small, precise welds that are attainable through the use of it. A thermostat hooked up on the operator side will help the operator regulate a consistent temperature of 225 degrees Fahrenheit in the box. The top part of the box was bolted through the bottom part of the oven box and all was bolted to the channel that is connected to the chain.

Figure 16. The Belt Guide Rails Installed Inside the Oven Box

The last part of the oven box that needed to be fabricated on was the attachment for the ventilation fan. A small scrap piece of 4" ID stainless steel pipe was graciously donated by McCarthy Steel to act as a mounting base for the power venter. As seen in Figure 17

below, the pipe was TIG welded to the top middle part of the oven box to aid in keeping the power venter stable and ridged when turned on. 5/16" Holes were drilled through the pipe in order to bolt the power venter to the pipe.

Figure 17. Pipe Mount to Hold the Power Venter to the Top of the Oven Box

The Hopper

The hopper had to be constructed based on the width dimension of the chain belt of 24 inches. The threshold for the hopper had to be 1 and a half inches tall in order to feed the seasoned almonds onto the belt in a 1" high, evenly spread fashion. The side walls of the hopper were bent at 5 inches to provide a significant amount of holding room in the hopper for the almonds before being loaded onto the belt. The threshold and the base of the hopper had to be cut and bent in two separate pieces and TIG welded together as shown below in Figure 18.

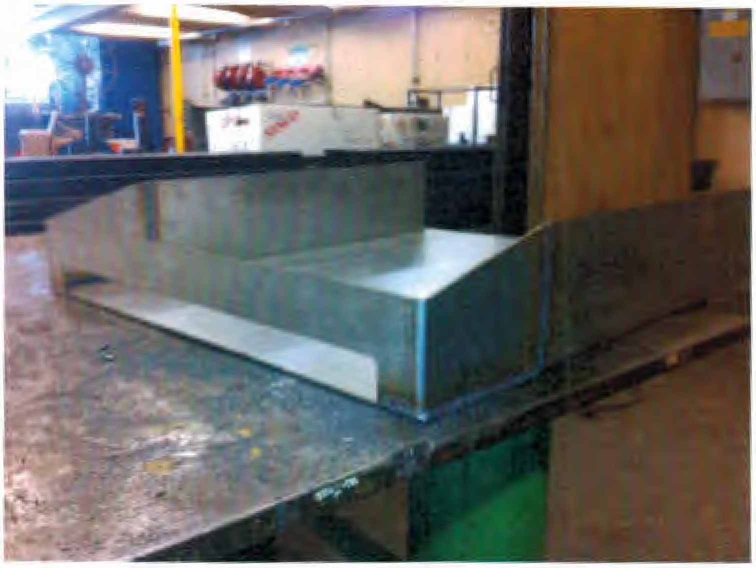

Figure 18. The Finished Hopper After Being TIG Welded

A set of tabs, as shown in Figure 19, had to be TIG welded on the rear end of the hopper to connect the turnbuckle to enable easy adjustment of the hopper angle.

Figure 19. Turnbuckle Attachment Tabs on Bottom of Hopper

The hopper had to be constructed entirely of stainless steel as USDA requires that any material touching a food surface needs to be constructed of stainless steel. The hopper was attached to the main frame with one bolt on either side going through the 1 and a half square tube. The reason for the hopper design is for an upright tumbler to be able to feed into the conveyer to start the drying process. The completed hopper and turnbuckle attachment connected to the conveyor can be seen below in Figure 20.

Figure 20. Finished Hopper with Turnbuckle Connected for Hopper Angle Adjustment

Completed Conveyor System

Figure 21. Completed Conveyor System

RESULTS

Cost of Production

The initial bill of materials was created based on the materials and parts required to construct the original design of the conveyor. Throughout the construction phase of the project, it became apparent that there were extra parts that were necessary to purchase for the assembly. One part, for example, was the control panel to protect all of the electrical components. This could not be ordered until all of the electrical parts were received and a panel size large enough to house all of the components could be determined. Table 1 displays the final bill of materials list used to build the conveyor system. The total cost of the project including materials, tax and consumables came to $10,275.71.

Table 1. Bill of Materials

Bill of Materials

Part Needed	Source	Part Description	Part #	Quantity	Unit	Price/Each ($)	Total Cost ($)
Door Handle	ACE-SLO	Cleat 6" - Stainless Steel	8090730	1	N/A	14.99	14.99
Door Locks	ACE-SLO	Hinge Extrude 2" * 3"	8091787	2	N/A	11.99	23.98
Self Tapping Stainless Steel Screws	ACE-SLO	Self-Drill Stainless Steel Screw - 1/2"	H4105	2	50.00	9.49	18.98
5/16" Stop Nuts	ACE-SLO	USS Stop Nut - 5/16"	H180150	1	100	8.79	8.79
5/16" Washers	ACE-SLO	C-PAK USS Flat Washer - 5/16"	H270058	1	100	5.29	5.29
5/16" * 1-3/4" Bolts	ACE-SLO	HX Bolts USS - 5/16" * 1-3/4"	H190099	1	100	19.99	19.99
5/16" * 3/4" Bolts	ACE-SLO	HX Bolts USS - 5/16" * 3/4"	H190084	1	100	11.49	11.49
Caster Wheels	Home Depot	5" Polyurethane Caster W/ Brake	745232	8	N/A	11.97	95.76
24" Wide Stainless Steel Chain Belt	Wire-Mesh	24" Stainless Steel Chain Belt W/ 1" Side Shingles	N/A	24	Ft.	89.00	2136.00
4" Stainless Steel Sprocket	Wire-Mesh	4" OD B Hub - 11 Teeth - Stainless Steel Sprocket	N/A	4	N/A	125.00	500.00
16 GA Stainless Steel Sheet - 5' * 10'	B&B Steel	16 GA T-304 Stainless Steel Sheet	N/A	166	Lbs.	2.20	365.20
12 GA Stainless Steel Sheet - 5' * 5'	B&B Steel	12 GA T-304 Stainless Steel Sheet	N/A	111	Lbs.	2.25	249.75
5/8" D. Stainless Steel Round Bar - 12'	B&B Steel	5/8" Stainless Steel Rounds	N/A	12	Lbs.	2.60	31.20
3" Mild Steel Channel - 20'	B&B Steel	3" - 4.1# - Standard Channel	N/A	82	Lbs.	0.76	62.32
2" D. Stainless Steel Round Bar - 2'	B&B Steel	2" Stainless Steel Rounds	N/A	21	Lbs.	2.50	52.50
1-1/2" Mild Steel Square Tube - 36'	McCarthy Steel	1-1/2" * 1-1/2" * 0.188 Steel Square Tube	26-12098	36	Ft.	3.83	137.88
1/4" Mild Steel Plate - 2' * 2'	McCarthy Steel	1/4" Steel HR Plate	1448HRP	40.8	Lbs.	1.05	42.84
1" Mild Steel Square Tube - 30'	McCarthy Steel	1" * 1" * 0.120 Steel Square Tube	N/A	30	Ft.	1.92	57.60
40:1 Gear Reducer	Surplus Center	40:1 RA Gear Reducer - Right Output	13-175	1	N/A	130.95	130.95
20:1 Gear Reducer	Surplus Center	20:1 RA Gear Reducer - Left Output	13-133	1	N/A	92.95	92.95
1/2 HP Electric Motor	Surplus Center	1/2 HP 1750 RPM 56C Motor	10-270	1	N/A	150.95	150.95
20 Tooth 5/8" Sprocket	Surplus Center	20T 5/8" Bore 40P Sprocket	1-21234	1	N/A	7.30	7.30
10 Tooth 5/8" Sprocket	Surplus Center	10T 5/8" Bore 40P Sprocket	1-21242	1	N/A	4.45	4.45
40 Pitch Roller Chain	Surplus Center	#40 - 10 Box of #40 Roller Chain	1-11632	1	N/A	13.95	13.95
Exhaust Air Vent	Global Industrial	Tjernlund Power Venter - 150 CFM	B589561	1	N/A	248.95	248.95
Cooling Fans	Global Industrial	Workstation Fan - Global 12"	294492	2	N/A	43.95	87.90
1/2 HP VFD	Automation Direct	1/2 HP HPAC Drive VFD 120V	GS1-10PS	1	N/A	117.00	117.00
6" Turnbuckle	Grainger	1/2"; 6" Take-Up Turnbuckle	4DV17	1	N/A	27.10	27.10
5/8" Flange Bearings	Grainger	Mounted Ball Bearing; Flange; 5/8" Bore	3FCX1	8	N/A	50.50	404.00
Thermostat	MOR Electric	Chromalox, 7', Thermostat	AR-215KC	1	N/A	300.00	300.00
Infrared Heating Elements	MOR Electric	LTE Salamander Ceramic IR Heating Element	IRCER12530	4	N/A	65.03	260.12
High Temp. Electrical Wire	MOR Electric	12 GA TGGT Electrical Power Wire	HT10002	50	Ft.	1.05	52.50
2 Pole Terminal Blocks	MOR Electric	TB2J - 2 Pole Cermaic Terminal Block	TB10002	8	N/A	3.38	27.04
4 Pole Terminal Terminal Blocks	MOR Electric	TB4J - 4 Pole Ceramic Terminal Block	TB10005	4	N/A	5.06	20.24
Panel for Electrical	Automation Direct	N4/12 Single Door Wall Mount 16*12*6 IN	N412161206C	1	N/A	165.00	165.00
Panel Backing Plate	Automation Direct	SubPanel, N412 16*12 Enclosure	NP1612C	1	N/A	19.00	19.00
Tubing for Electrical Wires	Automation Direct	Flex Tubing 3/8" ID 98 ft.	GSI-12K	1	N/A	28.00	28.00
ON/OFF Switches	Automation Direct	PB 22MM Metal 2-Way Red/Green N.O/N.C	GCX1152	2	N/A	13.50	27.00
ON/OFF Switch Covers	Automation Direct	PB ENC 22mm 2-Hole GRY 74mm Deep Plastic	SA106-40SL	2	N/A	9.00	18.00
Cube Relays	Automation Direct	Cube Relay 10A 4PDT 120 VAC Coil LED Indicator	QL4N1-A120	2	N/A	11.50	23.00
Labor Cost				165	Hrs.	15.05	2483.25
					Sub - Total:		$ 8,543.21
					Sales Tax:	7.50%	$454.50
					Shipping:	$672.00	$672.00
					Consumables:	10%	$606.00
					Grand Total:		$10,275.71

Feasibility

After comparing the drying method used by Nunes Farms Inc. and the conveyor system, it is apparent that conveyor system is more cost effective and efficient than that of the oven drying method currently in use. One reason for the decreased cost of production with the conveyor system is because of the smaller area being heated to dry the almonds. The 180 cubic foot oven currently being used compared to the 15 cubic foot heat box on the conveyor shows the difference in volume that needs to hold a steady 225 Degrees Fahrenheit temperature. The oven box on the conveyor does need to stay heated a longer time, as seen in the calculations in Appendix B; however, it is more cost effective in regards to energy use as can be seen in the next two pages of calculations. The industrial oven can hold a larger quantity of almonds in it at one time than the oven box; however it is heating a much larger space which is inefficient and expensive. The oven box has a lower capacity of almonds running through it at any given time, but it is continuously moving almonds through it while only heating the small area of the box. The calculations below show that the conveyor system operating costs are $2.07 less than the conventional drying method per 150 lb. batch.

Current Oven Drying Practices vs. Conveyor System Cost Comparison

Given:

Current Electricity Costs (Gustine, CA): $0.1323 / KW – HR (Pacific Gas & Electric)
Current Propane Costs (Gustine, CA): $2.70 / Gallon (Pacific Gas & Electric)
1 Gallon of Propane Produces 91,600 BTU's (www.knoxenergy.org)

Required:

Find the operating costs per 150 lb. batch of seasoned almonds for the current drying practices of Nunes Farms Almonds Inc. and the proposed operating costs of the new conveyor system for drying the seasoned almonds.

Solution:

Nunes Farms Current Drying Practices

- 180 cubic foot propane powered industrial oven
  Capacity – 250,000 BTU's / Hr.
  Run Time = 20 Min.

  Propane Costs = ((250,000 BTU's / Hr.) ÷ (91,000 BTU's / Gallon)) × 0.33 Hrs.
  = 0.91 Gallons × $2.70 / Gallon
  = $2.45

- MaxxAir 36" Air Circulator Fan 9,000 CFM – 345 Watts
  Run Time = 30 Min. (After the almonds exit the oven)

- 24" 1-HP Roof Ventilation Fan 7,425 CFM – 912 Watts
  Run Time = 20 Min. (While the almonds are in the oven)

  Electricity Costs = ((345 Watts) ÷ (1,000 Watts / Kilowatt)) × (($0.1323 / KW – Hr.) × 0.5 Hrs.) + ((912 Watts) ÷ (1,000 Watts / Kilowatt)) × (($0.1323 / KW – Hr.) × 0.33 Hrs.
  = $0.17

  Total Costs = Propane Costs + Electricity Costs
  = $2.45 + $0.17
  = $2.62

Drying Seasoned Almonds Using the Conveyor System

- MOR Electric LTE Salamander Ceramic Infrared Elements (4 Elements) – 400 Watts / Each
- Tjernlund HS1 150 CFM Power Venter – 95 Watts
- Global Industrial 12" Workstation Fan (2 Fans) – 60 Watts
- ½ HP 115 VAC 56C TEFC Leeson Electric Motor – 437 Watts
- Run Time = 110 Min.

Electricity Costs = (((400 Watts × 4) + (95 Watts) + (60 Watts × 2) + (437 Watts)) ÷ (1,000 Watts / Kilowatt))) × ($0.1323 / KW- Hr.) × 1.83 Hrs.
= $0.55

Total Costs = Electricity Costs
= $0.55

The labor costs are significantly lower for the conveyor when compared to the labor required for the conventional drying method. There are a few significant and timely steps that aren't required when drying with the conveyor system. A few of these processes that are avoided are the rigorous loading, unloading and handling of the almonds. The conveyor is a system equipped with all of the equipment necessary to perform the drying process with little human interference of the nuts. As shown in Table 2 and Table 3 below, the conveyor requires only one worker to operate and supervise the drying process whereas the conventional drying method often requires two workers for certain steps throughout the process. The labor costs savings is $20.02 per batch of almonds with the conveyor drying system.

Adjusted Employee Hourly Wage Calculations

Hourly Base Wage = \$10 / Hr.

Additional Hourly Costs to Employer

Social Security = 3.1% of hourly wage
= \$10 × 0.031
= \$0.31 / Hr.

Workers Compensation = 12% of hourly wage
= \$10 × 0.12
= \$1.20 / Hr.

Unemployment = 6.86% of hourly wage (Combined State & Federal)
= \$10 × 0.0686
= \$0.69 / Hr.

Medicare = 1.45% of hourly wage
= \$10 × 0.0145
= \$0.15 / Hr.

Health Insurance = 27% of hourly wage
= \$10 × 0.27
= \$2.70 / Hr.

Total Additional Costs = \$0.31 + \$1.20 + \$0.69 + \$0.15 + \$2.70
= \$5.05 / Hr.

Adjusted Hourly Wage = \$15.05 / Hr.

Table 2. Cost of Labor for Conventional Oven Drying (For 150 lb. Batch)

Task	**Time (Minutes)**	**# of Workers Required**	**Total Time (Hours)**	**Wage ($/Hr.)**	**Cost of Labor ($)**
Preparation of almonds, seasoning & supplies	15	2	0.5	15.05	7.53
Tumbling of almonds and application of seasoning ingredients	10	1	0.17	15.05	2.56
Supervision of initial baking time	5	1	0.083	15.05	1.25
Unloading of baking sheets from oven and placement in front of cooling fan	15	2	0.5	15.05	7.53
Dumping of almonds from baking sheets into off load bin	10	2	0.33	15.05	4.97
Cleaning of Baking Sheets	30	2	1.0	15.05	15.05
Total			**2.58**		**38.89**

Table 3. Cost of Labor for Conveyor System Drying (For 150 lb. Batch)

Task	**Time (Minutes)**	**# of Workers Required**	**Total Time (Hours)**	**Wage ($/Hr.)**	**Cost of Labor ($)**
Preparation of almonds, seasoning & supplies	30	1	0.5	15.05	7.53
Tumbling of almonds and application of seasoning ingredients	10	1	0.17	15.05	2.56
Supervision of initial baking time	5	1	0.083	15.05	1.25
Conveyor Clean Up	30	1	0.5	15.05	7.53
Total			**1.25**		**18.87**

DISCUSSION

One goal of the conveyor was to create a drying process that was faster than the oven method of drying. A few major components of the conveyor that needed consideration in order to decrease processing time were temperature, belt speed and almond volume on the belt. Due to the space limitations in the warehouse, the conveyor had to be designed to a smaller scale than what was ultimately desired. With a set volume of almonds capable of traveling through the heat box at any given time, the only other two factors that could potentially quicken the process were belt speed and temperature. If the temperature were increased from the standard 225 Degrees Fahrenheit, the belt speed could theoretically be sped up as well. The only concern with increasing the temperature was the uncertainty of improper drying, or burning of the almonds. With the non-alterable volume of almonds on the belt and the standard set temperature, there was no other option than to keep the belt speed at approximately 6 inches/minute to obtain the optimum heat exposure to the nuts for drying.

The section, *Time Calculations*, in Appendix B shows that a 150 lb. batch of almonds will spend a total time of 110 minutes traveling through the oven box. This doesn't account for 88 additional minutes it takes for the nuts to travel into the box and exit passing through the cooling fans and into the offload bin. The total time of the process from the first almonds entering the belt to the last of the almonds exiting the belt is 198 minutes or 3 hours and 20 minutes. This overall time of the process is longer than that of the drying process in the oven, however this time includes the drying and cooling of the nuts so when they exit the belt, they are ready for the baggage assembly. The oven drying time for the conventional method takes 20 minutes, but as seen above in Table 2, there is an excess of unproductive time through the handling of the almonds. When comparing Table 2 and Table 3 above, the time savings of the overall drying process is 1.33 hours or 1 hour and 20 minutes with the conveyor drying process. Supervision of each system during the cooking time is not required and is the reason there is a time savings with the conveyor system. Once each system is running, the employee has other tasks to address rather than standing in front of the oven watching the almonds dry. It eliminates all of the manual labor of handling, transferring, as well as the space needed for the drying process.

Another aspect of the conveyor is that it was designed to be versatile for the Nunes Farms operation. With the variety of seasoned snack foods they sell, the conveyor can potentially be used for a variety of other drying or roasting applications. Three main components that add variability to the system are the VFD (Variable Frequency Drive), the thermostat and the easily accessible drive sprockets. The VFD can electronically control the speed of the AC electric motor from a high of 60 Hz to a low of 10 Hz. The thermostat can be adjusted to keep the internal temperature of the oven box from temperatures of 0 Degrees Fahrenheit to 700 Degrees Fahrenheit by turning off the heaters when the desired temperature is reached. The easily accessibility of the driver sprocket from the 20:1 gear reducer as well as the driven sprocket on the drive shaft allow for the sprockets to be changed to attain the desired gear ratio. The capability of adjusting these three components allows for the operator to adjust the belt speed and the temperature of the oven box with ease.

RECOMMENDATIONS

There are numerous different approaches through the construction phase that could have been performed to increase time efficiency throughout the process of the build. The conveyor had to be built in phases due to backordered items and unavailability of materials when they were needed. One of the most critical parts of the conveyor is the belt. Due to length and style requirements needed for the conveyor, the belt had to be custom built by a conveyor belt manufacturer. All of the external and internal components of the conveyor system were designed around the size and design of the belt. The placement and position of components such as the fan frame, main frame cross braces and heat box were all designed to not disrupt the belts motion. Once the belt was received and placed on the conveyor system, it was apparent that the belt had a fair amount of sag due to the excessive weight. This caused the belt to rub on undesirable surfaces and was the cause for modifications to be made to the frames cross braces and placement of the motor and gear reducers. The belt should be the first part to be purchased and the conveyor should be built around its design and dimensions.

A majority of the time throughout the construction was dedicated to machining custom parts for the conveyor on the mill and lathe. One such process was milling the keyways for the belt sprockets on the end shafts. In a production environment, it would be cost efficient to reduce labor costs by purchasing shafts that already have the desired size and length keyways milled into them.

If this same style conveyor system were to be built again, it would be beneficial to group all of the jobs together for each machine or piece of equipment needed for the job. With the construction phase being completed in stages, there was a lot of traveling to and from different machines, which was not time efficient. If all of the parts that needed to be machined or cut or welded were done at once, construction and fabrication time could be greatly minimized.

The conveyor is assembled of stainless steel in areas that are in close proximity or in contact with a food surface. The other mild steel that was used primarily for the frame assembly was painted with a high temperature resistant paint. There is stainless steel hardware for every bolt or screw attachment on the conveyor. The electronics are securely enclosed in a metal control panel away from the high temperature of the heat box. The conveyor can be conveniently washed after each use without worry of rust forming and will last numerous years if properly cared and maintained for.

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APPENDIX A

HOW PROJECT MEETS REQUIREMENTS FOR THE ASM MAJOR

HOW PROJECT MEETS REQUIREMENTS FOR THE ASM MAJOR

ASM Project Requirements

The ASM senior project must include a problem solving experience that incorporates the application of technology and the organizational skills of business and management, and quantitative, analytical problem solving. This project addresses these issues as follows.

Application of Agricultural Technology. The project involves the application of mechanical systems, power transmission, and fabrication technologies.

Application of Business and/or Management Skills. The project will involve business/management skills in the areas of machinery management, cost and productivity analyses, and labor considerations.

Quantitative, Analytical Problem Solving. Quantitative problem solving will include the cost analysis and the bending allowance calculations for stainless steel sheet metal in the brake press.

Capstone Project Experience

The ASM senior project must incorporate knowledge and skills acquired in earlier coursework (Major, Support and/or GE courses). This project incorporates knowledge skills from these key courses.

- BRAE-129: Laboratory Skills and Safety
- BRAE-133: Engineering Graphics
- BRAE-142: Agricultural Power and Machinery Management
- BRAE-151: AutoCAD
- BRAE-203: Agricultural Systems Analysis
- BRAE-301: Hydraulic and Mechanical Power Systems
- BRAE-321: Agricultural Safety
- BRAE-324: Agricultural Electrification
- BRAE-342: Agricultural Materials
- BRAE-343/344: Mechanical & Fabrication Systems
- BRAE-418/419: Agricultural Systems Management I & II
- English-145: Professional Writing

ASM Approach

Agricultural Systems Management involves the development of solutions to technological, business or management problems associated with agricultural or related industries. A systems approach, interdisciplinary experience, and agricultural training in specialized areas are common features of this type of problem solving.

Systems Approach. The project involves the integration of multiple functions (Conveyance, power transmission, thermal heating properties), as well as machinery equipment that must be controlled by an operator in effort to further mechanize the Nunes Farms Almonds operation.

Interdisciplinary Features. The project incorporates aspects of mechanical systems, electrical systems and thermodynamics.

Specialized Agricultural Knowledge. The project applies specialized knowledge in the areas of mechanical systems, fabrication systems, and food science.

APPENDIX B

DESIGN CALCULATIONS

Design Calculations

Time to Run a 150 lb. Batch of Seasoned Almonds

Given:

1 lb. of almonds (shelled/whole) = 3 cups
40 lbs. of almonds = 120 cups
120 cups = 1 cubic foot
1 lb. of almonds = 0.025 cubic feet [3 cups ÷ 120 cups]
150 lbs. of almonds = 450 cups = 3.75 cubic feet

Required:

Based on the given time, volume and temperature used by Nunes Farms to dry a 150 lb. batch of almonds in their oven, extrapolate the information to determine how long a replica batch size of almonds would take in the conveyor system given the conveyor dimensions, belt size and internal temperature.

Solution:

Nunes Farms Current Drying Practices

- Roll-In industrial size propane powered oven
- Time to run a 150 lb. batch of almonds is 20 minutes
- Temperature setting is 225 Degrees Fahrenheit
- Roll-In baking sheet rack w/ accommodation for 40 baking sheets (16" × 10"/ Each)
- Each baking sheet can accommodate a full sheet of almonds 1" high
- Calculations for baking sheet capacity:

  Load (lbs.) per Baking Sheet = (150 lb. batch ÷ 40 sheets)
  = 3.75 lbs. per sheet

  Volume per Sheet = Length × Width × Height
  = (16" ÷ 12") × (10" ÷ 12") × (1" ÷ 12")
  = 0.093 cubic feet / sheet

Conveyor System Drying Calculations

- Oven Box Dimensions: 5' Long × 2.17' Wide × 1.5' High
- Belt Width: 2'
- Temperature in Oven Box: 225 Degrees Fahrenheit

- Belt Velocity = (60" (Length of Oven Box) / 20 min.)
  = **3" / min.**

- Total Belt Length Required:

  150 lb. Almond Volume = 3.75 cubic feet = 6,480 cubic inches

  Total Belt Volume = 6,480 cubic inches

  Total Belt Volume = (Belt Length) × (1") × (24")

  Belt Length = 270"

The belt length must start at X=0" and the end of the belt must finish at X=60"

  Therefore, Belt Travel = 270" + 60" = **330"**

- Time Required = (330") ÷ (3"/min.)
  = 110 minutes

Power Transmission, Sprocket and Gear Sizing Calculations

Given:

- 2" Diam., 10 Tooth Drive Sprocket
- 4" Diam., 20 Tooth Driven Sprocket
- 40:1 Gear Reducer
- 20:1 Gear Reducer
- ½ HP Motor @ 1750 RPM

Required:

Calculate the belt speed using the given gear and sprocket configuration

Solution:

Motor w/ Gear Reducers = (1750 RPM) ÷ (40 × 20 (For 40:1 and 20:1 Reducers))
= (1750) ÷ (800)
= 2.1875 RPM

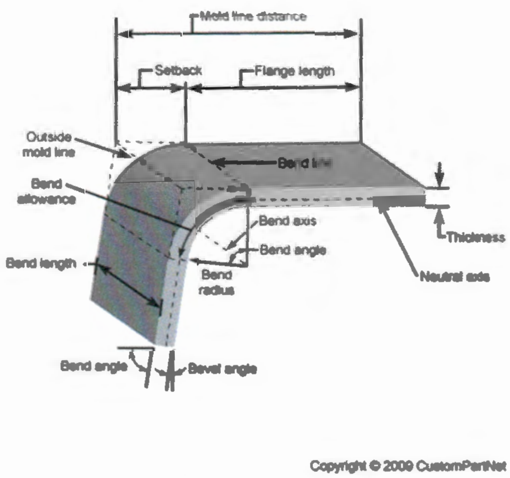
Speed of Belt w/ Sprocket Reduction = (2.1875 RPM) ÷ (20/10 (20T & 10T Sprockets))
= (2.1875) ÷ (2)
= 1.09 RPM

Belt Speed w/ Overall Reduction = (1.09 RPM) × (4" (Diam. of driven sprocket) × PI)
= (1.09) × (12.57)
= 13.7 inches / minute

The steel mesh belt used for the conveyor is a positive drive, no slip belt equipped with roller chain on each side of the belt. The roller chain on the belt is rested on 4" OD sprockets which are the same dimension as the driven sprocket. Since the size of the sprocket driven by the motor and the size of the sprockets supporting the chain are the same, using the 4" Diam. driven sprocket in the calculations will provide a belt speed adequate enough to where we can tune the desired speed of 3"/min. with the Variable Frequency Drive (VFD).

Calculations for Oven Box Bends on Brake Press

Given:



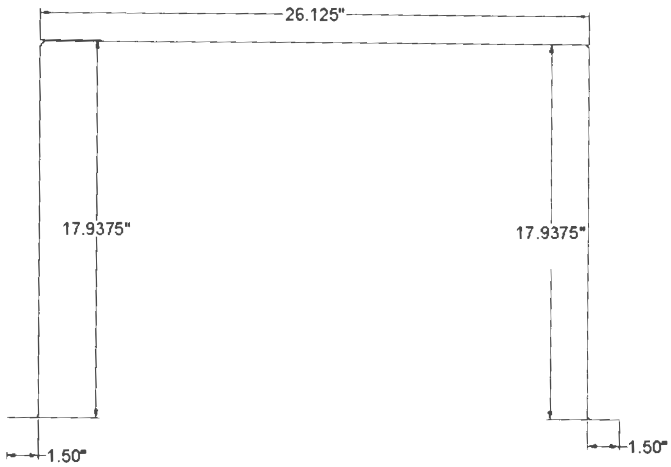
(Picture taken from www.jrmachinery.com)

- Outside Set Back = Tan (Angle/2) × (Radius × Thickness)
- Bend Allowance = Angle × (PI/180) × (Radius + K-Factor × Thickness)
- Bend Compensation = Bend Allowance – (2 × Set Back)
- True Length = Overall length (w/o Bend Comp.) + (Bend Comp. × (# of bends))
- K-Factor
  - Radius < Thickness, K = 0.25
  - Radius < (2 × Thickness), K = 0.33
  - Radius > (2 × Thickness), K = 0.5

Required:

Find the distance on the 16 GA stainless steel sheet for each 90 degree bend needed to form the desired box shape.

Solution:



- 16 GA stainless steel sheet thickness = 0.0625 inches
- Radius of each bend = 0.125 inches
- K – Factor:

TRY: Radius < (2 × Thickness)
= 0.125" < (2 × 0.0625")
= (0.125") = (0.125)

TRY: Radius > (2 × Thickness)
= 0.125" > (2 × 0.0625")
= (0.125") = (0.125")

So there is a need to interpolate and find the K-Factor in between the two given factors

= (0.33 (For Radius < (2 × Thickness)) + (0.5 (For Radius > (2 × Thickness)) ÷ (2)
= 0.42

- Overall Length (w/o bend comp.) = Length of all sides without bends
= 1.5" + 17.9375" + 26.125" + 17.9375" + 1.5"
= 65"

- Outside Set Back = Tan (Angle/2) × (Radius × Thickness)
= Tan (90/2) × (0.125" × 0.0625")
= 0.1875"

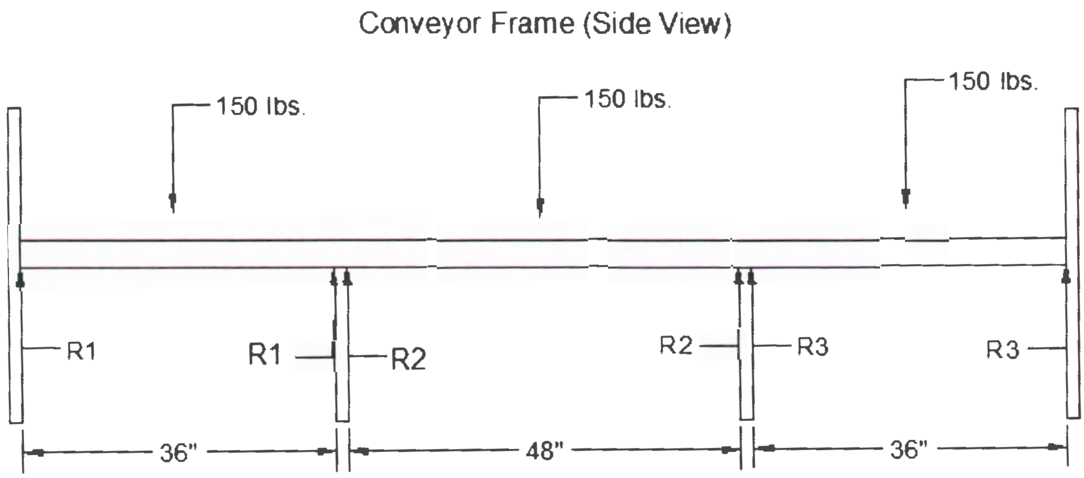
- Bend Allowance = Angle × (PI/180) × (Radius + K-Factor × Thickness)
= 90 × (PI/180) × (0.125" + 0.42 × 0.0625")
= 0.2376

- Bend Compensation = Bend Allowance – (2 × Set Back)
  = 0.2376 – (2 × 0.1875)
  = - 0.1374

- True Length = Overall length (w/o Bend Comp.) + (Bend Comp. × (# of bends))
  = 65" + (-0.1374 × 4)
  = 64.45"

<u>Point Load on Frame Calculations</u>

Given:



- 3" Channel Exposed to a load of 150 lbs. at 3 separate points
- C3 × 4.1 lbs. /ft.
- Section Modulus (S) = 1.10 cubic inches
- A36 Mild Steel allowable stress (Fb) = 22,000 psi

Required:

Find the maximum moment (Mmax) and the required steel section modulus (S) at each point load and determine if the 3" mild steel channel is adequate to support the load.

Solution:

<u>Load on R1</u>

R = V = (P/2) = (150 lbs. ÷ 2) = 75 lbs.

Mmax = ((P × L) ÷ 4)
= ((150 lbs. × 36") ÷ 4)
= 1,350 in. lbs.

$S = (Mmax \div Fb)$
$S = (1{,}350 \text{ in. lbs.} \div 22{,}000 \text{ psi})$
$S = 0.061$ cubic inches

Load on R2

$R = V = (P/2) = (150 \text{ lbs.} \div 2) = 75$ lbs.

$Mmax = ((P \times L) \div 4)$
$= ((150 \text{ lbs.} \times 48") \div 4)$
$= 1{,}800$ in. lbs.

$S = (Mmax \div Fb)$
$S = (1{,}800 \text{ in. lbs.} \div 22{,}000 \text{ psi})$
$S = 0.082$ cubic inches

Load on R3

$R = V = (P/2) = (150 \text{ lbs.} \div 2) = 75$ lbs.

$Mmax = ((P \times L) \div 4)$
$= ((150 \text{ lbs.} \times 36") \div 4)$
$= 1{,}350$ in. lbs.

$S = (Mmax \div Fb)$
$S = (1{,}350 \text{ in. lbs.} \div 22{,}000 \text{ psi})$
$S = 0.061$ cubic inches

*** From the above calculations we can determine that the load imposed on the 3" mild steel channel is more than adequate to support the 150 lb. load on the span areas of the frame by comparing the section modulus required and the section modulus of the steel channel used***

APPENDIX C

CONSTRUCTION DRAWINGS

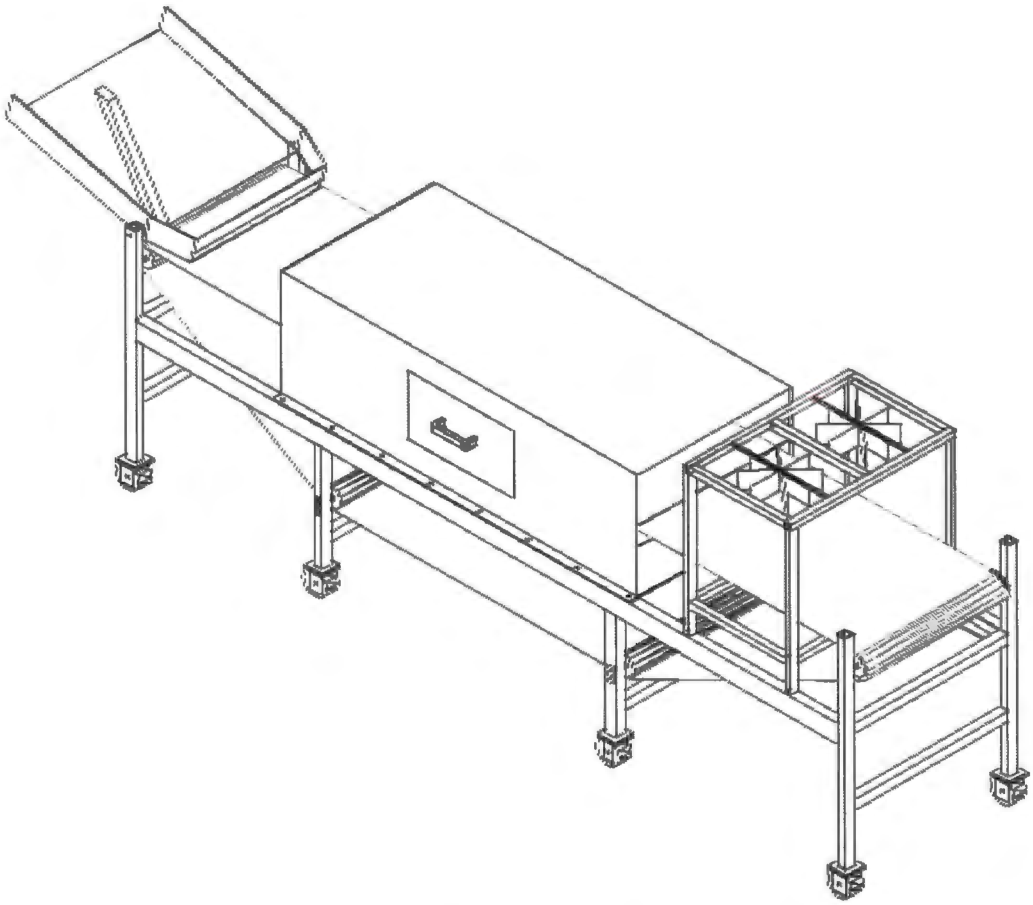


Figure 22. AUTOCAD Drawing of the Conveyor System
(Southeast Isometric View)

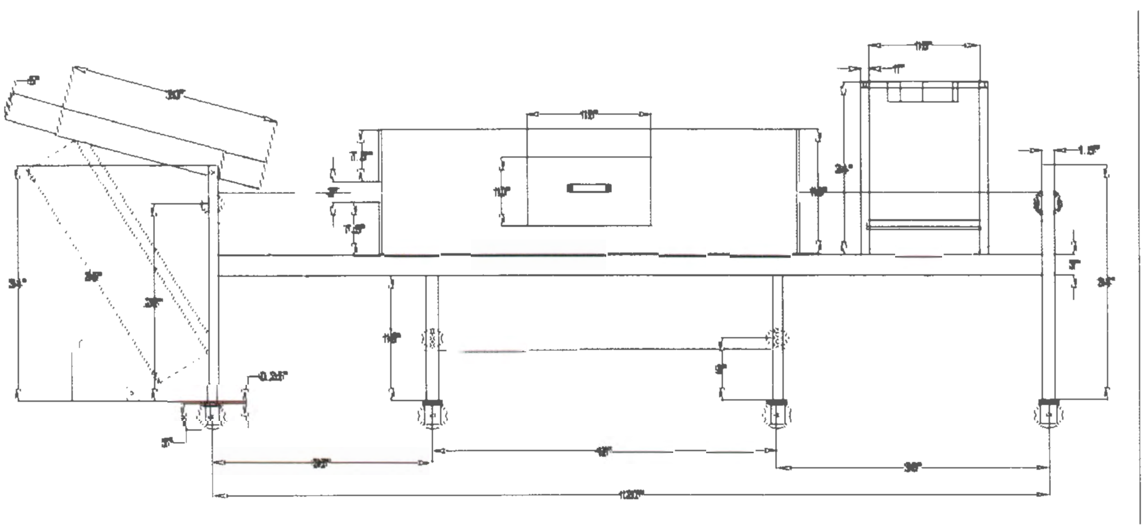


Figure 23. AUTOCAD Drawing of the Conveyor System
(Side View w/ Dimensions)

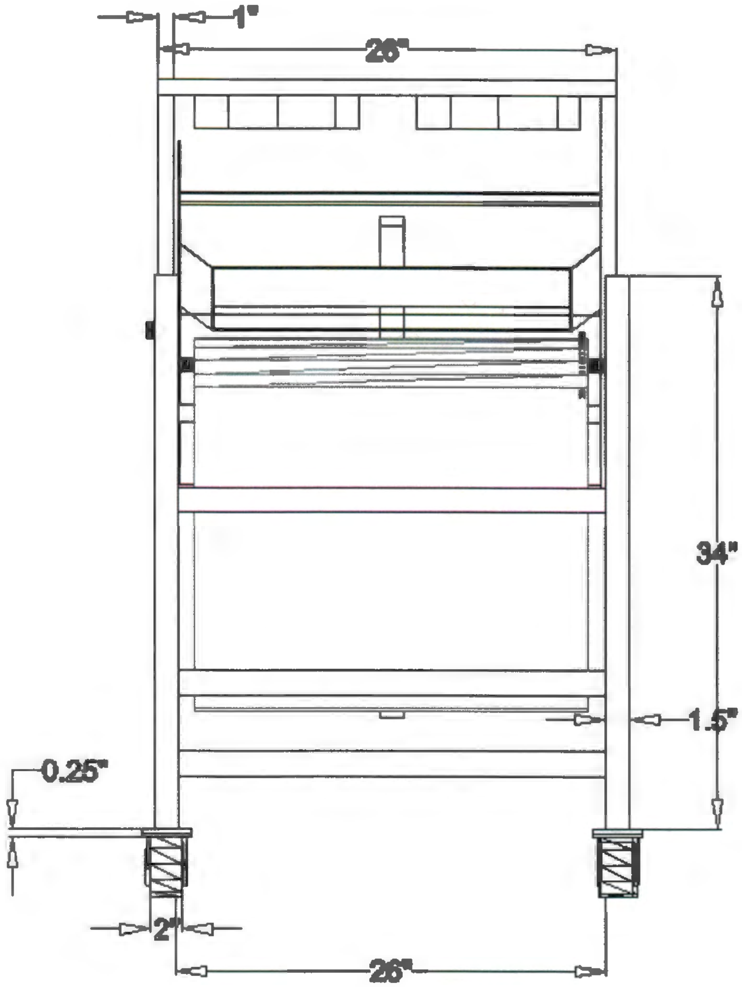


Figure 24. AUTOCAD Drawing of the Conveyor System
(Rear End View w/ Dimensions)