PLEASE NOTE THAT THE APPENDICES HAVE BEEN REMOVED FROM THIS VERSION OF THE REPORT BECAUSE OF SIZE CONSTRAINTS. THE COMPLETE FILE WAS TOO LARGE TO UPLOAD WITH ALL OF THE ASSOCIATED APPENDICES TO THE SITE.

April 29th, 2016

Cumberland Inc., GSI

Mr. Adam Weiss:

We were excited to work on this project that focuses on automating the opening and closing of commercial poultry feed bin gates. This report focuses on the final design for the mounting of a set of linear actuators on a system of three feed bins, as well as its associated costs and feasibility. Considerations for a tandem two bin set-up are also included.

A design utilizing one linear actuator per gate was selected. These linear actuators, in combination with proximity sensors on each bin, will tie into the current climate control system used in large commercial poultry houses through a set of relays. Both current concerns about weather durability and user safety of the mounting options, as well as feasibility of design, are included in the enclosed report. In order to determine the feasibility of the design, a number of factors were assessed. These include a force analysis of the necessary strength needed to open the gates, along with ease of installation, which were crucial in determination of the final recommendation. A cost estimate of the materials necessary to implement the design as well as a payback period cost analysis are also included in the packet.

The design described in this report is recommended because it meets the assessment criteria described above. This side-mounted actuator system design utilizes a slotted pivot arm mechanism to connect the actuator to the slide gate. The remaining portion of the unit will be installed between the slide gate between the plastic transition piece below the boot and the feed auger connections. This low cost alternative ($179.00 per bin) will not require the existing bins to be modified in any manner. Instead, this design acts as a retrofit kit, so no change in the design of Cumberland Inc's products will be required. Additionally, having the linear actuator housed in galvanized steel sheet metal ensures both weather durability and user safety.

Feel free to call us at 123-456-7890 with any questions you may have about the report.

Sincerely,

Richard Colley III *Richard Colley III*

Brock Daughtry *Brock Daughtry*

Holly Haber *Holly Haber*

Enclosure: Engineering Report

AUBURN UNIVERSITY

BIOSYSTEMS ENGINEERING

Project Title: Design of a Low-Cost Automated Feed Bin Gate System

Project Client: Adam Weiss, Cumberland Inc.

Group Members: Richard Colley III, Brock Daughtry, Holly Haber

April 29, 2016

A design report compiled for the fulfillment of course requirements in BSEN 4310: Senior Design in Biosystems Engineering.

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AUTOMATED FEED BIN GATE SYSTEM

Richard Colley III, Brock Daughtry, Holly Haber

EXECUTIVE SUMMARY

Poultry feed bins are commonly used in commercial broiler production to hold feed that is delivered to the houses where the birds are raised. One opportunity for technological advancement in this field is automating the slide gate opening at the bottom of the feed bin cone, which would eliminate lapses in feeding and ensure greater profit for both the farmer and the integrator. The overall goal of this senior design project is to produce a durable, cost-effective mechanism that will accurately sense the presence of feed in the hopper boot of the feed bins and automatically open and close the slide gate. This report focuses on a final design recommendation for an electrically actuated gate that can be installed on individual bins of two and three bin systems. Design costs were evaluated, resulting in a cost estimate of $179.00 per feed bin. The final product is one that is easily retrofitted to old systems and also smoothly incorporated into the construction of new bins.

BACKGROUND

The United States produces approximately 8.5 billion broilers annually (NASS). These birds are housed in 100,000 different broiler houses across the country. Large companies dominate the broiler production industry, vertically integrating and managing the processes associated with the chicken from the egg to the dinner plate. Integrator companies comprised of hatcheries, feed mills, and processing facilities allow the process of broiler production to transition smoothly between the various growth stages of the bird. Chicks and feed are provided by the integrator, while housing, utilities, and husbandry are provided by the grower. Farmers typically manage a farm with multiple houses usually around 500 feet in length, and capable of housing thousands of birds. These farmers manage the farm around the clock throughout the year, continuously monitoring the status of all houses under

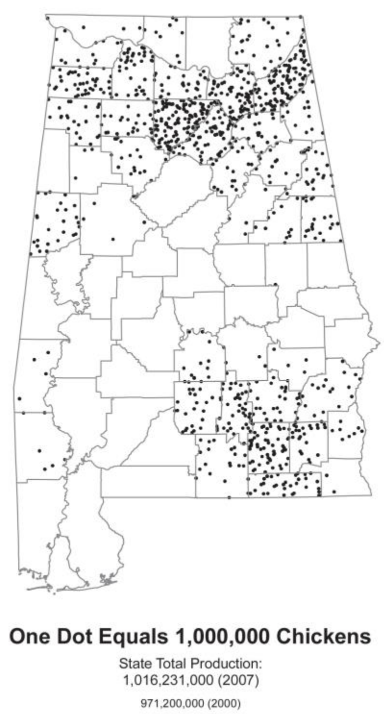

Figure 1. Distribution of Broiler Chickens (Alabama DOT, 2007)

his supervision. Typically the farmer will sign a contract with an integrator company who provides chicks and feed for the farmer. At the farmer's request, feed from the integrator's feed mill is delivered by truck to the farm and placed in large aluminum feed bins until ready to be consumed by the broilers.

Each poultry house, utilizes a mechanized feeding system to deliver pelleted feed to the birds. Feed is stored in the large aluminum bins outside of the houses and carried to the feed lines inside the house through a flexible auger system. These systems are comprised of two bin and three bin systems. Two bin systems empty into one poultry house, while the three bin system feeds two houses (Figures 2 and 3). In a typical operation, the first bin of the storage system feeds the auger conveyance system until empty, then additional bins are manually opened using slide gates at the base of the bins.

Note: Feed flows in both directions

Figure 2. Three bin, two house system

Note: Feed flows in one direction

Figure 3. Two bin, single house system (GSI, 2011)

Specific to feed management, the farmer currently goes out to the feed bins and uses a large pole with a rubber piece attached to the end and hits the bins in order to manually estimate the feed level inside of them. Differences in the sound of impact when striking indicate the level of feed in the bin. When the farmer determines the last bin is empty or close to empty, he or she either closes the slide on that bin and open another, or calls the feed truck driver to come refill the feed bins. The feed truck driver brings feed to the poultry farm and deposits it into the bin using an auger attached to the truck. He then uses a system of visual indicators, such as colored magnets, to express what type of feed he has put in the bin; green signifies starter feed, yellow for grower feed, and red for when finisher feed is in the bin (Figure 4).

Figure 4. Magnet indicators at King Trail Farms

Feed level monitoring is a process of continuous anxiety for the farmer and needs to be monitored all day and throughout the night. Load cells placed under the feed bin give a very accurate estimation of the total feed in the bin, but are very costly for the farmer and are difficult to install on existing farms. One opportunity for improvement in this system is automating the opening of these feed bins in a variable order based on bin indicators (Figure 3). If the metal slide gate can be automated, farms could save both time and money. Farmers are paid based on a bird weight to feed amount delivered ratio, so any amount of time broilers spend without feed results in a decrease of farm profit due to a reduction in broiler weight that cannot be compensated for in the life of that flock. Additionally, a farmer who does not have to manually open and close slide gates on his bins can spend that time working on other issues within the houses, hence, making his farm have an overall higher efficiency.

OVERVIEW OF FEEDING OPERATIONS

The team was able to gain a first-hand perspective on slide gate automation during a visit with a farmer at King Trail Farm, a commercial poultry production facility in Newsite, Alabama, that utilizes feeding systems very similar to those currently in production by Cumberland Inc. This visit allowed the team to observe just how instrumental the project will be in fluidizing the process of feed bin transitions, and its lasting effect on the poultry industry.

Cumberland Inc. is a member of the GSI Group of companies and is a major producer of commercial poultry production equipment, including feeding systems and storage. They produce many climate control systems, all of which have numerous monitoring and controlling capabilities over various parameters throughout the poultry facility. This design recommendation will utilize many components featured in their new Edge Controller. These control systems consist of hundreds of relay cards with multiple inputs, ranging from 0-5V, and are capable of easily handling any operation on the poultry farm. Sensors, mechanisms, and other methods of monitoring parameters are all hardwired into a dry contact relay in a central location on the house. From there, the controls can be monitored on any type of remote access device such as tablets and cell phones. Compatibility with the current controller allows the device to be easily inserted into existing systems without much change to the farmer’s current setup. This design recommendation will nicely complement the user-friendly interface by allowing the farmer customizable options for the bin sequence.

The other main component of the feeding systems includes the feed bins and associated equipment used to transition feed from these bins to the poultry houses where the birds consume the feed. Feed is stored in large metal feed bins that connect to flexible augers. These augers transition the feed to the houses. They connect to the bins below the boot transition and gate cover within an auger housing. The recommended design will fit between the auger housing and that boot transition with the addition of a small spacer to ensure a tight seal, making it easily retrofitted to the existing system.

EXISTING SYSTEM

Current feed delivery systems consist of the boot of the bin, black plastic transition piece, metal slide gate, and the auger housing. These components are depicted in Figure 5. Traditionally, the slide gate resides inside of the boot transition piece until acted on by a manually induced force to open the gate. This design recommendation will insert three pieces into the existing system that all combine into a solitary unit; a fabricated sheet metal frame, a spacer, and a slotted pivot arm. This compact unit fits between the auger housing and the boot transition with limited change in vertical height of the current system.

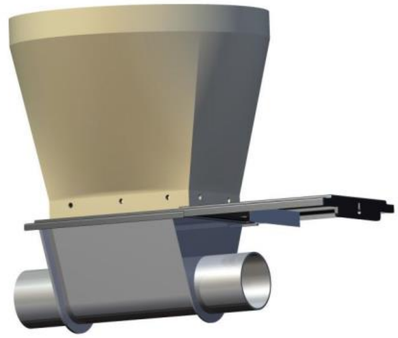

Figure 5. Existing components of feed bin boot systems

Monitoring systems are installed in poultry houses across the United States. These versatile systems control temperature while monitoring moisture, feeding rates, watering rates, and numerous other parameters. Cumberland Inc.'s Edge controller is an example of the type of systems installed in commercial poultry farms. The system utilizes a number of relay cards that are all housed in a central control box. Figure 5 shows the existing control system at King Trail Farms. The incorporation of this system into the design recommendation will ensure we meet our objective of compatibility with the existing controller. Open slots for new relay cards in the existing system are in place for user-friendly addition of control components. A farmer may wire multiple inputs at both low and high voltages. Proximity sensors for each of the respective bins will be hardwired into the relay, which will switch on and off the linear actuator system.

Figure 6. Control system with visible relay cards

Design objectives

1. **Mechanical**: Design a cost-effective, weather durable mechanism to be implemented in a commercial broiler facility's feed storage system that will automatically close the slide gate of three bulk feed bins while simultaneously opening the gate of the adjacent bin.
2. **Control Logic**: Create the framework to interface with the current climate control system that will initiate the start of the mechanism when the first feed bin is emptied, continuing through two subsequent bins, while also alerting the controller when all feed bins are empty.

JUSTIFICATION

At the start of the design process, both a proximity sensor and a comparative valve system were considered in a preliminary literature review. Cumberland Inc. currently manufactures a product called Flow Hammer (Figure *7*) that mounts to the collar portion of a poultry feed bin and serves to discourage feed bridging in the boot. The Flow Hammer utilizes a proximity sensor to monitor flow of feed through the boot of the bin and activates the mechanism when the flow of feed stops. These mounts were considered in a preliminary design for the project that was later ruled out; however, the proximity sensor remains incorporated into the final design.

Figure 7. Cumberland Inc. Flow Hammer and proximity sensor mounted to feed bin collar

Material Dynamics Inc. produces a pneumatically operated slide gate. This particular model is specified to the exact dimensions of the cone currently in place on Cumberland Inc.'s feed bins. A pneumatically actuated housing and mount for the feed bin will have to be custom made and a not-to-scale estimate of the product is provided in Appendix B. As a reference for the potential cost associated with a similar final design, a quote was requested by the team. They quoted a price of $3,300 in order for this company to manufacture this product to meet the dimensions and specifications needed for this particular application. This high price is due to the extreme amount of precision required. While, the current market offers a solution to the problem, it comes at a cost that is too high for the average farmer in the poultry industry. The goal of our design is to produce a low tech, low cost version of this slide gate for feed bin purposes.

Design Constraints

Existing bin configurations limit the amount of space available to install a mechanism (visible in Figure 5). Not pictured in Figure 8 for aesthetic appeal are support brackets linking the cone of the bin to the outer legs. These brackets further complicate the space constraints by using some of the 2.5 foot radius that could have been used for this project. Furthermore, when a flock cycle concludes and leftover feed resides in the tank, a truck driver will place a portable auger under the feed bin to collect the remaining feed. This portable auger limits the amount of space the current auger housing can drop vertically. A farmer at King Trail Farm was consulted in order to determine the maximum amount of space the housing could be displaced before it interfered with this system. Based on the observed tank system, a one inch drop was found to be the maximum allowable drop. This leaves the team 12.3” of space to work with in the vertical direction.

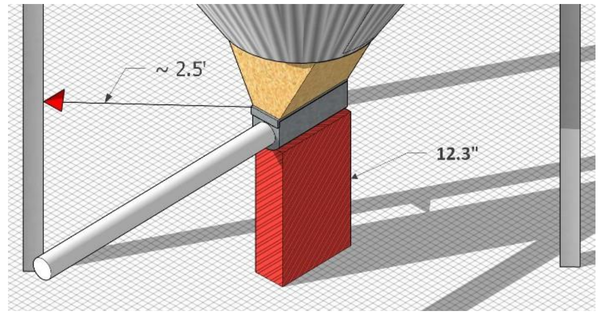

Figure 8. Clearance under feed bin and available installation space

In addition, commercial feed bins are exposed to a variety of climates. Poultry farms in the northern United States are exposed to ice, snow, and extreme cold while southern poultry farms deal with extreme heat and humidity. The pelleted feed used across the poultry industry can disintegrate throughout the filling and feeding process. This disintegration pushes a high dust content to the surrounding areas leading to buildup of particles on all exposed equipment. When the dust and moisture concerns are prevalent simultaneously, any moving pieces have a high chance of becoming corroded. Figure 9 displays the high levels of moisture and dust at King Trail Farm the team visited.


Figure 9. Exposure to moisture and high dust environment

Design Considerations

Downforce on Slide Gate

The feed bins observed during the visit to King Trail farm could hold approximately 35,000 lbs of feed. Such a large amount of feed will produce a significant downward force on the slide gate. Some of this force is mitigated by the formation of the cone, but there is still a substantial resistance that impedes the opening the slide gate. An analysis of the downward force on the gate and the force required to open the gate was conducted and can be seen in Appendix A. This component of the design process ensures that sufficient force is supplied by the linear actuator system to open and close the slide gates. From the analysis utilizing the Janssen equation (1) below, it was determined that a downward force of 289 lbs was enacted on the slide gate.

$$P_{!"} = \frac{!!"}{!!!}[1 - e^{(\frac{!!!"}{! \; *!})}] \quad (1)$$

where ρ is bulk density (lb/ft^3)

g is the gravitational constant (32.2 ft/sec)

A is the cross-sectional area of the bin (ft^2)

μμ is the wall friction coefficient fo the bin (unit-less)

c is the circumference (ft)

h is the vertical height between the bin apex and the transition (ft)

This friction force was then calculated by multiplying the downforce by the static coefficient of friction (2) collected from Bahnasawy & Mostafa (2011). A linear force of 145 lbs was determined to be the maximum force needed to open and close the slide gate of a feed bin filled to maximum capacity.

$$P_{!} = \mu\mu \, P_{!!} \quad (2)$$

where $\mu\mu = 0.5$ is the coefficient of static friction of pelleted feed and side of the bin

$P_{!!}$ is the vertical force on the slide gate (lbs)

SAFETY EMPHASIS

Several ASABE design standards were considered in the final design in order to ensure user safety. They include ANSI/ASAE S354.5 JAN2006 (R2011) (Safety for Farmstead Equipment) and S493.1 JUL2003 (R2012) (Guarding for Agricultural Equipment). For reference, they can be found in Appendix C. Safety for Farmstead Equipment applied primarily to the wiring components of the design as well as the ease of access for service. This standard discusses the need for an electrical shut off close to the controller for the slide gate system, along with electrical codes to which the wiring is subject. The control room of each poultry house typically has multiple power shut off switches that are already incorporated into the controller design and satisfies this standard. Also, per Safety for Farmstead Equipment, access for service should be designed for easy open and closing of the access. The retrofit acts as an add-on to the existing feeding system, requiring no change in design to the bins and thus causing no change in access for service. The second standard used, Guarding for Agricultural Equipment, provided restrictions on the type and extent of shielding needed. The sheet metal component with slide guide and actuator mount is bolted to the black plastic transition piece and slide gate shield. This ensures that it is rigidly fixed to the point that it cannot be removed without the use of a tool. Additionally, safety signs are included stating that the system should not be operated without ample clearance around the moving components.

FINAL DESIGN RECOMMENDATION

MECHANICAL

Overview

The galvanized steel slotted pivot arm, shown in Figure 9, is attached to a linear actuator at one end and the slide gate at the other to close the gate when the actuator extended and open the gate when the actuator retracts. An electromechanical actuator is housed within the fabricated sheet metal frame that is positioned in line with the existing system between the boot of the feed bin and the auger housing. A small spacer is placed between the plastic boot transition that exists on all feed bins, and the sheet metal housing for the linear actuator, to allow for a secure fit around existing bends on the boot transition. This design creates a very minimal loss of space, less than half an inch, between the bottom of the auger housing and the concrete slab all feed bins are installed on. This design also allows for the product to be easily installed on existing feed bins without having to make any changes to the existing construction.

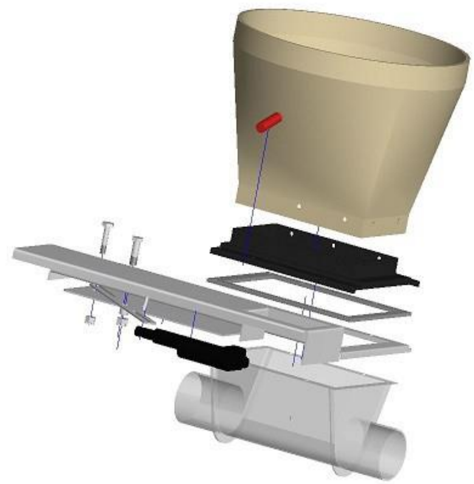

Figure 10. Exploded view of linear actuated sliding mechanism system with proximity sensor for single bin

Fabricated Sheet Metal Frame

The sheet metal frame braces and guides the actuated movement of the slide mechanism. Galvanized steel 11 gauge sheet metal is cut, bent, and punched minimally in order to reduce manufacturing costs. A more detailed flat pattern, ready to send to the manufacturer, may be found attached in Appendix G. These sliding tracks will also keep any lateral forces off the slide gate thereby keeping it from binding with the plastic transition piece as it slides in and out. The outer frame, which mounts the linear actuator is braced by bends on the lip of the piece.

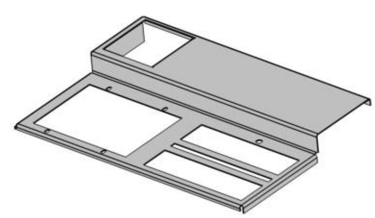

Figure 11. Fabricated sheet metal frame

Spacer

The spacer piece is a simple component of the design. As it exists, the black transition piece and gate cover has a lip that hangs over the auger housing. The spacer ensures a quality seal will still exist after the sheet metal piece is inserted below transition and above the housing. Further specifications of the piece, including the flat pattern are available for review in Appendix H.

Figure 12. Fabricated sheet metal spacer

Actuator

An electromechanical linear actuator was chosen to induce the linear motion needed throughout the design process. Our recommendation for a linear actuator is the Progressive Automotive PA-16 electromechanical linear actuator. This low profile, durable actuator has a load capacity of 330 lbs, a force well above the 145 lbs we need for our design. The PA-16 actuator, the pivot bar, and the sheet metal housing piece all have tracks cut in them during the manufacturing process to keep the slide, hinge, and actuator in line to ensure full opening and closure each time the slide needs to be opened and closed. Initially, design considerations were given to a track actuator, which reduced the overall length by 6 inches; however, concerns of buildup of feed particles, specifically when moisture is incorporated, in the track moved us to consider a telescoping actuator. The standard actuator recommended essentially behaves as a self-cleaning device; as the arm retracts into the cylinder, any buildup on the arm will be removed from the shaft. The actuator will be controlled by a proximity sensor connected to the plastic boot of the feed bin and logic statements written for Cumberland Inc.'s control systems.

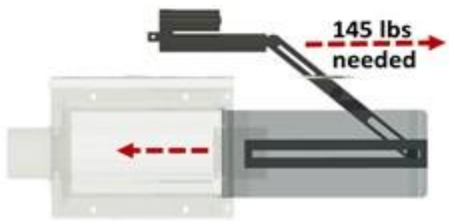

Figure 13. Overview of linear actuator, pivot bar, and sliding track

Slotted Pivot Arm Geometry

The slide design geometry allows the actuator to be offset from the linear path of motion away from the feed bin. It was calculated that a force of 145 lbs is needed at the point of actuation. Slide gate and actuator motion will be inverted, allowing the pivot point to be in a centrally located, and easily accessible position. Easily cut galvanized steel sheet metal comprises the slotted pivot arm, for ease of manufacturability and corrosion resistance. By locating the pivot point at a set position, the slide can travel 2.3 times the length of the actuator stroke; this allows the actuator load requirements to be minimal. Simple bolts with spacers draped over them ease the slide of the mechanism and easily travel through the guides both on the sheet metal piece as well as the actuator.

Maitenance Plan

Ensure the system is powered off completely before starting any maintenance procedures. It is recommended to annually inspect all bolts to make sure that none are excessively worn or damaged. Replace those that are broken or damaged as required. Monthly lubricate links and pins with a light machine oil. Examine the sheet metal frame, spacer, and slotted pivot arm for rust or physical damage yearly and make any necessary replacements or repairs at that time.

Once the physical inspection portion of preventative maintenance is complete, check functioning of the linear actuator. Select the 'service' function on the on the Edge controller to complete this check. Ensure that extending and retracting of the linear actuator is not impeded. If needed, refer to actuator repair information provided by the manufacturer.

ELECTRICAL

Proximity Sensor

The CT1-AP-1A capacitive proximity sensor from Automation Direct was chosen to monitor feed levels in the bins. A proximity sensor does not require contact with the feed it's monitoring, allowing it to be mounted to the outside of the feed bin. This eliminates the chance of impeding the flow of feed. Additionally, a proximity sensor would not be affected by the presence of dust in and around the bin, like a laser sensor would be for example. The Flow Hammer product that is currently in production by Cumberland Inc. utilizes a proximity sensor to monitor flow of feed through bins in order to detect bridging, sending a signal to the Flow Hammer to agitate the bin. This sensor is adapted to standard feed bins, allowing for easy installation. Incorporating this sensor into the final design reduces the overall manufacturing cost of the product.

Figure 14. CT1-AP-1A capacitive proximity sensor

Control Logic

In order to fulfill design objective 2, the sensory system must interface with the existing climate control system currently in place at the farm. Because the exact type of climate control system utilized by each farm may vary, a series of logic statements were generated that provide a methodology to be later programmed into each specific system. At startup of the system as well as after each feed delivery, farmers will be able to select the sequence they want the bins to be emptied in based on the current situation at that particular house. This can vary depending on feed type in each bin, for example. After the sensor reads the last bin as empty, the farmer will be alerted to the need for refilling of the bins and the system will require a new bin order input. Logic statements are provided for both a two bin system and well as the larger three bin system, the may be seen on the following page:

Table 1. Control Logic for Two Bin System

Two bins, one house
**Note, in logic below, order of bins chosen is assumed as A, B*

Upon power up, close all gates and go to program

program:
User input on touch screen control panel of Edge Controller
Input dialogue box: "Which bin would you like to begin with?" [ ]
User will pick A or B from touch screen
Go to (***loop***)

loop:
Read proximity sensor from [user selection]
If sensor reads [A] as (full), open gate A (relay on) and go to next step
If sensor reads [A] as (full) and relay is on, keep relay A on and go to (***end***)
Or if sensor reads [A] as (empty), close gate A (relay off) and open gate B (relay on) and proceed to next step
Read proximity sensor from second sensor
If sensor reads [B] as full and relay is on, keep relay B on and go to (***end***)
Or if sensor reads [B] as empty, send alert for refill and go to (***reset***)

end:
wait 10 minutes and restart (***loop***)

reset:
go back to input dialogue box

Table 2. Control Logic for Three Bin System

Three bins shared between two houses
*Note, in logic below, order of bins chosen is assumed as A, B, C

Upon power up, close all gates and go to (program)

program:
User input on touch screen control panel of Edge Controller
Input dialogue box 1: "Which bin would you like to begin with?" [ ], go to dialogue box 2 selection
User will pick A, B, or C from touch screen
Input dialogue box 2: "Which bin would you like to open second?", go to dialogue box 3 selection
User will pick A, B, or C from touch screen
Input dialogue box 3: "Which bin would you like to open last?"
User will pick A, B, or C from touch screen
Go to (***loop***)

loop:
Read proximity sensor from [first user selection]
If sensor reads [A] as (full), open gate A (relay on) and go to next step
If sensor reads [A] as (full) and relay is on, keep relay A on and go to (***end***)
Or if sensor reads [A] as (empty), close gate A (relay off) and open gate B (relay on) and proceed to next step
Read proximity sensor from [second user selection]
If sensor reads [B] as (full) and relay is on, keep relay B on and go to (***end***)
Or if sensor reads [B] as empty, close gate B (relay off) and open gate C (relay on) and proceed to next step
Read proximity sensor from [third user selection]
If sensor reads [C] as full and relay is on, keep relay C on and go to (***end***)
Or if sensor reads [C] as empty, send alert for refill and go to (***reset***)

end:
wait 10 minutes and restart (***loop***)

reset:
go back to input dialogue box selection

Wiring Schematic

All electrical components from the design recommendation are hardwired straight into the control unit. Relay cards in the controller link the linear actuator with the proximity sensor, these cards accept an input of 0 - 5 Volts and recognize electrical signals to initiate actuation of the gate. The wiring schematic is displayed below in Figure 15:

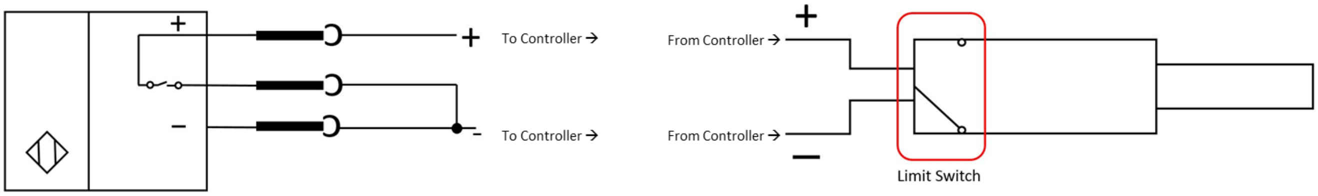

Figure 15. Capacitive proximity switch and linear actuator wiring Schematic

Cost Estimate

Table 3 below details an estimate of the cost for the suggested final design. The estimated final cost of this design is $179.00 per bin ($358.00 for a two bin system and $*573* for a three bin system). Comprehensive calculations of the manufacturing costs are available in Appendix I.

Table 3. General cost estimate per bin

Unit/Operation	Cost Per Unit (U.S. Dollars)	Number of Units	Total Cost (U.S. Dollars) for Unit/Operation
Linear Actuator*	56/actuator	1	56.00
11 Ga. Galvanized Steel Sheet Metal (4'x2')**	18	1	18.00
Misc. Hardware	3	1	3.00
Wiring Kit*	12	1	12.00
Proximity Sensor*	30	1	30.00
Manufacturing Costs	60	-	60.00
Total Cost of Alternative	-	-	179.00

Source: ASABE Quarter Scale document (Appendix E)
*-Estimated cost is 40% of retail value
**-Estimated cost is 70% of retail value

One unique characteristic of this recommended design is the market potential it has in the poultry industry. The United States has around 100,000 poultry houses that are currently operational (NASS 2015). If an assumption is made that 50% of the houses use two bin feeding systems and 50% of the houses use three bin feeding systems, then there is an estimated

175,000 feed bin slide gates in the country. Figure 16 illustrates various profit margins and profit totals based on the team’s final cost analysis for the recommendation, found in Table 3. Conservatively estimating that 5% of the market is comprised of newly constructed poultry houses, implementing this system into only these houses with a profit margin set at 10% produces a net profit of $78,750 for the company.

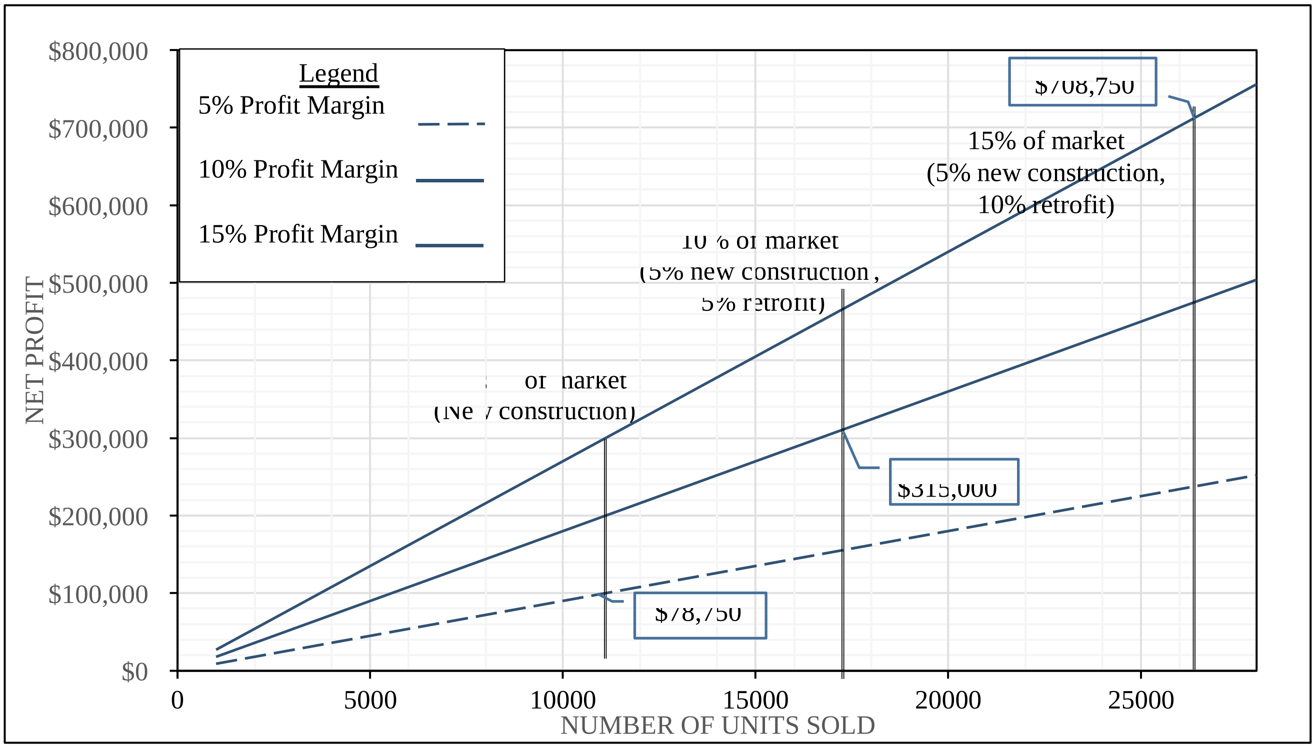

Figure 16. Market Potential and Profitability of Automated Feed Bin Opening System

Note: Cost analysis above based on estimates provided by our team. Profit margins and market percentages may need to be adjusted accordingly at Cumberland Inc.’s discretion.

Based on the profitability analysis conducted, our recommendation to Cumberland Inc. is to target a set profit margin of 10%. Implementing the automated slide gate system for 10% of the total market (5% of newly constructed poultry houses and 5% of existing systems as retrofit kits) with this target will provide an estimated total net profit of $315,000.

SUMMARY

The final design developed utilizes a PA-16 linear actuator to automate movement of the slide gate and a proximity sensor currently in production by Cumberland Inc. to monitor feed levels in each bin. Tying into the climate control system of the poultry house through a set of relays will allow the ‘smart’ components of the design to initiate

movement of the actuator, which is pinned to a slotted pivot arm that pulls and pushes on the slide gate. A thin sheet metal frame installed between the boot transition of the feed bin and the auger housing houses the actuator, mounting it to the side of the bin and shielding it to ensure safety.

The mechanism detailed in this design report will be very attractive to a consumer because it's cost-effective and can be easily retrofitted to existing systems. Because of this, the product could be sold for new construction or as a retrofit kit to bins currently in operation. In addition to the short payback period from the increased efficiency gained with installation of the system, the relatively low cost of production, under $200 per bin, will keep the purchasing price reasonable for the farmer. No major changes in the set-up of the feeding system currently in place will need to be made which ensures ease of installation. Additionally, ample spacing under the bin makes sure filling is not impeded, which further encourage implementation of this new system.

Meeting the constraints set out as well as coming in under budget, this compact configuration results in a cost-affordable and space saving product that will benefit the commercial poultry industry greatly. Due to the cost effective and durable design, our product may be implemented in a variety of agricultural industries including: swine production, generic feed storage and many other agricultural uses.

ACKNOWLEDGEMENTS

The design team would like to acknowledge Dr. Jeremiah Davis of Auburn University and Dr. Jess Campbell of the National Poultry Technology Center for all of their continued guidance and support through the senior design process, Mr. Jim Branch of King Trail Farms for facilitating the site visit to his poultry farm, as well as Mr. Adam Weiss of Cumberland Inc. for his integral role in the project development.

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APPENDICES

- Appendix A: Force Analysis Calculations
- Appendix B: Material Dynamics, Inc Quote
- Appendix C: Standards-Title Pages and Highlights
- Appendix D: Linear Actuator Specifications
- Appendix E: ASABE Quarter-Scale Pricing Sheet
- Appendix F: Proximity Sensor Specifications
- Appendix G: Sheet Metal Bracing Flat Pattern
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- Appendix I: Manufacturing Cost Calculations