Crab Offloading Equipment

ME 487 Project Final Report

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Executive Summary

The purpose of this report is to present our work on an improved commercial crab boat offloading system. This is a solution to a problem presented to us by Garret Evridge and Taylor Holshouser from Alaska Ocean Cluster.

Covered here is a summary of the entire design process and an in depth presentation of our final design proposal. The problem we were presented with was to improve upon the existing system of offloading commercial crabbing vessels by speeding it up and minimizing deal loss to the crab being offloaded. The constraints for this project were largely dependent on the approach we took to solving the problem. We wanted to make sure that the existing process for catching crab did not need to be changed, meaning that our system would have to be either separate from the vessel or out of the way of work on the deck while crabbing. While we had no specific budget, a system that was cost effective and marketable to the industry was required. Our initial design concepts focused on drastically decreasing offload times by modifying crabbing vessel holds to allow crab to be filled directly into brailer bags that could then be lifted out. This approach was by far the most efficient one we looked at in terms of offload times, however, the associated time and monetary costs to implement and maintain such a system led us to deem the concept unfeasible for this problem.

The other broad concept idea was a system that was separate from the vessel and thus could be used on multiple boats without requiring each one to be retrofitted. This option entails a less drastic deviation from the existing process which leads to a smaller decrease in offload times but also much lower costs. Ultimately the decision was made to take this approach to the problem. We designed a conveyor belt system to move crab in the hold to the hatch and then up and out of the hatch to be brought to the processor. Our design is twofold, with the main focus of our design being on a framework that could lower a conveyor belt down into the hold as grab are offloaded. The second aspect of our system is modular conveyor belt sections that can be laid out in the hold leading into the vertical conveyor belt which allow workers to offload crab more efficiently as they need only to be placed onto a nearby conveyor belt to be offloaded. The vertical conveyor belt assembly is designed to weigh less than 1 ton as this is roughly the capacity of many of the cranes available to move it. The modular sections are designed to be roughly 35 lbs each making them portable by hand.

Also included are future ideas and changes that would likely need to be pursued in order to successfully implement this system. What we present here is what we believe to be a viable concept for improving the crab offloading process. While it is not likely that a usable system will look exactly like what we have presented here, we believe that the overall form and functionality of the system is in accordance with the problem presented.

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1 Background

In the process of commercial crabbing the crabs that are caught in traps are placed in a large space under the deck of the boat called the hold where they are kept alive until offload. The crab enters the hold through a small hole roughly 2 feet by 2 feet, but varying by boat. The hold is equipped with a seawater circulation system that pulls cool seawater from under the boat and fills the hold via pipes running along the bottom of the hold in order to keep the crab alive. When the hold is full to capacity or the boat's quota has been filled the boat must head to a processing plant to offload. Ahead of the offloading process the water is pumped out of the hold. When the boat has docked and offload can begin, a larger hatch, like the one pictured below, is opened on the deck roughly 6 feet by 6 feet, varying by boat, to allow processing plant employees to get into the hold and load the crab into large baskets called brailers.

Image above shows the current offload process with a brailer and inline scale. (Photo: Edward Paulson)

The brailers are moved around via crane and when a brailer is full the weight of the brailer is recorded using an inline scale. The brailer is then taken into the processor and emptied where the dead crab or ‘deadloss’ is sorted out and placed in a separate container. When the crab are being loaded into these brailers from the boat by hand the employees must stand on the crab which results in an increase in deadloss. Additionally this process can take between 10 and 20 hours in which time a portion of the crab will freeze to death resulting in yet more deadloss. When the offload process is completed the total deadloss is weighed and that weight subtracted from the total offloaded and that amount is what the processor will pay for. The aim of our project is to redesign the offload process in order to decrease the deadloss and streamline the offload process.

2 Specifications and Requirements

The new design should be more efficient than the existing system and take less than 10-20 hours to offload a boat depending on the size of the hold.

The new design should be relatively cost effective.

The new design should not require extensive training to use.

The new design should be durable to both low temps and seawater as this is a marine application and the crabbing season does extend into winter months.

The new design should not modify the boat in any capacity or affect the fishing process.

The new design should be able to be used on multiple boats with little to no modification.

The design should unload a boat hold that is up to 12 feet deep.

2.1 Applicable Codes and Standards

- Title 50 - Wildlife and Fisheries, Part 679 - Equipment and Operational Requirements
  - Crab must be weighed during the offloading process with a National Marine Fisheries Service (NMFS) approved scale.

While designing our system we agreed that the already existing scales used by the processors would be sufficient. These scales are NMFS approved and are in-line with the crane. Since our final design still uses the existing cranes and brailers this would not become an additional cost.

- Title 46 - Shipping, Part 111 - Electrical Systems
  - Electrical systems must be safe to use in maritime applications.

In our final design, we have a few electrical components. Since we included these components into our design, we have to consider this regulation. We made sure any electronics we had were safe in the often very wet and damp environment they are in.

- Occupational Safety and Health Administration Standard 1918.83 - Stowed cargo, tiering and breaking down
    - Safety associated with unloading cargo (including bulk cargo) that could shift.

Since all of the crab is generally loaded into a single hold, this classifies it as bulk cargo. Crab can also move, thus making this regulation relevant to the safety of the offloading process.

- Alaska Department of Fish and Game - Statewide King and Tanner Crab Commercial Fishing Regulations
    - Covers what both crabbers and processors must do when dealing with crab.

This document only relates to the offloading process in that it states the crab has to be weighed when being offloaded (mentioned in Title 50), but it also gives the standards of what crab can be harvested and the quality they have to be in for both the crabbers and processors to reference.

3 Constraints

Our design must be able to utilize the existing crane at the processing plant where offload takes place. Most processors have a 1 ton crane. This means that our vertical conveyor system and frame needs to weigh less than 1 ton fully assembled.

Our design should utilize standard shore power which may be a generator or a standard grid. This means our design should run off of a standard 110V system.

The modular sections of our design should be individually moveable by hand which means they should have an individual gross weight of at most 50 pounds.

The electrical elements of our design must be safe for maritime applications and therefore all components should be equipped with washdown duty drivers.

4 Design

One goal of this project is to have a design that is usable on a variety of boats with varying hold sizes, however for design and analysis the assumed dimensions of our boat hold will be 12 feet deep with an approximate capacity ranging from 100,000 to 200,000lb of crab. We also assumed the dimensions of the hatch to be 6 feet by 6 feet.

Design 1.1 - Full Depth Brailers

When initially generating ideas for this project, our main goal was to save as much time as possible. One of the largest sources of down-time when offloading the crab in the traditional way was loading the crab into small brailers (with a typical capacity of 1 ton), unloading that brailer onto shore, and repeating that process over 100 times (depending on the size of the hold). In order to save time our initial thought was to have the brailers already in-place and spanning the depth of the hold with an area slightly smaller than that of the hold opening.

If we were to proceed with this idea, we would save a tremendous amount of time. This is because the only down-time would be waiting for the crane to unload the brailers and reposition back to the hold opening, which is the same type of down-time from the traditional process. With brailers 12' deep and an area of roughly 36 ft^2 (typical size of a hold opening), we would only need 12-15 brailers. Having such a dramatic reduction in the amount of brailers needed to unload a hold full of crab would save a large portion of time.

When further discussing this idea we came to the understanding that there were multiple problems with this design. The first, and most obvious problem we came across, was that the brailers would be too heavy for the majority of on-shore cranes used at processor plants. Brailers that are 12 feet deep and 6 X 6 feet at the opening would weigh over 2 tons, with a generous crab packing density (refer to Appendix A for calculations), making them weigh too much for the typical 1-ton canes found at the processor plants. Another problem we found was that, if the brailers were fixed in-place under the deck of the boat it would be difficult to fill all the brailers evenly. On a crab boat there are generally only a few small openings to the hold to place the crab in, and from those holes the crab would float to empty spots in the hold. If the Brailers were already in-place this would impede the “flow” of crab around the entire hold, thus making it difficult to fill the entire hold. The last problem we encountered was that moving the brailers into position to unload would be tedious. If there was only one hold opening in the boat all of the brailers would have to eventually go to that opening from wherever they are in the hold, which would be difficult because each one could weigh over 2 tons.

There were a few ideas to solve each problem, which resulted in a few other variations in our design. To solve the first problem of weight, we could simply ask if the processor plants could get larger cranes, or we could come up with a new design (elaborated in Design 1.3). To solve the second problem related to the “flow” of crab, we thought of lifting the brailers as the crab level rose (elaborated in Design 1.2). Solving the last problem, related to moving the brailers to the hold opening, we thought of developing a rail system on the underside of the boat deck to help move the brailers more easily. Ultimately we decided that this particular design would require extensive boat modifications and possibly a new crane, both of which can be very expensive. Following this conclusion we continued with more design options.

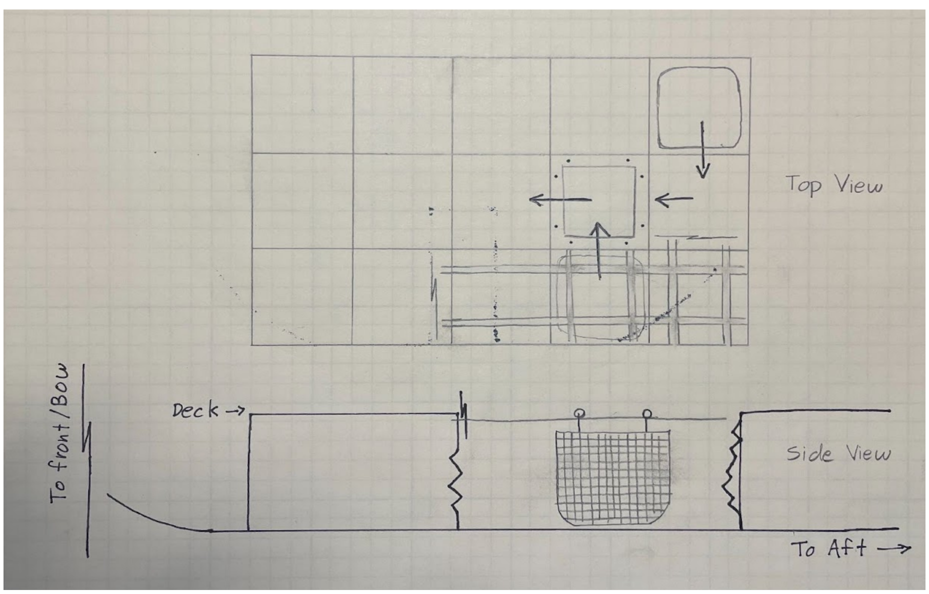


Figure 1.0 Moveable brailer sketches

Design 1.2 - Full Depth Brailers with Lifting System

The goal of this design is to: save time while evenly filling all of the brailers in the hold. As mentioned in Design 1.1, there was a problem concerning how every brailer would get filled evenly. This could be solved with the design described in this segment.

This design features a lifting system that would slowly raise the brailers as crab was deposited into the hold. The motors would be mounted on the underside of the main deck. These motors would be attached to the top of the brailers and be responsible for lifting them when needed. Having the brailers move up with the level of crab would help the crab move to all sections of the hold and eliminate empty space while saving time by eliminating the need to load small brailers during the traditional offloading way.

This design would be more beneficial than design 1.1, but still does not solve all of the problems described in design 1.1. The main problem of making the brailers too heavy for existing cranes to lift them still persists with this design. There is also the logistical issue of having to move the brailers to the single access hatch in the hold. This problem could be mitigated by adding more access hatches to the hold. Ultimately the weight of the brailers was the problem that made us move to our next design.

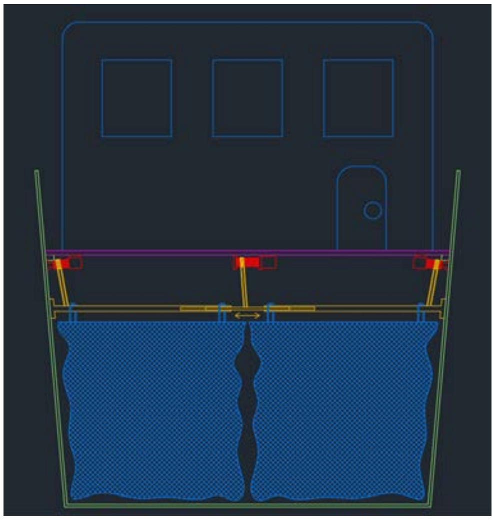


Figure 1.1: View of a boat hold, perpendicular to the length of the boat

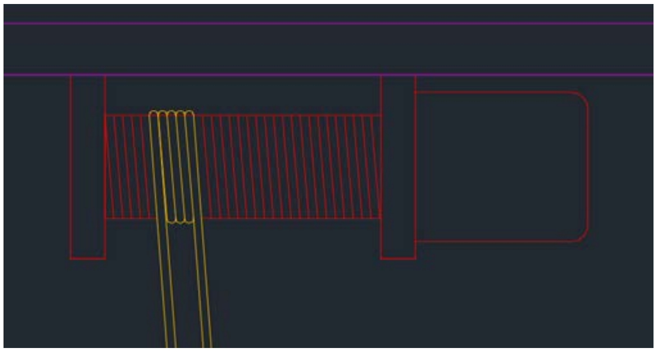


Figure 1.2: Magnified view of the lifting mechanism

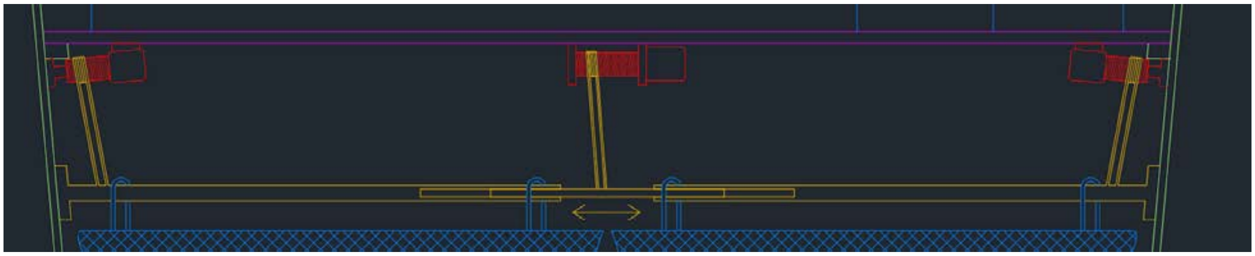


Figure 1.3: brailer lifting motors

Design 1.3 - Half Depth Brailers

After a basic weight analysis from the full depth brailers and coming to the conclusion that a 12 foot deep column of crab roughly 6 feet by 6 feet was in fact much heavier than the existing 1 ton cranes could handle, the idea of halving the depth of these brailers was the solution to the weight issue. The concept of half depth brailers would solve the weight problem but presented us with the challenge of deploying the second layer of brailers. Firstly, we had to decide how the fisherman would know when the hold was at half capacity and thus when it would be time to deploy the second layer of brailers. Secondly, we had to solve how the second layer would be deployed while fishing without disrupting the fishing process.

Before we were able to invest much time and effort into solving these issues, our mentors decided that they did not want us to modify the fishing vessel in any way. This new constraint steered us in a much different direction.

Design 2.1 - Archimedes Screw

With a new major requirement added, we needed to develop more ideas to accommodate it. Without modifying the vessel, we explored a few new designs, ultimately leading to the design we decided to pursue. Having this requirement added late in the design process, meant we had to choose and develop a new design quickly.

An archimedes screw concept was explored initially because it would take up less space in the hatch to allow for modular sections of conveyor system, discussed below, to be passed into the hold. The archimedes screw principle uses a screw to lift mass from one location to another via its thread pattern. Ultimately we decided that an archimedes screw would be difficult to use with a living mass such as crab and we would be unable to model it sufficiently.

Design 2.2 - Vertical Conveyor

A vertical conveyor system was discussed such that it would occupy a similarly small amount of space as the archimedes screw concept but would be significantly easier to work with a mass such as crab. Again after some simple drafting we came to the conclusion that horizontal shelves or cleats would not hold the crab sufficiently and some sort of bucket would be needed or the conveyor would need to be redesigned. We decided against a bucketed conveyor for a number of reasons but primarily because buckets would be more difficult to manufacture and model.

Design 2.3 - Angled Conveyor

In order to keep the crab on the conveyor belt we changed the design from being vertical to being at an angle of 60 degrees. This design will occupy more of the hatch but will move crab more efficiently. The conveyor system we chose is readily available from Dorner Conveyors and is to be used with a telescoping frame that we designed. We chose to use an existing conveyor system because parts and maintenance will be more readily available than if it were a proprietary design. The setup is designed such that the whole thing can be picked up by the crane and placed on the deck such that the frame spans the hatch and the conveyor can be lowered into the hold as the level of crab drops.When the crew reaches the bottom of the hold the modular sections, discussed below, can be passed into the hold and setup to feed into the vertical lifting portion. At the top a brailer bag or separate conveyor can be placed next to the outfeed and filled. When one brailer is full it can be picked up and weighed by the crane with the inline scale and taken into the processor while a new brailer is being filled. Alternatively a conveyor with built in scales could be used to continuously move crab up to the processing plant. Our design is meant to work with either of these options.

This portion of our final design is more expensive but will have a longer product life and should not need maintenance or parts as frequently as the modular sections may. When maintenance and parts are required, the conveyor portion of this design is chosen from a manufacturer to ensure parts and service will be readily available. The specifications for the conveyor portion of this component are found in the figure below.

The conveyor belt is mounted on telescoping arms which are attached to the main support frame. The bottom of the telescoping arm is fixed to the bottom of the angled conveyor belt and the top of the conveyor belt is constrained to the telescoping arms using a system of channels and rollers. Each telescoping arm contains pulleys and steel cables which are used to constrain the movement of the arms in such a way that they can be driven by a single connection on the innermost arm and will extend and contract in a uniform manner. The construction of these arms is aluminum with HDPE liners between each extending section. Deflection of these arms when fully extended is a concern though our initial stress analysis indicated that aluminum arms would be able to sufficiently support the load (figure 2.9). Below are screenshots of the internals of the telescoping arms (figures 2.5, 2.6). The telescoping arms are designed to be driven by a cable attached to the innermost section of each arm. This cable will be attached to a spool driven by a self contained hydraulic powerpack mounted on the frame.

As can be seen in the images below (figure 2.7) the top of the conveyor belt extends above the top of the telescoping arms when fully retracted. As a result of this geometry, a single roller and channel can not be used to guide the top of the conveyor belt through its full range of travel. To solve this problem we designed a roller system that employs two channels - one attached to the conveyor belt and one attached to the telescoping arm. When the conveyor is in its lowest position (fully extended), a roller attached to the conveyor belt rolls in a channel attached to the shell of the telescoping arm (figure 2.2). As the top of the conveyor belt is retracted past the top of the arms, this roller comes out of its track and a second channel, which is attached to the conveyor, interfaces with a roller on the telescoping arm. This roller then supports the conveyor until it is fully retracted (figures 2.1, 2.3).

Figure 2.1 - Fully retracted

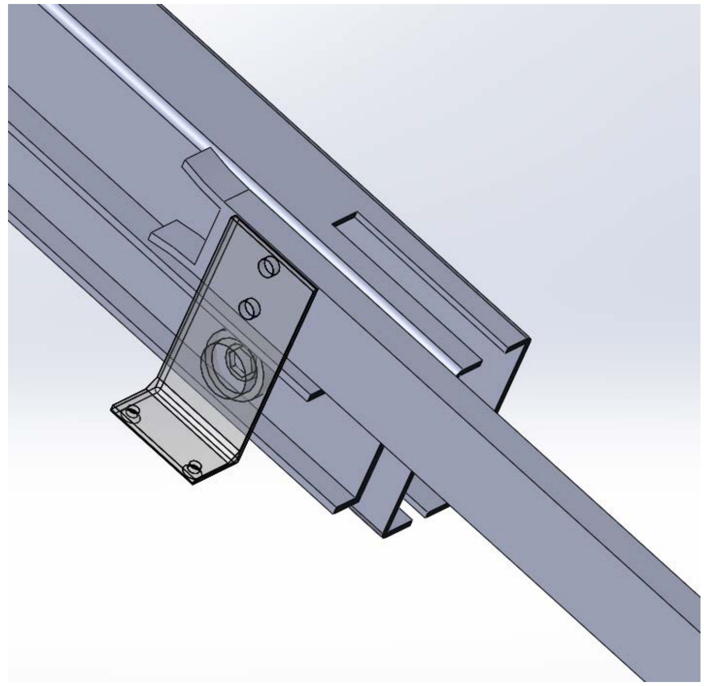


Figure 2.2 - Fully extended

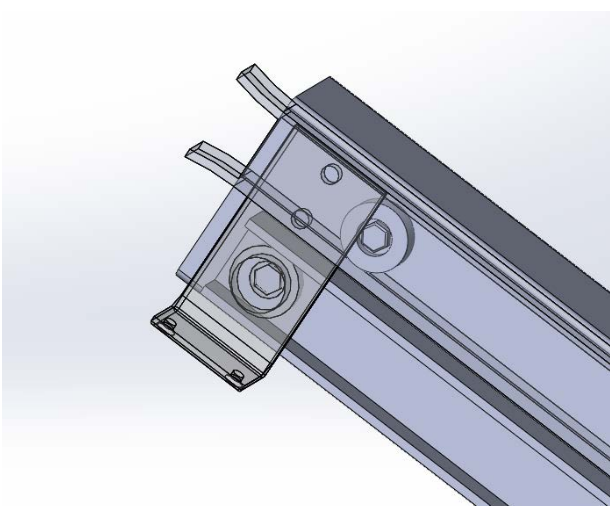


Figure 2.3 Transition between rollers

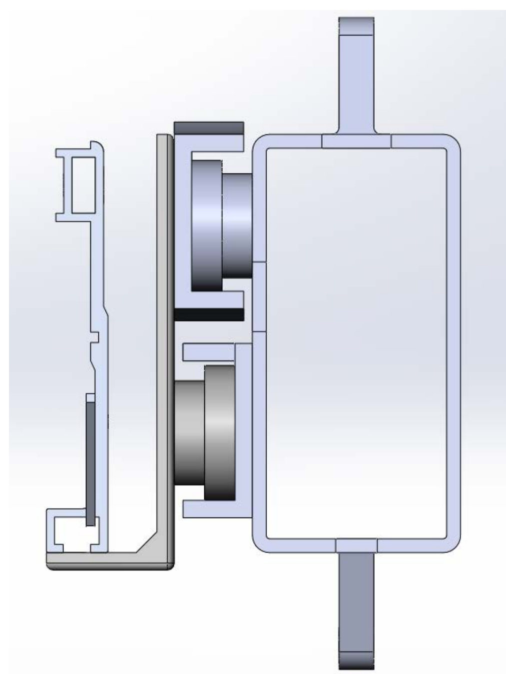


Figure 2.4 Rollers and tracks end view

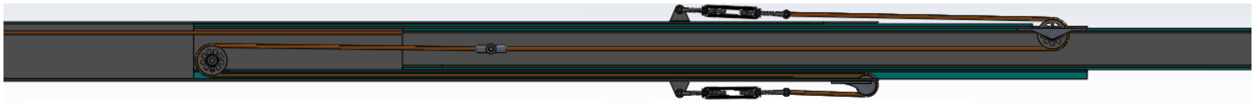
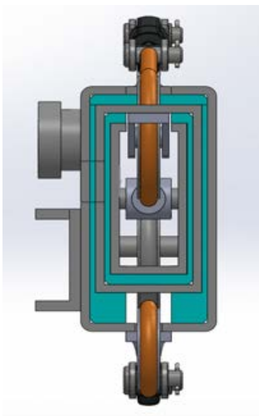


Figure 2.5 Telescoping arm cross section



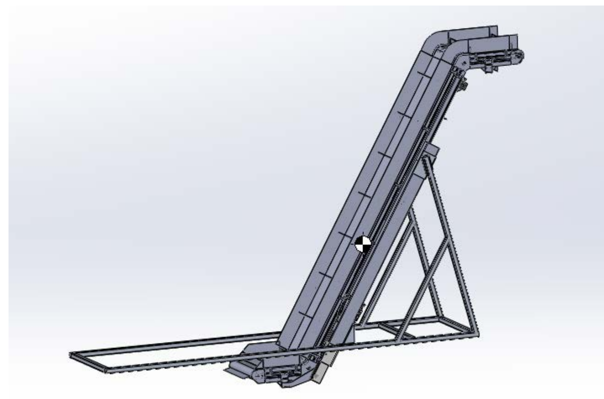


Figure 2.6 telescoping arm end view

Figure 2.7 Full conveyor system

Figure 2.8: Lists the manufacturer specifications for the conveyor section of this design.

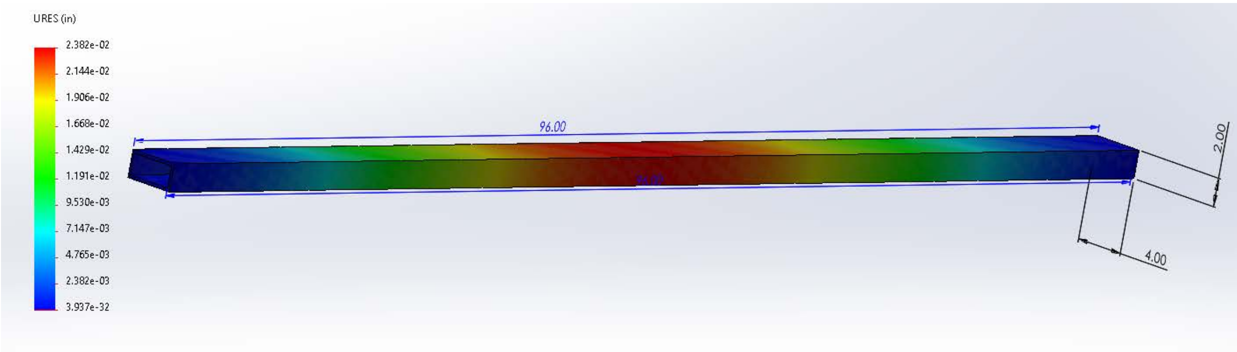


Figure 2.9 Aluminum rectangular tubing, with a maximum deformation of 0.02”

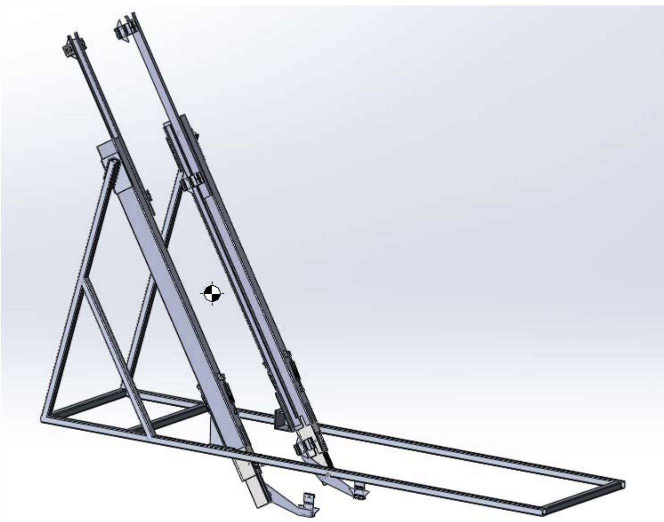


Figure 2.10: Frame for vertical conveyor.

Figure 2.11 Frame for vertical conveyor

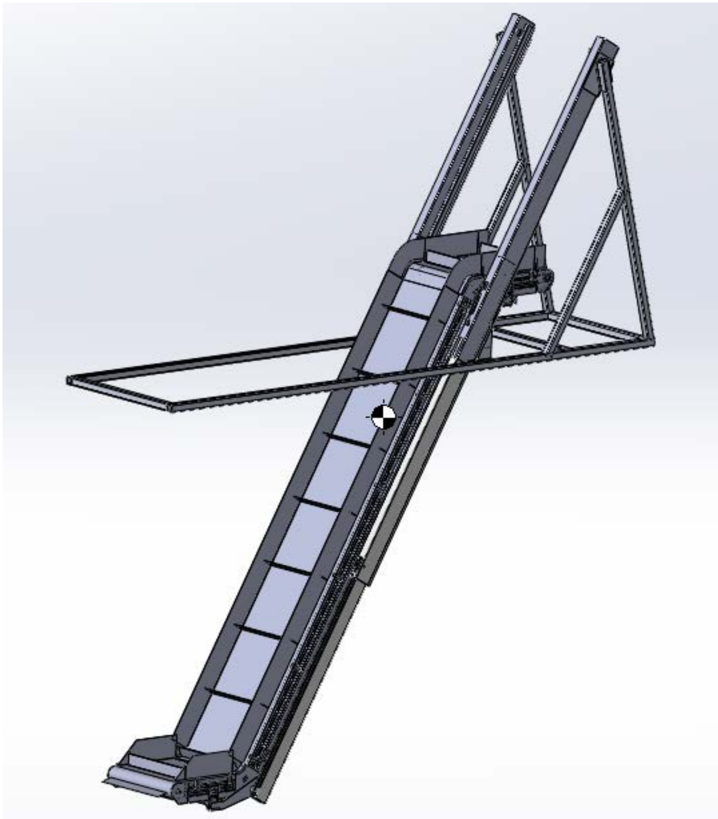


Figure 2.12: Fully assembled and lowered vertical conveyor system

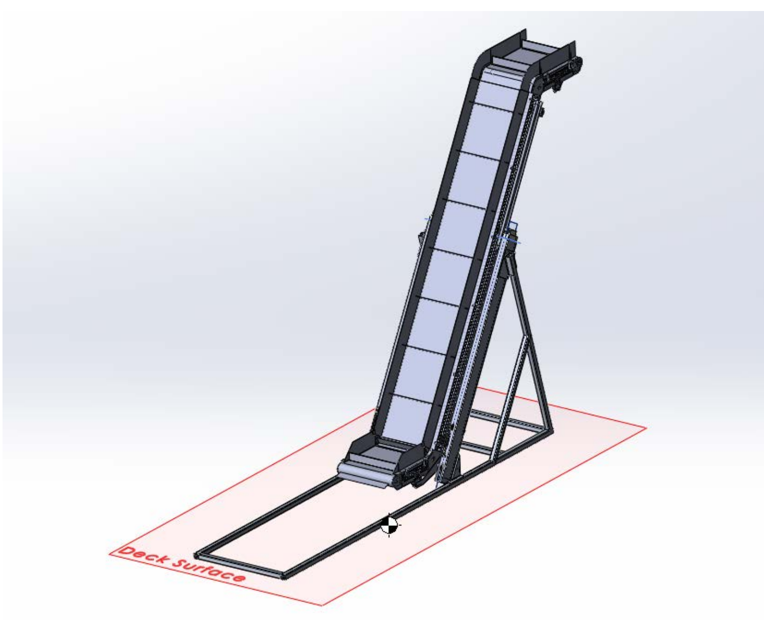


Figure 2.13: Fully assembled and raised vertical conveyor system

Design 3.1 - Modular Sections

In order to move crab from different places in the hold to the hatch opening more efficiently, a modular conveyor belt system would need to be developed. Designing the system to be modular would benefit the offloading crew, because they could attach or detach sections as needed, depending on where they were in the hold. Adding this system, in conjunction with the angled conveyor belt system, would save time by reducing the time needed to transport the crab to the hatch opening.

This design was influenced by an already existing system used by companies in the aircraft industry. Their system uses modular sections, like the one shown below, to help baggage and cargo handles move luggage and other objects to the access hatch of the aircraft. Cargo and large passenger planes generally have a long body, so having a system that helps move cargo the distance to the access hatch will save time needed to offload everything.

Our design has a few different requirements that need to be met in order to work effectively in a crab boat hold. Firstly, it has to be electrically safe to use in maritime applications and run on standard shore power (110V). Each section of the conveyor belt cannot exceed 50 lbs, so that it will not be difficult for the crew to move by hand. Lastly, this design needs to withstand the rough nature of crab and the offloading process in general.

Conveyor belts are conventionally designed with a tapered driver pulley with a larger diameter and a smaller diameter tail pulley. The driver pulley is a tapered, stainless steel, 4 in diameter pulley. The taper in the driver pulley helps with maintaining belt tension and belt tracking. The tail pulley is a lightweight aluminum pulley with a 1 15/16" diameter. The belt material for this design was PVC composite chosen for its inexpensiveness, accessibility, and wear properties. The motor is a washdown duty 1/12 hp motor that will utilize a sprocket and v drive belt to drive the driver pulley. These will be powered by a standard 110V plug and each section will plug into the previous one for power. The frame is aluminum bar stock construction for weight reduction in order to make these moveable by hand.

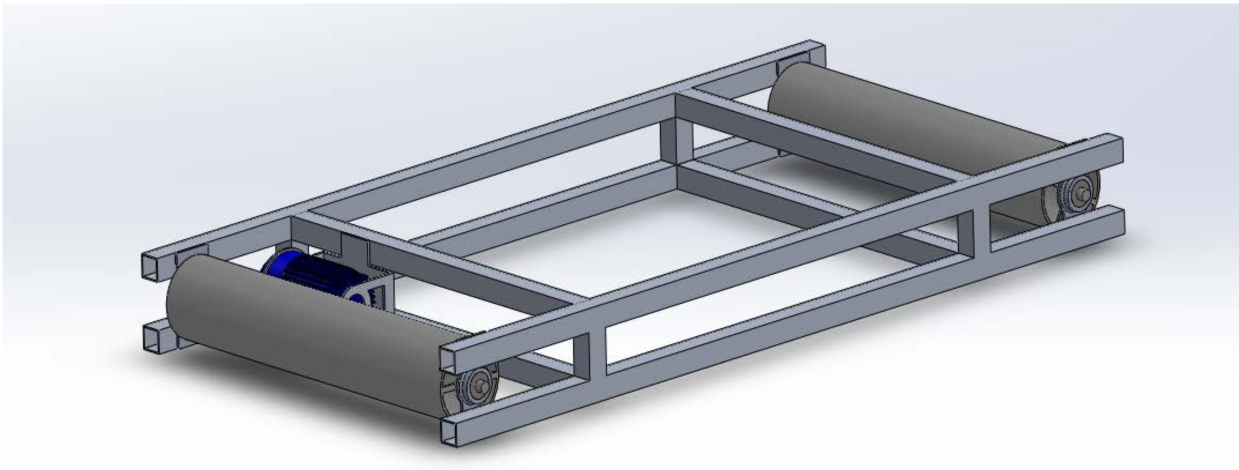


Figure 3.1 Modular Sections preliminary design

Design 3.2 - Modular Sections with Foldable Legs

This design was developed to help the offloaders manage fatigue. In design 3.1, the system is meant to be laid on the ground, meaning that the crew would experience fatigue at a fast rate, because they would have to bend over many times to place the crab on the conveyor belt. To reduce fatigue, simple foldable legs would be added to the conveyor belt, so that it would be lifted off the ground and be at a level where the offloader would not have to bend over as much. The addition of legs as can be seen below also allowed accommodation for the floor of the hold which is often not flat and has pipes running along the floor. The legs will be foliding to maintain the easy storage position, as well as adjustable to allow for application with a diverse fleet. The conveyor components of this design remain the same as version 3.1.

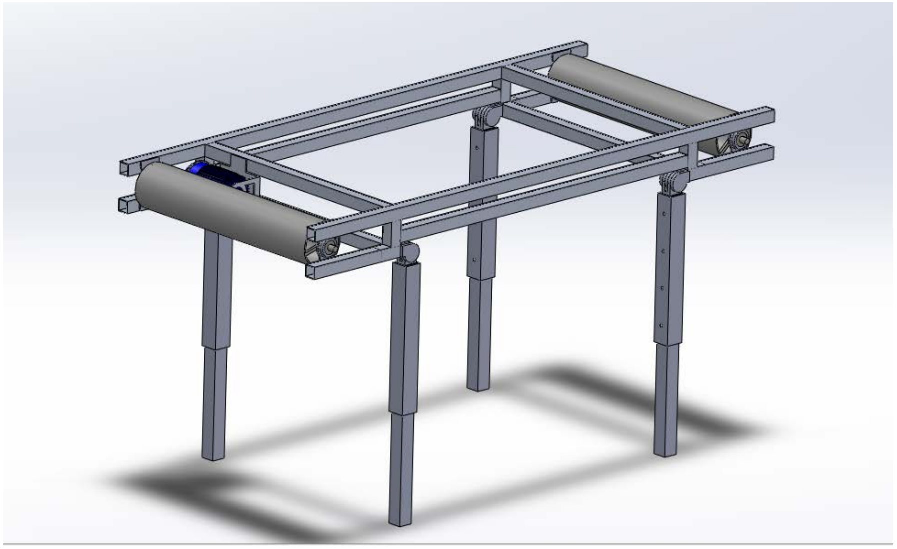


Figure 3.2: Modular conveyor sections with legs extended

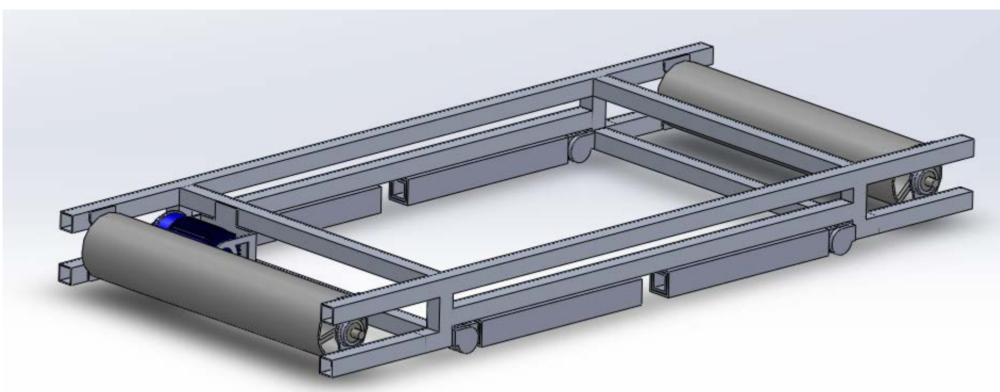


Figure 3.3: Modular conveyor section with legs folded for storage.

5 Analysis

A brief cost breakdown of the final design can be seen below. This cost does not include shipping or assembly costs.

Part	**Per unit cost**	**Units Needed**	**Cost**
PVC belting	$27.81/ft	84	$2,336.04
Splicing clips 12 in	$180.15 (pkg of 4)	3	$540.45
Tail pulley roller	$28.82	10	$288.20
Driver pulley	$177.76	10	$1,777.60
Driver motor	$477.00	10	$4,770.00
Sprockets	$11.00	10	$110.00
Drive belts	$8.50 (pkg of 3)	4	$34.00
Mounting bracket	$5.00	10	$50.00
Aluminum for frame			$4,070.00
Z-Conveyor	$15,146.00	1	$15,146.00
Hydraulic Power Pack	$3,000.00	1	$3,000.00
TOTAL COST			$32,122.29

Figure 5.1 Cost breakdown for the whole project.

As is stated earlier, the vertical conveyor portion costs significantly more overall than a full set of modular sections. This division of cost was intentional as the vertical section is intended to have a longer product life and should not need repairs as frequently. The cost distribution can be seen below.

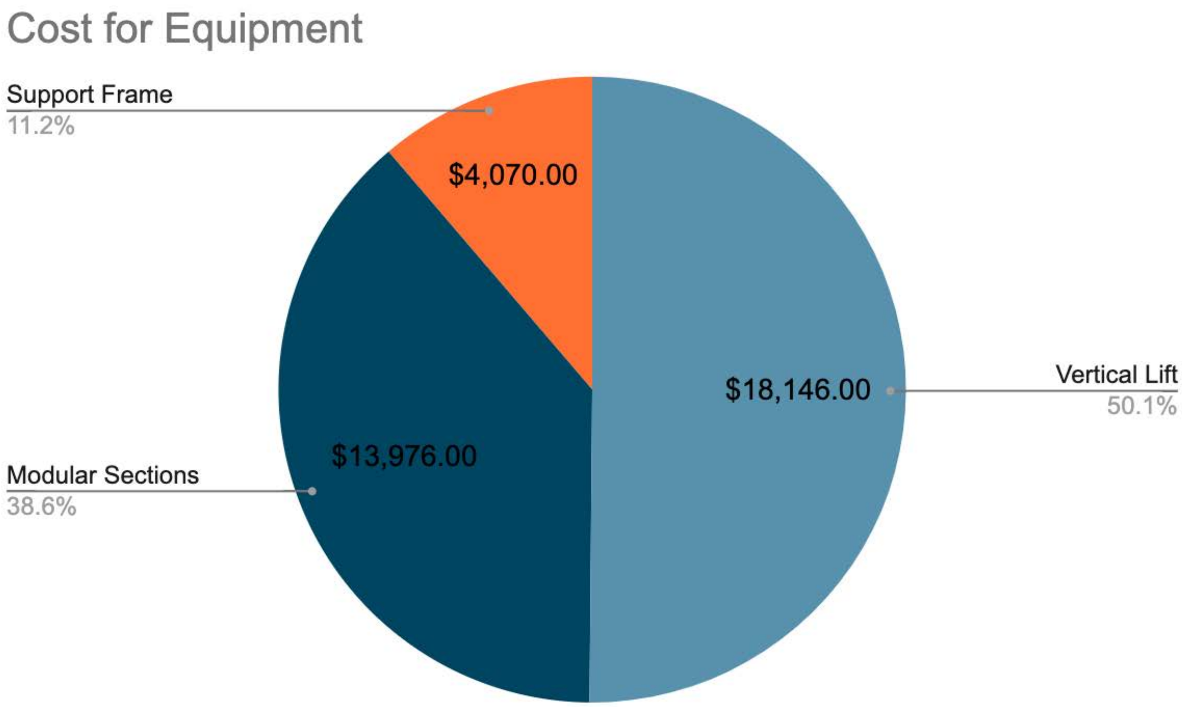


Figure 5.2 shows the cost distribution for different aspects of this design.

Overall this project is high dollar, however, commercial crabbing is a high dollar industry. Relative to the industry in which this product is intended to be used, we do not believe that this project is financially unfeasible.

Weight was also a constraint for this project. As such we have done a weight analysis on each section separately to ensure they meet their respective requirements. Firstly the vertical portion should weigh less than one ton as to ensure the processors can use the cranes they already have. A solidworks analysis of the vertical crab conveyor system states its gross weight as being 750 lbs which is less than our limit of 1 ton. The modular sections were given a weight limit of less than 50 lbs per section to allow the crew to move them by hand easily. The same solidworks analysis of the modular section frame states its weight as 10 lbs. This combined with the weights of the motor and pulleys results in a weight of around 34 lbs per section which is well under our limit of 50 lbs.

Finally, our goal for the project was to improve upon the existing process for crab offload. As such we attempted to estimate the time saved by implementing our system. According to this analysis and based on some assumptions about the size of the hold and worker efficiency, we estimate that our system can save roughly 9 hours of labor for every 200,000 lbs of crab (see appendix). This is roughly a 30% increase in efficiency from the existing system as seen in the figure below.

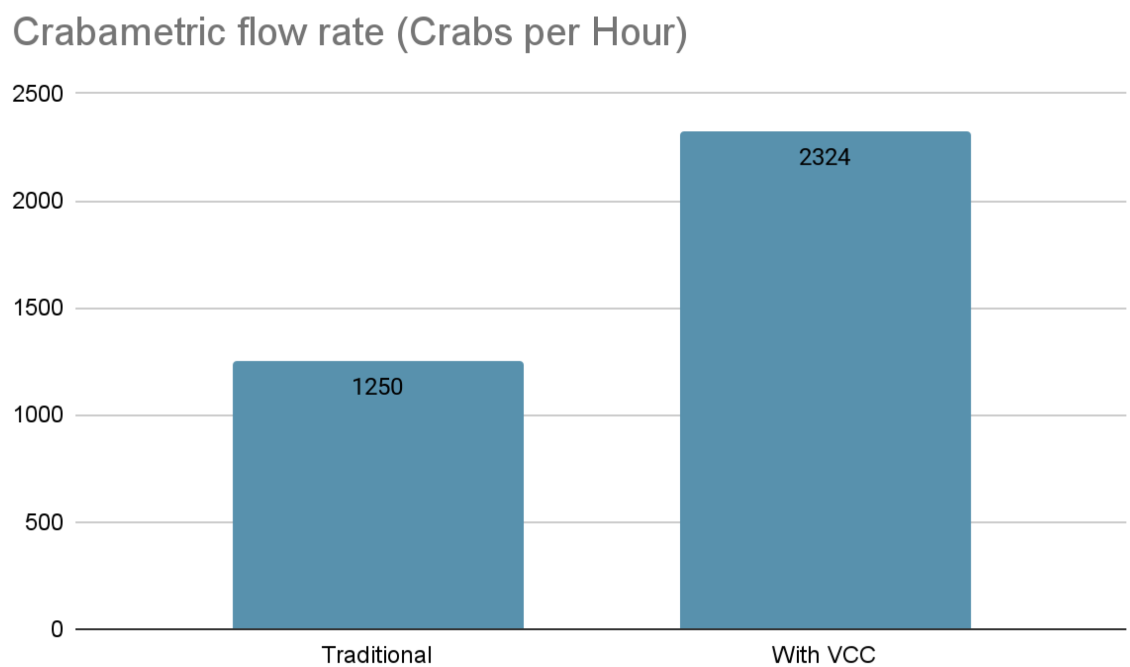


Figure 5.3 System Efficiency Comparison

6 Conclusions and Recommendations

The current design we have is not perfect; however, it can be made and physically tested with sufficient funds. As with any design, there can always be improvements. Some of the recommendations we have for furthering the development of this mechanism are discussed in the following paragraphs.

Our first recommendation would be to add a “Y” at the top of our system. This would be beneficial because it would further reduce the time needed to change brailers. Once one brailer was full, it could direct the flow of crab into another brailer without needing to stop. A wider conveyor belt would likely be needed to handle larger species of crab such as king crab.

Another recommendation we had from our mentors and a crab boat owner is to develop a larger conveyor belt that would feed the crab directly into the processing plant. To do this one would have to consider a few challenges to overcome. The first challenge would be keeping the crab alive by limiting their exposure to the freezing air when being transported, this could be overcomed by enclosing the conveyor belt and heating it simultaneously. One would also have to consider the tides as well, and how it affects the height of the boat relative to the shore. This challenge could be solved by adding a hinge connecting our system to the larger conveyor belt leading to the plant, so that the angle can change freely without any input from the crew during the changing tides.

The product we developed has been through multiple iterations, but before considering commercialization, we would want to test it in the field. As in most subjects, “real-world” application can reveal some overlooked aspects of the design. With offloading tests we could find potential problems and address them before continuing to commercialize the design. If the design was to be commercialized, we have found vendors that readily supply the components we would need to assemble the product economically.

Our biggest challenge for this project and likely the biggest challenge moving forward is that without a full scale prototype and a crab boat we can only roughly approximate its success. Crab as a biomass are nearly impossible to model as they are not only odd shapes and sizes, but also alive and moving, and as such, we cannot 'test' the viability of this design without building and testing a full scale model. We would also need to find a boat and/or processor willing to let us test this design during the crabbing season which may also prove to be a hard sell.

7 References and Citations

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Appendix A Sample Calculations

Sample Calculation: Weight of a full depth brailer

Known:

Crab Packing density with 5% mortality rate (Siikavuopio et al, 2014):

$\rho = 9.36 \frac{lb}{ft^3}$

Volume of brailer with 6' X 6' opening and 12' deep:

$V = 6 * 6 * 12 = 432\ ft^3$

Calculations:

Weight of brailer in pounds:

$W_{lbs} = \rho * V = 9.36 * 432 = 4043.5$ lbs

Weight of brailer in tons:

$W_{tons} = W_{lbs} * \frac{1\ ton}{2000\ lbs} = \frac{4043.5}{2000} = 2.02$ tons

Sample Calculation: Time saved

Known:

Vertical Lift Geometry

10' rise

60° angle

Belt Length = $\frac{10'}{sin(60°)}$ = 11.55 ft

Belt Speed = 58 ft/min = 0.967 ft/s

Space Between Cleats = 18 in/cleat = 1.5 ft/cleat

Average Crab Weight = 8 lbs

Amount of crab in a hold = 100,000 - 200,000 lbs

Traditional offloading time = 10 - 20 hours

Calculations:

Cleat rate = $\frac{Belt\ Speed}{Space\ Between\ Cleats} = \frac{0.967\ ft/s}{1.5\ ft/cleat} = 0.645\ Cleats\ /\ s$

Mass Flow Rate (assuming 1 crab per cleat):

$$\dot{m} = cleat\ rate\ *\ crabs\ per\ cleat\ = 0.645\ cleat/s\ *\ 8\ lb/cleat\ = 5.15\ lbs/s$$

Time to move 100,000 lbs = $\frac{100{,}000\ lbs}{5.15\ lbs/s} * \frac{1\ Hr}{3600\ s} = 5.38\ Hours$

Time to move 200,000 lbs = $\frac{200{,}000\ lbs}{5.15\ lbs/s} * \frac{1\ Hr}{3600\ s} = 10.79\ Hours$

Time Saved: 4.62 - 9.21 Hours.

Note: Time saved also depends on how effective the offloaders are on certain days, which can vary depending on fatigue, weather, etc.

Appendix B Reference Diagrams

	Time to offload	Volume of system	Weight of system	cost	number of parts	crab survival rate	crew members required to operate	Maximum offloading capacity
Maximum offloading capacity								
Crew members required to operate								●
Crab survival rate							▲	●
Number of Parts							■	
Cost					■	●	●	■
Weight of system				■	■		▲	●
Volume of System			■	●	■		▲	●
Time to offload				▲	▲	■	■	■

"Who" Columns sum 100	▲ – 1 ● – 3 ■ – 9	Who			How								Now
		Crew	Owners	Processor	Time to offload	Volume of system	Weight of system	cost	number of parts	crab survival rate	crew members required to operate	Maximum offloading capacity	Existing manual pickup system
What					↓	↓	↓	↓	↓	↑	↓	↑	1 – very bad
					hrs	ft³	lbs	$	#	%	#	lbs	5 – very good
Move Crab	Offloads Efficiently (minimum transfer time)	21	8	30	■				▲	▲	●	■	1
Keep Crab Alive	Doesn't interfere with RSW Circulation (maximum water flow)	8	20	28	●	●				■			5
	Does not crush crab during offload	8	20	28	■	▲				■		●	2
Not interfere with fishing operations	Fills effectively and easily	19	8	1	●			■		●	■		5
	doesnt take up too much space	8	14	1		■			●			▲	5
Durable	Non corrosive	6	14	10		▲	●	●	●				5
Easy to maintain	Minimal moving parts	12	6	1		●	●	■	■		●	●	5
	Easy to clean	18	10	1				●	●		●		5
				Importance (Crew)	18	8	3	18	12	12	17	13	100
				(Owner)	20	14	4	12	10	23	8	10	100
				(Processor)	32	7	2	3	4	28	6	19	100
				Existing system	10 20		5000	40k 120k	2	<95	6	20k 40k	
				Target	<10		<5000			>95			
				Threshold	12								

Figure 6: The QFD 'house' for this project.

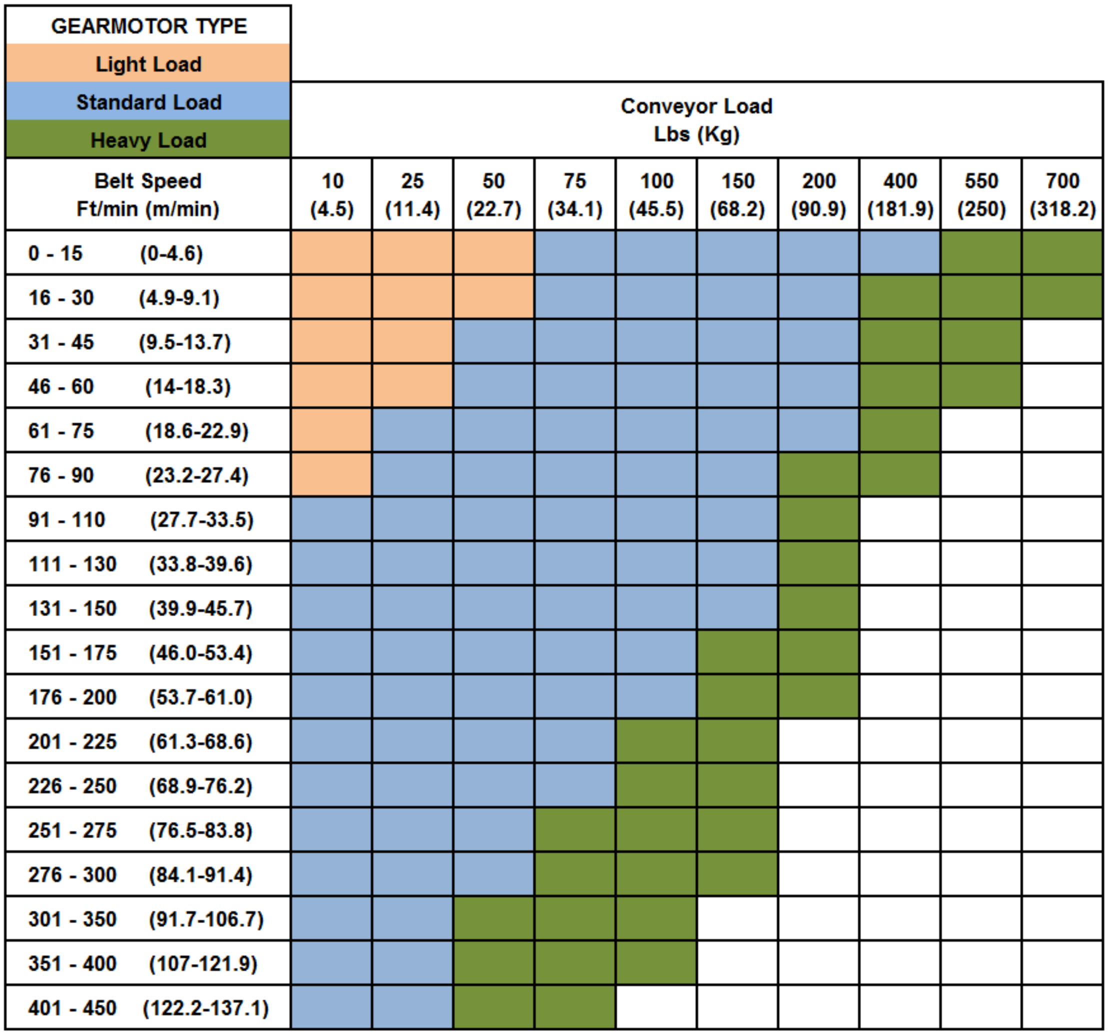

Figure 7: motor selection for the vertical conveyor driver from Dorner Conveyors.

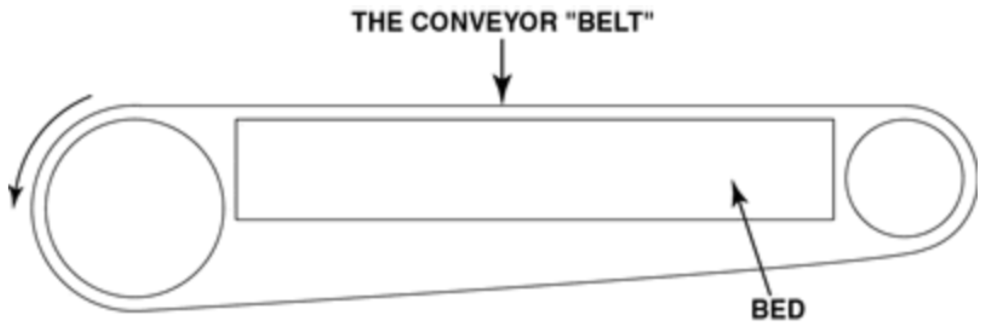

Figure 8: Standard convention for conveyor design.

Part	Weight (lb)	denotes estimated weight
PVC Belt	5	est.
Splicing clips	0.5	est.
Tail Pulley	2	est.
Driver Pulley	5	est.
Motor	11	
Mounting bracket	0.25	est.
Sprockets	0.25	est.
Frame	10	
TOTAL	34	per section

Figure 9: Weight breakdown for the modular conveyor sections