Design of Manual Livestock Restraint Chute Intended for Stunning Procedures

TATONKA INNOVATIONS

Tonkawa, Oklahoma

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Sponsored by: Brian Lane, Tonkawa Processing Corp

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Abstract

As a recipient of the Oklahoma Meat Processing Grant intended to provide supply chain improvements during the COVID-19 pandemic, Tonkawa Processing Corp. has chosen to construct new facilities to better serve their customers. Tonkawa Processing Corp. is a small livestock processing company located in Tonkawa, Oklahoma. At their facilities, they process all sizes of animals, ranging from sheep and goats to bison and cattle. Finding a structure suitable for this range of species is not only difficult, but also expensive. A team of students from Dr. Weckler's BAE Senior Design course was tasked to design and build a multi-species knock box.

This design meets the need faced by a majority of smaller packing facilities when harvesting multiple species. Since many small processors serve a diverse group of local producers, they usually harvest a more diverse group of livestock. This design will allow Tonkawa Processing Corps. to have a system which will make restraining livestock efficient and safe for both employees and livestock alike.

Mission Statement

Tatonka Innovations is dedicated to feeding the growing world population with quality and efficiency. We pride ourselves in designing and delivering processes for our clients, holding safety and animal welfare paramount.

Sponsor Background

Tonkawa Processing Corp is a meat processing facility in Tonkawa, Oklahoma. They currently harvest and process sheep, goats, pigs, cattle, and bison; in addition to this, they will also begin processing deer. It is owned and operated by Mr. Brian Lane and his wife, Theresa.

As a recipient of the Oklahoma Meat Processing Grant from the Oklahoma Department of Agriculture, Food and Forestry, Tonkawa Processing Corp has just built a brand new facility. This grant was designed to provide food supply chain improvements during the COVID-19 pandemic.

Introduction to the Problem

Problem Statement

To design and fabricate a chute system for Tonkawa Processing, Corp which allows for safe and efficient work to be completed during harvest. The solution should allow for manageable processing of hogs, sheep, cattle, and bison with the same design.

Work Breakdown Structure

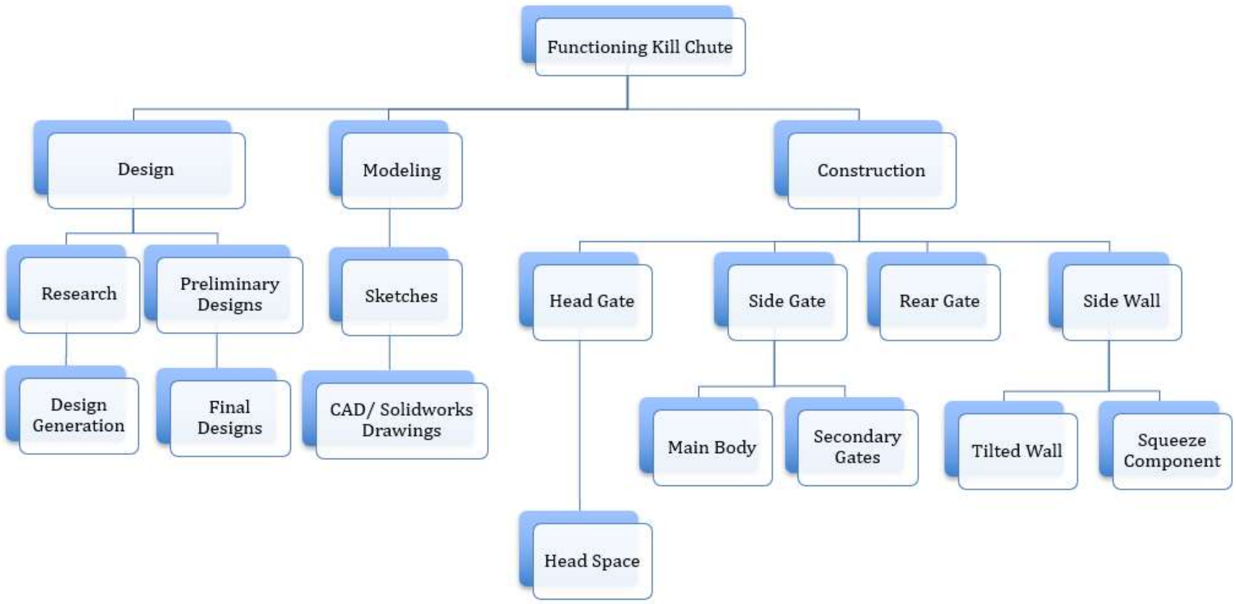

Figure 1. Image of Work Breakdown Structure Diagram

Statement of Work

Project Scope

The primary scope of this project is the design of a chute used for sheep, goats, swine, cattle, and bison. The dimensions will be based on accepted size standards of the above species'. The chute design will consist of the following parts:

Head gate:

Crash gate for large species

Secondary gate for smaller species

Side gate:

Standard swinging gate

Contains smaller gates (secondary head gate and access gates)

Rear gate:

Standard rear gate

Side panel:

Tilted wall

Squeeze component controlled with slack adjuster

The deliverables include Solidworks drawings of the design assembly and the chute is to be delivered to Tonkawa Processing upon completion.

Key Assumptions

Based on the standards collected on livestock measurements, the width of the chute must accommodate a range from 12 inches to 37 inches, the length must accommodate a range from 55 inches to 85 inches, and the height must accommodate up to 61 inches.

Additionally, it is assumed the facility where the chute will be placed will follow standard lighting, ventilation, and cleaning standards.

Safety

Due to the nature and intended use of this design, safety of all involved parties will be held paramount. During construction, proper safety measures will be taken for each task of assembly. Once the design is assembled and functioning, employees of Tonkawa Processing Corps. should be able to use it with confidence in regard to their safety and efficiency abilities. Additionally, livestock being sent through the completed chute should not actively relay their stress (ie. vocalizing, baulking, etc) during handling before stunning.

Technical Research

Before beginning the design process, research was conducted regarding current technology and practices used in the meat processing industry. A search was also conducted for industry standards, codes, and regulations.

Patent Searches

Patent US20180146639

Cattle Squeeze Chute Door Opening Assembly

This particular cattle squeeze chute door opening assembly was invented by Gary R. Hager, and published as a patent on January 7, 2020. This patent relates to the door opening device.

The Cattle Squeeze Chute Door Opening Assembly shows the composition of a restraint chute. This assembly includes a self closing door which serves as a head gate. The frame of the door is attached adjacent to the open-end of the cattle squeeze chute. The door frame provides constant support from the sidewall and consists of the upper frame and the lower frame. The gate is connected to the door's support in a way that can be rotated, allowing the door to be opened and closed. A foot actuator is attached to the door frame. When the foot actuator is pressed, the gate is lifted, and thus moves from the closed position to the opened position.

The door frame is attached to the adjacent open-end of a cattle squeeze chute with the support post separate from the relevant sidewall. The space between the support and the sidewall creates an access point. The door frame supports a gate which rotates between the open and closed positions. The foot actuator, consisting of a mount attached to the lower frame and a lift plate with the first and second ends, is located adjacent to the corresponding lower frame member. The foot actuator mounted on the corresponding door frame, when operated, moves the gate up from the raised and closed position. The first end extended over the lower frame is placed on the mount when the gate is in the closed position. The second end extends away from the mount, and moves upward as the gate moves down. When the second end moves downward, the gate rises and rotates outside the door frame.

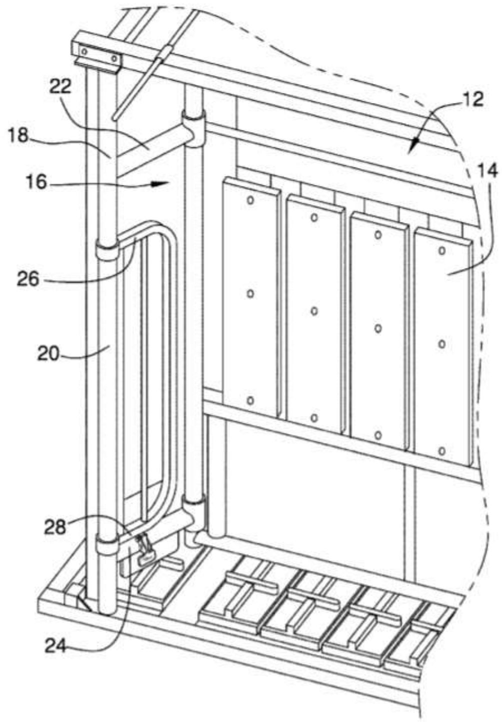

Figure 2. The door of the cattle squeeze chute (Hager, 2020)

The cattle squeeze chute door opening assembly is relevant to one of the things Tatonka Innovations needs to design for the meat processing facility. Specifically, a way to utilize a head gate as a means of restraining the livestock prior to stunning.

<u>Patent US20050132978A1</u>

<u>Livestock squeeze chute and headgate</u>

Livestock Squeeze Chute and Headgate was filed as a patent by Bentz James W. on December 23, 2003, and published on June 23, 2005. This patent relates to the cattle squeeze chute and the device for holding livestock during surgery. These devices should have a fast closing mechanism that, when the livestock is moved into the chute and tries to escape to the other side, closes quickly. When a person operates a chute while working with an animal, controls that open and close the chute entrance should be easily accessible and placed for operator comfort and convenience. If necessary, it should be reversible so that the user can operate on either side.

This patent shows the head gate was designed to be attached to the end frame or be a separate, movable unit. The design uses a mechanism that opens and closes the gate by raising or lowering rods along the neck opening. The neck bars have one end attached to the base of the frame and another end attached to the top of the door. Each bar consists of the lower and upper ends connected by pivots to each other. If the second end of the bar is raised, each pivot is pulled together, which causes the head gate to close. When the neck bar is pressed down, the pivots move away from each other and release the animal. A hydraulic cylinder can be used as a closing mechanism for opening and closing the headgate’s neck bar. Hydraulic pressure devices can also be used to move one of the sidewalls in and out. In addition to using hydraulic machines, the headgate can be devised using mechanically actuated devices such as simple handles.

This system also describes the sidewalls, which have vertical rods along the length and are tilted toward each other at the base. This particular method of operation uses a hydraulic actuator with the first sidewall. For this, the first side wall is pushed towards the second sidewall, making the animal immobilized. The first sidewall is hinged at the lower edge, while the upper edge is moved by the hydraulic mechanism. The second lateral wall is then secured between the two end frames. The cattle cannot move the side of the squeeze chute, which prevents an animal from pushing down the squeeze chute wall and injuring the operator.

The livestock squeeze chute also contains a rear gate attached to the entry and frame. The rear gate can be connected in the same way as the headgate. Additionally, it is similarly constructed and can be actuated hydraulically or manually. This composition means the headgate can be on either end. In other words, the squeeze chute can be used in a direction that is convenient for the operator to work in.

The control arm attached to the hydraulic control unit can also be moved for the operator’s convenience. It should be placed under the operator’s heart, which allows the operator to work without reaching up, thereby preventing arm fatigue. Of course, since the control arm’s position can be moved, it can be adjusted as needed by the operator. The control arm is also designed to move left and right through the one lateral wall, which can be dented according to the operator's preference. The control arm consists of the control device related to the headgate, the first side, and the rear gate.

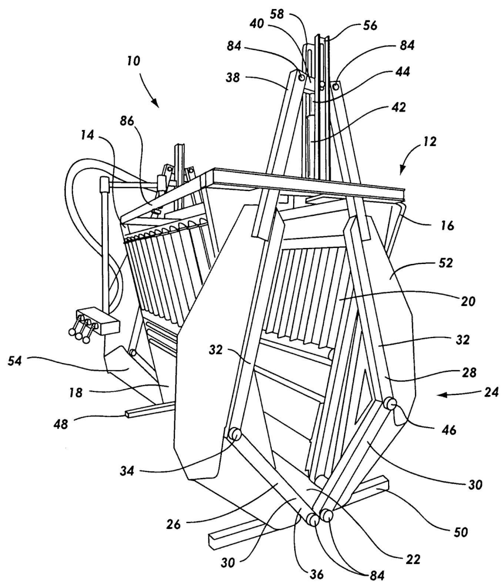

Figure 3. Cattle squeeze chute and headgate (Bentz, 2005)

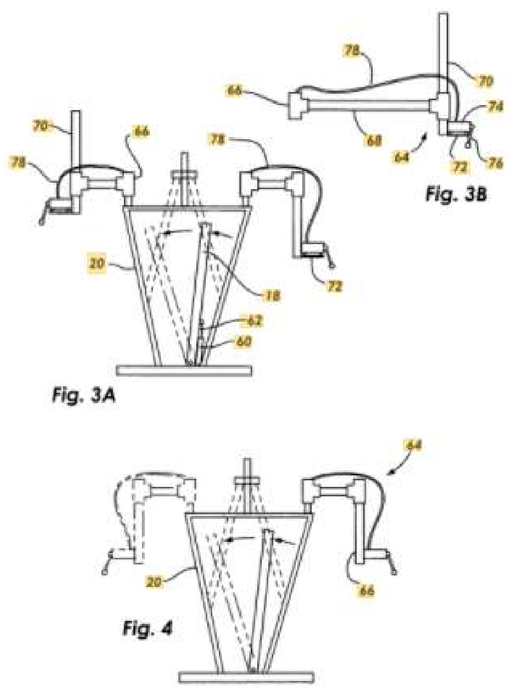

Figure 4. The operating mechanism of the neck bar and the pivots. (Bentz, 2005)

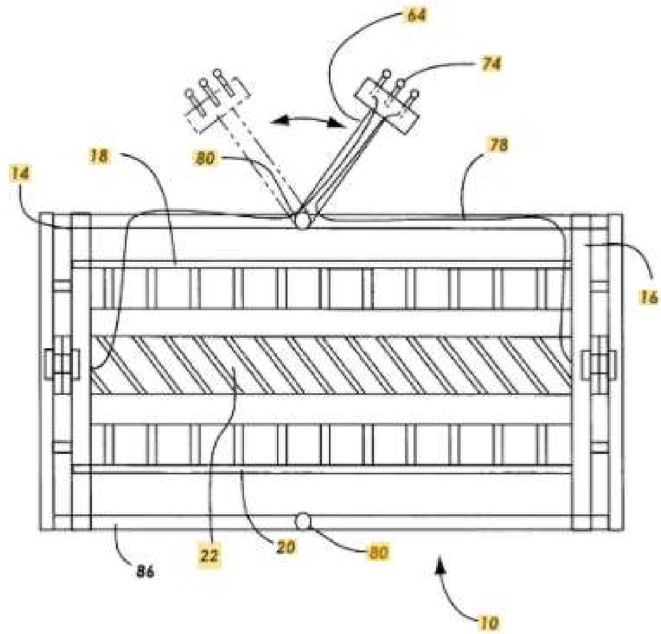

Figure 5. The side view of the neck bar's operating mechanism (Bentz, 2005)

As described above, by raising the neck bar, pivots gather and constrict the animal's neck. By pressing down on the neck bar, pivots are unfolded and releases the animal. This design is typically used for medical purposes. This may not seem relevant to the livestock kill chute, but all chutes and headgates have similar operating methods. This patent shows a successful combination of designs that serves a good reference point of design.

Design of Manual Cattle Chute

In addition, the team referred to the "Design of the Manual Cattle Chute" written by the Biosystems and Agricultural Engineering senior design group at Oklahoma State University in 2006. Custom Agricultural Solutions (CAS) designed a manually operated cattle chute. CAS completed extensive research related to animal size, health, and the force exerted on each component of the chute.

Headgate

CAS designed a two lever latch system to achieve a stable headgate latch mechanism. This design has front and rear latches to limit headgate panel movement.

The latches are operated using springs so each latch is closed without operator input. Each latch can operate separately from the selected lever. As shown in Figure 6, this design allows the latch to move downward and fix the headgate.

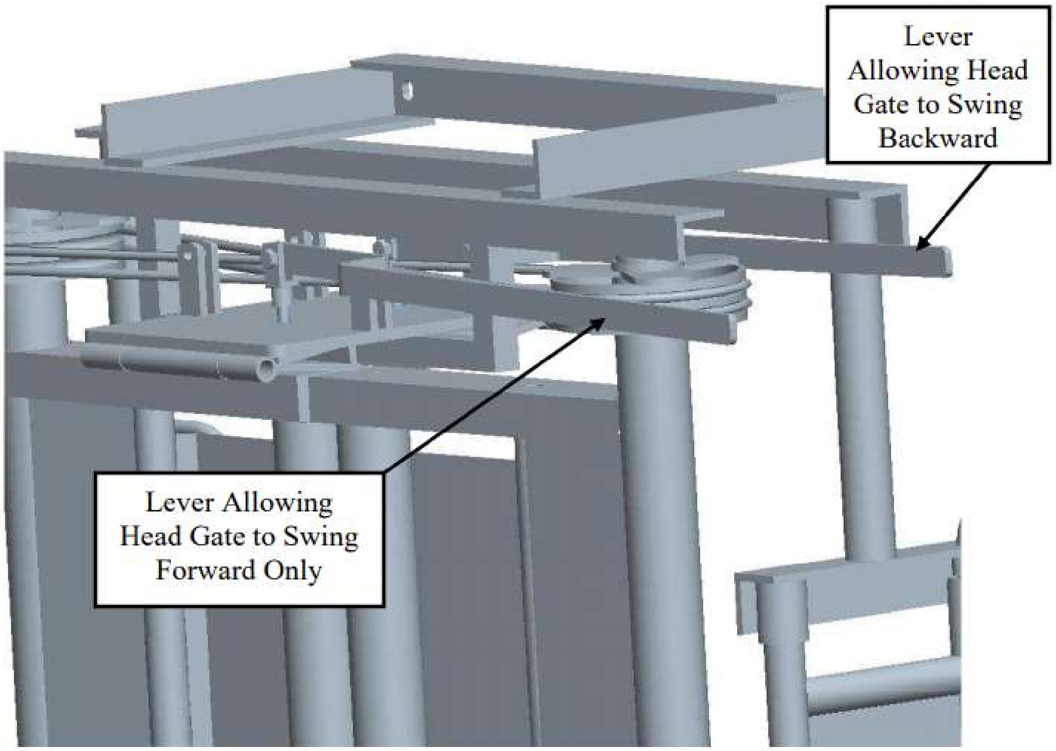

Figure 6. Headgate lever

In consultation with many producers, the main interest was access to the neck of cattle. The neck is where a large amount of drugs are administered. To address this issue, CAS designed a mobile neck access door that can open or be removed. Pulling the latch and swinging the gate forward as shown in Figure 7 opens the neck access door of the head gate easily. The gate can then be removed by pulling the top pivot after removing the gate from the bottom pivot.

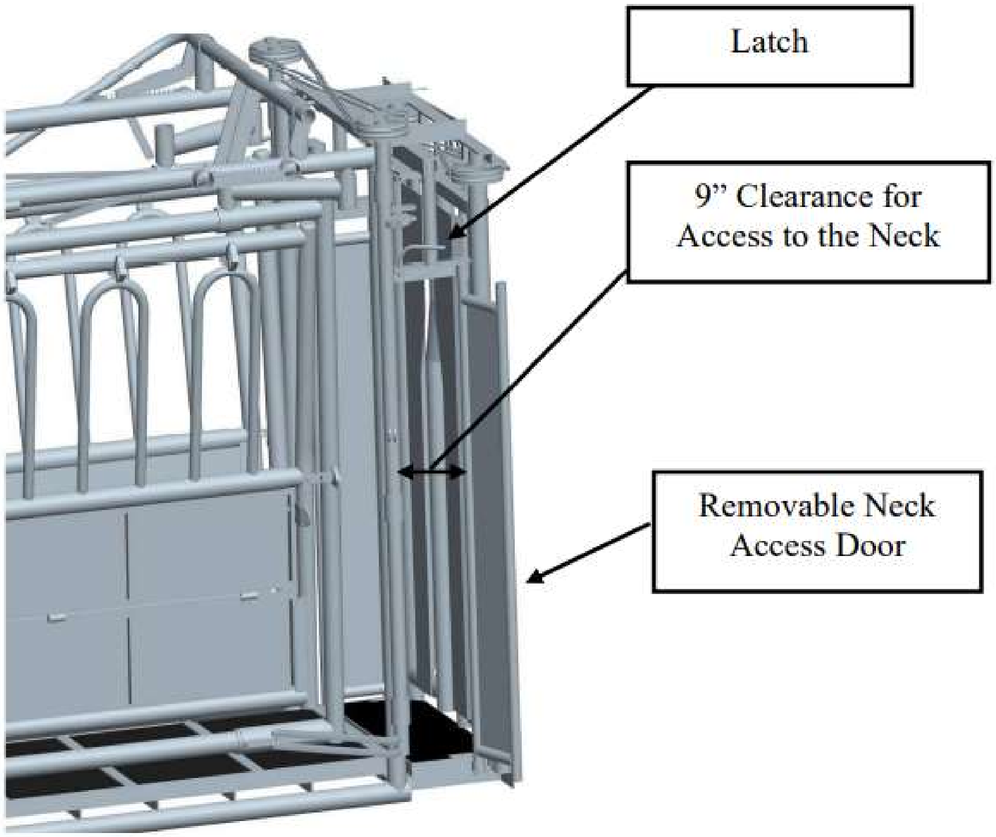

Figure 7. Neck Access Door

Squeeze Mechanism

CAS adopted an inward and forward-moving squeeze mechanism design within their chute. Mounting each squeeze panel on a pair of links that rotate equally together will squeeze both sides together. This provides a symmetrical squeeze. The compression is separated into the upper and lower compression sections. Each squeeze is operated by simply pulling the lever. If desired, the operator can pull the lever that operates the top part of the squeeze, and the bottom follows accordingly. In this mode, the squeeze panel moves cohesively, allowing the operator to efficiently operate the squeeze individually.

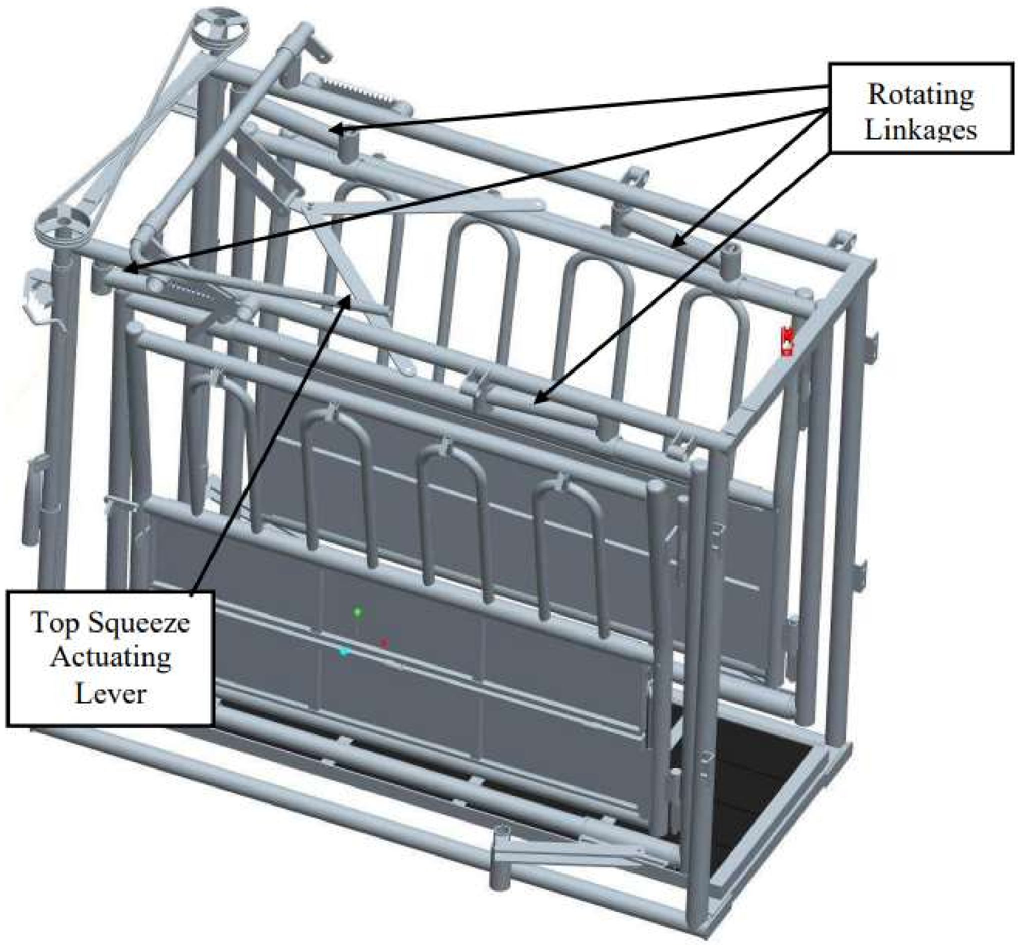

Figure 8. Squeeze implement

Literature Review

In addition to the considered patents, research was also completed on various technologies currently used within the industry. These technologies used within commercialized processes have been updated immensely over the last century. The main design concepts used in a multitude of operations include stationary chutes, with minimal moving parts, and squeeze chutes, with a moving side wall piece.

Stationary Chute

This system is similar to the current design in place at Tonkawa meats. However, there are slight modifications in terms of the moving parts being placed at the front of the chute, rather than the back. In the design, the head gate is on a rail system and is moved to meet the head of the animal. This process allows for the animal to stay in a single position and typically results in little reaction from the animal (Grandin, 2018).

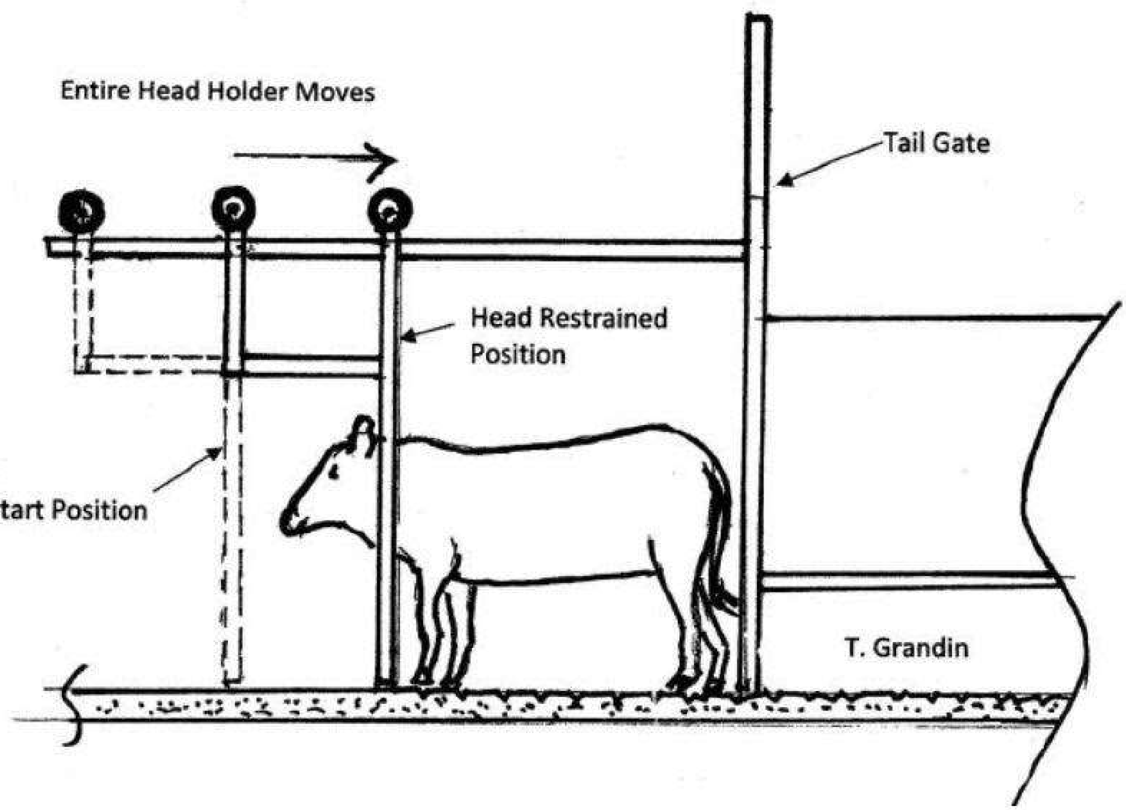

Figure 9. Stationary cattle chute with moving head holder design (Grandin, 2018)

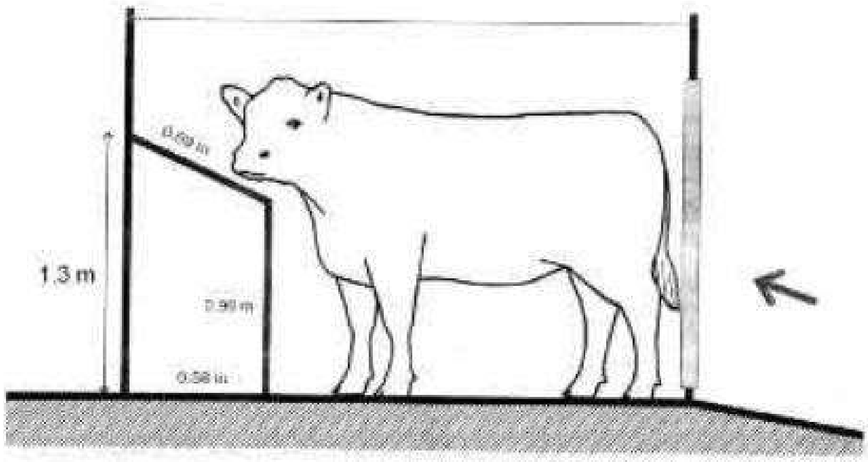

Figure 10. Stationary slanted block to hold cattle heads in knock chute (Grandin, 2018)

Another technology used within stationary chutes includes a mechanism to raise the head of the animal. If it is expected animals of similar sizes are being stunned, a stationary, slanted block can be put in place to hold the head up for proper stunning access (Grandin, 2018). The stationary block concept is illustrated in Figure 10. For a variety of animal species or sizes of animals, a swinging panel that can be locked at a variety of heights is useful (Grandin, 2018). The adjustable swinging panel is pictured in Figure 11.

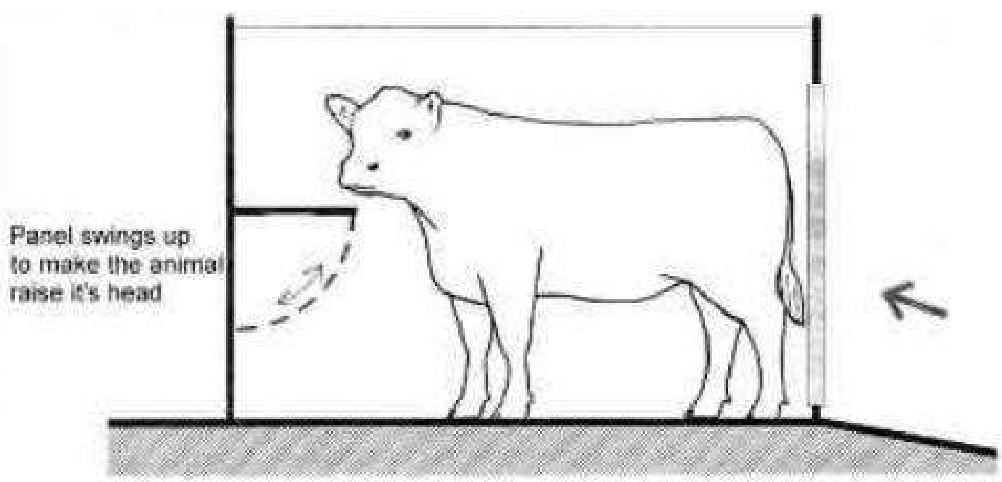

Figure 11. Swinging panel to hold cattle heads in knock chute (Grandin, 2018)

Moreover, another technology used within stationary chutes is a slanted wall. With the slanted wall, the angle aids the animal to lay or roll into a more convenient position to be shackled once stunned (Grandin, 2018). Thus, leading to safer and more efficient processing to be completed postmortem.

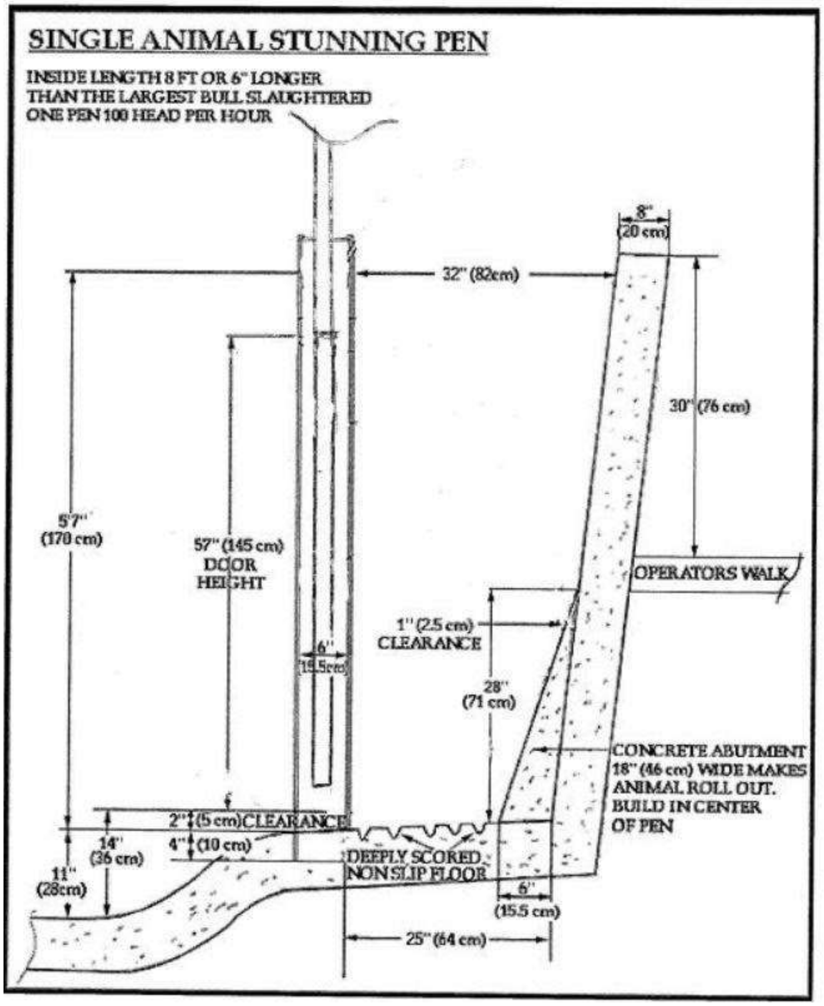

Figure 12. Stationary chute with slanted concrete wall and lifting gate design (Grandin, 2018)

<u>Squeeze Chute</u>

Not only do squeeze chutes hold the animal in place for restraining purposes, they can also aid with animal temperament. The squeezing of the animal provides a calming effect since it allows them to feel secure (Parish). Depending on the manufacturer or design, exits of the squeeze chute include points from the front and side of the equipment, both usually being hinged doors. Squeeze chutes include multiple levers to open, close, and squeeze different parts of the chute (Parish). With this, only one person is required to operate the chute (Parish). While it is not uncommon for producers to manufacture their own chute, there are a plethora of options that can be considered when purchasing one that has been commercially prepared (Parish 2015). Squeeze chutes are very popular throughout the industry since they can effectively restrain cattle, improve processing efficiency, and increase the overall safety (Parish 2015).

Engineering Specifications

For the initial design stages, assumptions were made for the average length, width, and height of bison, cattle, and hogs from Dimensions of Livestock and Poultry (1985).

Table 1: Expected livestock dimensions based on slaughter weight

Animal	Average Weight (lbs)	Height (in)	Length (in)	Width (in)
Cattle	~1300	50	85	37
Bison	~750	61	83	37*
Hogs	~285	30	55	12

**Estimation based on cattle measurements*

Based upon the values stated in Table 1, the dimensions of the final design were decided upon. The dimensions of the final assembly main body are outlined in Table 2.

Table 2. Dimensions of final design

	Length	Width	Height
Inner Dimension	96 in	32 in	81 in
Outer Dimension	106 in	36 in	92 in

Budget

The initial budget for this project was $5,000.00. The initial quote of the materials came in at an overestimation of $4800.00. After purchasing, the cost of materials was $3036.18. Additionally, the cost for labor is to be calculated upon fabrication completion to determine the overall price of the chute assembly.

Design Concept Generation

The approach taken to generate the final chute design included pairing multiple technologies found within industry for each component (ie. head gate, side gate, and side panel) to create one single, functional assembly. After considering multiple design options for each chute component, the following design was created and is illustrated in Figures 13- 24.

Final Design

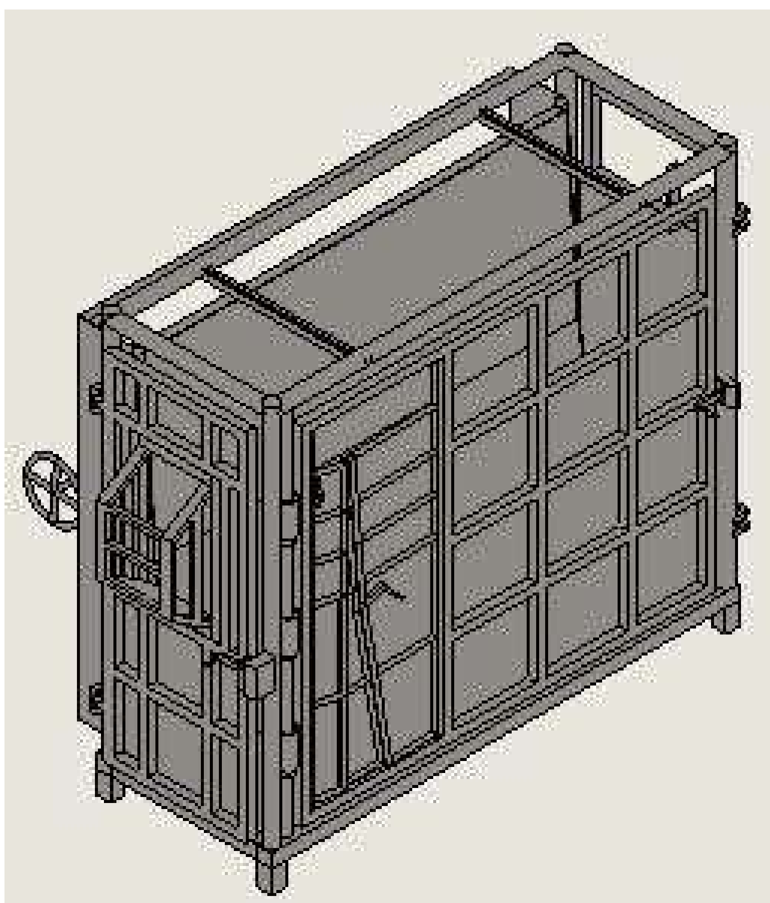

Figure 13. Image of entire modeled chute assembly

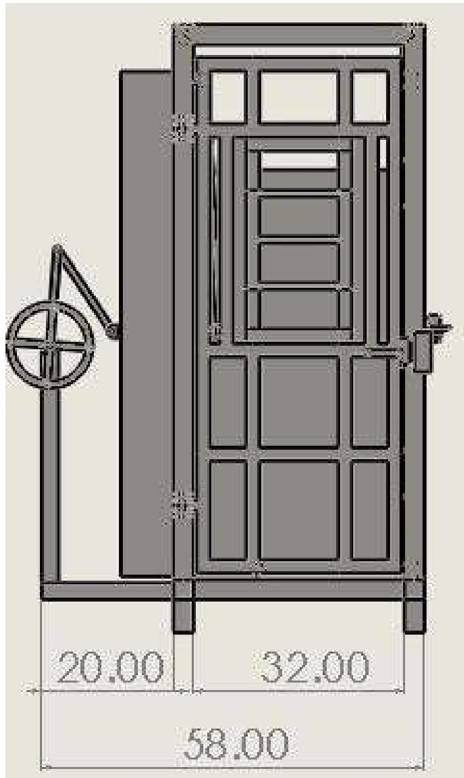

Figure 14. Image of front view of assembled chute model with dimensions (in inches)

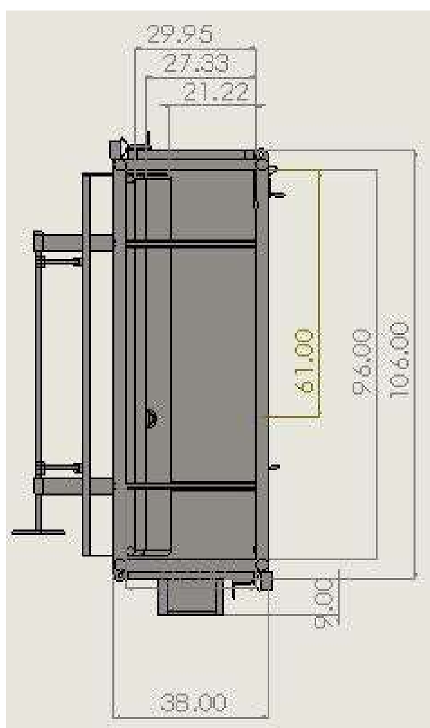

Figure 15. Image of top view of assembled chute model with dimensions (in inches)

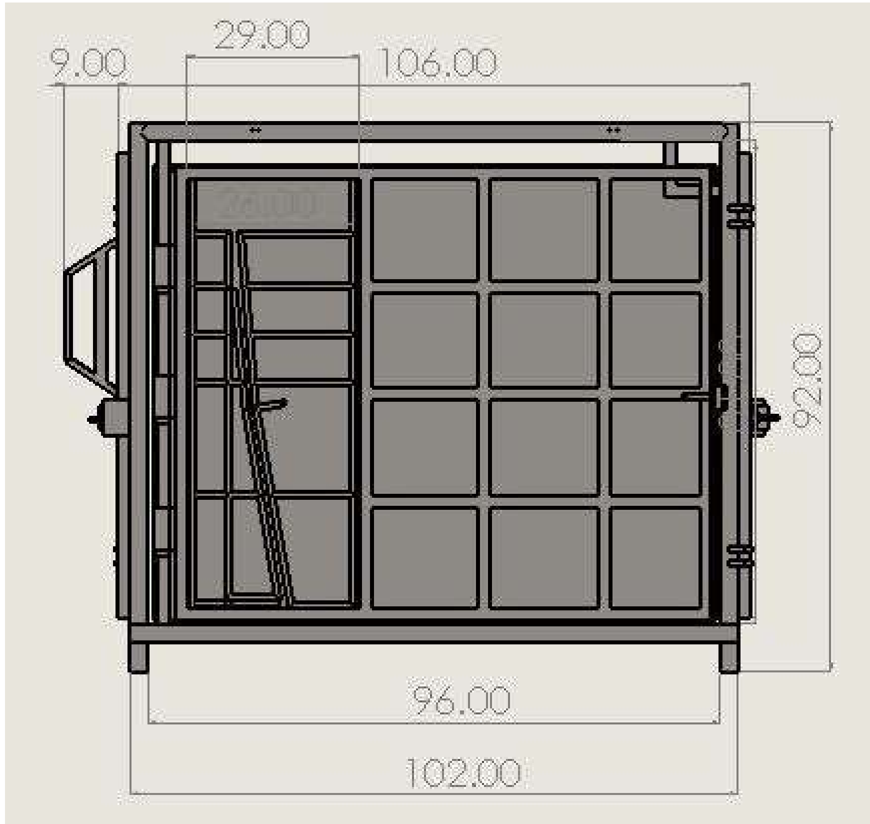

Figure 16. Image of side view of assembled chute model with dimensions (in inches)

The dimensions outlined in Figure 15 relate to the complete chute area as well as the restricted chute area, created with the squeeze implement and the secondary head gate. These dimensions are further addressed in Table 3. The size difference within the chute when comparing the entire chute and the restricted chute is further highlighted in Figure 17.

Table 3. Chute dimension comparison between entire chute and restricted chute

	Length	Width- Base	Width- Midway	Width- Top
Entire Chute	~96 in	~21 in	~27 in	~30 in
Restricted Chute	~61 in	~12 in	~18 in	~20 in

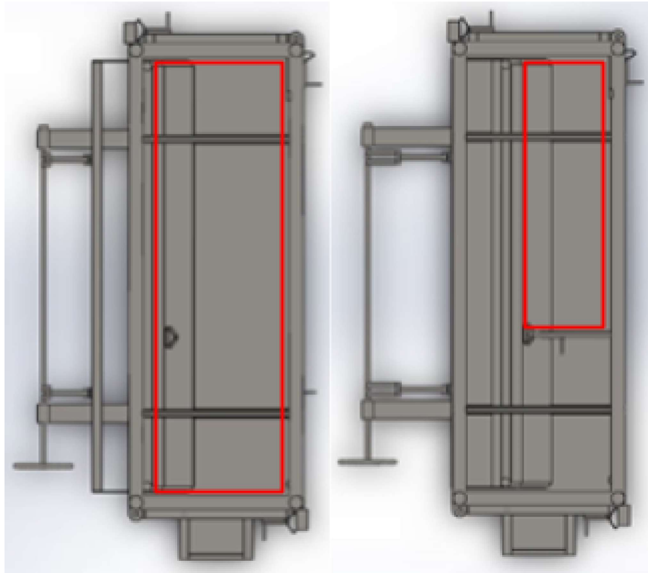

Figure 17. Highlighted comparison of entire (left) and restricted (right) chute sizes

Head Gate

The original design by the team for the head gate included a self catching feature which would restrain livestock by the base of their neck and shoulders. After considering postmortem body movements of livestock, it was concluded a self catching gate would become difficult to remove fallen livestock. Therefore, a crash gate was the most effective head gate option for the design. This feature allows for stunning access to larger livestock without creating a potential hazard after falling. Moreover, the head space addition allows the design to accommodate much larger animals which possess a longer head to tail length when compared to industry standards.

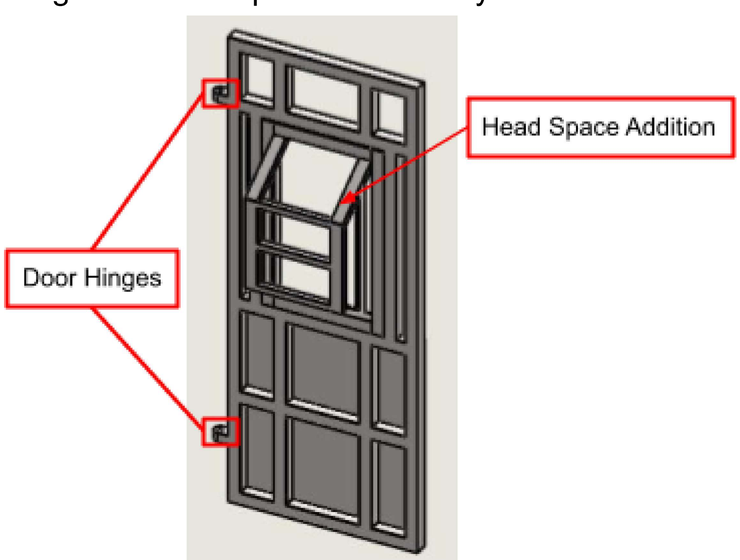

Figure 18. Image of head gate with head space model

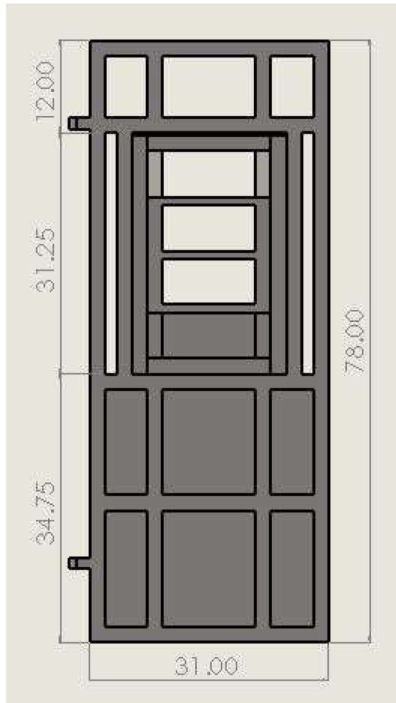

Figure 19. Image of front view of head gate with dimensions (in inches)

Side Gate

From the initial design present within Tonkawa Processing Corp.'s facility, an outward swinging gate was desired over their original overhead pull gate. Additionally, this gate features multiple smaller swinging gates in the front third of the design. These smaller gates serve two purposes. First, the secondary head gate allows the chute length to be shortened significantly to account for the smaller frame of swine, sheep, and goats. With the livestock being stationed farther back from the head space, employees at Tonkawa Processing Corp need an opening to reach the smaller livestock. Thus, the second purpose of the remaining gates is to allow for greater accessibility for employees when operating the restricted chute space, as it creates a doorway large enough for a person to step inside the front of the chute and stun livestock in the reduced section.

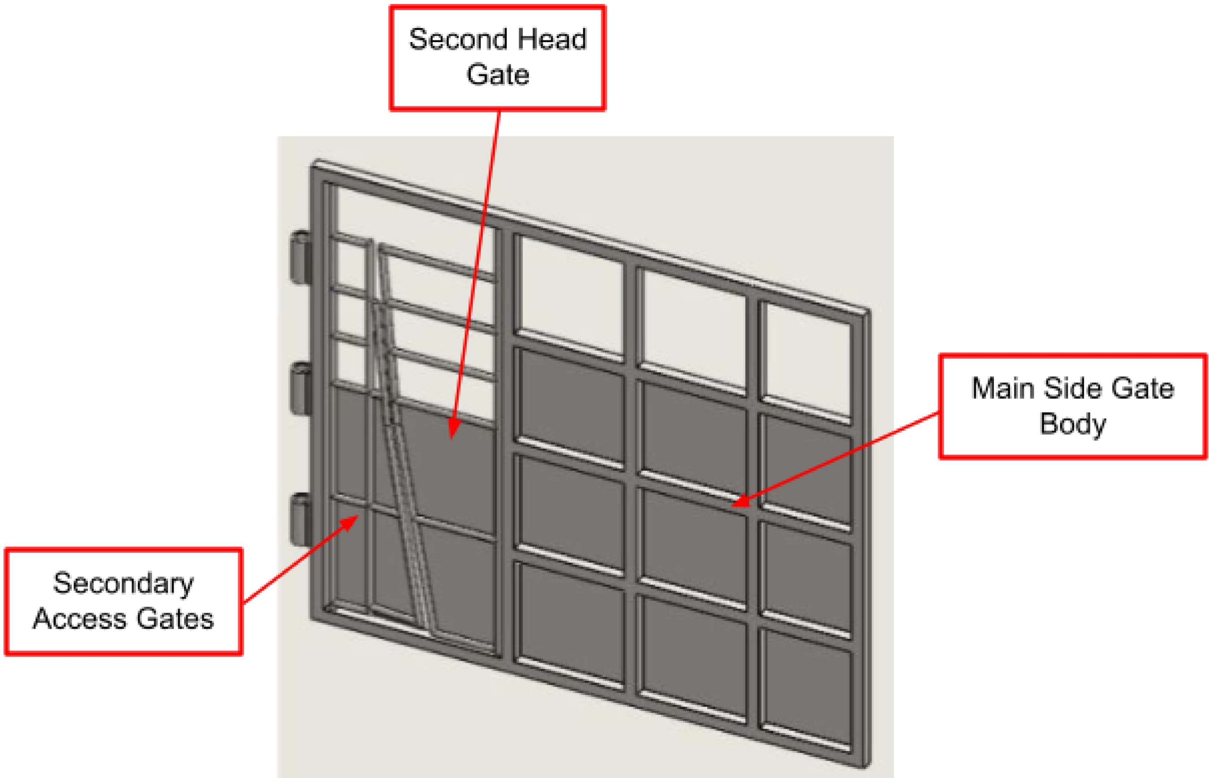

Figure 20. Image of side gate with attached secondary gates

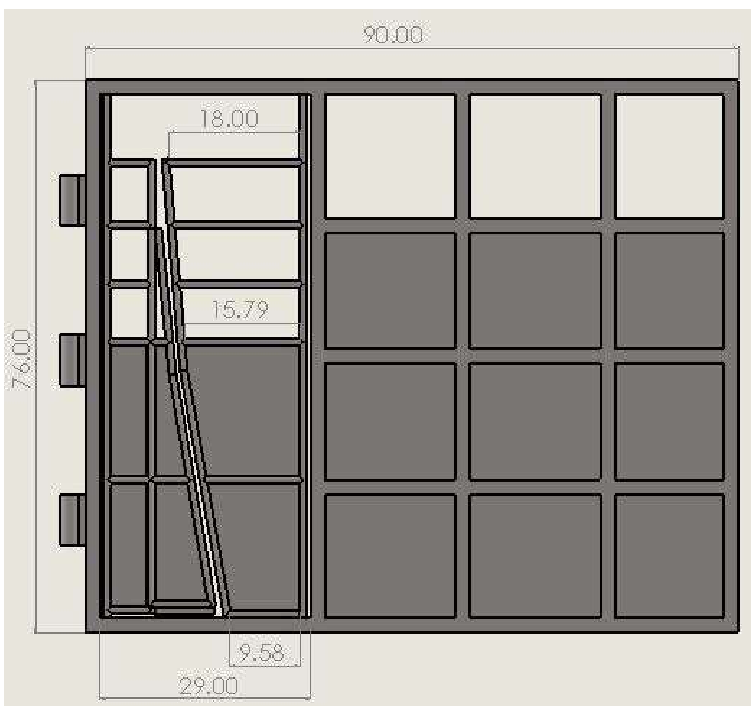

Figure 21. Image of side gate with secondary gates and dimensions (in inches)

Rear Gate

This design includes a standard outward-swinging rear gate with self-catching latches on the exterior.The main frame of this gate is similar to that of the front head gate.

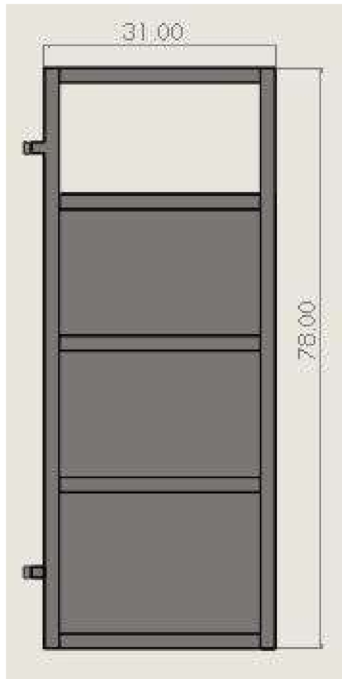

Figure 22. Image of rear gate with dimensions (in inches)

Other Components

The assembly did allow for a squeeze component as the opposing side panel. This tilted, solid panel moves on upper and lower tracks which allow the width to be adjusted from 21 inches to 12 inches at the floor. A slack adjuster is used to accomplish this movement.

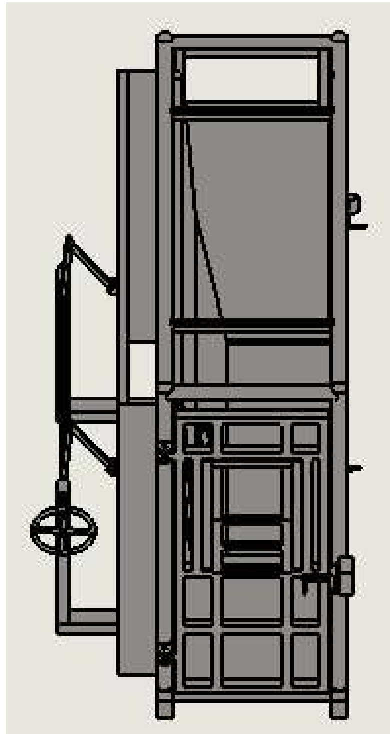

Figure 23. Image of side squeeze panel in “open” position

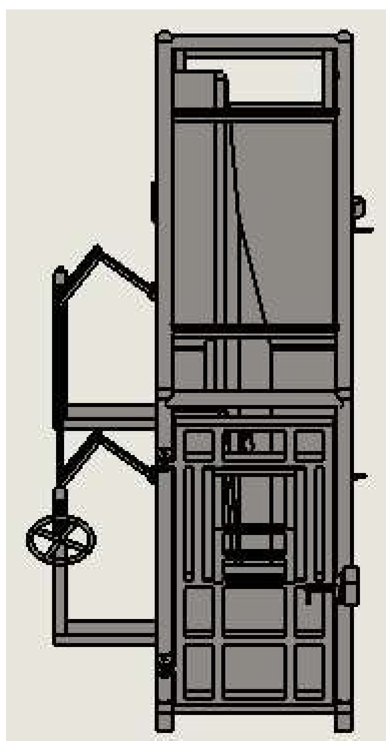

Figure 24. Image of side squeeze panel in “closed” position

Force Analysis

Calculations were conducted to determine the necessary weld amount at the areas deemed most likely to fail. Using material properties of A36 steel and equation 1, the required length of weld was determined.

Eq. 1 $$L = F/\sigma h$$

One area of concern was where the feet were welded to the bottom of the frame. Based on a ¼” weld leg and an assumed force of 4500 lbs, the required weld length came to ½” at each foot. With an actual fabricated weld of 8 ¼” at each foot, it was concluded that this weld would support the chute even with a large animal inside.

Weld calculations were also calculated at the latch pins attached to the gate and the catch plates on the frame. At the pin, a force was estimated of 2000 lbs from an animal kicking plus 25% of the weight of the gate, totalling approximately 2650 lbs. This force required a weld length of ½” on the latch; after fabrication is completed, each latch will have four sections of 2” weld, supporting the assumption that the latches will support this force. For the plate, the same 2000 lb force was assumed, resulting in a required weld of ¼”. Both sides of the plate will have 4 ⅛” of weld, which also implies that the gate closures will hold.

Since it was calculated that the three areas deemed most likely to fail will support a reasonable amount of force for this application, it was assumed that the chute as a whole will be able to also withstand this amount of force.

Appendices

Failure Modes and Effects Analysis

lean six sigma academy

Failure Modes Effects Analysis

Process or Product Name:	Livestock Knock Box	Prepared by:	Tatonka Innovations	Page:	1 of 1
Process Owner:	Tonkawa Processing Corp	FMEA Date (Orig):	4/13/2021	Rev.	

Key Process Step or Input	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Actions Recommended	Resp.	Actions Taken	SEV	OCC	DET	RPN
What is the Process Step or Input?	In what ways can the Process Step or Input fail?	What is the impact on the Key Output Variables once it fails (customer or internal requirements)?	How **Severe** is the effect to the customer?	What causes the Key Input to go wrong?	How **often** does cause or FM **occur**?	What are the existing **controls** and procedures that prevent either the Cause or the Failure Mode?	How well can you **detect** the Cause or the Failure Mode?		What are the actions for reducing the occurrence of the cause, or improving detection?	Who is Responsible for the recommended action?	Note the actions taken. Include dates of completion.				
Restraint Mechanisms	Squeeze implement doesn't work	Cannot restrain livestock	9	Squeeze implement is not functioning	4	Design, instruction manual, regular maintenance	10	360	Enforcing regular maintenance and inspection	All employees		9	4	10	360
Chute Material	Chute material not rated to withstand force	Chute design fails	10	Poor design	1	Force analysis and design	9	90	Completing force analyses	Designers		10	1	9	90
Device Instruction	Employees do not know how to operate the chute mechanisms	Improper use of equipment, potential safety issues	7	Inattention to instruction and best practices	5	Instruction manual	4	140	Creating and utilizing an instruction manual	Designers, every employee		7	5	4	140
Cleaning Ability	Chute surfaces are unable to be cleaned thoroughly	Potential food safety issues	10	Poor design, faulty cleaning materials	1	Design, current cleaning practices	6	60	Designing a lifted chute to fit into current cleaning methods	Designers, whoever cleans chute at EOD		10	1	6	60
Material Weight	Chute thickness is unable to withstand force, chute mechanisms are too heavy to manuever properly	Chute design fails	10	Unable to withstand force	1	Design	9	90	Design and fabricate chute strong enough to support own weight, livestock	Designers, fabricators		10	1	9	90
Closures	Break off, become stuck	Chute won't open or close	10	Regular wear	4	Regular oil & maintenance	3	120	Keeping up with appropriate maintenance	Whoever cleans chute at EOD		10	4	3	120
Chute Adjustability	Squeeze panle breaks, sticks, or slides loose	Chute cannot be adjusted appropriately	9	Regular wear, impact from livestock	5	Slack adjusters, tube-in-pipe tracks, and hanging tracks for supporting/moving panel	7	315	Correctly using slack adjuster to move panel	Livestock handler		9	5	7	315
Size of Chute	Not the correct size	Livestock cannot be properly restrained	4	Livestock size	2	Adjustable side panel, second head gate	10	80	Adjusting chute as much as possible for relevant	Livestock handler		4	2	10	80
Material Coating	Scratch, chip, or wear off	Potential cleaning issues, food safety	6	Regular Wear	4	Preventative design	8	192	Using galvanized steel instead of paint/powder coated	Designers/fabricators	Selection of galvanized steel 12/7/20	6	4	8	192

Figure 24. Failure Modes and Effects Analysis Table

From the table above, it can be concluded the squeezing panel and the gate latches are the elements of the design to be most concerned about. With these concerns, as well as the other design components, it is essential to inspect the design on a regular basis and complete maintenance tasks to reduce risks of failure. Additionally, when operating these mechanisms, it is essential to maintain consistent procedures to ensure their stability and functionality.

Cause & Effect Matrix

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Cause & Effect Matrix

#	KPIV	Employee Safety	Proper Animal Handling	Food Safety/ Quality	Design Efficiency	Aesthetic											Total	% Rank
Rating of Importance to Customer		10	9	9	8	2												
1	Chute Material	10	5	6	4	9											249	13%
2	Size of Chute	5	9	1	2	7											170	9%
3	Restrain Mechanisms (ie squeeze, head gate, etc)	8	10	3	7	5											263	14%
4	Device Instruction (Training /Manual)	9	7	4	6	1											239	13%
5	Chute Mechanism Adjustability	3	8	1	8	3											181	10%
6	Material Weight (Thickness, Load Ability,etc.)	9	4	1	7	6											203	11%
7	Cleaning Ability	2	4	10	8	8											226	12%
8	Closures	8	5	1	8	4											206	11%
9	Material Coating	1	1	10	1	10											137	7%
10																	0	0%
11																	0	0%
12																	0	0%
13																	0	0%
14																	0	0%
15																	0	0%
16																	0	0%
17																	0	0%
18																	0	0%
19																	0	0%
Total		55	53	37	51	53	0	0	0	0	0	0	0	0	0	0		

Figure 25. Cause and Effect Matrix Table

Considering the table above, Tatonka Innovations analyzed the following criteria: employee safety, proper animal handling, food safety and quality, efficiency, and aesthetic. From these, it was determined the components which held the greatest effect on the design were the chute's material, the restraint mechanisms used, the operator's ability, and the design's cleanability.

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