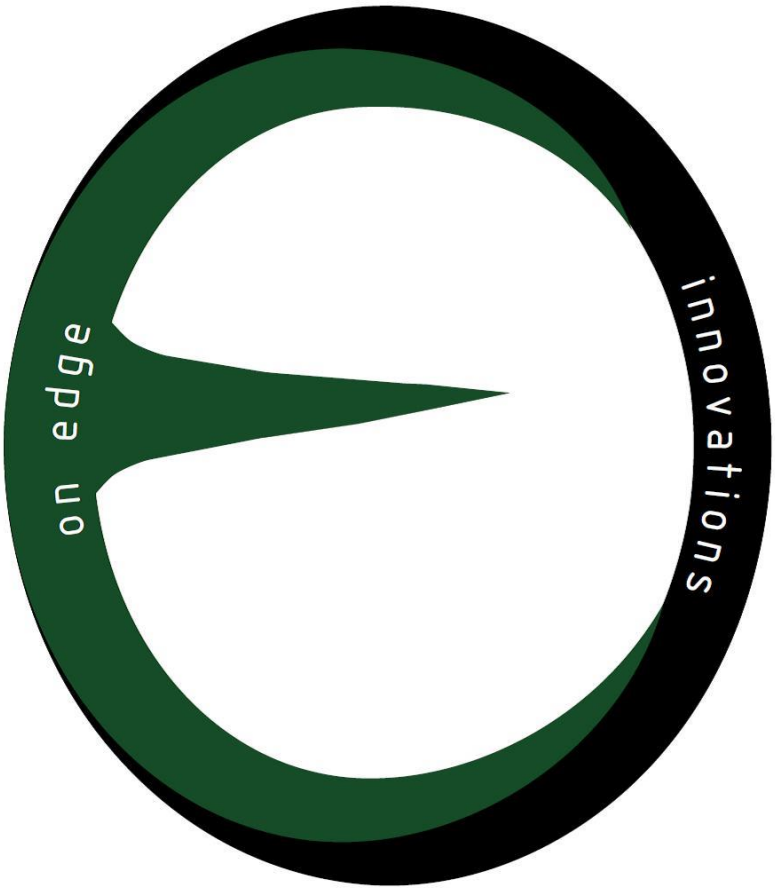
SPRING 2011 Design Report



28 APRIL 2011

Team Members:

Gary Gray – Team Leader, Engineer

Laura Merriman – Engineer

Evan Foster – Engineer

Alice White – Communications

Jeremy McCasland – Economics

Client:

Brad Lahman

Boxel Manufacturing

Caney, OK

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Appendix K – QBer User's Manual

MISSION STATEMENT

OEI works closely with their customers to make ideas become more than just a design, a prototype, or an unused patent. We convey our customer's ideas from the drawing board to production and into consumers' hands. With combined efforts, OEI strives to maintain pristine relationships with our customers and to provide quality, safe products for consumers.

PROBLEM STATEMENT

In order to provide excellent hay products at a minimal production cost, Boxel Manufacturing needed a safe, efficient and reliable hay bale collecting and banding system. In addition to designing such a product, OEI created a business and marketing plan for Boxel to promote and sell The Hay QBer.

STATEMENT OF WORK

Background

OEI designed a small, square bale bundler for Boxel Manufacturing. Boxel wished to produce and sell a machine capable of compressing small, square hay or straw bales and banding the "bundle" together to increase ease and efficiency of storing, transporting and loading/unloading bales. This machine fits the needs of small-scale hay producers wanting to add value to their small square bales. Additionally, the final bundle will be marketed to consumers who want convenient hay storage and transportation. From the proposed idea, OEI created the The Hay QBer.

Scope of Work

To meet Boxel's needs, the engineers of OEI collaborated to create a pull-along trailer mounted on a swinging tongue. The steel trailer has a bale elevator attached to the left side of the trailer that picks small, square bales out of the field and conveys them back to a laborer. In addition to the trailer and the bale elevator, OEI designed and constructed a compression system capable of compressing ten small, square bales, and a strapping system using plastic that tightens around the cube. A hand-held sealer

seals the plastic bands. In order to remove the cube of bales from the trailer, OEI designed a releasing mechanism to distribute the bundle to the ground without damaging it.

Physical Location

The construction of this project occurred at Boxel Manufacturing in Caney, Okla. OEI and Boxel communicated designs through SolidWorks drawings and distributed the construction according to the components needed at the time.

Period of Performance

The engineers of OEI began designing in SolidWorks in the fall semester. Concept design models were sent to Boxel on November 8th, 2010. By December 5th, OnEdge Innovation had a small-scale model constructed for final design concept review. The design was sent to Boxel March 7, 2011 with projected completion in April 2011.

Delivery Requirements

Table 1: Delivery Requirements:

Date	Item Due
02 October 2010	Competitive Analysis Report
05 November 2010	Work Breakdown Structure
9-10 December 2010	Design Proposal Report Design Proposal Presentation
Week 1, February 2011	Final Design Review
Week 1, March 2011	Delivery of Construction Drawings for Fabrication
Week 3, April 2011	Field Testing and Reevaluation of Design
28 April 2011	Project Report Project Presentation and Demonstration
03 May 2011	Design Notebooks Submission

Detailed Work

OEI began designing the bale bundling mechanism in the fall semester.

The trailer is 8 feet wide and 20 feet long, from tongue to tires. The maximum height, with the roof and canopy in operating position, is 10.5 feet. The minimum height, with the roof and canopy in traveling, position is 7 feet. OEI designed all components of the bale bundler before setting exact and final dimensions of the trailer. The trailer allows space for five bales in the reserve storage area, for a laborer to move about the trailer in order to stack the bales, and for the 10 bale compression system.

The bale elevator resembles a conveyor belt system that picks the bales from the field or from a baler and moves them to the stacking area. This part of the machine reduces the manual labor required to place bales on the trailer.

A tractor pulling the trailer will power the compression mechanism with hydraulics. It holds 10 bales; the compression area starts at 63” wide and when compressed reaches 48”. A sliding trolley mounted to a canopy tee beam holds the plastic strapping dispensers. This trolley’s range is controlled by two strategically placed magnets. One of the compression walls has a mechanism to hold the strap ends while the bales are stacked. The compression will occur from both sides. The tractor also powers the discharging mechanism with hydraulics, rotating the platform 112° to release the 10 bale cube back into the original field.

Payment Schedule

Boxel purchased the all supplies, including metals, hydraulics, cylinders and bearings. OEI required no payment for the work done on the Hay QBer project.

Acceptance of Criteria

Boxel demanded the creation of a single-laborer machine capable of bundling a minimum of 1200 bales per 10 hour work day. Boxel also required a durable, easily operated machine that complies with needs of a small-scale hay producer. A 80 HP tractor must be able to pull the machine. Additionally, shade has been provided for the laborer in the form of a removable canopy. Boxel budgeted the building expenses to not

exceed $10,000 in production costs and will sell the machine for $XXXX. Currently, Boxel does not know if they will market directly to consumers or market through another company.

Special Requirements

Due to the distance between Stillwater, Okla., and Caney, Okla., the OEI team and Boxel alternated travel between locations. During the project, both entities traveled between locations, once meeting Ada, Okla.

WORK BREAKDOWN SCHEDULE

Complete Work Breakdown Schedule and Task List can be found in Appendix A.

---------- Fall 2010 Semester ----------

1. ***Initial Research 9/14/10***
2. ***Develop Rough Budget 9/27/10***

   Reviewed initial research and consult with Boxel to develop a rough, projected budget for the prototype design and build.

3. ***Develop Design 10/1/10***

   The design development was divided into four different areas: hay elevation, hay compression, bundle banding, and bundle releasing.

---------- Spring 2011 Semester ----------

4. ***Build Prototype***

   4.1. Create Construction Drawings for each part

   Created drawings in SolidWorks including all initial dimensions and assembly specifications (welds, bolts, threads).

   4.2. Decide where to build machine

The trailer frame and larger fabrication was completed at Boxel. Small, detailed fabrication was completed at a machine shop located in Tushka, Okla.

4.3. Order parts through Boxel purchasing

4.4. Construct Prototype

Cut steel bars, rods, angles, sheet metal to desired sizes for framework and other parts. Drill holes in steel for various functions. Join/weld the framework. Attach via fasten or weld the other components (compression, elevation, banding, and release mechanisms) to the framework. Attach axles/wheels. Construct and attach the hitch system. Attach hydraulic components: cylinders, directional stack valve, hoses and motors.

5. Prototype Testing

5.1. Run tests on all components

Dr. Dan Storm (BAE) has loaned OEI 10 hay bales for testing. Hook implement to the tractor and run the implement as would in field conditions: laying 10 bales out in a row and testing all mechanisms and components.

5.2. Review Prototype Design

Made any necessary changes to design that arise from testing.

5.3. Review Construction Drawings

Made any necessary changes to dimensions that arise from testing.

5.4. Repeat Testing

6. Market Product

Developed business and marketing plan. Created a brochure for the product and add the product information to the Boxel website. Created a video of the machine in action.

7. Present Final Design with Prototype and Marketing Materials to Boxel Manufacturing

Created a presentation illustrating the prototype, marketing materials and business plan to Boxel, faculty and peers for product review.

COMPETITIVE ANALYSIS

OEI prepared the following report as an aid for the development of a 10 hay bale bundler for Boxel Manufacturing, a local fabrication and hay supplier company. The following material presents an industry, customer, competitor and technical analysis. This allowed OEI to develop a functioning design in SolidWorks ready for production by of December 5, 2010. The QBer's construction began March 7 in Caney.

INDUSTRY ANALYSIS

Breeders and producers must have a food source for their livestock, and large round bales are not feasible for producers with less than 30 head of livestock. These livestock producers must utilize small, square bales (14" x 18" x 40") to feed their stock. Some hay producers currently bundle small, square bales into larger bales ranging from 16 small bales to 60 small bales to ease transportation and storage. Customers for small square bales produces are the equine industry and show livestock industry.

The equine industry demands small square bales of alfalfa and grass hay for feed. According to IBISWorld, the equine industry created $1.6 billion in revenue in 2009[4]. Oklahoma alone hosts 15 national and world equine competitions every year[5]. In 2009, 1,100 competitors entered classes at the Grand National and World Championship Morgan Horse show. The horse show spanned eight days[7]. Most competitions run one to two weeks, and competitors haul from all parts of the United States and sometimes out of the country. Transporting horses, equipment and feed creates high costs and hassle. Trainers often times ship their horses and equipment and rely on the hosting facility to provide small square bales to feed their equines. This creates a market for 10 bale cubes in Oklahoma.

According to Stephen Boyles, a show steer should consume 4-5 lbs. of hay daily. At shows, show steers should receive one to two flakes of hay per feeding[9]. Oklahoma hosts 13 livestock shows across the state in January and February[10]. These shows require small square bales of both hay and straw on site for the exhibitors to purchase. The Oklahoma State Fair runs for 10 days and holds 12 divisions with multiple classes[11]. Hundreds of animals reside at the Fair, requiring hay and straw for maximum performance and comfort. The combination of cattle and equine competitions creates a demand for easily transported and stored small, square bales in Oklahoma.

According to USDA, the Oklahoma hay market has maintained steady prices throughout the weakening economy. Small square alfalfa bales sold at $150 to $210 per ton and small square grass hay bales sold at $85 to $140 per ton, depending on quality[1]. These prices demonstrate a constant demand for small square bales in the market, which strongly supports the need to produce haying equipment. Since the market for hay producers appears to remain strong, producers will find the most efficient production and marketing methods to increase their profit margin. Possessing a means to easily transport and store small, square bales will increase their profit margin.

The hay bale bundling company Bale Band-it began making bundlers in 1999 and has already doubled its production twice in recent years[2]. Hay bale bundlers are marketed several ways, including trade show exhibits and magazine advertisements. Trade shows are commonly held in conjunction with large horse shows, farm shows and agricultural expos. Trade shows such as KNID Agrifest in Enid, Okla., and the Fort Worth Stock Show and Rodeo in Fort Worth, Texas, could promote Boxel's bale bundler[6].

CUSTOMERS/BUYERS

To research Boxel's target consumers, OEI read testimonials given on competitors websites given by their clients. Based on the testimonials found in Appendix B, OEI has gathered specific aspects of a bale bundling machine that customers expect.

Boxel's target customers want quality machines capable of increasing their profit margin. They want to load more hay on trailers to reduce transportation and labor cost. By eliminating the need to load and unload small square bales by hand, input labor and labor costs would greatly reduce. Customers must be able to operate the equipment easily and without formal training. Therefore, Boxel's product must be simple to operate. As stated in Appendix B, producers are looking for "simplicity, with minimal moving parts…" Additionally, customers expect a machine to be safe to operate. Many of Boxel's target customers rely on family labor to manage and operate farm equipment. Customers not only want safe equipment for themselves, but also for the benefit of their family members and/or hired labor. Producers, such as Stephen T. Baltz, need to know their products "will travel safely down the interstate" once placed on a flatbed. For more of customer testimonial, see Appendix B.

Boxel will market the Hay QBer to the hay or wheat producer haying from 50 to 300 acres. With the smaller operations of Boxel's target customers, the need for fully automatic, high priced machinery is nonexistent. Boxel customers need a machine costing no more than $18,000. Customers are willing to partake in minimal manual labor.

BOXEL MANUFACTURING AND ITS RESOURCES

Boxel Manufacturing, Inc., is a 25-year-old metal fabrication company based in Caney, Okla. Brad Lahman owns and manages Boxel. Boxel currently produces livestock show supply boxes, grooming supply boxes and small cake feeders, as well as custom hay baling of round and small, square hay bales.

The operation is housed on Brad Lahman's ranch in a custom metal fabrication shop. The manufacturing shop consists of welding stations, a machine shop, press brakes and a plasma table. All Boxel products are made mostly of steel with certain non-steel components. These components, such as tires and wheels, are outsourced.

Boxel has developed seven prototypes of a bale bundler. His first designs bundled 18, 15, and 12 bales. Each of his machines required three laborers; one to toss the hay on

to the trailer and one to stack, band and shove the hay off of the trailer, and one to drive the tractor. The finished hay bundles lacked integrity and stable stacking ability.

COMPETITORS AND THEIR RESOURCES

The following machines are the current competition in the bale bundling market. Primary stacking competitors of Boxel in the bale bundling area are located throughout the United States. Potential secondary competitors include Bale Baron and Bale Band-It.

Figure 1: Bale Baron

http://www.kleine-balen.nl/en/machines/balen-bundelaars.html

Figure 2: Bale Band-It

http://pics.hoobly.com/full/YDK1JAHNDI6SA7TRGK.jpg

OEI created a single, scalable model with interchangeable parts so the customer can bundle 10 small square bales to meet their individual needs. The table below shows the different options each competitor offers for their bundler along with the Hay QBer.

Table 2: Competitive Analysis

Name	Bale Elevation	Stacking	Banding	Compression	Release	Cost
Bale Band-It	Baler only	Mechanical	Steel Strap	Hydraulic	Automatic	$70,273*
Bale Baron	Baler only	Mechanical	Plastic Twine	Hydraulic	Automatic	$62,321**
Arcusin	Ground pick up	Mechanical	Cord	Hydraulic	Automatic	$79,553*

TECHNICAL ANALYSIS

The technical analysis forecasts the direction of prices through the study of past market data, generally the price and the volume of product. The following sections contain all relevant published information which aided in the design of the product, such as standards and patents. This analysis also provides testing and modeling information completed during the development of the product.

STANDARDS AND REGULATIONS

In industry, standards and regulations establish uniform engineering and technical data, methods, processes and practices. Industry standards provide information for concept development and aid in reforming ideas that incorporate exchangeability among design components. The American Society of Agricultural and Biological Engineers publish volumes of industry standards for most any agricultural application.

OEI found numerous standards pertaining to the current design aspect, including terminology for hay handling equipment, standards for hydraulic cylinders and safety requirements. The basic terminology for hay handling equipment helps name different parts of the bundler in accordance with the current products on the market. Particular names will allow the customers understand each part of the bundler and recognize the terms familiar to them. For hydraulic cylinders, the standards helped to develop a

working hydraulic lift mechanism for the hay bale collector. OEI highlights some pertinent standards below, but all relevant standards and regulations are in Appendix C: Standards and Regulations.

The State of Oklahoma Department of Public Safety and Oklahoma Highway Patrol have issued a booklet of statutes pertaining directly to farmers and ranchers. Regulations and standards affecting the transportation of the hay bundler on public roads formed design constraints on trailer size. These standards and regulations also required safety features such as an official slow-moving vehicle emblem, hydraulic cylinder safety locks, red lights and red reflectors must be mounted on the back to signal other drivers, and chain or cable safety back-up devices must be installed in addition to the hitch.

The Occupational Safety and Health Administration has regulations limiting the noise level if a human operator is to be needed to operate the bundler. This determined the type of hydraulic motors used in the design.

PATENTS

Patents contain information used during design and concept development. The basic summary of the device, a full description of the device, how it is to be used, and what the device should achieve are found within patents. OEI used patents to view similar concepts and designs, which inspired our engineers' own creations. OEI found the following patents:

Patent Number	*Title*
7610851 B1	*Bale Stacker*

Inventor: Mark Horst (Marcrest Manufacturing) – Bale Baron
This patent involves a method for consolidating a plurality of bales into a bale bundle. An upstream opening brings the bales in a compression chamber. The bales are compressed from the bottom and the front. After compression the bundle is released to the downstream opening. This opening releases the bale back to the field[13].

6397738 B1 *Hay Bale Stacking and Bundling Method*

Inventor: Owen J. Brown, Jr. – Bale Band-It
This patent involves a method to form a bundle of twenty-one square bales. The apparatus will elevate the hay bale from the field, mechanically stack the hay into a bundle, compress the hay from one side, band the hay with two metal bands, then release the hay back into the field. The machine is computer controlled from the tractor operator and fully automated[13].

These patents were used to analyze the process used by patent holders when they developed their products. Complete patents can be found in Appendix C: Patents.

FIELD/PHYSICAL TESTING AND DATA

Boxel tested the integrity of a 10 small, square bale cube. The cube can be stacked at least three cubes high in a barn without losing integrity. A forklift can easily move a cube without pallets, and the cube can be transported on a trailer or truck bed.

Orientations of compression were tested on the 10 bale cube to determine if 2 - directional compression was needed or optional. Degree of compression testing coincides with the testing of the hydraulic system. OEI chose the 2 – directional compression because of the hydraulic configuration and reduction of force on the trailer framework.

Different stacking and banding systems have been tested on a 10 bale cube. Stacking three bales flat side on the bottom row, four bales on edge in the middle and three bales flat side on the top maintained the best integrity. See Figure 9 in the Square Bale Stacking segment of this report for further stacking information.

OEI researched banding machines to bind the 10 bale cube. Boxel and OEI looked at banders that would tighten the bands automatically or manually. OEI and Brad Lahman met with representatives of Omni-Packaging November 19, 2010. After testing the

Zapak ZP36 and the Strapex BXT-80, Boxel chose to use the Zapak ZP36. More information regarding the Zapak ZP36 can be found on in the Bundle Banding segment of this report.

SIMULATION AND MODELING

OEI modeled preliminary ideas to help visualize concepts and communicate with client fabrication specifications. We used SolidWorks to model components and generate computer assemblies.

ENVIRONMENTAL AND GLOBAL IMPACTS

The Boxel Hay QBer could potentially impact the regional environment and socioeconomics on a small scale. To produce the QBer, steel, aluminum and hydraulic components will be used. The use of such resources not only limits the amount within the market but also contributes to pollutants. However, such actions are on a small scale and would not provide great amounts to the environment. Additionally, the QBer has potential to decrease fuel cost by increasing transportation efficiency. The unique stacking and banding of the hay cubes will make transporting multiple 10 bale stacks more effective. Regarding the social impacts of the QBer, one can consider the labor costs and benefits. The QBer will decrease the amount of physical labor required to stack, transport and store small square bales. However, the reduction of physical labor does not decrease the need for a laborer. A laborer will still need to be present to stack bales into the QBer and drive a forklift for transporting and storing, but the amount of physical work required is reduced, benefiting society.

DESIGN CRITERIA

Boxel Manufacturing required the final hay bundle design to incorporate the following components:

1. Mobile – move through a field, not a stationary unit
2. Hay Compression

3. Banding
4. Release of the bundle back to the field
5. Use of a human operator – to keep cost low relative to fully automated systems
6. Manufacturability
7. Shade for operator comfort

CONCEPT DEVELOPMENT

OEI divided the design of the project into six major categories:

1. Hay bale elevation from the field
2. Hay bale stacking
3. Hay compression on the trailer
4. Automated bundle banding system
5. Bundle release to the original field location
6. Trailer framework

This allowed the design of each component to meet requirements and requests of customers along with industry standards. OEI developed a design concept for each category. OEI adjusted these concepts to meet the design criteria, as discussed in the following sections.

INITIAL DESIGN CONCEPT

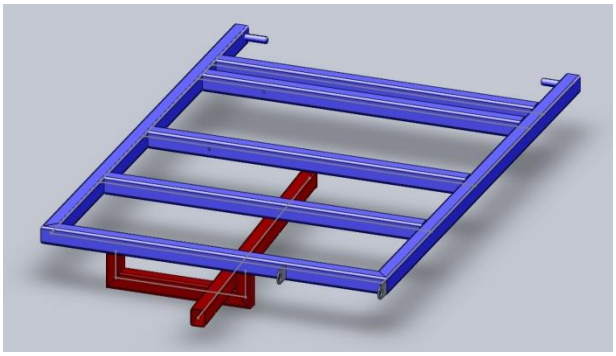


Figure 1: Trailer Frame and Telescoping, Pivoting Tongue

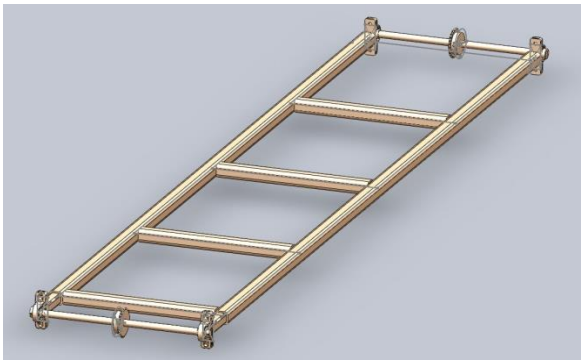


Figure 2: Lifting Mechanism

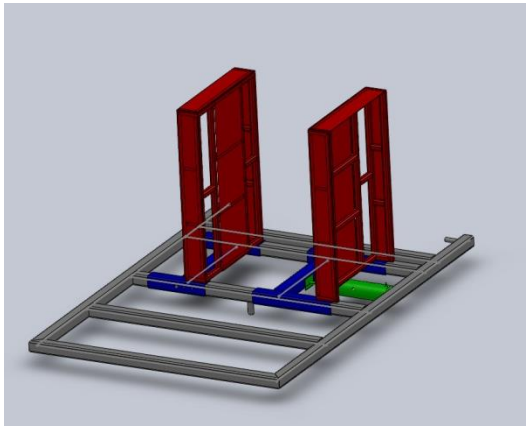


Figure 3: Compression Assembly Mounted on the Trailer Frame

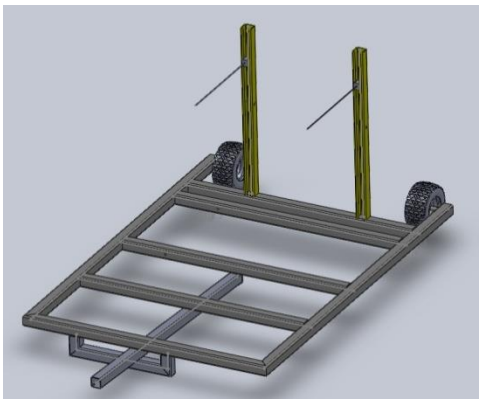


Figure 4: Banding System

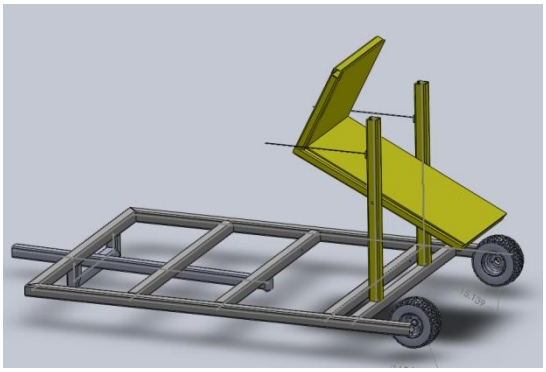


Figure 5: Releasing System – Releasing Position

Initial Design Concept

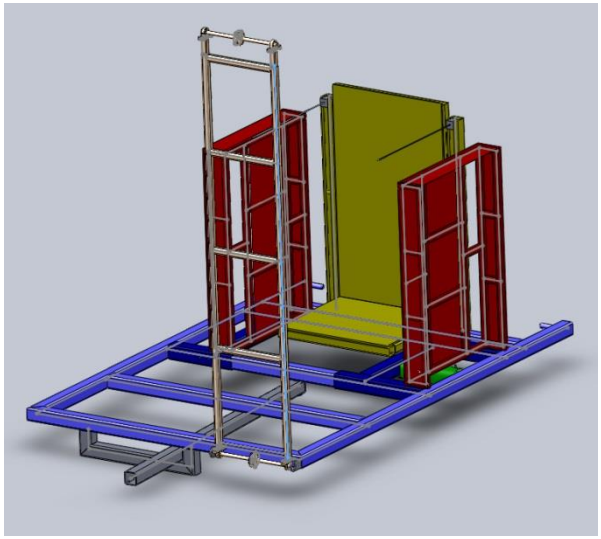


Figure 6: Initial Model Design

FINAL DESIGN

Building from the above design concepts constructed in the fall, OEI created a final design for the Boxel Hay QBer.

Trailer

The trailer framework will function in the field and travel safely down public roads. OEI built the trailer to measure 8 feet wide, avoiding the need for “wide load” signs or signals. The length of the trailer is 20 feet.

The trailer is made of 3” x 5” x 3/16” rectangular tubing. Bracing has been placed across the trailer to support the compression mechanism, releasing apparatus and the bale storage area. The bracing is made of 3” x 3” x 3/16” square tubing.

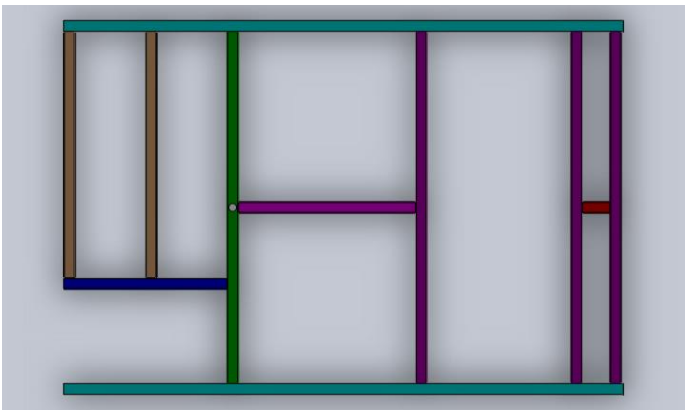


Figure 4: Trailer Framework

A pivoting tongue will allow the customer freedom to 1) directly attach the bundler to a square hay baler or 2) attach the bundler to a tractor, offsetting the bundler so the elevation mechanism will directly align with square hay bales. The back of the trailer is equipped with a height adjustment system. This is used to position the hay elevation system in the optimal position relative to the ground for the hay bale pick-up. Shock absorbance is also achieved with this system. Two 2.5” x 8” hydraulic cylinders, controlled by the operator on the platform, are used to achieve these functions.

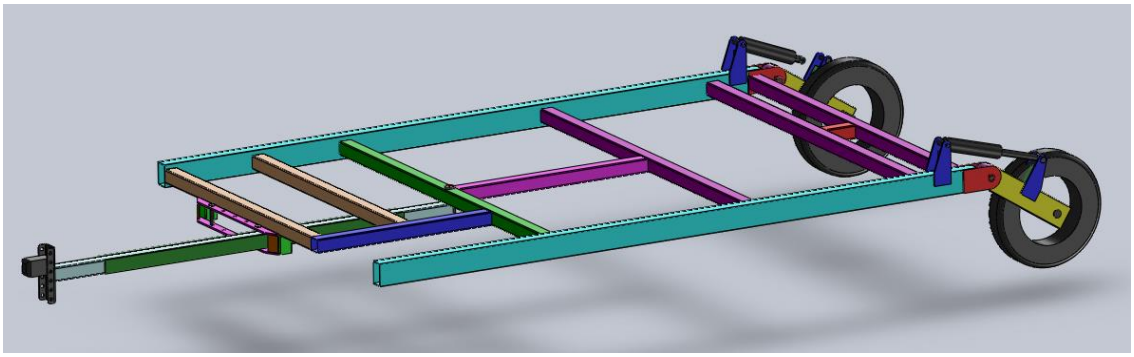


Figure 5: Trailer Framework with Height Adjustment and Pivoting Tongue

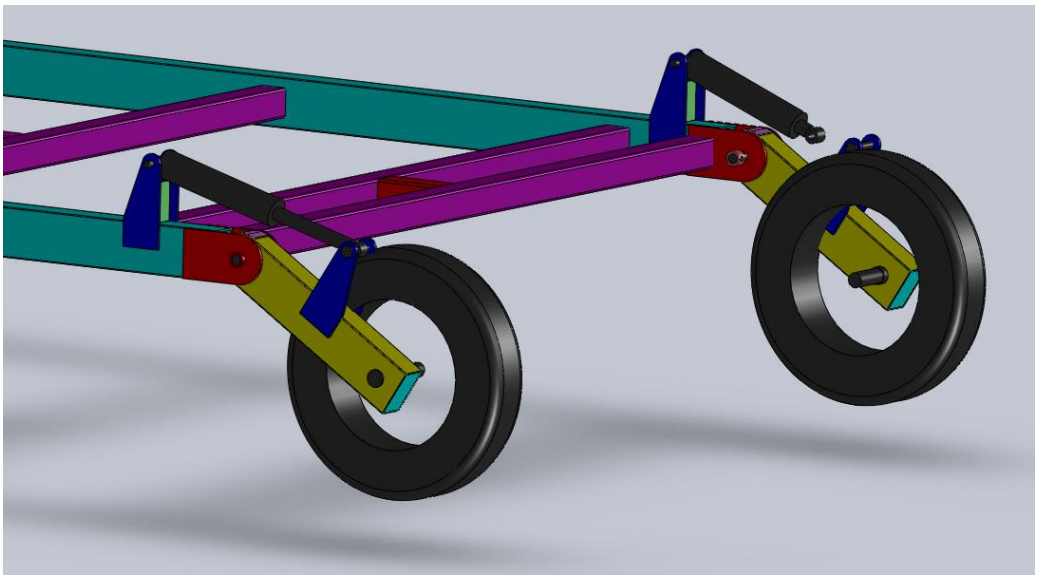


Figure 6: Height Adjustment Framework

This framework allows OEI to incorporate all mechanisms needed to bundle 10 square bales into one cube.

Bale Elevation

The bundling process begins by elevating the small square bales from the ground. The elevator consists of a hydraulic gear motor that drives two lift chain assemblies with a common shaft. The lift chains operate continually during use of the bundler and allow the bales to move from the ground to the operator station at a constant rate. The controls and variable flow valve for the hydraulic motor are located on the machine to ease operation. The assembly also implements a collector mounted to the starting end. This allows an alignment error of the bale stream. The collector aligns the hay stream with the lift chains to maintain a continuous steady-state flow. For the traveling position, the table folds under the bale storage table (See Bale Storage). It is then pinned to the trailer frame to keep stationary.

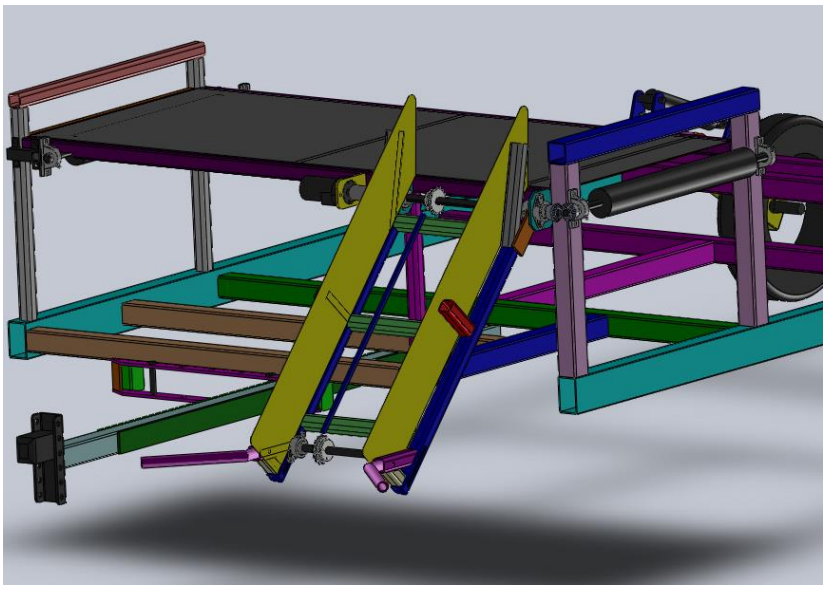


Figure 7: Hay Elevation – Operating Position

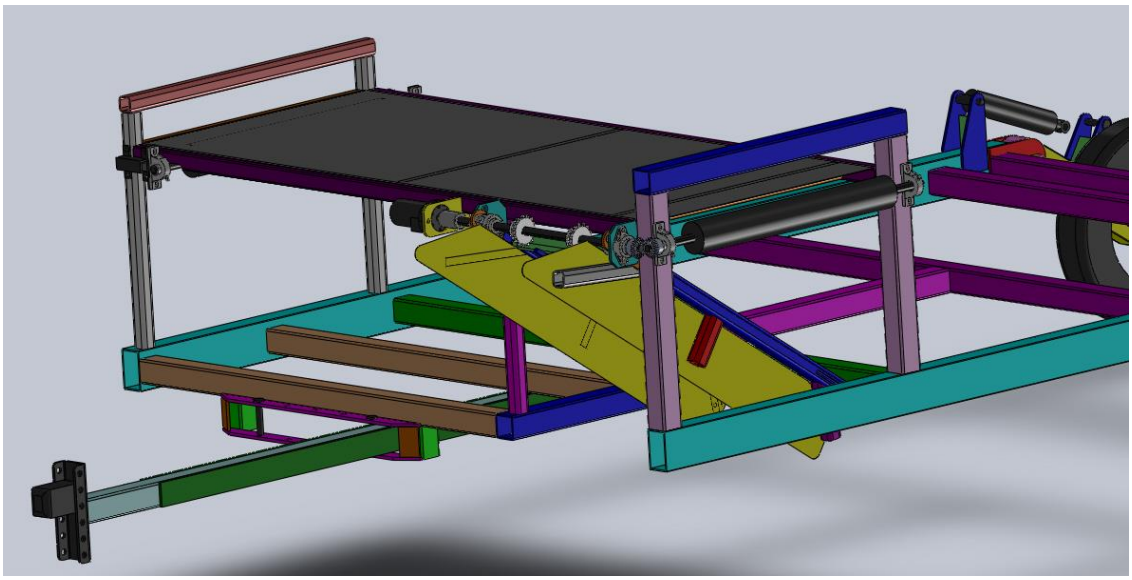


Figure 8: Hay Elevation – Traveling Position

A step for the operator was added to make transporting bales from the storage area to the compression station less labor-intensive.

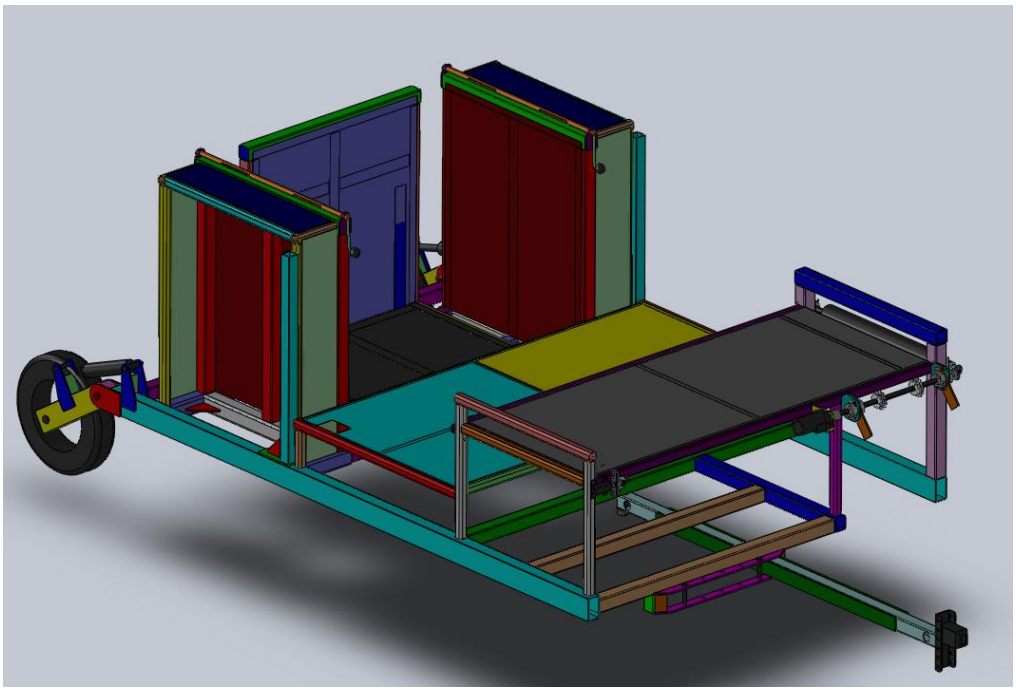


Figure 9: Raised Platform for Operator

Bale Storage

OEI original design concepts lacked an area to allow bales to accumulate while the operator stacked. In order to create a more efficient cubing process, OEI added a storage station. After a bale reaches the top of the elevation structure, it will make a 90° directional change by a smooth conveyor belt. This conveyor is operated by the same hydraulic motor. Miter gears (1:1) are used to transfer the rotation from the common shaft to the conveyor rollers.

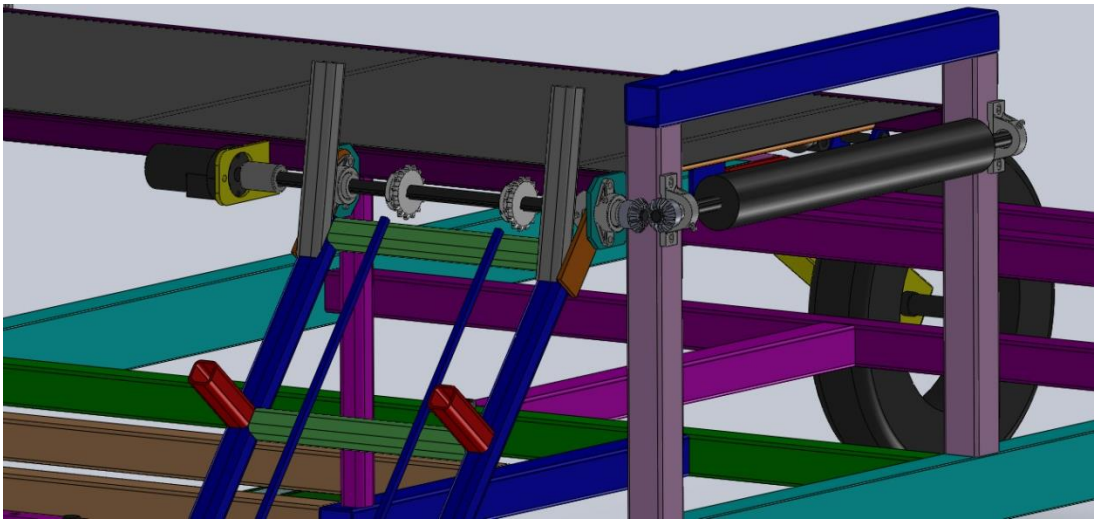


Figure 10: Hydraulic Cylinder Operation

The length of the bale storage table is 7.5 feet. This allows enough storage for five 14” x 18” x 40” bales to rest while the operator stacks and the driver continues driving through the field.

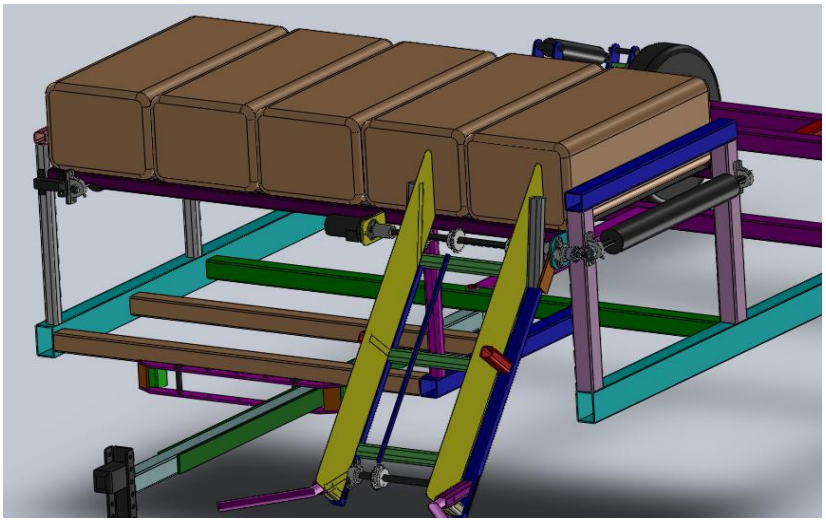


Figure 11: Bale Storage

Bale Compression

The original fall design concept displayed the hydraulic compression cylinder on the side of a compression wall. However, after consideration, OEI moved the cylinder underneath the compression area to remove pressure from the main frame. This

increases the structural integrity of the frame. The final compression system is formed from two walls connected to a hydraulic cylinder. The walls are made of 2” x 2” x 3/16” square tubing and 16 gauge sheet metal. Both walls are 43.5 inches wide, 53.75 inches tall, and 13.5 inches deep. The dimensions were determined from the dimensions of the 10 small square bale bundle configuration.

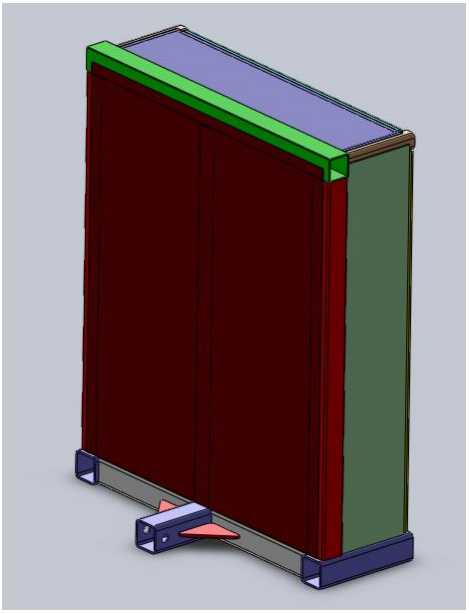


Figure 12: Compression Wall – Front

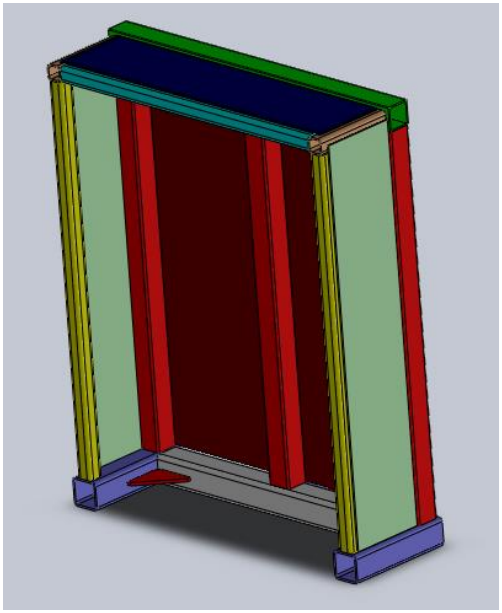


Figure 13: Compression Wall – Back

The two compression walls are connected with a hydraulic cylinder (4” x 16”). When contracted, the walls will compress the square bales. The operator easily controls this cylinder. When the cylinder retracts and extends, it slides the two walls with the main trailer frame supports as their track.

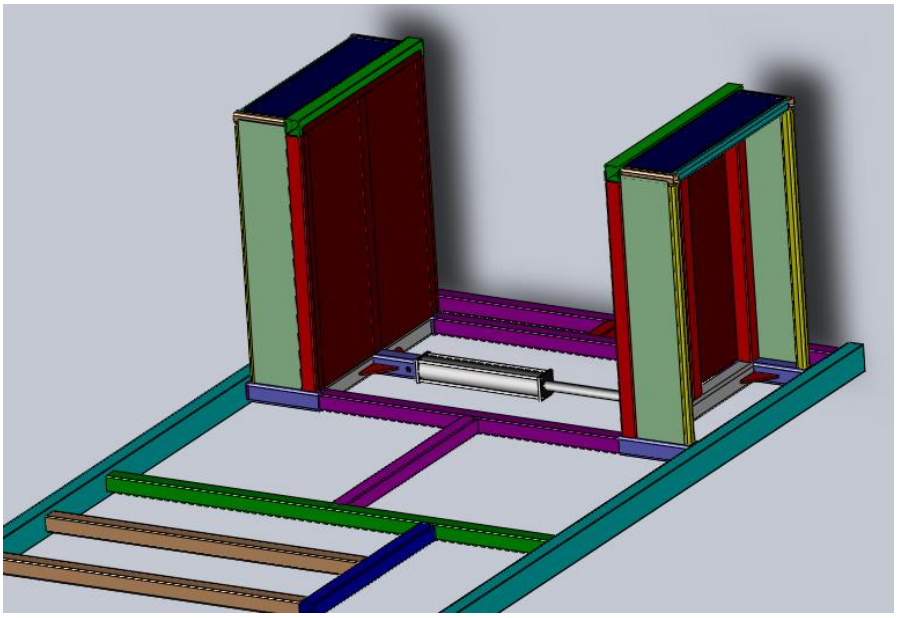


Figure 14: Compression System

Bundle Banding

The design concept created in the fall lacked an efficient banding system. Creating a unique, functional and efficient banding system challenged OEI. After much thought, the team created a banding system that utilizes a human operator, a tee beam, a trolley, magnets and a hand-held tensioning and sealing device.

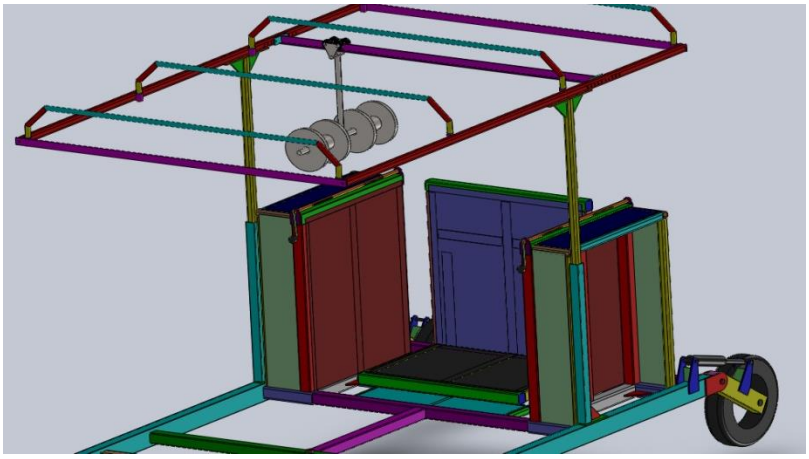


Figure 15: Banding System

Before stacking the bales, the operator will pull plastic strapping from spools across the floor of the stacking area. The bands are secured on the opposing side by sliding them

through a holding device that rotates 270 degrees, holding the band in place while the operator stacks the 10 bales between the compression walls as shown below.

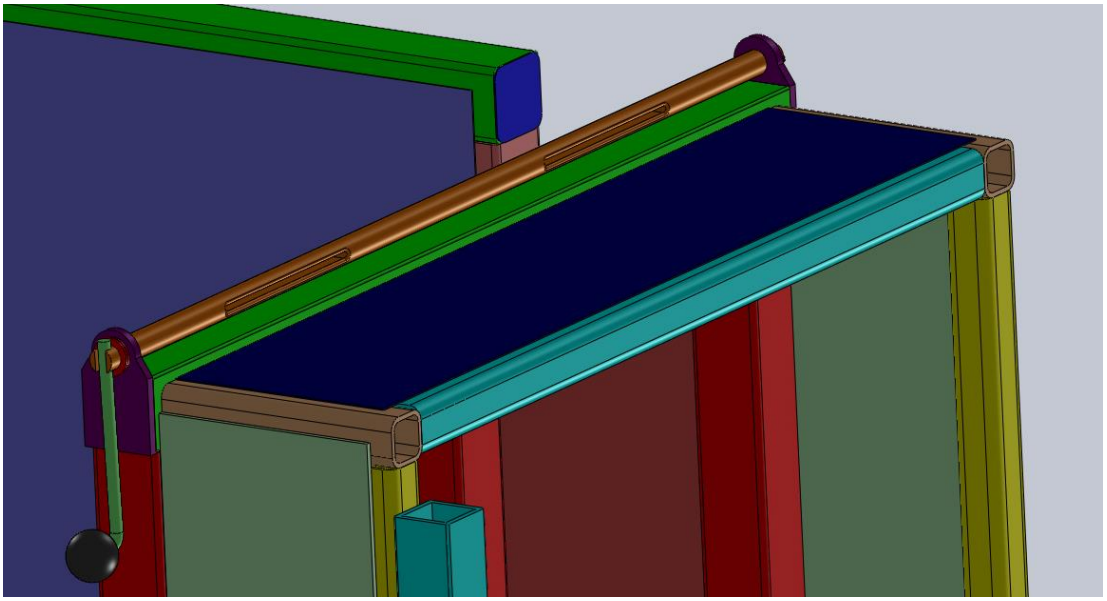


Figure 16: Plastic Strap Locking Rotating Shaft

After stacking the bales, the compression cylinder is engaged. While the stack remains compressed, the operator releases the strap-locking shaft and slides over the trolley. This aligns the bands and allows the operator to use a hand-held tensioning, sealing, and trimming device (See page 30). A right or left-handed individual can comfortably operate the trolley and locking shaft process. After the banding is complete, the trolley is slid back into its starting position.

Banding Material and Device

Figure 17: Plastic Strapping

OEI tested the Zapak ZP26 and the Strapex for utility, speed and power.

Table 3: Bander Comparison

Hand-Held Banding Tool	Battery Operated	Sealing Time Range	Tension Maximum	Warranty	Cost
Zapak ZP26	Lithium Ion	0.6 - 4.8 seconds	726 lbs	3 Year Parts &Service	$2,100.00
Strapex	Lithium Ion	2-5 seconds	900 lbs	No Warranty	$3,200.00

The Zapak ZP26 automatic hand-held bander from Omni-Packaging is used by the operator to tighten the of 5/8th inch wide and a thickness of 5/100th inch plastic strapping around the hay bundle and seal the straps together. The sealing time of the Zapak ZP26 is two seconds. This ZP26 is battery operated so cords will not be a safety issue.

Zapak ZP26

Bundle Release

The bundle release apparatus relocates the hay bundle from the trailer to the field. This mechanism also acts as the hay stacking platform.

The frame will be made of 3” x 3” x 3/16” square tubing and 16 gauge sheet metal. The dimensions are 49 inches tall, 46 inches wide, and the bottom platform extends 35 inches from the back support.

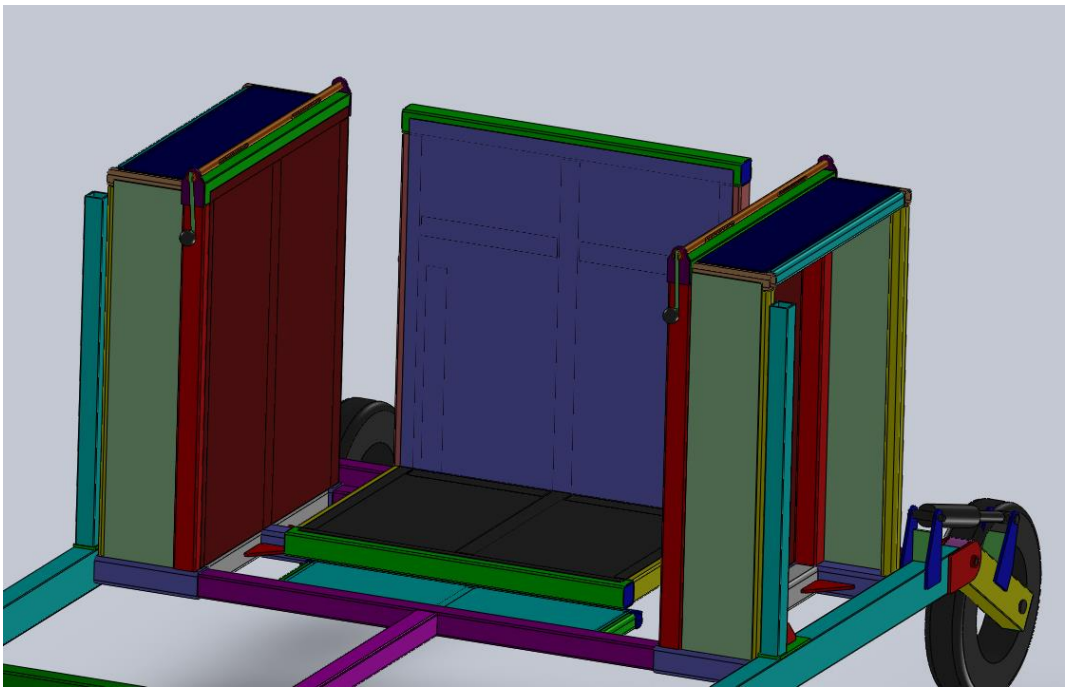


Figure 18: Releasing System – Resting Position

A hydraulic cylinder (2” x 10”) is used to flip the platform approximately 112°, sliding the bundle into the field. The extending end of the cylinder attaches just below the pivot point of the platform, and the fixed point attaches to a framework on the back of the trailer.

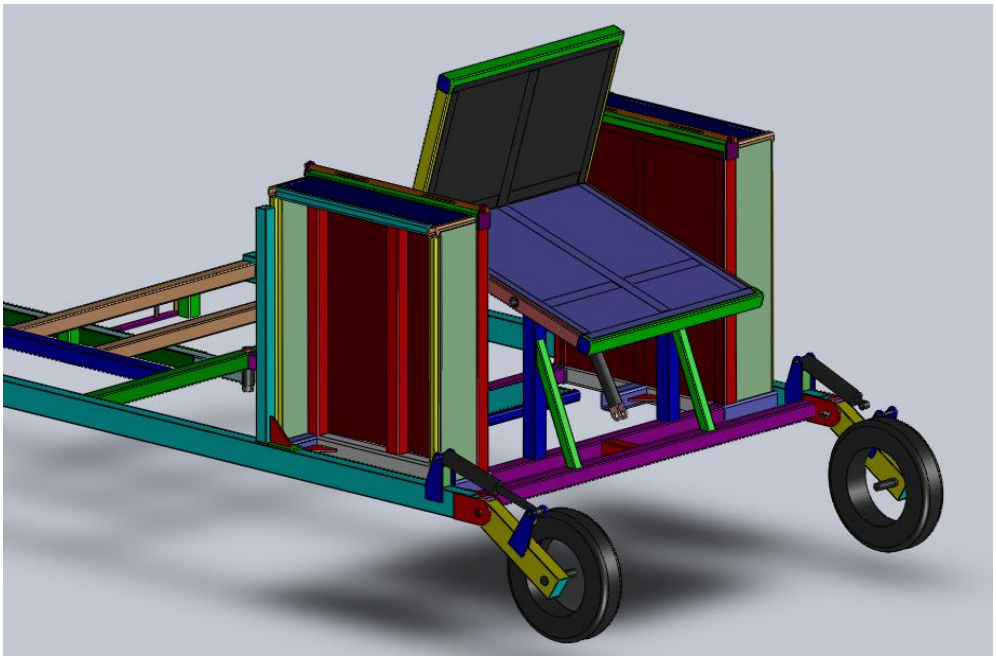


Figure 19: Releasing System – Releasing Position

A safety step was added under the releasing table for the operator's safety.

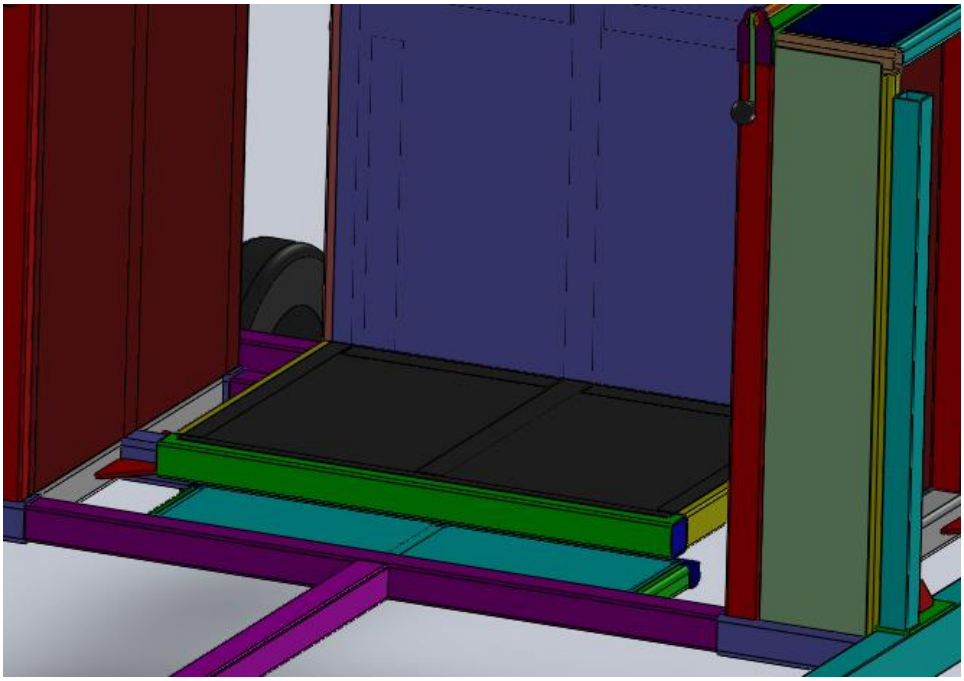


Figure 20: Safety Step

Canopy and Tarp

The canopy is made of aluminum because it will allow the operator to raise and lower depending on if the machine is in operation or being transported. Unlike the rest of the machine, the canopy structure is can all be broken down. It is not all welded together. This allows ease of delivery from Boxel Manufacturing to customers and dealers.

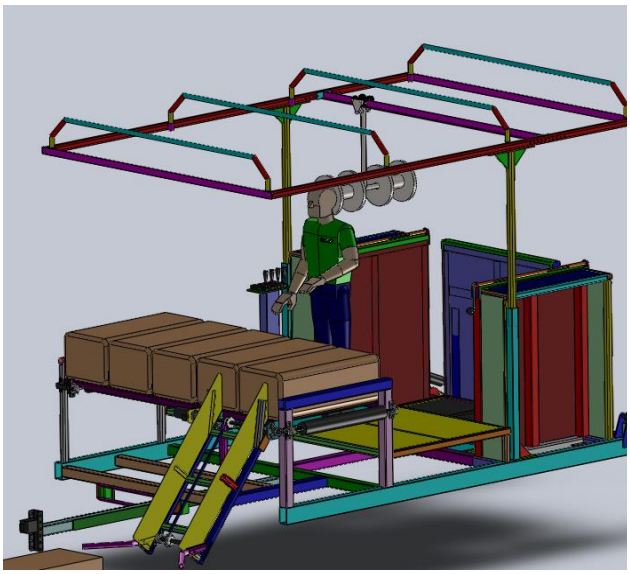


Figure 21: Boxel Qber in Operating Position

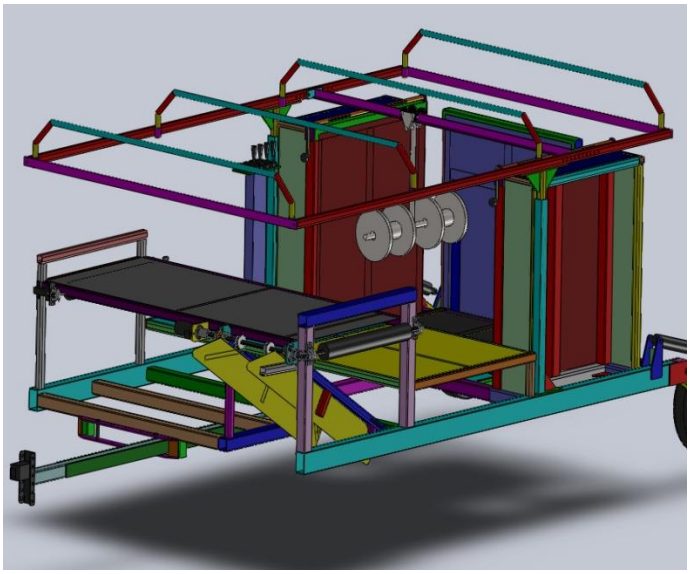


Figure 21: Boxel Qber in Traveling Position

Boxel purchased the tarp from Edwards Canvas in Pauls Valley, Oklahoma. The Cooley fabric blocks UV rays but still allows wind through to provide comfort for the operator. Bungee cords secured to hooks around the top supports of the canopy. These bungee cords create easy removal of the tarp for traveling or off-season storage.

Hydraulics

The primary driving function of the QBer consists of a basic closed-center hydraulic network. This hydraulic system allows the operator to be in full control of all of the mechanical motion functions of the machine.

The QBer hydraulic system consists of the following components:

1. Two Welded Gland 2.5” X 8” Prince Royal Line Cylinders
2. One Tie Rod 2” X 10” Prince Majestic Line Cylinder
3. One Tie Rod 4” X 16” Prince Majestic Line Cylinder
4. One Prince ADM Series Gerotor Hydraulic Motor
5. One Prince Wolverine Line MonoBlock Four Function Valve
6. One Sun Direct-Acting, Pressure Reducing Valve Assembly
7. One Brand Full Range Pressure Compensating Variable Flow Control

The two 2.5” x 8” cylinders each lift one side of the rear frame. These two cylinders require one pressure line as needed for lifting; the return function is gravity driven.

The 2” x 10” cylinder powers the releasing assembly function and requires two pressure lines to operate, each for either the power-in or power-out motion. The cylinder is located vertically behind the rotating releasing frame.

The 4” x 16” cylinder, located directly beneath the releasing assembly, connects the two compression wall frames together in the center of the machine. It requires two separate hydraulic pressure lines, one for compression and decompression of the cube.

The critical control of all of the hydraulic components is managed by the Prince MonoBlock® valve assembly, a hydraulic manifold equipped with four hand levers. Each lever connects to a four-way, three-position spool valve that allows independent control of every other hydraulic function of the system. Each lever is the operator function control of each cylinder as well as the hydraulic motor. The valve manifold is found on the passenger side of the machine on a pedestal mount located to allow for a comfortable user interface.

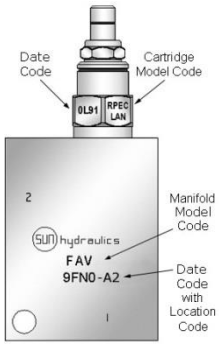
A hydraulic Gerotor® motor found on the front center of the QBer creates rotational power and drives the elevating assembly as well as the storage table assembly. The fully reversible motor permits operators to quickly unload a busted bale if necessary. A pressure-reducing valve assembly controls the base operating pressure of the hydraulic motor because the required motor has an operating pressure below the system operating pressure.

The operator of the QBer fully controls the hydraulic system beyond the initial engaging or disengaging flow.

Royal Line 2.5” X 8” Welded Gland Cylinder*

Prince Wolverine MonoBlock 4 Function Valve Assembly*

Majestic Line 2” X 10” and 4” X 16” Tie Rod Cylinders*



Prince Variable Flow Control Valve*

Sun Direct Acting Pressure Reducing Valve Assembly**

Prince ADM Series Hydraulic Motor*

*http://www.princehyd.com

**http://www.sunhydraulics.

Figure 21: General Hydraulics Layout

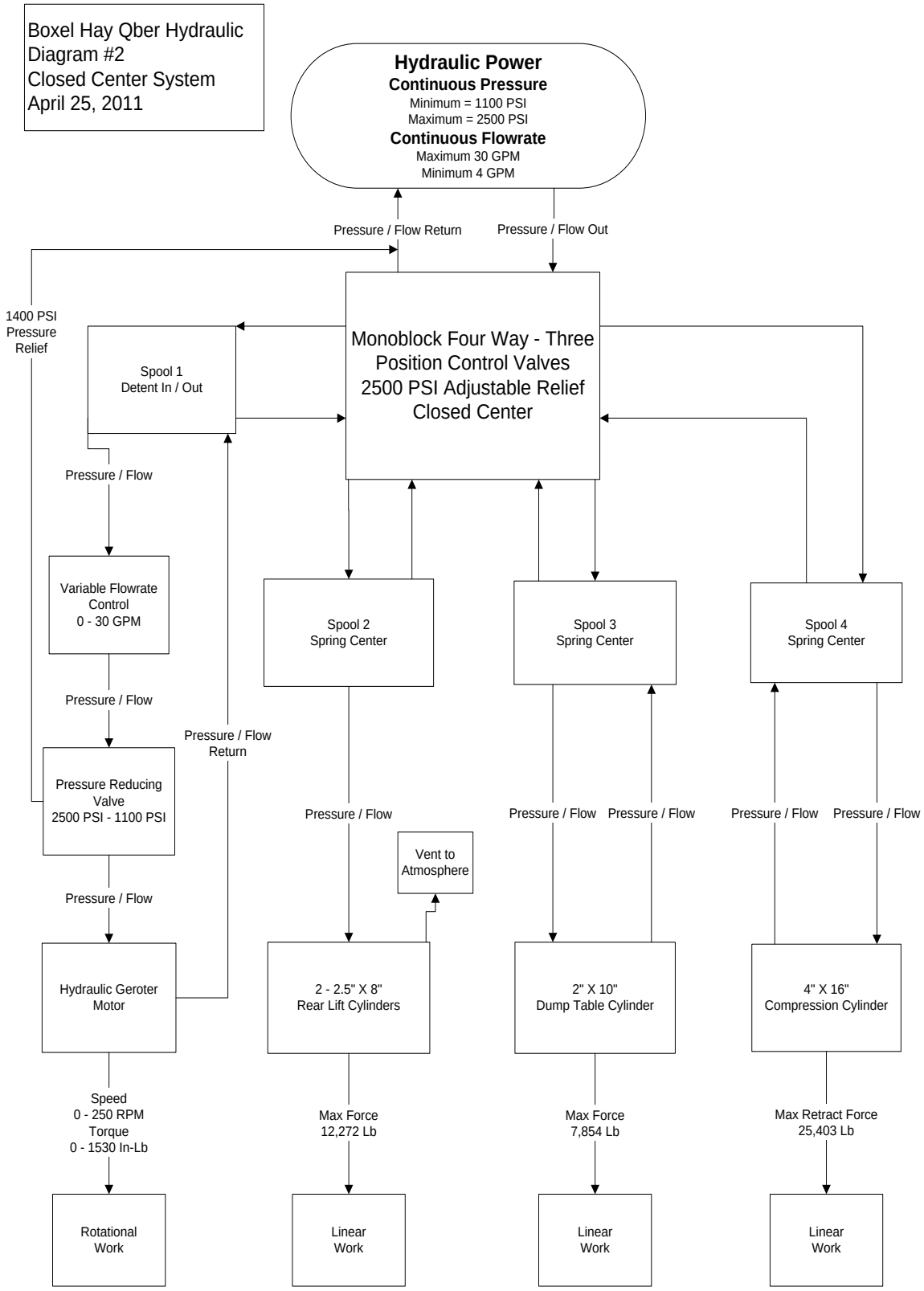
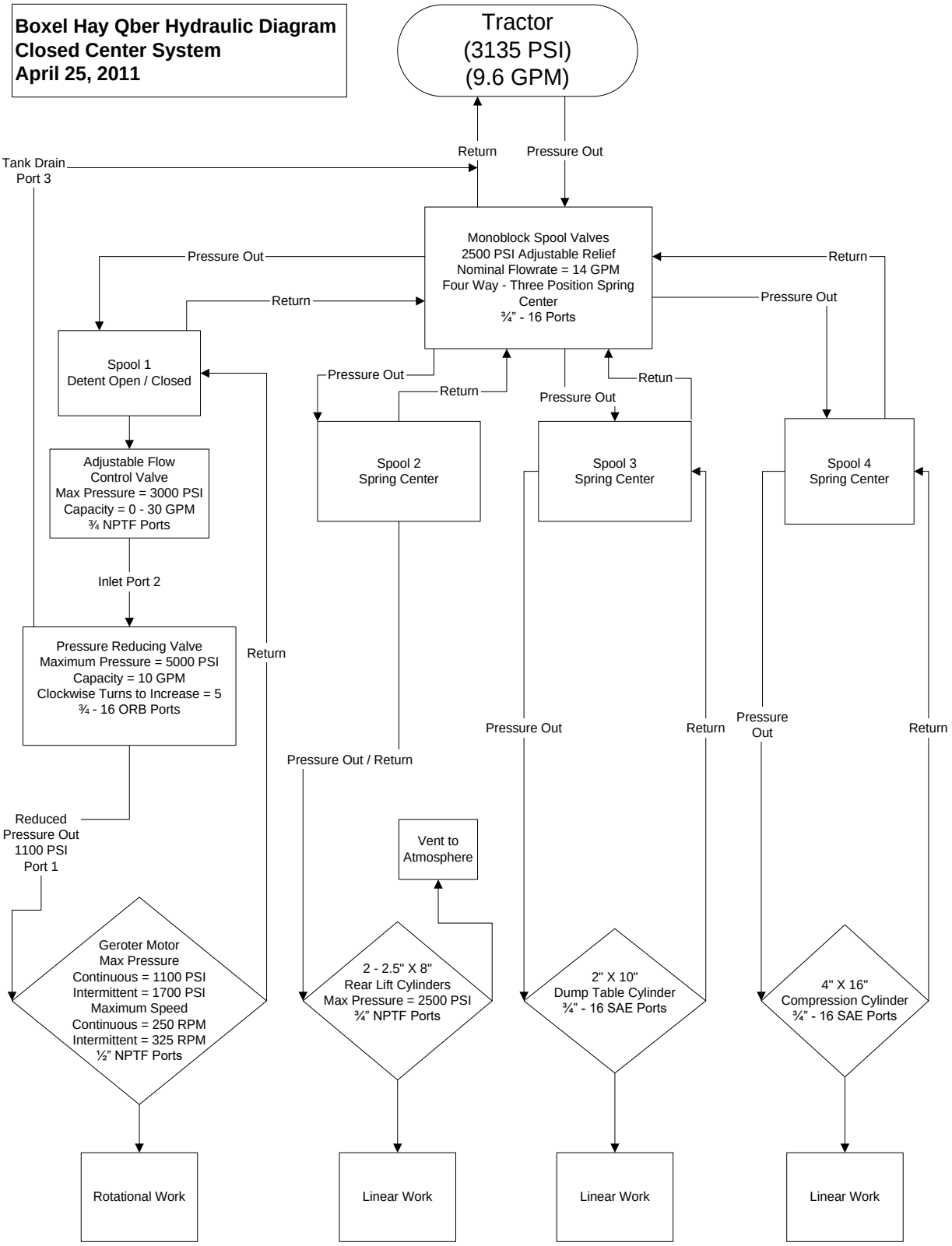


Figure 22: Specific Hydraulics Layout


Boxel Hay Qber Hydraulic Diagram
Closed Center System
April 25, 2011
Tractor
(3135 PSI)
(9.6 GPM)
Return
Pressure Out
Tank Drain
Port 3
Monoblock Spool Valves
2500 PSI Adjustable Relief
Nominal Flowrate = 14 GPM
Four Way - Three Position Spring Center
¾" - 16 Ports
Pressure Out
Return
Return
Pressure Out
Spool 1
Detent Open / Closed
Pressure Out
Return
Pressure Out
Retun
Spool 2
Spring Center
Spool 3
Spring Center
Spool 4
Spring Center
Adjustable Flow
Control Valve
Max Pressure = 3000 PSI
Capacity = 0 - 30 GPM
¾ NPTF Ports
Inlet Port 2
Pressure Reducing Valve
Maximum Pressure = 5000 PSI
Capacity = 10 GPM
Clockwise Turns to Increase = 5
¾ - 16 ORB Ports
Return
Pressure Out / Return
Pressure Out
Return
Pressure Out
Return
Reduced
Pressure Out
1100 PSI
Port 1
Vent to
Atmosphere
Geroter Motor
Max Pressure
Continuous = 1100 PSI
Intermittent = 1700 PSI
Maximum Speed
Continuous = 250 RPM
Intermittent = 325 RPM
½" NPTF Ports
2 - 2.5" X 8"
Rear Lift Cylinders
Max Pressure = 2500 PSI
¾" NPTF Ports
2" X 10"
Dump Table Cylinder
¾" - 16 SAE Ports
4" X 16"
Compression Cylinder
¾" - 16 SAE Ports
Rotational Work
Linear Work
Linear Work
Linear Work

Final Design

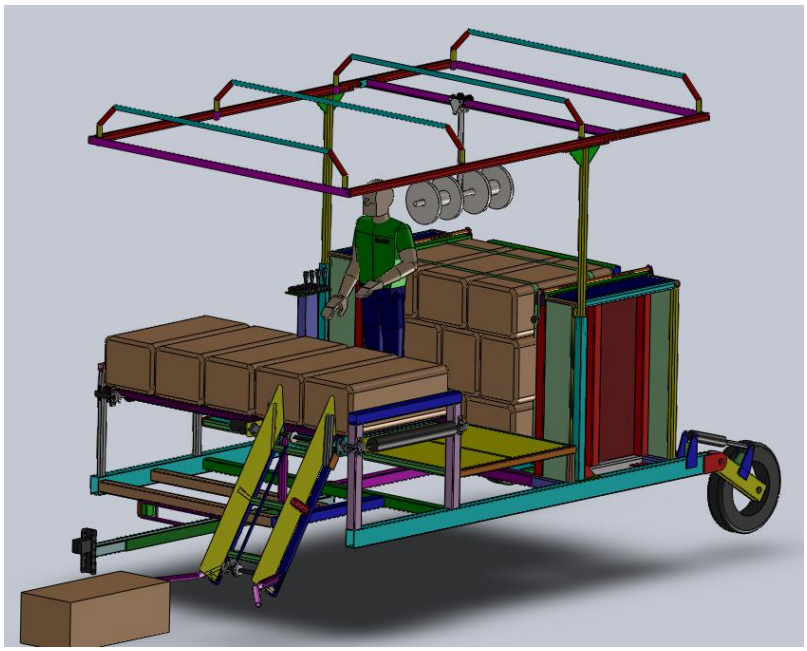


Figure 22: Final Model Design

BALE STACKING

A human operator will stack square bales (18 inches wide, 14 inches tall and 40 inches deep). This operator will stack the bales in a specific scheme as shown in Figure 9. The starting bundle dimensions are approximately 50 inches tall, 54-58 inches wide, and 40 inches deep. After compression, the approximate dimensions are 46 inches tall, 48 inches wide and 40 inches deep. These dimensions were provided by Boxel after testing design concepts with a previous prototype.

Figure 7: Bale Stacking Scheme

This stacking scheme creates optimum storing and transporting of the bundle in a standard semi-truck trailer (100 inches) (14), a standard pallet (4 feet by 4 feet) (15) and setting the cube in the back of a customer's full size truck (62.4 inches) (16) after purchase. This stacking scheme makes the bundles ideal for stacking on top of each other in a hay storing facility. The staggered edges in the middle increase the integrity of the bale after banding.

TESTING AND RESULTS

SOLUTION ANALYSIS

Hydraulics will be modeled using Hydraulic Automation Studio software. This software simulates cylinder movement, flow lines, heat dissipated and motor movements. It was instrumental in modeling different hydraulic functions and issues.

Engineering calculations and stress analysis models aided in resolving structural integrity issues. This analysis will determine the best component combinations while meeting all specifications and requirements.

TRACTOR REQUIREMENTS

See Appendix G

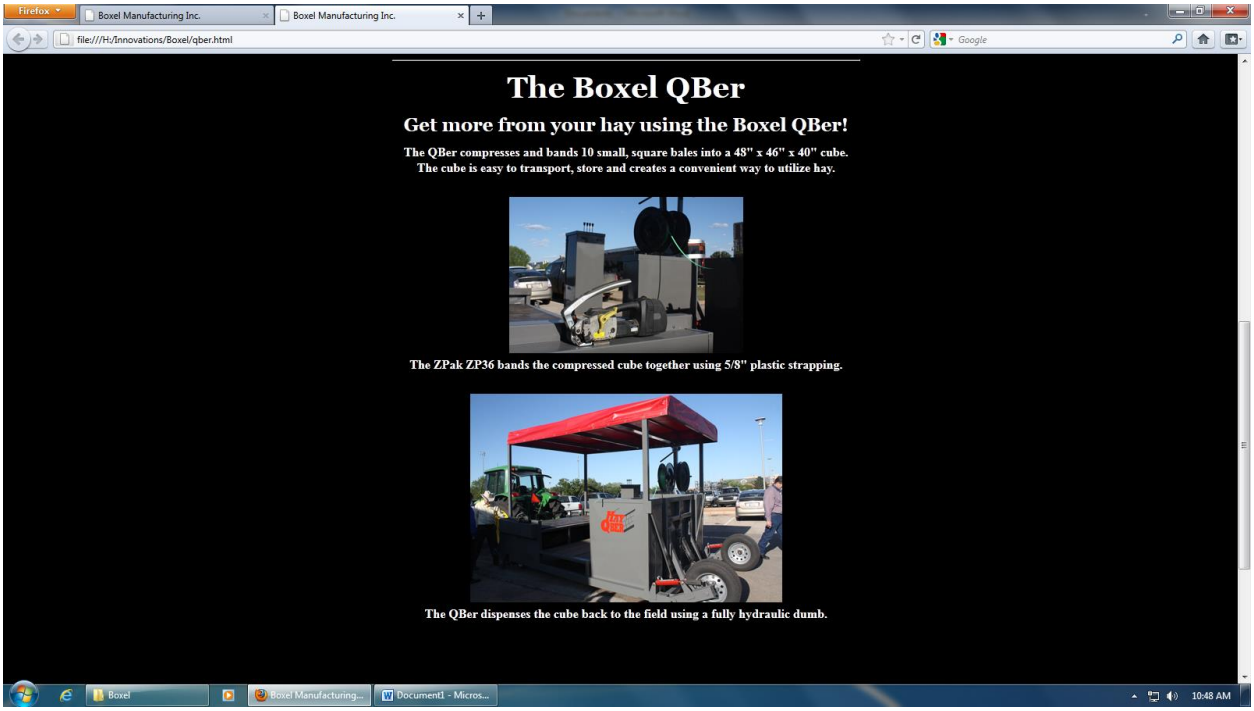
HYDRAULIC COMPONENTS / CALCULATIONS

See Appendix H

PROPOSED MEDIA / COMMUNICATIONS PLAN

OEI will promote the final product created through means of paper publications, Internet sites and trade shows prominent in Oklahoma and northern Texas.

OEI originally planned to initially market the QBer through Boxel's website, www.boxelmfg.com. We created a new page for the QBer, highlighting its functions, the benefits of cubing hay, and how it can increase profit margins. We had hoped to have a full video showing the QBer in full action, however, weather stalled construction and a video could not be accomplished. This website has a link to the Owner's Manual as well as to spread sheets exhibiting the value-added of cubed hay. OEI stresses the benefits of selling cubed hay through an interactive spread sheet showing how much money producers can sell cubed hay compared to simply selling free bales. The Business and Financial plan exhibits the figures reiterated on the website. This is our main marketing tactic.



Additionally, OEI has designed advertisements for Boxel to place in magazines circulating to hay producers. *Hay and Forage Grower, Fastline* and *High Plains Journal* are potential magazines to contact about advertising space. *The High Plains Journal* produces a monthly publication strictly for new products. *The High Plains Journal* also

has banner and tile ad space available on their website for $1200 and $300 per month, respectively. A press release has been written if Boxel chooses to send it to different farm publications.

The new Boxel Hay QBer compresses and bands 10 small, square bales, making storage and transportation easy. This "cube" can be moved by a forklift and transported in the back of a standard truck bed.

The QBer picks bales from the ground and moves them to a conveyer-storage area that holds five bales. A stacker stacks 10 bales in the compression area and engages the hydraulic walls. The final cube measures 48" by 46" by 40." Using a ZPak ZP 36 bander, the stacker bands the cube with 5/8" plastic strapping. The hydraulic dispense mechanism releases the cube back to the field.

See more on the QBer at www.boxelmfg.com!

OEI has also created brochures exemplifying the characteristics of the QBer. While attending many of the trade shows in Oklahoma and northern Texas, brochures can be distributed to hay producers. The brochures highlight the QBer and consist mostly of pictures. Potential customers are encouraged to view Boxel's website for further information. The color scheme was chosen to complement the red and gray of the QBer.

PROPOSED BUSINESS PLAN / FINANCIAL ANALYSIS

In the current stages of the economy, individuals must find methods of production that can satisfy needs, maximizes profits and produce at a price level meeting firms' budget capabilities. Our client Brad Lahman, owner and operator of Boxel Manufacturing, currently makes show boxes and feeders for today's youth and agriculturists. As a professional custom hay harvest, Lahman envisioned an innovative bale bundler with the ability to bale 10 small square bales into one bundle. Hay producers will experience a cost efficient, well-made bale compressing accumulator 80 percent less in price than the accumulator models currently in the market. The 10 bale cubes will be easily moved, decreasing transportation time from the field to the barn. This decrease will

lower the high labor inputs of loading, transporting and stacking square bales, making relocation and unloading easier than that of the 21 bale bundle.

Boxel Manufacturing's QBer is suited for individuals entering into custom hay harvesting markets who might not have the cash flow to meet prices of other bale bundlers in the market place. This product's price falls under a smaller farm's budget constraint, including hobby farms.

OEI created a safe, dependable product available to small farmers. Boxel originally set a maximum manufacturing cost of $6000. The final production cost of the QBer was $XXXX. The original expected retail price of the QBer was $XXXX. Boxel will set an asking price of $XXXX.

PROJECT SCHEDULE

Complete Work Breakdown Schedule and Tasks can be found in Appendix A

The following seven pages include the Gantt Chart for the project.

COST ANALYSIS

The graph below demonstrates the different ways to bale Bermuda grass and the price that relates to the method[12].

Table 4: Price Comparison of Bales

Prices of Bales **Information based on current prices of Bermuda grass weighting 66.7Lbs/Bale*				
Type of Harvest	**price per unit**	**Weight**	**Price per Lb.**	**Price per Ton**
Large Round Bale	$35	1500Lb	$0.023	$46.667
Small Square Bale	$3.75	67LB	$0.056	$111.940
Large Square Bale	X	x	x	x
21 Bale Bundle	$84	1400Lb	$0.06	$120.00
10 Bale Bundle	$60	667Lb	$0.09	$179.91

The table below lists the cost of materials necessary to manufacture the baler.

Table 5a: Cost of Manufacturing - Steel

COST OF STEEL					
Component	**Quantity**	**Price/ft**	**Price/ft^2**	**Unit Price**	**Cost of Good**
Large Grade Expanded Metal #3	x	x	$1.99	$63.70	x
Medium Grade Expanded Metal #6	x	x	$1.67	$53.40	x
Small Grade Expanded Metal #9	x	x	$0.95	$30.50	x
4.5" 4.5" 0.25" Steel Tube	x	x	x	x	x
4" 4" 0.25"	x	$6.37	x	x	x
2" 2" 0.25"	x	$2.80	x	x	x
16ga Sheet metal	x	$1.18	x	$37.60	x
14ga Sheet Metal	x	x	$1.42	$45.35	x
1/4" Sheet Metal	x	x	$4.39	$140.35	x
Shaft Material	x	$1.58	x	x	x
Total Cost					**0**

Table 5b: Cost of Manufacturing – Hydraulics

COST OF HYDRAULIC COMPONENTS			
COMPONENT	**QUANTITY**	**UNIT PRICE**	**COST OF GOOD**
P-Clamps	20	$2	$40
Cylinders	4	$200	$800
Multi-Lever Manifold	1	$150	$150
Hydraulic Hoses	x	x	
Necessary Fittings/Couplings	x	$50	50
Motors	2	$300	$600
Total Cost			**$1,640**

Table 5c: Cost of Manufacturing – Banding

COST OF BANDING			
COMPONENT	QUANTITY	UNIT PRICE	COST OF GOOD
ZPAC ZP26	1	$2,195	$2,195
Plastic Strapping (4200 ft Spool)	1	$80	$80
Battery	1	175	175
Total Cost			$2,450

Table 5d: Cost of Manufacturing – Miscellaneous

COST OF MANUFACTURING - MISCELLANEOUS			
COMPONENT	QUANTITY	UNIT PRICE	COST OF GOOD
Wheels & Tires	2	$59.99	$119.98
Tail lights	2	$29.99	$59.98
Clearance Lights	4	$2.99	$11.96
Spindles	2	$60	$120.00
Electrical Wires 16GA	x	x	x
Bale Chain	1	$60	$60.00
Journal Bearings	10	$10	$100
Bearing Castings	10	$10	$100
Tongue Hitch	1	$20	$20.00
Jacks	1	$35	$35.00
Hub Assemblies (5-Bolt)	2	$22	$44.00
Rollers	10	$15.12	$151.20
Total Cost			$778.12

Table 5e: Manufacturing Costs – Estimated Total

Estimated Total Cost	
Component	***Subtotals***
Steel	*~$2,500*
Hydraulics	*$1,640*
Banding	*$2,450*
Miscellaneous	*$778.12*
Total Cost	***$7,448.12***

To determine the business cost and a breakeven analysis, OEI compared The QBer, the Bale Band-It and the conventional method of hay-hauling using fixed standards for our assumptions. The standards consist of a 50 acre field, cut twice a year that yields 2 tons per acre off the first cutting and 1.5 tons the second cutting. These assumptions create a total yield of 3.47 tons per acre and 5,146 hay bales produced for the year. One day of work consists of eight hours and a bale price is set at $6 per bale, with total revenue reaching $30,876 ($6*5146).

OEI analyzed the QBer cost of production based off the standards listed prior and off a 100 bale per hour operation. The QBer, at minimum speed, takes 6.4 days to remove all 5,146 bales from the field to the barn, bundled in a 10 bale cube. Labor consists of $0.25 per bale totaling labor cost to $1,286.50 ($.25*5146bales). Fuel cost and banding cost included a $3.80 per gallon of diesel and a gallon consumption of 2.64 gallons an hour, totaling cost of fuel at $516.25 ($3.80*51.46hours). Banding costs include $1.66 per cube creating a total cost of banding $854.24 ($1.66*515Cubes). After calculations, OEI found revenue minus expenses to total $28,219.02.

The Bale Band-It's cost of production based off the assumptions listed and a 300 bale per hour minimum operation speed, the Band-It takes 2.14 days to remove all 5146 bales off the field bundled in 21 bale bundles. Labor consisted of $0.125 per bale labor, making total labor cost $643.25 ($.125*5146). Fuel cost including a price of diesel being $3.80 per gallon and a consumption per hour of fuel being 3.2 gallons hour, total fuel cost being $208.57 ($3.80*17.2hours). Banding cost includes a price of $1.26 per bundle for a total cost of bundling $308.70 ($1.26*245). Revenue minus expenses totaled to $29,715.48

The conventional method of hay-hauling cost of production is also based off the prior figures and an 80 bale per hour minimum operation speed. Hay-hauling takes 8.04 days of operation to remove all 5,146 bales off the field to the barn. Labor consisted of $1.00 per bale, total labor cost being $5146 ($1*5146bales). Fuel cost including the price of diesel being $3.80 per gallon and a consumption of a farm truck being 3.5 gallons per hour, total fuel cost being $855.46 ($3.80*64.3hours). Revenue minus expenses $ 24,874.54

The charts below are based off a daily minimum production output per unit.

Table 6: Comparison

Machine	Gross Income per Bale	Bales for Payoff	Days in Operation	Acres to Payoff
QBer	$ 5.48	3376	4.22	57
Band-It	$ 5.77	13873	5.78	236
Conventional	$ 4.83	NA	NA	NA

Gross incomes per bale for the machines are completed by subtracting the cost for each figure. Bales to payoff, days in operation, acres to payoff based off estimated MSRP per unit.

Table 6b: Value-Added

Machine	Value Added Per Bale	Bales for Payoff	Days in Operation	Acres for Payoff
QBer	$ 0.65	28,461	35	482
Band-It	$ 0.94	85,106	35	1,442

Value-added per bale is computed by subtracting conventional method of hauling hay at $4.83 per bale. The difference for the QBer and the Bale Band-It's bale price minus expenses. Bales to payoff, days in operation, acres to payoff based off estimated MSRP per unit.

Table 6c: Price of Bales

Prices of Bales				
Type of Harvest	Price per Unit	Weight (lb)	Price/lb	Price/Ton
Large Round Bale	$35.00	1500	$0.02	$46.66
Small Square Bale	$4.83	67	$0.06	$111.94
21 Bale Bundle	$121.17	1400	$0.09	$180.00
The Boxel Cube	$54.80	667	$0.08	$160.00

Information based on current prices of Bermuda grass weighting 66.7 lbs/Bale

Steve Swigert – Samuel Roberts Noble Foundation: Ardmore, OK

The figure above is based off the type of harvest price per unit minus the cost of production per unit divide by the weight per bale.

These tables exhibit the increase in profits hay producers can achieve by selling cubed hay as opposed to unbound hay. These figures will help market the QBer by showing the value-added its final product.

CONCLUSION

OEI created a new product for Boxel Manufacturing to help expand its business in the hay implement market. The QBer will be competitive in the market, scalable and functional. OEI used the information gathered in the Fall Report, including market research, patent search, industry standards and our own ideas, to develop a design meeting all goals. Our final product passed field testing and, as shown in our economic research, will increase hay producers' profits.

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16) General Motors Company. 2010. http://www.gmc.com/sierra/1500/specsDimension.jsp. Accessed 14 November 2010

17) Omni Packing. 2010. http://omnipackaging.shoppkg.com/shop/C1951.aspx. Accessed 14 November 2010

- **Initial Research**
    - 7.1. Research Boxel Manufacturing
        - 7.1.1. Determine who they are
        - 7.1.2. Determine what they do
        - 7.1.3. Determine what their resources are
            - 7.1.3.1. Determine Boxel's supplier(s)
    - 7.2. Research Industry
        - 7.2.1. Determine industry size
        - 7.2.2. Determine market size
    - 7.3. Research Competitors
        - 7.3.1. Research Competitor Resources
        - 7.3.2. Research Competitor Products
            - 7.3.2.1. Determine their products
            - 7.3.2.2. Identify what is unique to their product
                - 7.3.2.2.1. Determine what is good about the competitors' products
                - 7.3.2.2.2. Determine what is bad about the competitors' products
            - 7.3.2.3. Determine competitors prices
    - 7.4. Research Dealers
    - 7.5. Research Customers
        - 7.5.1. Identify customers' need
        - 7.5.2. Learn what they like about existing hay bundlers
        - 7.5.3. Learn what they don't like about existing hay bundlers
    - 7.6. Research Technical Sources
        - 7.6.1. Research Standards
            - 7.6.1.1. Research ASABE standards
        - 7.6.2. Research Patents

8. Develop Rough Budget

8.1. Review Initial Research

8.2. Created Budget

8.3. Submit to senior design professors for review

9. Develop Design

9.1. Develop an hay pick-up concept

9.1.1. Review Initial Research

9.1.1.1. Look at previous patents

9.1.1.2. Look at previous standards

9.1.1.3. Look at competitor products

9.1.2. Draw final concepts in SolidWorks

9.2. Develop a hay compression concept

9.2.1. Review Initial Research

9.2.1.1. Look at previous patents

9.2.1.2. Look at previous standards

9.2.1.3. Look at competitor products

9.2.2. Look at hay bundle dimensions to decide on compression specifications

9.2.3. Drew final concepts in SolidWorks

9.3. Develop a bale banding concept

9.3.1. Research different types of banding material

9.3.2. Research different types of hand-held banders

9.3.3. Review Initial Research

9.3.3.1. Look at previous patents

9.3.3.2. Look at previous standards

9.3.3.3. Look at competitor products

9.3.4. Looked at geometry of bundle to find length of material per bale to design mechanism to get band around the bale

9.3.5. Drew final concepts in SolidWorks

9.4. Develop a bundle release mechanism

9.4.1. Research different types of release systems

9.4.2. Review Initial Research

9.4.2.1. Look at previous patents

9.4.2.2. Look at previous standards

9.4.2.3. Look at competitor products

9.4.3. Drew up final concepts in SolidWorks

9.5. Calculations/Testing

9.5.1. Calculate hay compression force requirements

9.5.2. Calculate hydraulic flow requirements needed for each (3 total) hydraulic cylinder and the hydraulic motor.

9.5.3. Test the hand-held bander's seal integrity

9.5.4. Miscellaneous calculations (on all other necessary components)

9.6. Finalize Design

9.6.1. Decide on final hay pick-up concept

9.6.2. Decide on final hay compression concept

9.6.3. Decide on final bale banding concept

9.6.4. Decide on final bundle release system

9.6.5. Create a full assembly of all parts

9.6.6. Create a presentation of all work completed

9.6.7. Present to Boxel, Faculty and Peers

---------- **Spring 2011 Semester** ----------

10. **Build Prototype**

    10.1. Create Construction Drawings for each part

        10.1.1. Create drawings in SolidWorks

        10.1.2. Include all initial dimensions

    10.2. Decide where to build machine

        10.2.1. Frame and larger fabrication – Boxel

        10.2.2. Small, detailed fabrication – OSU BAE Lab and Shop

    10.3. Order parts through Boxel purchasing

    10.4. Construct Prototype

        10.4.1. Cut steel bars, rods, angles, etc. to desired sizes for framework and other parts

        10.4.2. Drill holes in steel for various parts

        10.4.3. Join/Weld the framework together

        10.4.4. Attach (fasten or weld) the other components (compression, pick-up, banding, release mechanisms)

        10.4.5. Attach the axles/wheels

        10.4.6. Construct and attach the hitch system

        10.4.7. Attach hydraulic components: cylinders, values, manifold, hoses, motor

11. Prototype Testing

    11.1. Run tests on all components

        11.1.1. Dr. Dan Storm loan 10 bales of hay for testing

        11.1.2. Hook implement to tractor

        11.1.3. Run implement as would in field conditions – laying 10 bales out in a row and testing all mechanisms and components

11.2. Review Prototype Design

11.2.1. Make any necessary changes to design that come up in testing

11.3. Review Construction Drawings

11.3.1. Make any necessary changes to dimensions that come up in testing

11.4. Repeat

12. Market Product

12.1. Develop a Business Plan

12.2. Develop Marketing Ideas

12.2.1. Create brochure for product

12.2.2. Add product information to Boxel Web site

13. Present Final Design with Prototype and Marketing Materials to Boxel Manufacturing

13.1. Create a Presentation

13.2. Present prototype, marketing materials, and business plan to Boxel, Faculty, and Peers

Bale Band-It

“Our expectations of the Bale Band-It were well surpassed, just by the simple operation of the machine. Loading 21 bales at one time is awesome and not to mention fast and easy, especially with a loader tractor. When we were using our crews to pick up and stack the bales, we had to take from our contract jobs or use more labor. Now we use 2 people to make the hay and the rest of our crews are only working on payable contract jobs, not on the farm. On average we would handle 20,000 bales/year now with the bundles we are averaging 100,000 bales/year. We can load and strap 420 bales in less than 1 hour, that means one man loading and 1 man strapping. In the old day approximately 350 bales stacked on the same trailer using 5 men 3 hours, if the bales did not weigh over 40 lbs/bale. With the Bale Band-It we are up to approximately 65 lbs/bale. More hay per load = more pay per ton. The old way 7 tons per load, with the Bale Band-It 13.65 tons per load = almost 2 to 1.” - Stanley Bordelon

“We at Creekside Farm have purchased straw bales from the Riley Brothers in Adams, Tennessee for 12 years. Within the last 2 years our straw has been delivered 21 bales to the bundle. This process of bundling has greatly reduced our labor costs. Load time is cut to minutes and on the site loading of our spreading trucks can all be done by machine.

It is also a secure feeling to know that the 21 bales that are bundled together, placed on a flatbed truck with other large bundles and then bound down will travel safely down the interstate. We look forward to many years of using this great process. Thank you for your product. Stephen T. Baltz Creekside Farm, Inc.”

Bale Baron

“Steve and his partner Penny grow 450 acres of grass in Lincolnshire specifically for the equine market. The introduction of the Bale Baron® has enabled us to bale and stack upto 4000 bales per day into the barn, with the help of only one loader driver. I like the Bale Baron® for it's simplicity, with minimal moving parts and the proven double knot

system of the Hesston knotters, identical to our own big baler. The Bale Baron® works quickly and does not hinder our Welger 830 baler. Moving bales from the field is always a slow process, not with the Bale Baron®, trailers are loaded with 500/600 bales in approx half an hour. With a slight modification The Bale Baron® will tie packs of twelve, this is a great advantage to our small bale haylage business as we can wrap packs of twelve quickly and then wrap them as individuals when time allows. This season we baled 35,000 hay bales and approx 8000 straw, in 2011 we aim to bale 60/70,000 hay and 10,000 straw. Lorries were previously loaded by hand, not any more, packs are loaded easily by teleporter, the only time we handle the bales is when we deliver to customers unless of course they have a machine!!!"

"Convinced I needed to tap into the premium small bale equine market I was converted to small bale packing 5 years ago. I ran a Bale Bandit in the first year but could not achieve the capacity I required and therefore purchased a second Bale Bandit.

I continued for two years and eventually purchased an Arcusin Bale Packer to try to solve the problem of putting through the desired quantity of bales. I still found myself struggling and in desperation started to convert my customers over to big bales until I was introduced to the Bale Baron. Bale Baron UK convinced me that the Bale Baron® would meet the capacity and reliability that I needed.

In the first year I have baled over 42,000 bales and couldn't have been more impressed with the Bale Baron and I am convinced that in a normal yielding year I could have easily baled the 60,000-70,000 bales that I am looking for. On top of all the other benefits of the Bale Baron® I have been able to use up my big bale twine left over from last year!"

Arcusin Multipack B-14

No Testimonials found

The Boxel QBer

Spring 2011

Gary Gray
Team Leader
Biosystems Engineering

Evan Foster
Biosystems Engineering

Alice White
Agricultural Communications
Agribusiness

Jeremy McCasland
Agricultural Economics

Laura Merriman
Biosystems Engineering

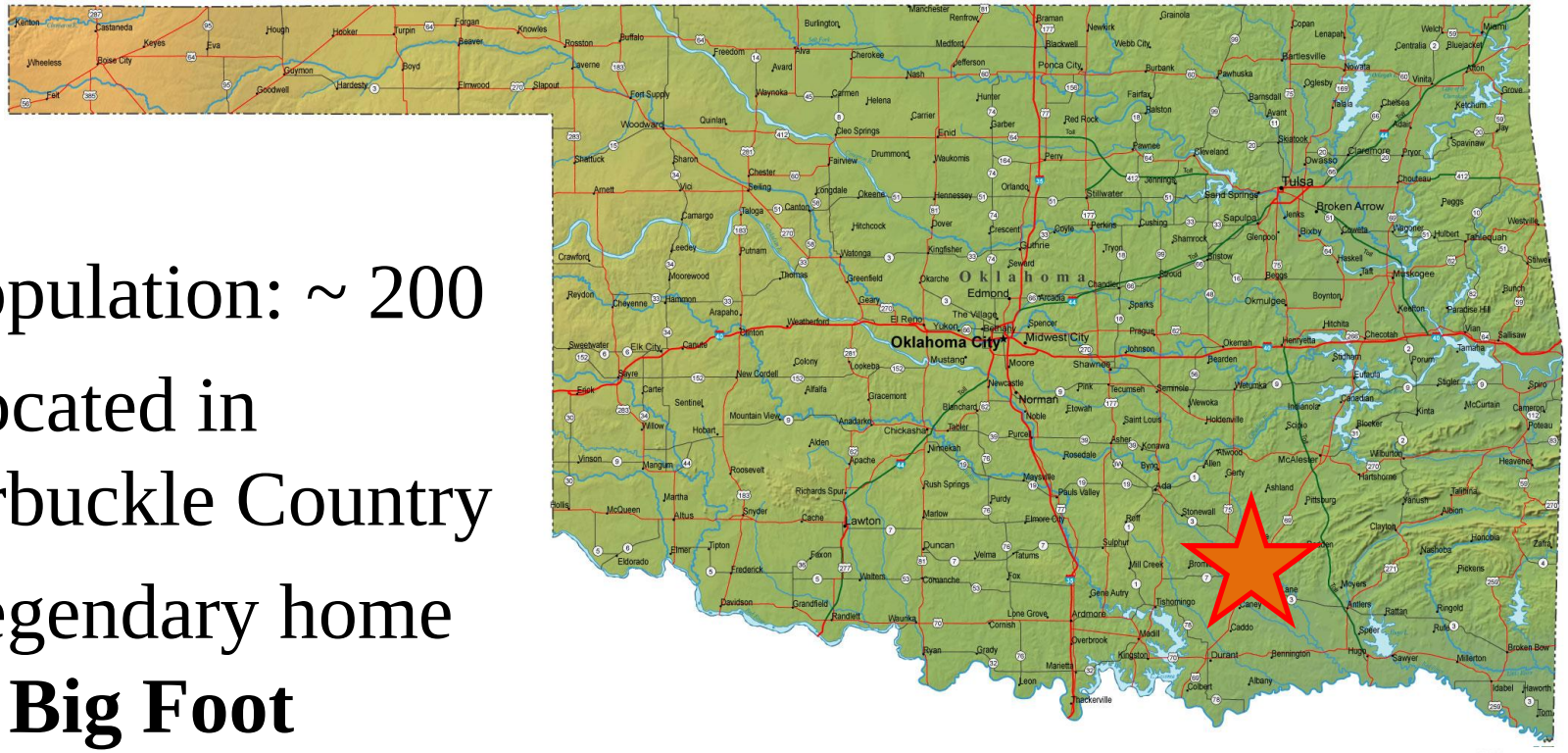
Client

BOXEL

MANUFACTURING INC.

- Owned by Brad and Vickie Lahman
- Operating since 1985
- Located in Caney, Oklahoma

Caney, OK



- Population: ~ 200
- Located in Arbuckle Country
- Legendary home of **Big Foot**

Boxel's Current Products

Feed Cake Transporters

Sullivan Show Boxes

The Boxel QBer

Statement of Work

OEI improved the design of and build a prototype hay bale bundling machine for Boxel Manufacturing to produce and sell.

The Boxel QBer will:

1. Collect small square bales from the ground or from behind a square baler.
2. Compress 10 bales into a specific cube.
3. Band the bales together with 2 plastic straps.
4. Release the finished cube to the ground.

Fall 2010 Semester

- Research
  - Industry
  - Customers
  - Competitors
- Develop Budget
- Cost Estimations
- Preliminary Marketing Strategies
- Patent Research
- Develop Preliminary Design Recommendations
  - Create Solidworks® Solid Model
  - Input/Output of Hay Flow
  - Compression
  - Banding
- Hydraulic Requirements and Design

Spring 2011 Semester

- Finalize Design
  - Complete SolidWorks® Solid Design Model with complete Assembly and Parts Drawings
- Build Prototype
  - Model Hydraulics System and Record Pertinent Design Data
- Test Prototype
- Complete Design Budget and Cost Recommendations
- Create Marketing Campaign Materials

Market Analysis

Small producers - Utilize small square bales (14” x 18” x 40”)

- Equine
  - Oklahoma hosts 15 national and world competitions
- Specialty Cattle Producers
  - Registered or Commercial Cattle Producers
- Feed Yard Cattle Producers
  - Custom Feeding Operations
- Show Stock
  - Oklahoma hosts many livestock shows
    - State Fairs
    - Oklahoma Youth Expo
    - County Youth Jackpot Shows

http://www.okyouthexpo.com/

Market Analysis

Customer Requirements:

- An Increased Profit Margin
  - Transportation and labor costs
- An Easily Operated Machine
  - Simple/Reliable Operation
  - Require No Formal Training
- Safe Operation

http://www.thirddayranch.com/hay.php

Secondary Competitor: Bale Band-It

- Fully Automated Bale Banding Machine
  - Hydraulically collects, stacks, and bands 21 bales
  - Operates off of tractor hydraulic power
- Base Price
  - **$80,000.00**

http://www.balebandit.com/

Secondary Competitor: Bale Baron

- Fully Automated Bale Banding Machine
  - Hydraulically Collects, Stacks, and Ties 21 Bales.
  - Self Contained Diesel Engine or Tractor Hydraulically Powered
- Base Price
  - **$90,000.00**

http://www.balebaron.com/

Primary Competitor: Kuhn's Manufacturing

- 10 Bale Accumulator
  - Mechanical
  - $9,200.00
- 10 Bale Grappler
  - $2,900.00
- Total Investment
  - **$12,100.00**

http://www.kuhnsmfg.com

Primary Competitor: Hoelscher Handling Equipment

- Hoelscher 10 Bale Accumulator
  - Hydraulic
  - $11,500.00
- Hoelscher Bale Grapple
  - $4,250.00
- Total Investment
  - **$15,750.00**

http://www.hoelscherinc.com/

Primary Competitor: Steffen Systems

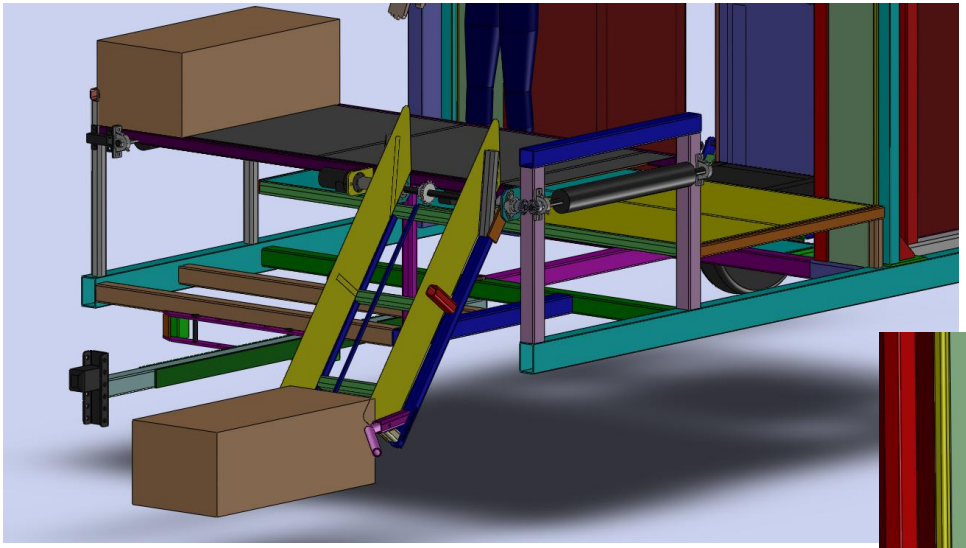
- 10 Bale Accumulator
  - Mechanical and Hydraulic
  - $13,000.00
- Bale Grappler
  - $5,510.00
- Total Investment
  - **$18, 510.00**

http://www.steffensystems.com/

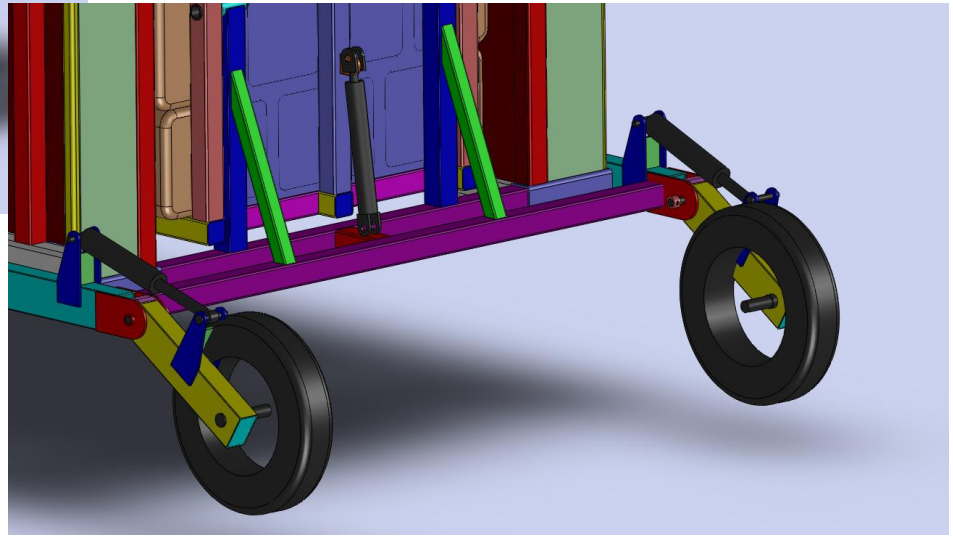
The Boxel QBer

Design Components

Bale Elevator and Table



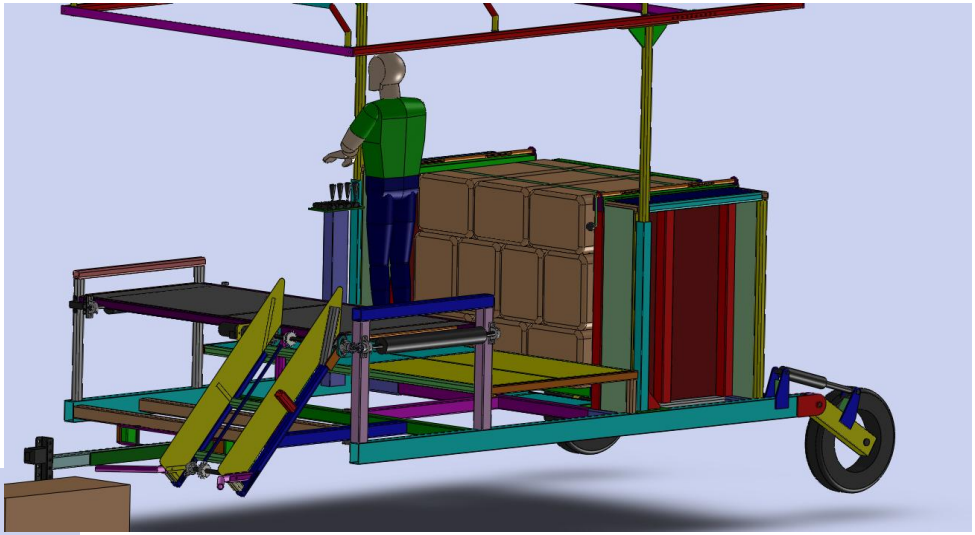
Height Adjustment

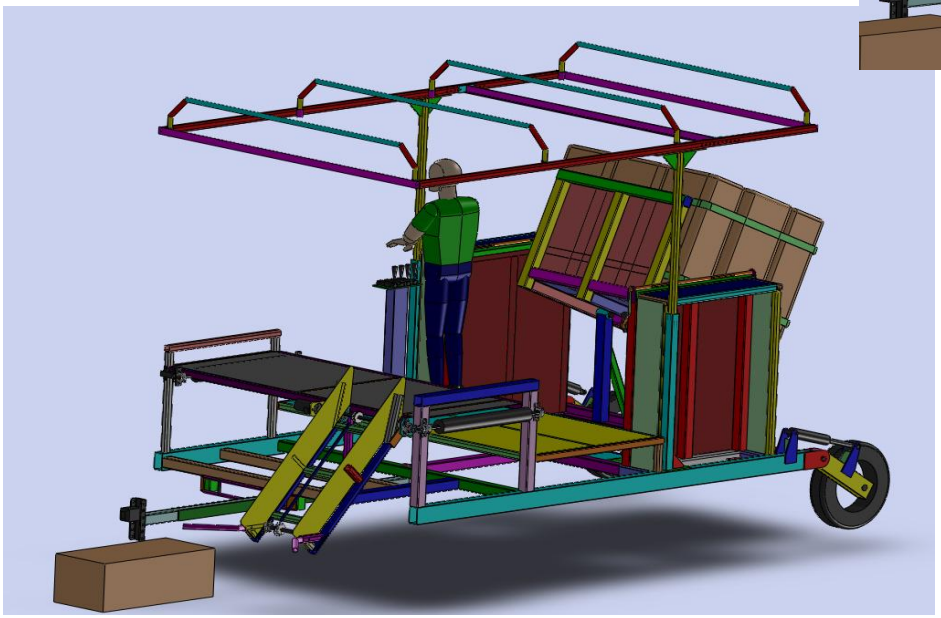


Design Components

Stacking &

Compression





Banding &

Releasing

Required Equipment for Operation

- Tractor or Power Unit Capable of:
  - Output Pressure
    - Minimum = 1100 PSI
    - Maximum = 2500 PSI
  - Output Flowrate
    - Minimum = 4 GPM
    - Maximum = 30 GPM
- Automatic Hand Operated Banding Machine
- Two Poly-Band Rolls
- Two Human Operators

http://www.strapex.com

http://www.zapak.com.tw/p1-product_zp26.asp

Engineering Calculations

- Beam Stresses

$$\sigma_{max} = {My}/{I}$$

  - Max Sustained Moment ~ 19, 300 ft-lb
    - Maximum Normal Shear Stress ~ 12,700 PSI
    - Maximum Sustainable Shear Stress ~ 19,320 PSI
- Shaft Stresses

$$\tau_{max} = {Tr}/{J}$$

  - Max Torsion Member ~ 1,800 ft-lb
    - Maximum Torsional Shear Stress ~ 1,650 PSI
    - Maximum Sustainable Torque ~ 1,400 PSI

Operation Specifications

- Hydraulic Specifications
  - Machine Lift Cycle
    - 8 Seconds
  - Compression Cycle
    - 12 Seconds
  - Cube Releasing Cycle
    - 10 Seconds
  - Bale Elevation Cycle
    - Hydraulic Geroler Motor

      Chain Speed ~ 2.1 ft/sec

      Belt Speed ~ 2.1 ft/sec
- Banding Specifications
  - Electronic Bander
    - Full Tension/Weld/Cut Cycle
      - 8 Seconds
- Human Performance
  - Machine Preparation
    - Preparing Bands
      - 10 Seconds
  - Stacking the Cubes
    - Full 10 Bales
      - 60 Seconds
- Total Operation Cycle

  ~ 2.0 Minutes

Construction of Prototype

Construction of Prototype

Construction of Prototype

Operation of Hydraulics

The Boxel QBer

The QBer in Action!

Future Options & Upgrades

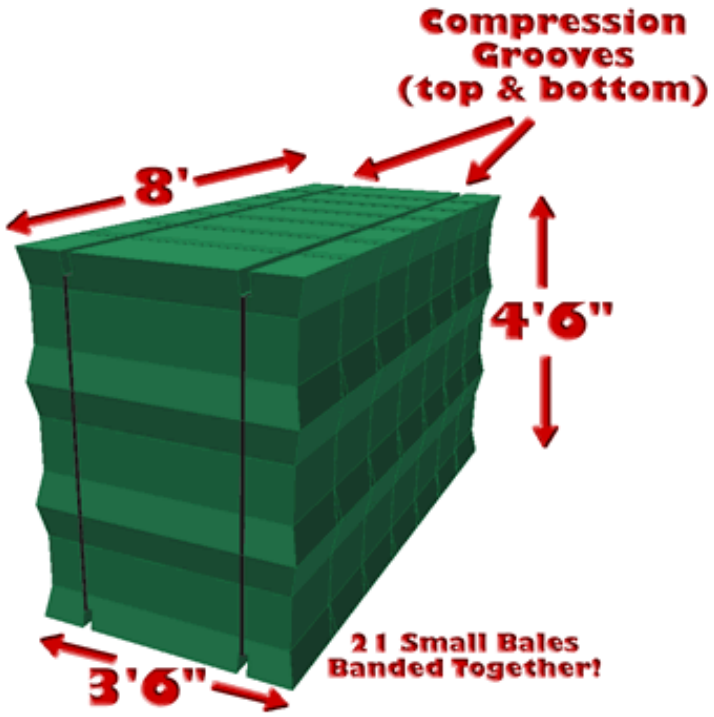
- Mobile Hydraulic Power Pack
- Additional Equipment/Tool Storage
- Solar Powered Fan
- Water Cooler Holder
- Operator Seat

The Cube After Compression

The Cube

Competitor Stack

- The Band-It
- The Bale Baron
  - Immovable from the end
  - Decreased stack integrity
  - Steel bands
  - Cutting tool required



http://www.balebandit.com/

The Cube Advantages

- Standard Pickup Bed Dimensions
  - 8’ Long
  - 4’ Wide (Between Wells)
  - Easily holds **2 Cubes**
- Plastic Straps v. Steel Straps
  - No Recoil
  - One Hand Separation of Bands
- Ease of Transport

Cost Analysis

50 Acre Net Comparison

- Estimated Yield Assumptions:
  - 2 Field Cuttings
  - National Average of 3.5 tons per acre
  - 5100 bales per 50 acres
  - 1 day = 8 hours
  - $6.00 per bale
  - Total Revenue of $31,000

Cost Comparison: Boxel QBer

- Estimated Revenue from Cubes: $31,000
  - 6.5 Days in Operation
  - $1,300 - Total Labor Cost
  - $500 - Fuel Cost
  - $850 - Banding Cost at $1.66 per Cube

- **Estimated Income: $28,000**

Cost Comparison: Band-It

- Estimated Revenue from Bundles: $31,000
  - 2 Days in Operation
  - $650 - Total Labor Cost
  - $200 - Fuel Cost
  - $300 - Banding Cost at $1.26 per Bundle

- **Estimated Income: $29,000**

Cost Comparison: Conventional

- Estimated Revenue from Bundles: $31,000
  - 8 Days in Operation
  - $5100 - Total Labor Cost
  - $850 - Fuel Cost

- **Estimated Income: $25,000**

Cost Comparison: Breakdown

Machine	Gross Income per Bale	Bales for Payoff	Days in Operation	Acres per Day	Acres to Payoff
QBer	$ 5.48	3376	4.22	13.6	57
Band-It	$ 5.77	13873	5.78	40.8	236
Conventional	$ 4.83	NA	NA	10.88	NA

Value Added of QBer

Machine	Value Added Per Bale	Bales for Payoff	Days in Operation	Acres for Payoff
QBer	$ 0.65	28,500	35	480
Band-It	$ 0.94	85,100	35	1,440

Cost of Bale Comparison

PRICES OF BALES*				
Type of Harvest	Price per Unit	Weight (lb)	Price/lb	Price/Ton
Large Round Bale	$35.00	1500	$0.02	$46.66
Small Square Bale	$4.83	67	$0.06	$111.94
21 Bale Bundle	$121.17	1400	$0.09	$180.00
The Boxel Cube	$54.80	667	$0.08	$160.00

*Information based on current prices of Bermuda grass weighting 66.7 lbs/Bale

Steve Swigert – Samuel Roberts Noble Foundation: Ardmore, OK

Marketing


Boxel
Manufacturing Inc.
HOME
ABOUT
STORAGE MODULES
HAY QBER
OTHER PRODUCTS
BOXEL FARMS
CONTACT
349 Davis Creek Road
Caney, Oklahoma 74533
Toll Free: 1.866.889.0064
Office: 580.889.2444
Fax: 580.889.6446
Email: info@vanguardstoragemodules.com

Marketing

- Internet
  - www.boxelmfg.com
  - YouTube
- Advertisements
- Trade Shows
- Brochures

Now you can with

QBer

The Boxel QBer compresses 10 small, square bales into a cube. The cube is banded with 2 plastic straps and then mechanically dispensed back to the field.

Step 1: The QBer picks bales from the field and transfers them to a storage area.

Step 2: A laborer then stacks the bales in the compression area and inacts the hydaulically powered compression walls.

Step 3: While compressed, the laborer uses the ZPak ZP26 to band the cube

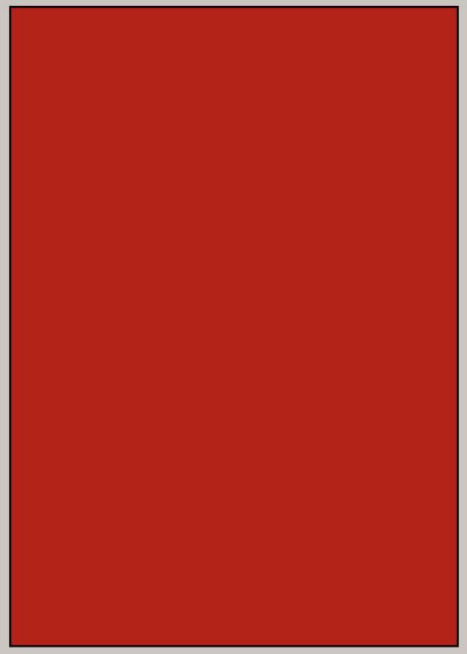
Step 4: The compression walls move back to resting position and the laborer dispenses the cube with the dispensing mechanism.

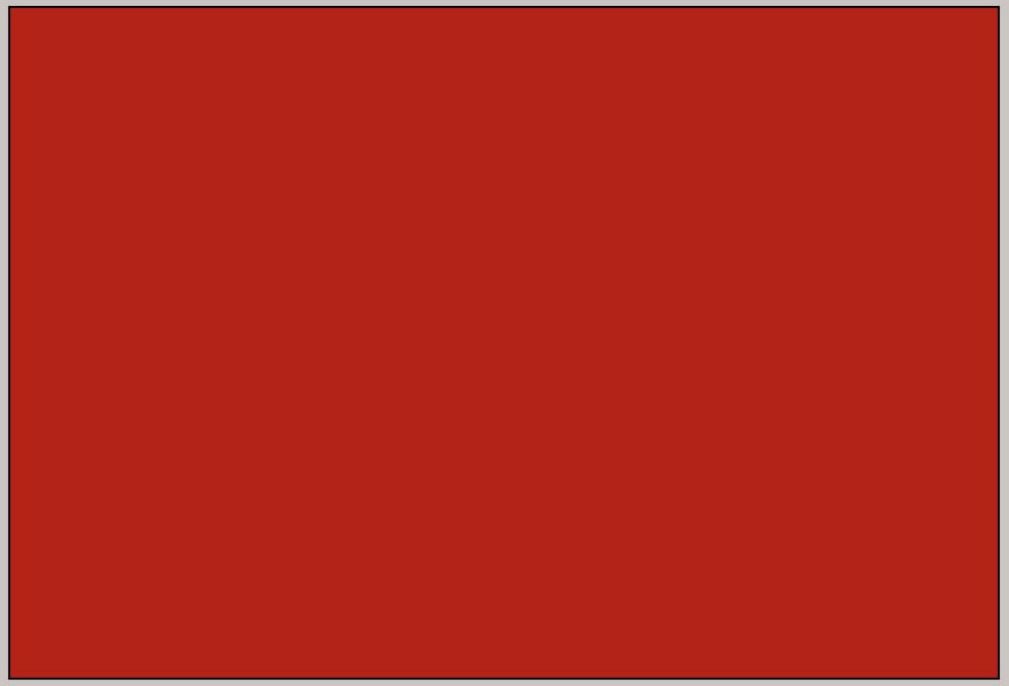
The final Cubes:

- Are easily moved with a forklift
- Can be stacked 3 high
- Fit 2 in a standard pick-up truck

See the QBer in action at www.boxelmfg.com!

Compress 10 bales into a banded, 48” x 46” x 40” cube for easy transport, storage and feeding.

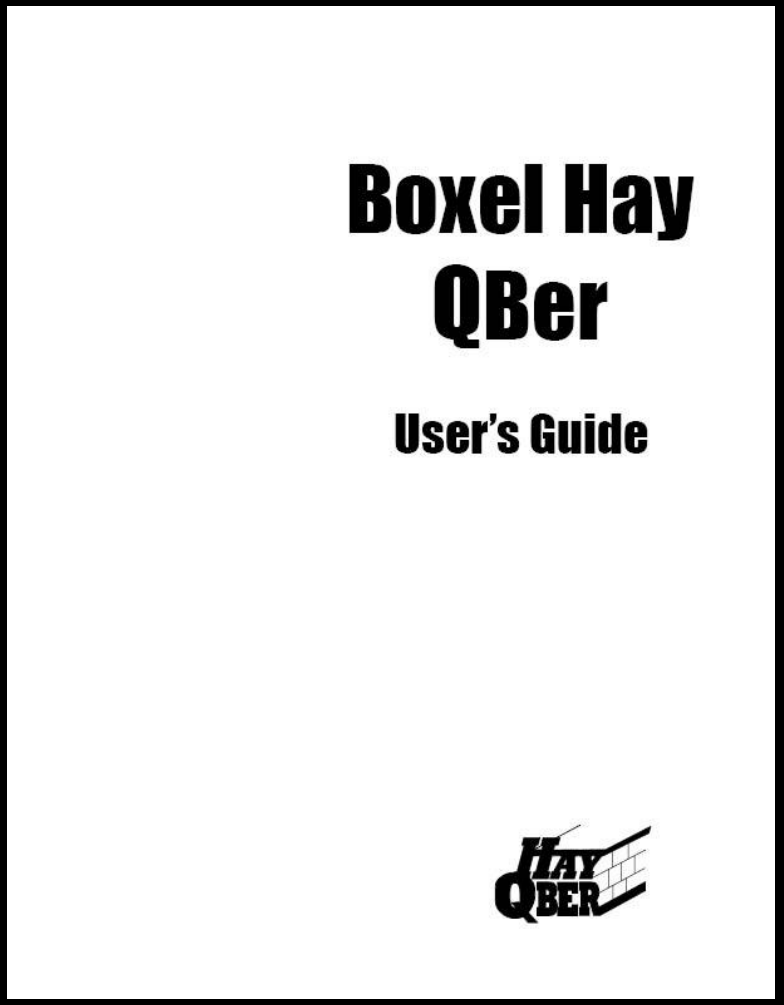




Get more for your bales with the Boxel Hay QBer

See the QBer in action at www.boxelmfg.com!

User’s Guide



Marketing

- Highlight
  - Ease of operation
  - Ease of transportation
  - Ease of storage
  - Value added of product
    - Show demand through excel sheet found on website

Thank You to Our Supporters

Boxel Manufacturing
- Brad and Vickie Lahman
  - Caney, Oklahoma

Womack Machine Supply
- Jake Martens
  - Tulsa, Oklahoma

Omni – Packaging Incorporated
- Dennis Lashley
  - Oklahoma City, Oklahoma

McMaster-Carr Distribution
- Tulsa, Oklahoma

Grainger Distribution
- Oklahoma City, Oklahoma

Edwards Canvas
- Pauls Valley, Oklahoma

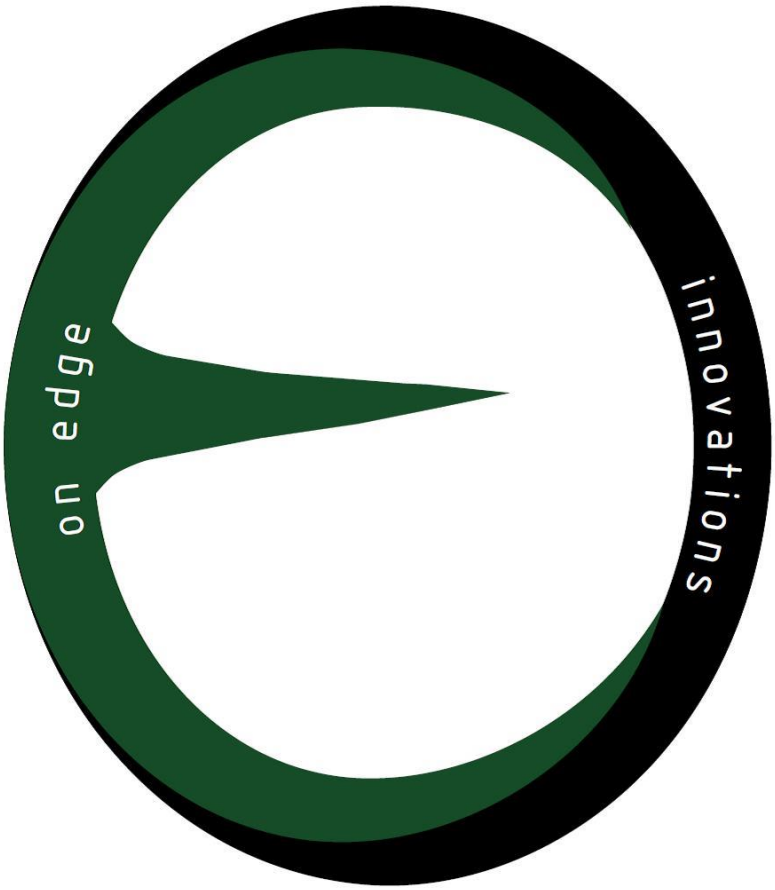
Ryerson Metals
- Tulsa, Oklahoma

J & I Metals
- Madill, Oklahoma

Redneck Trailer Manufacturing
- Chickasha, Oklahoma

Innovations Professors
- Dr. Cindy Blackwell
- Dr. Rodney Holcomb
- Dr. Dan Tilley
- Dr. Paul Weckler

Fall 2010 Design Report



15 November 2010

Team Members:

Gary Gray – Team Leader, Engineer

Laura Merriman – Engineer

Evan Foster – Engineer

Alice White – Communications

Jeremy McCasland – Economics

Client:

Brad Lahman

Boxel Manufacuring

Caney, OK

TABLE OF CONTENTS

APPENDICES

PROBLEM STATEMENT

In order to provide excellent hay products at a minimal production cost, Boxel Manufacturing needs a safe, efficient, and accurate hay bale collection and banding system. In addition to designing such a product, OnEdge Innovations will create a business and marketing plan for Boxel regarding the promotion and sale of the hay bale collection and banding system.

MISSION STATEMENT

OnEdge Innovations works closely with their customers to make ideas become more than just a design, a prototype, or an unused patent. We convey our customer's ideas from the drawing board to production and into consumers' hands. With combined efforts, OnEdge Innovations strives to maintain pristine relationships with our customers and to provide quality, safe products for consumers.

STATEMENT OF WORK

Background

OnEdge Innovations built a hay bale bundler for Boxel Manufacturing. Boxel wished to produce and sell a machine capable of compressing small, square hay or straw bales and banding the "bundle" together to increase ease and efficiency of storing, transporting and loading/unloading bales. This machine fits the needs of smaller hay producers and consumers who want convenience. From the proposed idea, OnEdge Innovations created the Boxel QBer.

Scope of Work

The engineers of OnEdge Innovations collaborated to create a pull-along trailer mounted on a swinging tongue. The steel trailer has a bale elevator attached to the left side of the trailer that picks small, square bales out of the field and conveys them back to a laborer. In addition to the trailer and the bale elevator, OnEdge Innovations constructed a compression system capable of compressing ten small, square bales, and a strapping system using plastic that tightens around the bundle. A hand-held

sealer seals the bands. In order to remove the bundle of bales from the trailer, OnEdge Innovations designed a releasing mechanism to distribute the bundle to the ground without damaging it.

Physical Location

The construction of this project occurred in Oklahoma State University's Biosystems and Agricultural Engineering Laboratory and Boxel Manufacturing in Caney, Okla. OnEdge Innovations and Boxel communicated designs through SolidWorks drawings and distributed the construction according to the components needed at the time.

Period of Performance

The engineers of OnEdge Innovations began designing in SolidWorks in the fall semester. Concept design models were sent to Boxel on November 8th, 2010. By the end of the fall semester, December 5th, 2010, OnEdge Innovation had a small-scale model constructed for final design concept review. The design was sent to Boxel March 7, 2011. with projected completion in March 2011.

Delivery Requirements

Table 1: Design Requirements:

Date	Item Due
02 Oct 2010	Competitive Analysis Report
28 Oct 2010	Statement of Work
05 Nov 2010	Work Breakdown Structure
08 Nov 2010	Task List
15 Nov 2010	Design Proposal Report Draft
9-10 Dec 2010	Design Proposal Report Design Proposal Presentation
13 Dec 2010	Team Website
13 Dec 2010	Project Notebooks Self and Peer Evaluations
13-17 Dec 2010	Team Leader Interviews

Detailed Work

OnEdge Innovations began designing the bale bundling mechanism in the fall semester.

The trailer is 8 feet wide, feet high and 12 to 14 feet long. OnEdge Innovations designed all components of the bale bundler before setting exact and final dimensions of the trailer. The trailer has enough space available for three bales waiting for stacking, a laborer to move about the trailer in order to stack the bales, and for the compression system, which will hold 10 bales.

The bale elevator resembles a conveyor belt system which will pick the bales from the field or a hay baler and move them to the stacking area. This part of the machine reduces the manual labor require to place bales on the trailer. Dimensions and workings are currently unknown.

A tractor pulling the trailer will power the compression mechanism with hydraulics. It will hold 10 bales, making the approximate dimensions 46” x 54” x 40”. One side of the compression mechanism will hold a drum containing plastic strapping. The other will have a mechanism to hold the strap ends while the bales are stacked. The compression will either occur from one side or both sides. ***Add magnet shenanigans***

Payment Schedule

Boxel Manufacturing will purchase the majority of supplies, including metals, hydraulics, cylinders and bearings. Oklahoma State University will provide various small parts necessary for construction, such as nuts, bolts and equipment for testing. OnEdge Innovations requires no payment for the work done on the bale bundler project.

Acceptance of Criteria

Boxel demanded the creation of a single-laborer machine capable of bundling a minimum of 1200 bales per 10 hour work day. Boxel also required a durable, easily operated machine which complies with needs of a small hay producer. A 45 hp tractor must be able to pull the machine. Additionally, shade has been provided for the laborer in the form of a removable canopy. Boxel budgeted the building expenses to not exceed

$8,000 in production costs and will sell the machine for $16,000. Currently, Boxel does not know if they will market directly to consumers or market through another company.

Special Requirements

Due to the distance between Stillwater, Okla., and Caney, Okla., the OnEdge Innovations team and Boxel alternated travel between locations. During the project, both entities traveled between locations, once meeting Ada, Okla.

WORK BREAKDOWN SCHEDULE

Complete Work Breakdown Schedule and Task List can be found in Appendix A.

---------- Fall 2010 Semester ----------

1. Initial Research 9/14/10

1.1. Research Boxel Manufacturing

Determine Boxel's resources, products, suppliers and employees. OnEdge Innovations must design a product that Boxel will have the capabilities to manufacture in the future.

1.2. Research Industry

Determine the economic conditions affecting the industry, key industry gatherings (trade shows, conferences, and meetings), industry size and growth, and relevant trade publications. Develop knowledge of the potential market from industry growth.

1.3. Research Competitors

Determine competitors by researching their resources and products to define what is unique (good and bad) about their products and the price of their products

1.4. Research Customers

Identify customers' needs – learn what they like and do not like about existing hay bundlers.

1.5. Research Technical Sources

Identify relevant standards and regulations (American Society of Agricultural and Biological Engineers, Oklahoma Department of Transportation, Department of Public Safety) that will drive the direction of the prototype design. Research relevant patents and evaluate their importance in the project.

2. Develop Rough Budget 9/27/10

Review initial research and consult with Boxel to develop a rough, projected budget for the prototype design and build.

3. Develop Design 10/1/10

The design development will be divided into four different areas: hay elevation, hay compression, bundle banding, and bundle releasing.

3.1. Develop an hay elevation concept

Review initial research to determine the customer requirements and requests for picking the hay out of the field to the operator working on the platform. Draw final concepts in SolidWorks.

3.2. Develop a hay compression concept

Review initial research to determine the customer requirements and requests for compressing the 10 square bales into one bundle. Review hay bale and bundle dimensions to decide on the compression specifications. Draw final concepts in SolidWorks.

3.3. Develop a bale banding concept

Research different types of banding material (plastic, metal, net wrap) and hand-held banders to form a banding concept feasible for bundling hay. Review initial research to determine the customer requirements and requests for banding the bundle. Review hay bundle dimensions to determine the length of material per

bale. This required length will aid in economic analysis and prototype design. Draw final concepts in SolidWorks.

3.4. Develop a bundle release mechanism

Review initial research to determine the customer requirements and requests for releasing the hay back to the original field for later transportation. Draw final concepts in SolidWorks.

3.5. Calculations/Testing

Calculate the force required to compress the hay to desired dimensions. Test the hand-held bander's seal integrity. Calculate hydraulic flow requirements needed for each hydraulic component (four cylinders and two motors). Geometry calculations will determine placement of cylinders for optimal performance.

3.6. Finalize Design

Decide on a final concept each component of the design: hay elevation, hay compression, banding the bundle, and bundle release. Create a full assembly of all parts and a presentation of all work completed. Present to Boxel, faculty and peers for design review.

---------- Spring 2011 Semester ----------

4. Build Prototype

4.1. Create Construction Drawings for each part

Create drawings in SolidWorks including all initial dimensions and assembly specifications (welds, bolts, threads).

4.2. Decide where to build machine

The trailer frame and larger fabrication will be completed at Boxel. Small, detailed fabrication will be completed at the OSU BAE Laboratory and Machine Shop.

4.3. Order parts through Boxel purchasing

4.4. Construct Prototype

Cut steel bars, rods, angles, sheet metal to desired sizes for framework and other parts. Drill holes in steel for various functions. Join/weld the framework. Attach via fasten or weld the other components (compression, elevation, banding, and release mechanisms) to the framework. Attach axles/wheels. Construct and attach the hitch system. Attach hydraulic components: cylinders, directional stack valve, hoses and motors.

5. Prototype Testing

5.1. Run tests on all components

Dr. Dan Storm (BAE) has loaned OnEdge Innovations 10 hay bales for testing. Hook implement to the tractor and run the implement as would in field conditions: laying 10 bales out in a row and testing all mechanisms and components.

5.2. Review Prototype Design

Make any necessary changes to design that arise from testing.

5.3. Review Construction Drawings

Make any necessary changes to dimensions that arise from testing.

5.4. Repeat Testing

6. Market Product

Develop business and marketing plan. Create a brochure for the product and add the product information to the Boxel website. Create a video of the machine in action.

7. Present Final Design with Prototype and Marketing Materials to Boxel Manufacturing

Create a presentation illustrating the prototype, marketing materials and business plan to Boxel, faculty and peers for product review.

COMPETITIVE ANALYSIS

OnEdge Innovations prepared the following report as an aid for the development of a 10 hay bale bundler for Boxel Manufacturing, a local fabrication and hay supplier company. The following material presents an industry, customer, competitor and technical analysis. This allowed OnEdge Innovations to develop a functioning design in SolidWorks ready for production by of December 5, 2010. The building of the bale bundler will commence in the early spring 2011.

INDUSTRY ANALYSIS

Breeders and producers must have a food source for their livestock and large round bales are not feasible for producers with less than 30 head of livestock. These livestock producers must utilize small square bales (14" x 18" x 40") to feed their stock. Some hay producers currently bundle small square bales into larger bales ranging from 16 small bales to 60 small bales to ease transportation and storage. Customers for small square bales are the equine industry and show livestock industry.

The equine industry demands small square bales of alfalfa and grass hay for feed. According to IBISWorld, the equine industry created $1.6 billion in revenue in 2009[4]. Oklahoma alone hosts 15 national and world equine competitions every year[5]. In 2009, 1,100 competitors entered classes at the Grand National and World Championship Morgan Horse show. The horse show spanned eight days[7]. Most competitions run one to two weeks, and competitors haul from all parts of the United States and sometimes out of the country. Transporting horses, equipment and feed creates high costs and hassle. Trainers often times ship their horses and equipment and rely on the hosting facility to provide small square bales to feed their equines.

According to Stephen Boyles, a show steer should consume 4 -5 lbs. of hay daily. At shows, show steers should receive one to two flakes of hay per feeding[9]. Oklahoma hosts 13 livestock shows across the state in January and February[10]. These shows require small square bales of both hay and straw on site for the exhibitors to purchase. The Oklahoma State Fair runs for 10 days and holds 12 divisions with multiple

classes[11]. Hundreds of animals reside at the Fair, requiring hay and straw for maximum performance. The combination of cattle and equine competitions creates a demand for easily transported and stored small square bales in Oklahoma.

According to USDA, the Oklahoma hay market has maintained steady prices throughout the weakening economy. Small square alfalfa bales sold at $150 to $210 per ton and small square grass hay bales sold at $85 to $140 per ton, depending on quality[1]. These prices demonstrate a constant demand for small square bales in the market, which strongly supports the need for haying equipment for production. Since the market for hay producers appears to remain strong, producers will find the most efficient production and marketing methods to increase their profit margin. Possessing a means to easily transport and store small square bales will increase their profit margin.

The hay bale bundling company Bale Band-it began making bundlers in 1999 and has already doubled its production twice in recent years[2]. Hay bale bundlers are marketed several ways, including trade show exhibits and magazine advertisements. Trade shows are commonly held in conjunction with large horse shows, farm shows and agricultural expos. Trade shows such as KNID Agrifest in Enid, Okla., and the Fort Worth Stock Show and Rodeo in Fort Worth, Texas, could promote Boxel's bale bundler[6].

CUSTOMERS/BUYERS

To research Boxel's target consumers, OnEdge Innovations read testimonials on competitors websites given by their clients. Based on the testimonials found in Appendix B, OnEdge Innovations has gathered specific aspects of a bale bundling machine that customers expect.

Boxel's target customers want quality machines capable of increasing their profit margin. They want to load more hay on trailers to reduce transportation and labor cost. By eliminating the need to load and unload small square bales by hand, input labor and labor costs would greatly reduce. Customers must be able to operate the equipment easily and without formal training. Therefore, Boxel's product must be simple to operate.

As stated in Appendix B, producers are looking for “simplicity, with minimal moving parts…” Additionally, customers expect a machine to be safe to operate. Many of Boxel’s target customers rely on family labor to manage and operate farm equipment. Customers not only want safe equipment for themselves, but also for the benefit of their family members and/or hired labor. Producers, such as Stephen T. Baltz, need to know their products “will travel safely down the interstate” once placed on a flatbed. For more of customer testimonial, see Appendix B.

Boxel will market Boxel’s bale bundler to the hay or wheat producer haying from 100 to 300 acres. With the smaller operations of Boxel’s target customers, the need for fully automatic, high priced machinery is nonexistent. Boxel customers need a machine costing no more than $16,000. Customers are willing to partake in minimal manual labor.

BOXEL MANUFACTURING AND ITS RESOURCES

Boxel Manufacturing, Inc., is a 25-year-old metal fabrication company based in Caney, Okla. Brad Lahman owns and manages Boxel. Boxel currently produces livestock show supply boxes, grooming supply boxes and small cake feeders, as well as custom hay baling of round and small square hay bales.

The operation is housed on Brad Lahman’s 2,000 acre ranch in a custom metal fabrication shop. The manufacturing shop consists of welding stations, a machine shop, press brakes and a plasma table. All Boxel products are made mostly of steel with certain non-steel components. These components, such as tires and wheels, are outsourced.

Boxel has developed four prototypes of a bale bundler. His first designs bundled 18, 15, and 12 bales. Each of his machines required two laborers; one to toss the hay on to the trailer and one to stack, band and shove the hay off of the trailer. The finished hay bundles lacked integrity and stable stacking ability.

COMPETITORS AND THEIR RESOURCES

The following machines are the current competition in the bale bundling market. Bale bundling competitors of Boxel in the bale bundling area are located throughout the United States. Potential competitors include Bale Baron, Bale Band-It and Arcusin.

Figure 1: Bale Baron

http://www.kleine-balen.nl/en/machines/balen-bundelaars.html

Figure 2: Bale Band-It

http://pics.hoobly.com/full/YDK1JAHNDI6SA7TRGK.jpg

Figure 3: Arcusin

http://www.mascus.com/Agriculture/Used-Self-loading-trailers/Arcusin/Multipack+B14/images

OnEdge Innovations created a single, scalable model with interchangeable parts so the customer can bundle 10 small square bales to meet their individual needs. The table

below shows the different options each competitor offers for their bundler along with the Boxel QBer.

Table 2: Competitive Analysis

Name	Bale Elevation	Stacking	Banding	Compression	Release	Cost
Bale Band-It	Baler only	Mechanical	Steel Strap	Hydraulic	Automatic	$70,273*
Bale Baron	Baler only	Mechanical	Plastic Twine	Hydraulic	Automatic	$62,321**
Arcusin	Ground pick up	Mechanical	Cord	Hydraulic	Automatic	$79,553*

TECHNICAL ANALYSIS

The technical analysis forecasts the direction of prices through the study of past market data, generally the price and the volume of product. The following sections contain all relevant published information which aided in the design of the product, such as standards and patents. This analysis also provides testing and modeling information completed during the development of the product.

STANDARDS AND REGULATIONS

In industry, standards and regulations establish uniform engineering and technical data, methods, processes and practices. Industry standards provide information for concept development and aid in reforming ideas that incorporate exchangeability among design components. The American Society of Agricultural and Biological Engineers publish volumes of industry standards for most any agricultural application.

OnEdge Innovations found numerous standards pertaining to the current design aspect, including terminology for hay handling equipment, standards for hydraulic cylinders and safety requirements. The basic terminology for hay handling equipment helps name

different parts of the bundler in accordance with the current products on the market. Particular names will allow the customers understand each part of the bundler and recognize the terms familiar to them. For hydraulic cylinders, the standards helped to develop a working hydraulic lift mechanism for the hay bale collector. OnEdge Innovations highlights some pertinent standards below, but all relevant standards and regulations are in Appendix C: Standards and Regulations.

The State of Oklahoma Department of Public Safety and Oklahoma Highway Patrol have issued a booklet of statutes pertaining directly to farmers and ranchers. Regulations and standards affecting the transportation of the hay bundler on public roads formed design constraints on trailer size. These standards and regulations also required safety features such as an official slow-moving vehicle emblem, hydraulic cylinder safety locks, red lights and red reflectors must be mounted on the back to signal other drivers, and chain or cable safety back-up devices must be installed in addition to the hitch.

The Occupational Safety and Health Administration has regulations limiting the noise level if a human operator is to be needed to operate the bundler. This determined the type of hydraulic motors used in the design.

PATENTS

Patents contain information used during design and concept development. The basic summary of the device, a full description of the device, how it is to be used, and what the device should achieve are found within patents. OnEdge Innovations used patents to view similar concepts and designs, which inspired our engineers' own creations. OnEdge Innovations found the following patents:

Patent Number	*Title*
7610851 B1	*Bale Stacker*

Inventor: Mark Horst (Marcrest Manufacturing) – Bale Baron

This patent involves a method for consolidating a plurality of bales into a bale bundle. An upstream opening brings the bales in a compression chamber. The bales are compressed from the bottom and the front. After compression the bundle is released to the downstream opening. This opening releases the bale back to the field[13].

6397738 B1 *Hay Bale Stacking and Bundling Method*

Inventor: Owen J. Brown, Jr. – Bale Band-It
This patent involves a method to form a bundle of twenty-one square bales. The apparatus will elevate the hay bale from the field, mechanically stack the hay into a bundle, compress the hay from one side, band the hay with two metal bands, then release the hay back into the field. The machine is computer controlled from the tractor operator and fully automated[13].

These patents were used to analyze the process used by patent holders when they developed their products. Complete patents can be found in Appendix C: Patents.

FIELD/PHYSICAL TESTING AND DATA

Boxel Manufacturing has tested the integrity of a 10 hay bale bundle. The hay bundle can be stacked at least three bundles high in a barn without losing integrity. A forklift can easily move a bundle without pallets, and the bundle can be transported on a trailer.

By using testing and calculations completed with a hydraulic flow test machine (Power Pack), supplied by the BAE Laboratory, OnEdge Innovations determined the required hydraulic capacity. Required flow rate, pressure, hydraulic cylinder retraction and extension speeds, as well as hydraulic motor speeds, will all be tested to find the optimum system. **Give Results?**

Orientations of compression were tested on the 10 bale bundle to determine if 2 - directional compression is needed or optional. Degree of compression testing coincides with the testing of the hydraulic system.

Different stacking and banding systems have been tested on a 10 bale bundle. OnEdge Innovations found the best stacking method to maintain bale integrity is to stack all bales on edge with the three in the bottom row, four in the middle and three on top. See Figure 9 in the Hay Bale Stacking segment of this report for further stacking information.

OnEdge Innovations researched banding machines to bind the 10 bale stack. We were interested in a bander that would automatically seal plastic strap bands. Originally, we looked at banders that would tighten the bands automatically or have need for manually tightening. OnEdge Innovations and Brad Lahman met with representatives of Omni-Packaging November 19, 2010. After testing the Zapak ZP36 and the Strapex BXT-80, OnEdge Innovations and Lahman chose to use the Zapak ZP36. More information regarding the Zapak ZP36 can be found on in the Bundle Banding segment of this report.

The entire machine will be field tested for timing of processes, speed and the quality of bundle produced when the prototype is complete.

SIMULATION AND MODELING

OnEdge Innovations modeled preliminary ideas to help visualize concepts and communicate with client fabrication specifications. We used SolidWorks to model components and generate computer assemblies. ***Add More***

ENVIRONMENTAL AND GLOBAL IMPACTS

OnEdge Innovations took into consideration the environmental and global impacts a hay bundler might have. Beginning with the production stage, it is important to understand where the materials will come from and how they are manufactured.

Factors that could affect the environment consist of chemical runoff from manufacturing, maintenance materials like oil and grease, and disposal of no-longer-useful parts or units.

DESIGN CRITERIA

Boxel Manufacturing required the final hay bundle design to incorporate the following components:

1. Mobile – move through a field, not a stationary unit
2. Hay Compression
3. Banding
4. Release of the bundle back to the field
5. Use of a human operator – to keep cost low relative to fully automated systems
6. Manufacturability
7. Shade for operator comfort

CONCEPT DEVELOPMENT

OnEdge Innovations decided to divide the project into six major categories:

1. Hay bale elevation from the field
2. Hay bale stacking
3. Hay compression on the trailer
4. Automated bundle banding system
5. Bundle release to the original field location
6. Trailer framework

This allowed the design of each component to meet requirements and requests of customers along with industry standards. A design concept was developed for each of the categories. OnEdge Innovations adjusted these concepts to meet the design criteria, as discussed in the following sections. **How did we adjust? (if we did)**

POTENTIAL SOLUTIONS

Trailer Framework

The trailer framework was designed to function in the field and for safe travel down a public road. OnEdge Innovation constrained the trailer to only be 8 feet wide to avoid the need for “wide load” signs or signals.

The length of the trailer will be 12 feet, but could change depending on the required dimensions of the other components of the bale bundler (i.e. compression, banding, and releasing mechanisms).

The trailer will be made of 4” x 4” x ¼” square tubing. Bracing will be placed across the trailer for support of the compression mechanism and the releasing apparatus.

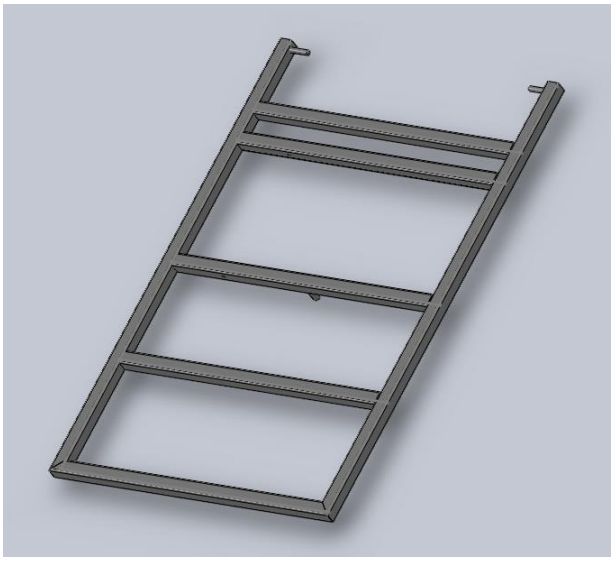


Figure 4: Trailer Framework

Two tires will be attached on the inside of the back of the trailer. Trailer tires will be used. The specifications for these tires are approximately 15” x 5” white spoke 4” - 4.5” bolt circle with 1,820 tire capacity.

Figure 5: Trailer Framework with Tires

The trailer will be equipped with a pivoting tongue so the customer will be free to 1) directly attach the bundler to a square hay baler or 2) attach the bundler to a tractor, offsetting the bundler so the elevation mechanism will directly align with square hay bales.

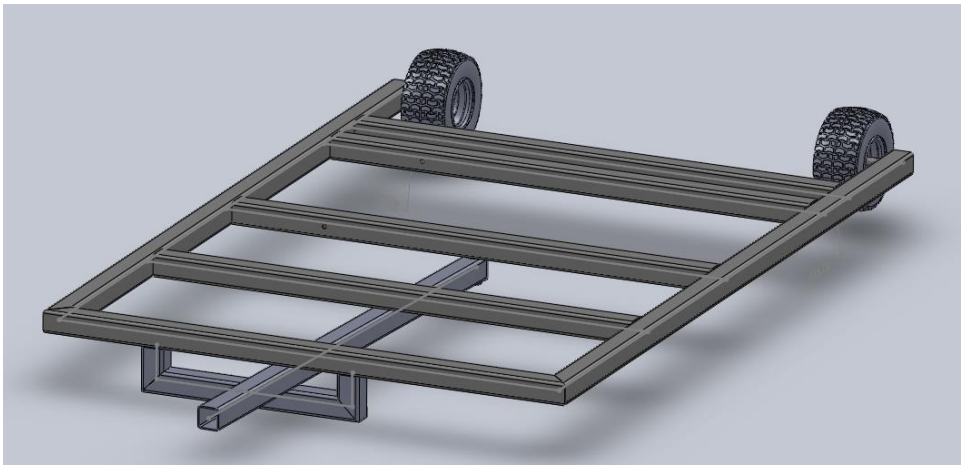


Figure 6: Complete Trailer Framework

This framework will allow OnEdge Innovations to incorporate all mechanisms needed to bundle 10 square bales into one cube.

Telescoping/Pivoting Tongue Function

OnEdge Innovations decided to incorporate a telescoping function into the pull tongue design. This will allow the trailer to attach to any baler or trator. As seen from the included picture, the tongue will have the ability to pivot left and right a limited amount of degrees as well as telescope in and out a limited amount of distance. Ultimately, the design will allow an infinite number of positions available to the bundler within the given boundaries. The operator can set the location of the bundler behind both the tractor and the hay baler. The swinging function is critical to the elevating portion of the design because it allows the bundler to swing from behind the tractor to an offset position allowing elevating table to be let down and operated. The telescoping function of the tongue will allow the bundler to hook to the back of the hay baler in the correct location for the elevating table to be hooked directly to the bale exit chamber of the hay baler.

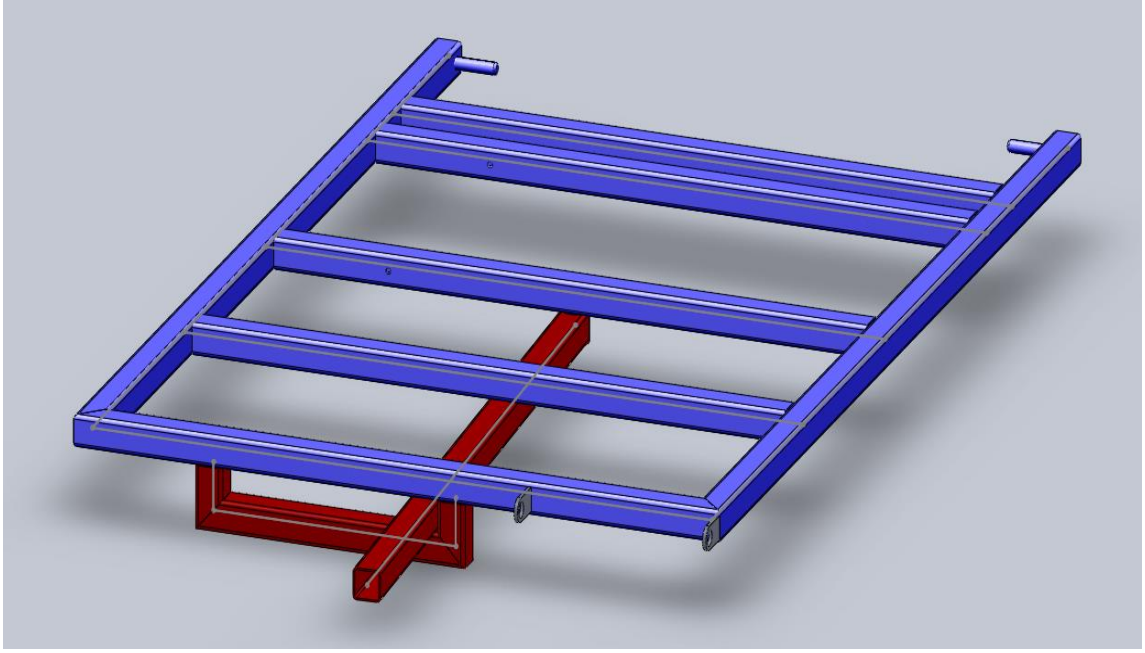


Figure 7: Trailer Frame and Telescoping, Pivoting Tongue

Hay Bale Elevation

The Boxel bundling process will begin by elevating the small hay bales from either the ground or from the back of the small square baler producing the bales. Initially, the bales will be elevated to a staging area in order for the operator to easily stack them into the compression mechanism. Technically, the elevator will consist of a hydraulic gear motor which will drive one single lift chain assembly through a common shaft. The lift chain will operate continually during use of the bundler allowing the hay to move to the operator station at a constant rate, either from the ground or from the hay baler. The assembly also will consist of a collection snout which will be mounted to the starting end, allowing for an alignment error of the hay stream. The collection snout will align the hay stream with the lift chain, allowing for a continuous steady-state flow. For folding purposes, the table will consist of one single hydraulic cylinder. The elevator will fold to a position pointing straight up for transport and fold down to variable operating position where it will be pointing straight forward, operating either directly beside the tractor or directly behind the hay baler. A picture is included below for clarification.

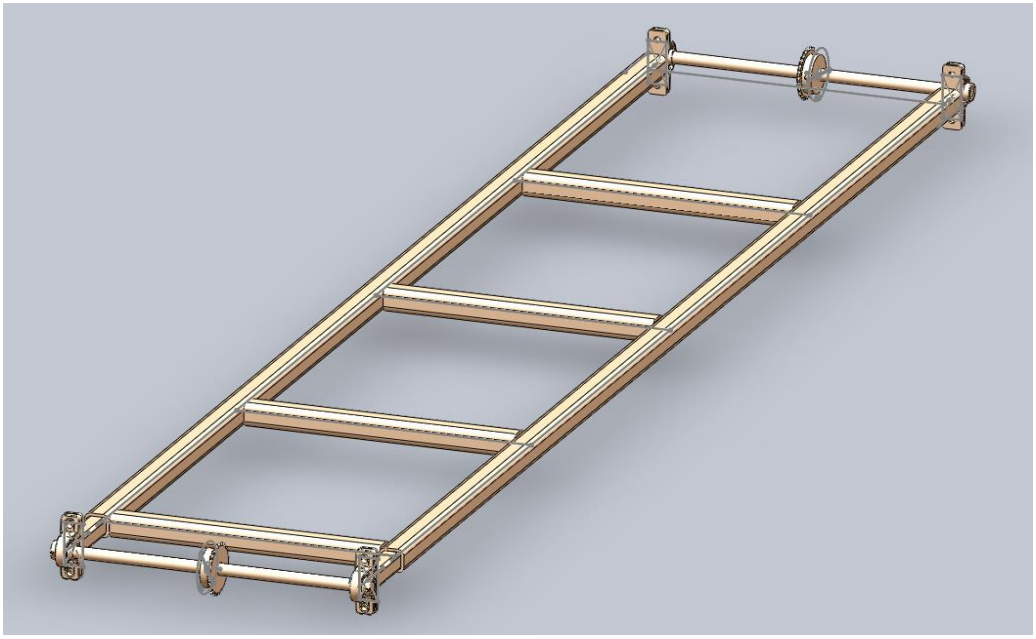


Figure 8: Lifting Mechanism

Hay Bale Stacking

A human operator will stack square bales (18 inches wide, 14 inches tall and 40 inches deep). This operator will stack the bales in a specific scheme as shown in Figure 9. The

starting bundle dimensions are approximately 50 inches tall, 54-58 inches wide, and 40 inches deep. After compression, the approximate dimensions are 46 inches tall, 48 inches wide and 40 inches deep. These dimensions were provided by Boxel after testing design concepts with a prototype. **Field Testing Data**

Figure 9: Bale Stacking Scheme

This stacking scheme creates optimum storing or transporting of the bundle in a standard semi-truck trailer (100 inches) (14), a standard pallet (4 feet by 4 feet) (15) and setting the cube in the back of a customer's full size truck (62.4 inches) (16) after purchase. This stacking scheme makes the bundles ideal for stacking on top of each other in a hay storing facility. The staggered edges in the middle increase the integrity of the bale after banding.

Hay Compression

The compression system will be formed from two walls: one stationary and one dynamic. The walls will be made of 2" x 2" x ¼" square tubing and 16 gauge sheet metal. Both walls are 42 inches wide, 62 inches tall, and 8 inches deep. The dimensions were determined from the dimensions of the 10 hay bale bundle.

Figure 10: Compression Wall

The dynamic wall will be connected to a 4.5” x 4.5” x ¼” square tubing track. This track will slide on the outside of the trailer framework, allowing the wall to move when the hydraulic cylinder is set into motion by the operator.

The stationary wall will be connected to a 4.5” x 4.5” x ¼” square tubing track similar to the dynamic wall. This track is meant to make the wall adjustable if the customer’s hay bales change dimensions. This wall will be locked into place with a pin on both sides.

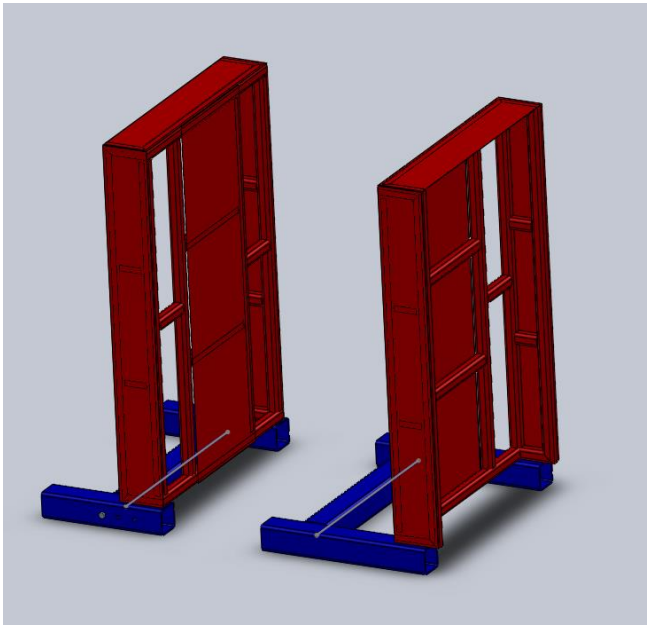


Figure 11: Compression Walls on the Tracks (Dynamic – Right, Stationary – Left)

The hydraulic cylinder will be mounted under the dynamic compression wall. The fixed end of the cylinder will be mounted to the inside of the trailer frame, and the extending end of the cylinder will be fixed to the track of the dynamic wall.

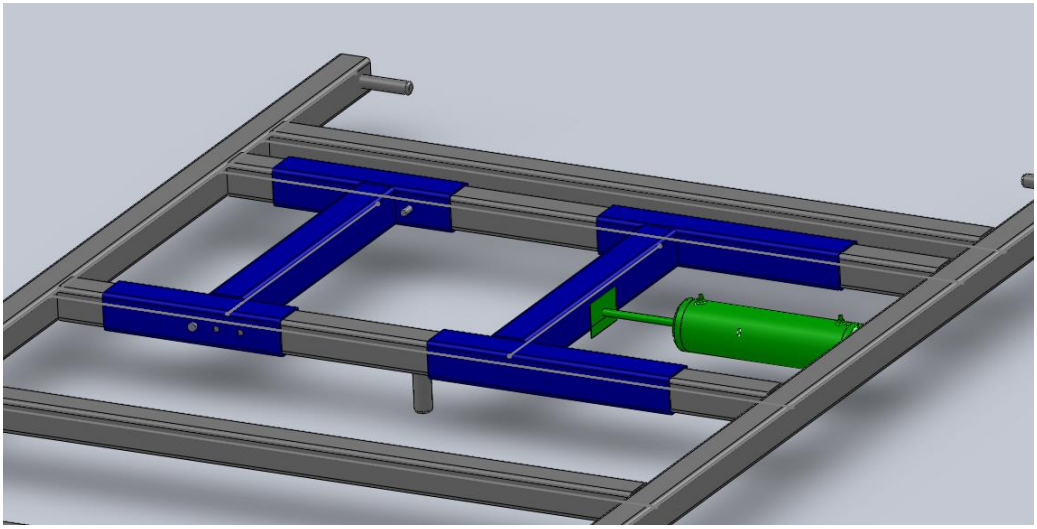


Figure 12: Track, Trailer Framework, and Hydraulic Cylinder

The full compression assembly is shown in Figure 13.

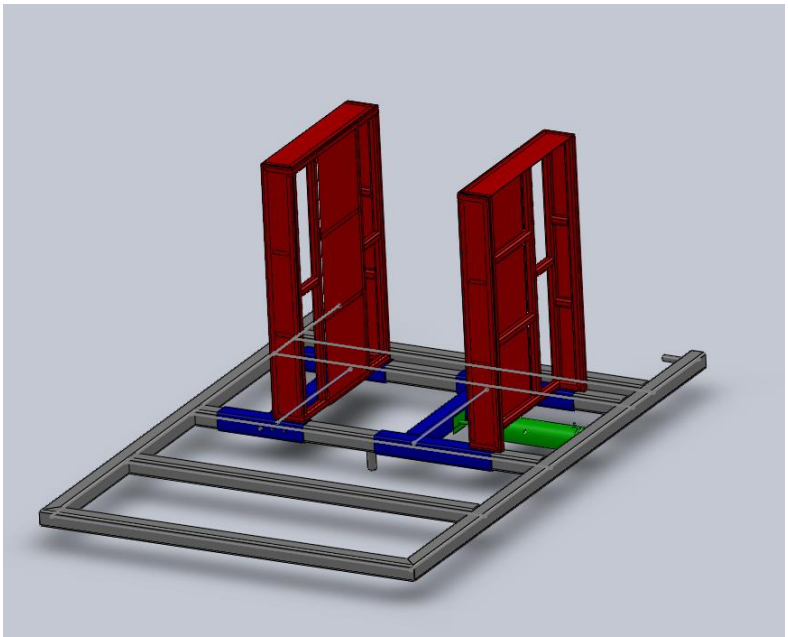


Figure 13: Compression Assembly Mounted on the Trailer Frame

Bundle Banding

The bundle banding system will utilize a human operator, magnets and a hand-held tensioning and sealing device.

5/8” plastic strapping will be used to bundle the hay. Two spools of the plastic strapping material will be attached to the left side of the stationary compression wall and will be accessible to the operator. These spring-loaded spools will prevent excess strapping material from dragging on the ground or into the moving hydraulic components. A clamping mechanism will be built on the right side of the dynamic compression wall. This will clamp the plastic strapping into a fixed location. ***engineers describe**

Figure 14: Plastic Strapping

OnEdge Innovations tested the Zapak ZP26 and the Strapex for utility, speed and power.

Table 3: Bander Comparision

Hand-Held Banding Tool	Battery Operated	Sealing Time Range	Tension Maximum	Warranty	Cost
Zapak ZP26	Lithium Ion	0.6 - 4.8 seconds	726 lbs	3 Year Parts &Service	$2,100.00
Strapex	Lithium Ion	2-5 seconds	900 lbs	No Warranty	$3,200.00

The Zapak ZP26 automatic hand-held bander from Omni-Packaging will be used by the operator to tighten the of $5/8^{th}$ inch wide and a thickness of $5/100^{th}$ inch plastic strapping

around the hay bundle and seal the straps together. The sealing time of the Zapak ZP26 is two seconds. This ZP26 is battery operated so cords will not be a safety issue.

Zapak ZP26

In order to get the plastic bands completely around the entire hay bundle, the machine utilizes a vertical rack and pinion system with protruding bars. A hydraulic motor controlled by the operator will operate the system.

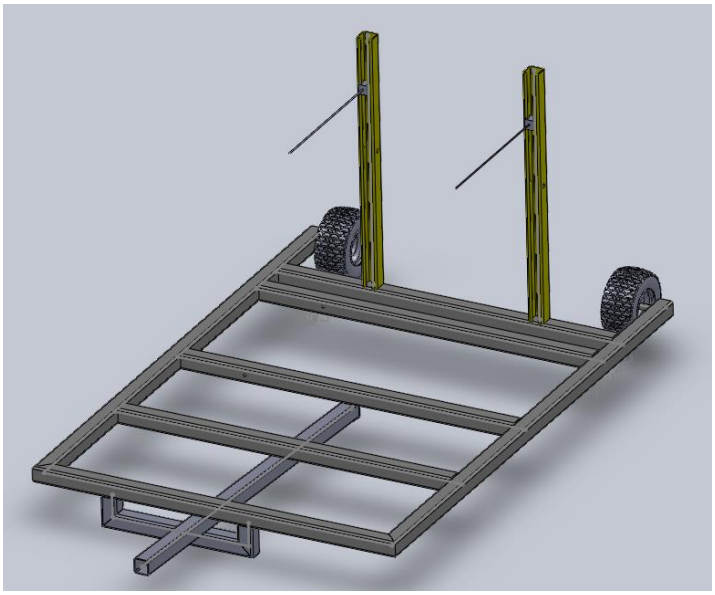


Figure 15: Banding System

Before the operator stacks the hay into the specific hay scheme, he/she will pull both bands from the spools on the left, under both of the protruding bars, then clamp the ends into the clamping mechanism on the right side. The operator will then engage the hydraulic motor, moving the straps down to the bottom of the hay stacking platform. Since the spools of plastic are spring-loaded, they will not recoil; therefore, the banding

system can be moved back up into its resting position. The operator will begin stacking the individual square bales into the machine, on top of the two bands. After stacking and compression is complete, the operator will cut the left side of the straps. The ends of the straps will then be tightened and sealed by the operator with the hand-held bander. Compression will be released, and the banding of the bundle is complete.

Bundle Release

The bundle release apparatus will relocate the hay bundle from the trailer to the field. This mechanism will also act as the hay stacking platform.

The frame will be made of 2” x 2” x ¼” square tubing and 16 gauge sheet metal. The dimensions are 68 inches tall, 39 inches wide, and the bottom platform extends 36 inches from the back support. The supports for the releasing system are the same supports for the banding system which will save space and materials. This support is made of 4” x 4” x ¼” square tubing and stands at 65 inches tall.

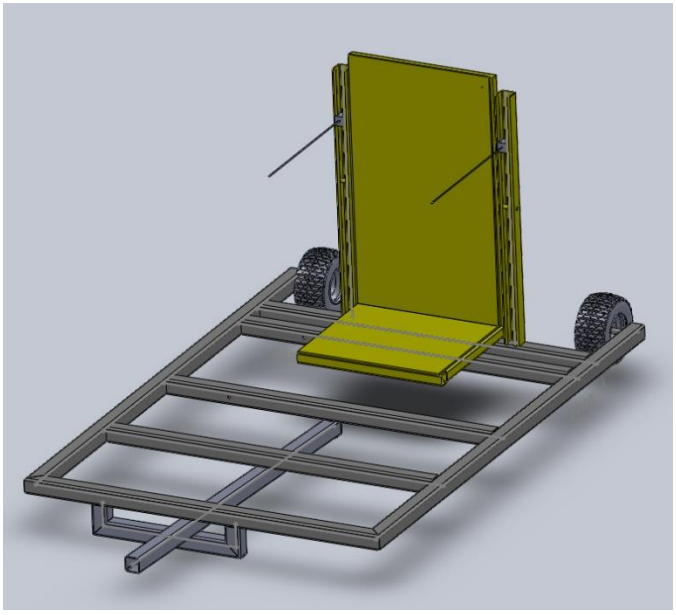


Figure 16: Releasing System – Resting Position

A hydraulic cylinder will be used to flip the platform approximately 120°, sliding the bundle of hay into the field. The extending end of the cylinder will be attached just below the pivot point of the platform, and the fixed point will be attached to a framework on the back of the trailer.

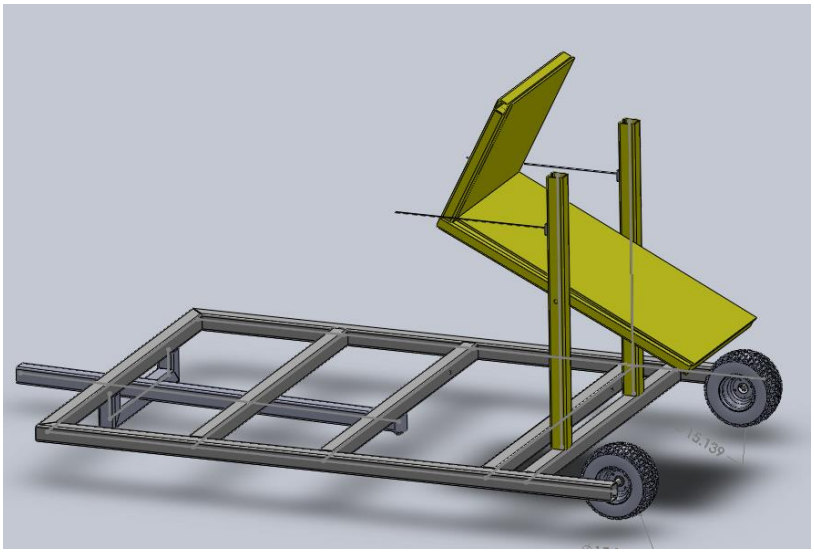


Figure 17: Releasing System – Releasing Position

Final Design

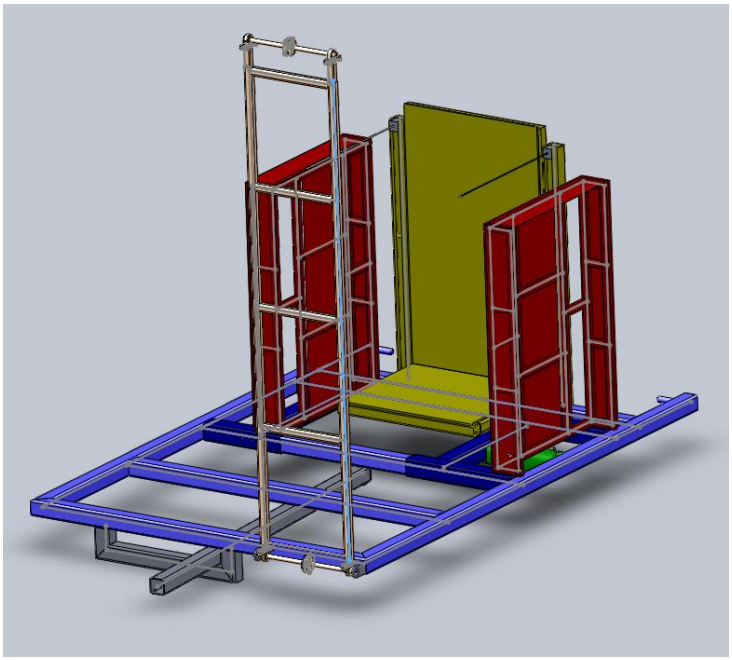


Figure 18: Final Model Design

POTENTIAL ISSUES

The design has many different hydraulic functions, some continuous. Depending on the size of the tractor hydraulic fluid reservoir, heat could build up in the hydraulic components. The excess heat will affect both safety and performance of the equipment. If heat does become an issue, OnEdge Innovations will utilize a satellite reservoir and/or an air to oil cooler designed into the bundler itself. It will not be an add-on to the tractor.

With the amount of force required to compress the hay bales, and the force required to flip the hay into the field by the releasing mechanism, structural integrity was a potential issue. OnEdge Innovations planned to reinforce the framework of said components if needed.

Debris could affect the performance of the hydraulic components if not properly cleaned. OnEdge Innovations recommends blowing out the components with an air compressor after every use.

SOLUTION ANALYSIS

Hydraulics will be modeled using Hydraulic Automation Studio software. This software simulates cylinder movement, flow lines, heat dissipated and motor movements. It was instrumental in modeling different hydraulic functions and issues.

Engineering calculations and stress analysis models aided in resolving structural integrity issues. This analysis will determine the best component combinations while meeting all specifications and requirements.

TRACTOR REQUIREMENTS

See Appendix G

HYDRAULIC COMPONENTS / CALCULATIONS

See Appendix H

PROPOSED MEDIA / COMMUNICATIONS PLAN

OnEdge Innovations will promote the final product created through means of paper publications, Internet sites and trade shows prominent in Oklahoma and northern Texas.

OnEdge Innovations created a video of the QBer in action. A link to the video can be found on Boxel's website www.varguardstoragemodules.com. This allows potential customers to view the QBer and its actions at a low cost for Boxel. Additionally, OnEdge Innovations has designed advertisements for Boxel to place in magazines circulating to hay producers. *Hay and Forage Grower, Fastline* and *High Plains Journal* are potential magazines to contact about advertising space. *The High Plains Journal* produces a monthly publication strictly for new products. OnEdge Innovations has also created brochures exemplifying the characteristics of the QBer. While attending many of the trade shows in Oklahoma and northern Texas, brochures can be distributed to hay producers.

insert cost table

PROPOSED BUSINESS PLAN / FINANCIAL ANALYSIS

In the current stages of the economy, individuals must find methods of production that can satisfy needs, maximizes profits and produce at a price level meeting firms' budget capabilities. Our client Brad Lahman, owner and operator of Boxel Manufacturing, currently makes show boxes and feeders for today's youth and agriculturists. As a professional custom hay harvest, Lahman envisions an innovative bale bundler with the ability to bale 10 small square bales into one bundle. Hay producers will experience a cheaper, well-made bale compressing accumulator 80% cheaper than the accumulator models currently in the market. A 10 bale bundle will be easily moved, decreasing transportation time from the field to the barn. This decrease will lower the high labor inputs of loading, transporting and stacking square bales, making relocation and unloading easier than that of the 21 bale bundle.

Boxel Manufacturing's QBer is suited for individuals entering into custom hay harvesting markets who might not have the cash flow to meet prices of other bale bundlers in the

market place. This product's price falls under a smaller farm's budget constraint, including hobby farms.

OnEdge Innovations created a safe, dependable product available to small farmers. Boxel originally set a maximum manufacturing cost of $6000. The final production cost of the QBer is $*****. The original expected retail price of the QBer was $16,000. Boxel will set an asking price of $****

PROJECT SCHEDULE

Complete Work Breakdown Schedule and Tasks can be found in Appendix A

The following seven pages include the Gantt Chart for the project.

COST ANALYSIS

The graph below demonstrates the different ways to bale Bermuda grass and the price that relates to the method[12].

Table 4: Price Comparison of Bales

Prices of Bales Information based on current prices of Bermuda grass weighting 66.7Lbs/Bale				
Type of Harvest	**price per unit**	**Weight**	**Price per Lb.**	**Price per Ton**
Large Round Bale	$35	1500Lb	$0.023	$46.667
Small Square Bale	$3.75	67LB	$0.056	$111.940
Large Square Bale	X	x	x	x
21 Bale Bundle	$84	1400Lb	$0.06	$120.00
10 Bale Bundle	$60	667Lb	$0.09	$179.91

The table below lists the cost of materials necessary to manufacture the baler.

Table 5a: Cost of Manufacturing - Steel

COST OF STEEL					
Component	**Quantity**	**Price/ft**	**Price/ft^2**	**Unit Price**	**Cost of Good**
Large Grade Expanded Metal #3	x	x	$1.99	$63.70	x
Medium Grade Expanded Metal #6	x	x	$1.67	$53.40	x
Small Grade Expanded Metal #9	x	x	$0.95	$30.50	x
4.5" 4.5" 0.25" Steel Tube	x	x	x	x	x
4" 4" 0.25"	x	$6.37	x	x	x
2" 2" 0.25"	x	$2.80	x	x	x
16ga Sheet metal	x	$1.18	x	$37.60	x
14ga Sheet Metal	x	x	$1.42	$45.35	x
1/4" Sheet Metal	x	x	$4.39	$140.35	x
Shaft Material	x	$1.58	x	x	x
Total Cost					**0**

Table 5b: Cost of Manufacturing – Hydraulics

COST OF HYDRAULIC COMPONENTS			
COMPONENT	QUANTITY	UNIT PRICE	COST OF GOOD
P-Clamps	20	$2	$40
Cylinders	4	$200	$800
Multi-Lever Manifold	1	$150	$150
Hydraulic Hoses	x	x	
Necessary Fittings/Couplings	x	$50	50
Motors	2	$300	$600
Total Cost			$1,640

Table 5c: Cost of Manufacturing – Banding

COST OF BANDING			
COMPONENT	QUANTITY	UNIT PRICE	COST OF GOOD
ZPAC ZP26	1	$2,195	$2,195
Plastic Strapping (4200 ft Spool)	1	$80	$80
Battery	1	175	175
Total Cost			$2,450

Table 5d: Cost of Manufacturing – Miscellaneous

COST OF MANUFACTURING - MISCELLANEOUS			
COMPONENT	QUANTITY	UNIT PRICE	COST OF GOOD
Wheels & Tires	2	$59.99	$119.98
Tail lights	2	$29.99	$59.98
Clearance Lights	4	$2.99	$11.96
Spindles	2	$60	$120.00
Electrical Wires 16GA	x	x	x
Bale Chain	1	$60	$60.00
Journal Bearings	10	$10	$100
Bearing Castings	10	$10	$100
Tongue Hitch	1	$20	$20.00
Jacks	1	$35	$35.00
Hub Assemblies (5-Bolt)	2	$22	$44.00
Rollers	10	$15.12	$151.20
Total Cost			**$778.12**

Table 5e: Manufacturing Costs – Estimated Total

Estimated Total Cost	
Component	***Subtotals***
Steel	*~$2,500*
Hydraulics	*$1,640*
Banding	*$2,450*
Miscellaneous	*$778.12*
Total Cost	***$7,448.12***

CONCLUSION

OnEdge Innovations created a new product for Boxel Manufacturing to help expand its business in the hay implement market. The QBer will be competitive in the market, scalable and functional. OnEdge Innovations used the information gathered in the Fall Report, including market research, patent search, industry standards and our own ideas, to develop a design meeting all goals. Our final product passed field testing and, as shown in our economic research, will increase hay producers' profits.

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APPENDIX A: WORK BREAKDOWN SCHEDULE

- **Initial Research**
    - 7.1. Research Boxel Manufacturing
        - 7.1.1. Determine who they are
        - 7.1.2. Determine what they do
        - 7.1.3. Determine what their resources are
            - 7.1.3.1. Determine Boxel's supplier(s)
    - 7.2. Research Industry
        - 7.2.1. Determine industry size
        - 7.2.2. Determine market size
    - 7.3. Research Competitors
        - 7.3.1. Research Competitor Resources
        - 7.3.2. Research Competitor Products
            - 7.3.2.1. Determine their products
            - 7.3.2.2. Identify what is unique to their product
                - 7.3.2.2.1. Determine what is good about the competitors' products
                - 7.3.2.2.2. Determine what is bad about the competitors' products
            - 7.3.2.3. Determine competitors prices
    - 7.4. Research Dealers
    - 7.5. Research Customers
        - 7.5.1. Identify customers' need
        - 7.5.2. Learn what they like about existing hay bundlers
        - 7.5.3. Learn what they don't like about existing hay bundlers
    - 7.6. Research Technical Sources
        - 7.6.1. Research Standards
            - 7.6.1.1. Research ASABE standards

7.6.2. Research Patents

8. Develop Rough Budget

8.1. Review Initial Research

8.2. Created Budget

8.3. Submit to senior design professors for review

9. Develop Design

9.1. Develop an hay pick-up concept

9.1.1. Review Initial Research

9.1.1.1. Look at previous patents

9.1.1.2. Look at previous standards

9.1.1.3. Look at competitor products

9.1.2. Draw final concepts in SolidWorks

9.2. Develop a hay compression concept

9.2.1. Review Initial Research

9.2.1.1. Look at previous patents

9.2.1.2. Look at previous standards

9.2.1.3. Look at competitor products

9.2.2. Look at hay bundle dimensions to decide on compression specifications

9.2.3. Drew final concepts in SolidWorks

9.3. Develop a bale banding concept

9.3.1. Research different types of banding material

9.3.2. Research different types of hand-held banders

9.3.3. Review Initial Research

9.3.3.1. Look at previous patents

9.3.3.2. Look at previous standards

9.3.3.3. Look at competitor products

9.3.4. Looked at geometry of bundle to find length of material per bale to design mechanism to get band around the bale

9.3.5. Drew final concepts in SolidWorks

9.4. Develop a bundle release mechanism

9.4.1. Research different types of release systems

9.4.2. Review Initial Research

9.4.2.1. Look at previous patents

9.4.2.2. Look at previous standards

9.4.2.3. Look at competitor products

9.4.3. Drew up final concepts in SolidWorks

9.5. Calculations/Testing

9.5.1. Calculate hay compression force requirements

9.5.2. Calculate hydraulic flow requirements needed for each (3 total) hydraulic cylinder and the hydraulic motor.

9.5.3. Test the hand-held bander's seal integrity

9.5.4. Miscellaneous calculations (on all other necessary components)

9.6. Finalize Design

9.6.1. Decide on final hay pick-up concept

9.6.2. Decide on final hay compression concept

9.6.3. Decide on final bale banding concept

9.6.4. Decide on final bundle release system

9.6.5. Create a full assembly of all parts

9.6.6. Create a presentation of all work completed

9.6.7. Present to Boxel, Faculty and Peers

---------- **Spring 2011 Semester** ----------

10. **Build Prototype**

    10.1. Create Construction Drawings for each part

        10.1.1. Create drawings in SolidWorks

        10.1.2. Include all initial dimensions

    10.2. Decide where to build machine

        10.2.1. Frame and larger fabrication – Boxel

        10.2.2. Small, detailed fabrication – OSU BAE Lab and Shop

    10.3. Order parts through Boxel purchasing

    10.4. Construct Prototype

        10.4.1. Cut steel bars, rods, angles, etc. to desired sizes for framework and other parts

        10.4.2. Drill holes in steel for various parts

        10.4.3. Join/Weld the framework together

        10.4.4. Attach (fasten or weld) the other components (compression, pick-up, banding, release mechanisms)

        10.4.5. Attach the axles/wheels

        10.4.6. Construct and attach the hitch system

        10.4.7. Attach hydraulic components: cylinders, values, manifold, hoses, motor

11. Prototype Testing

    11.1. Run tests on all components

        11.1.1. Dr. Dan Storm loan 10 bales of hay for testing

        11.1.2. Hook implement to tractor

        11.1.3. Run implement as would in field conditions – laying 10 bales out in a row and testing all mechanisms and components

11.2. Review Prototype Design

11.2.1. Make any necessary changes to design that come up in testing

11.3. Review Construction Drawings

11.3.1. Make any necessary changes to dimensions that come up in testing

11.4. Repeat

12. Market Product

12.1. Develop a Business Plan

12.2. Develop Marketing Ideas

12.2.1. Create brochure for product

12.2.2. Add product information to Boxel Web site

13. Present Final Design with Prototype and Marketing Materials to Boxel Manufacturing

13.1. Create a Presentation

13.2. Present prototype, marketing materials, and business plan to Boxel, Faculty, and Peers

APPENDIX B: TESTIMONIALS

Bale Band-It

“Our expectations of the Bale Band-It were well surpassed, just by the simple operation of the machine. Loading 21 bales at one time is awesome and not to mention fast and easy, especially with a loader tractor. When we were using our crews to pick up and stack the bales, we had to take from our contract jobs or use more labor. Now we use 2 people to make the hay and the rest of our crews are only working on payable contract jobs, not on the farm. On average we would handle 20,000 bales/year now with the bundles we are averaging 100,000 bales/year. We can load and strap 420 bales in less than 1 hour, that means one man loading and 1 man strapping. In the old day approximately 350 bales stacked on the same trailer using 5 men 3 hours, if the bales did not weigh over 40 lbs/bale. With the Bale Band-It we are up to approximately 65 lbs/bale. More hay per load = more pay per ton. The old way 7 tons per load, with the Bale Band-It 13.65 tons per load = almost 2 to 1.” - Stanley Bordelon

“We at Creekside Farm have purchased straw bales from the Riley Brothers in Adams, Tennessee for 12 years. Within the last 2 years our straw has been delivered 21 bales to the bundle. This process of bundling has greatly reduced our labor costs. Load time is cut to minutes and on the site loading of our spreading trucks can all be done by machine.

It is also a secure feeling to know that the 21 bales that are bundled together, placed on a flatbed truck with other large bundles and then bound down will travel safely down the interstate. We look forward to many years of using this great process. Thank you for your product. Stephen T. Baltz Creekside Farm, Inc.”

Bale Baron

“Steve and his partner Penny grow 450 acres of grass in Lincolnshire specifically for the equine market. The introduction of the Bale Baron® has enabled us to bale and stack upto 4000 bales per day into the barn, with the help of only one loader driver. I like the

Bale Baron® for it's simplicity, with minimal moving parts and the proven double knot system of the Hesston knotters, identical to our own big baler. The Bale Baron® works quickly and does not hinder our Welger 830 baler. Moving bales from the field is always a slow process, not with the Bale Baron®, trailers are loaded with 500/600 bales in approx half an hour. With a slight modification The Bale Baron® will tie packs of twelve, this is a great advantage to our small bale haylage business as we can wrap packs of twelve quickly and then wrap them as individuals when time allows. This season we baled 35,000 hay bales and approx 8000 straw, in 2011 we aim to bale 60/70,000 hay and 10,000 straw. Lorries were previously loaded by hand, not any more, packs are loaded easily by teleporter, the only time we handle the bales is when we deliver to customers unless of course they have a machine!!!"

"Convinced I needed to tap into the premium small bale equine market I was converted to small bale packing 5 years ago. I ran a Bale Bandit in the first year but could not achieve the capacity I required and therefore purchased a second Bale Bandit.

I continued for two years and eventually purchased an Arcusin Bale Packer to try to solve the problem of putting through the desired quantity of bales. I still found myself struggling and in desperation started to convert my customers over to big bales until I was introduced to the Bale Baron. Bale Baron UK convinced me that the Bale Baron® would meet the capacity and reliability that I needed.

In the first year I have baled over 42,000 bales and couldn't have been more impressed with the Bale Baron and I am convinced that in a normal yielding year I could have easily baled the 60,000-70,000 bales that I am looking for. On top of all the other benefits of the Bale Baron® I have been able to use up my big bale twine left over from last year!"

Arcusin Multipack B-14

No Testimonials found

APPENDIX C: STANDARDS AND REGULATIONS

APPENDIX D: PATENTS

APPENDIX E: PURCHASED PRODUCTS INFORMATION

APPENDIX F: HYDRAULIC COMPONENTS INFORMATION

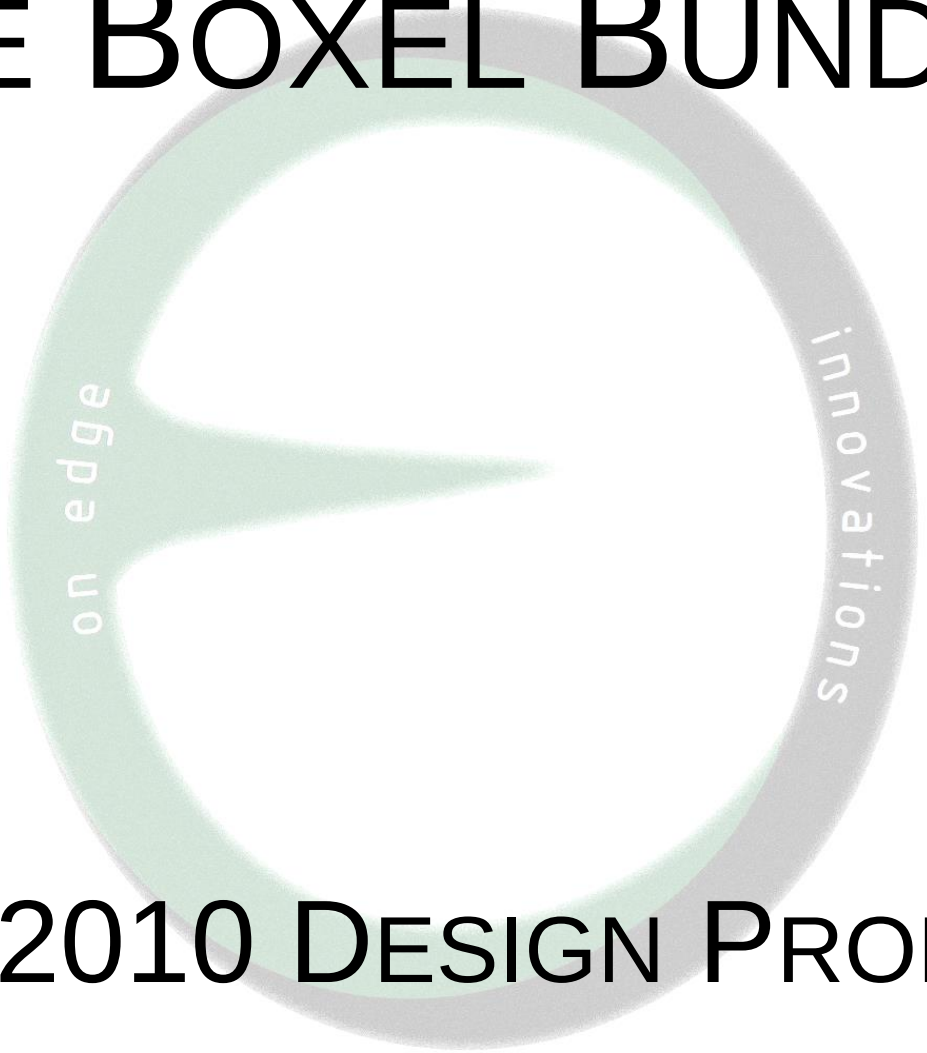
APPENDIX G: DESIGN CONSTRAINTS

APPENDIX H: HYDRAULIC EQUATIONS

APPENDIX I: PROTOTYPE PICTURES

APPENDIX J: OUTSIDE COMPANY CONSULTING

The Boxel Bundler



Fall 2010 Design Proposal

Gary Gray
Team Lead
Biosystems Engineering

Evan Foster
Biosystems Engineering

Alice White
Agricultural Communications/Agribusiness

Jeremy McCasland
Agricultural Economics

Laura Merriman
Biosystems Engineering

For further information, please contact us at
GERRAD.GRAY@OKSTATE.EDU
Cell: 918-650-5797

Mission Statement

OnEdge Innovations works closely with their customers to make ideas become more than just a design, a prototype, or an unused patent. We convey out customer's ideas from the drawing board to production and into consumers' hands. With combined efforts, OnEdge Innovations strives to maintain pristine relationships with our customers and to provide quality, safe products for consumers.

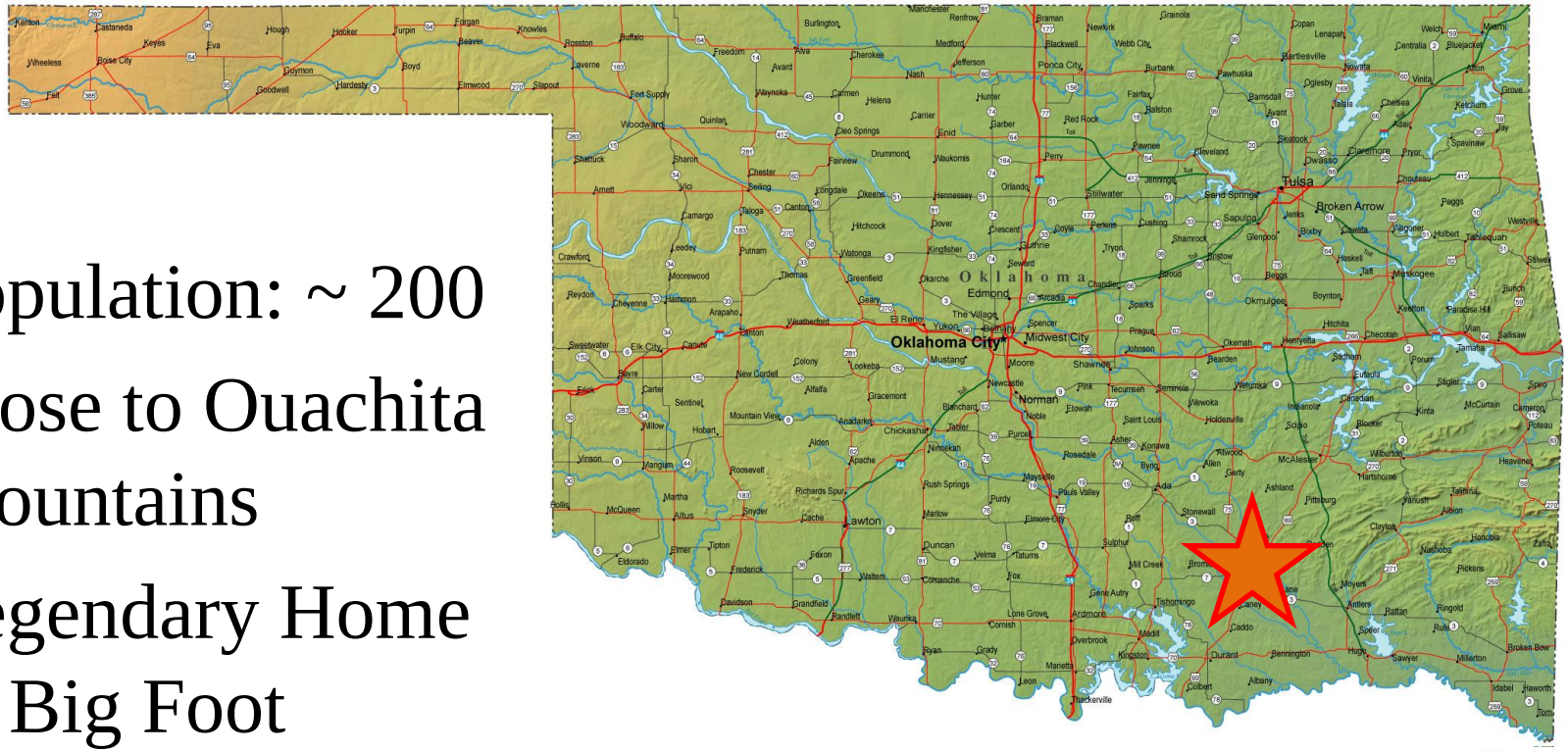
Client

BOXEL

MANUFACTURING INC.

- Owned by Brad Lahman
- Operating since 1985
- Located in Caney, Oklahoma

Caney, OK



- Population: ~ 200
- Close to Ouachita Mountains
- Legendary Home of Big Foot

Boxel Current Products

Feed Cake Transporters

Sullivan Show Boxes

Vanguard Storage Modules

The Boxel Bundler

Statement of Work

OEI will design and build a prototype hay bale bundling machine for Boxel Manufacturing to produce and sell.

- The Boxel Bundler will:
  1. Collect small hay bales from the ground or an operating hay baler.
  2. Compress ten bales together into a specific cube.
  3. Band the bales together with two plastic straps.
  4. Release the cube to the ground.

Fall 2010 Semester

- Research
  - Boxel Manufacturing
  - Industry
  - Customers
  - Competitors
  - Design Standards
- Develop Budget
- Cost Estimations
- Preliminary Marketing Strategies
- Develop Primary Design Recommendations
  - Input/Output of Hay Flow
  - Compression
  - Banding
- Hydraulic Requirements and Design
- Patent Research

Spring 2011 Semester

- Finalize Design
  - Complete SolidWorks Design Model and Drawings
- Build Prototype
  - Model Hydraulics System and Record Pertinent Design Data
- Test Prototype
- Complete Design Budget and Cost Recommendations
- Distribute Marketing Materials
- Launch Advertising Campaign

Competitive Analysis

Industry

- Small producers
  - Utilize small square bales (14” x 18” x 40”)
- Equine
  - Oklahoma hosts 15 national and world competitions
- Show Stock
  - Oklahoma hosts many livestock shows
    - State Fair
    - Oklahoma Youth Expo

Competitive Analysis

Industry

- Hay Market
  - High quality small square alfalfa ~ $150 to $210 per ton
  - Regular Small square grass ~ $85 to $140 per ton
  - Remained steady in slow economy
  - Value Added Product
    - A product whose value has been increased especially by special manufacturing, marketing, or processing.
- Hay Producers
  - Custom Hay Producers
  - Independent Hay Producers

USDA National Hay, Feed, and Seed Weekly

Target Customers

- Small-Scale Hay Producers
  - 100 – 300 acres of baseline production ground
- Customers want:
  - Increase Profit Margin
    - Transportation and labor costs
  - Easy to Operate
    - Simple operating principles
    - No formal training to operate
  - Safe

Competitors: Bale Band-It

http://pics.hoobly.com/full/YDK1JAHNDI6SA7TRGK.jpg

Competitors: Bale Baron

http://www.kleine-balen.nl/en/machines/balen-bundelaars.html

Competitors: Arcusin

http://www.mascus.com/Agriculture/Used-Self-loading-trailers/Arcusin/Multipack+B14/images

Competitor Comparison

Name	Bale Elevation	Stacking	Banding	Compression	Release	Cost
Bale Band-It	Baler only	Mechanical	Steel Strap	Hydraulic	Automatic	$70,273*
Bale Baron	Baler only	Mechanical	Plastic Twine	Hydraulic	Automatic	$62,321**
Arcusin	Ground pick up	Mechanical	Cord	Hydraulic	Automatic	$79,553*

**www.fwr.co.uk* ***www.balebaronuk.co.uk*

Technical Analysis

- Standards and Regulations
  - Oklahoma State Department of Transportation
    - Width, Height, Length Regulations
    - Lights, Brakes, Safe Public Road Travel
  - State of Oklahoma Department of Public Safety and Oklahoma Highway Patrol
  - Occupational Safety and Health Administration
    - Safe operation of farm equipment

Technical Analysis

- Patents
  - Bale stacking machines or mechanisms
    - Bale Band-It
    - Bale Baron
  - Hay bale stacking and bundling methods
    - Two bands manually
  - Hay stack configurations
    - The Boxel Bundle (10 Bales)
- See Report Appendices

Field Testing

Field Testing

Field Testing

Field Testing

Omni-Packaging

- Oklahoma City, Oklahoma
  - Dennis Lashley

http://www.omnipackaging.com/

Banding: Zapak ZP26

Zapak ZP26

Automatic Handheld Bander

- Met Our Client's Needs
- Within Budget
- 3 Year Parts & Service Warranty
- Light & Durable Structure

http://www.zapak.com.tw/p1-product_zp26.asp

Zapak ZP26

Features

- Battery Operated Plastic Strapping Tool
- Adjustable Tension (maximum 726 lbs)
- Adjustable Sealing Time for Strap Specifications
- Easy One Step Insertion of Straps
- Light Weight to Reduce Hand Fatigue
- Includes a BOSCH 30 Minute Charger

Zapak ZP26

Specifications

- Battery Life Supports up to 2,000 Charges
- Supports a Strap Width of 5/8 inch & Thickness of 5/100th inch.
- Sealing Time Range of 0.6 - 4.8 seconds
- Tool Weight 8.53 lbs (includes battery)

Other Banders

Strapex STB-80

- Out of Price Range
- Fully electronic adjustments
- Difficult Parts Exchange
- No Warranty

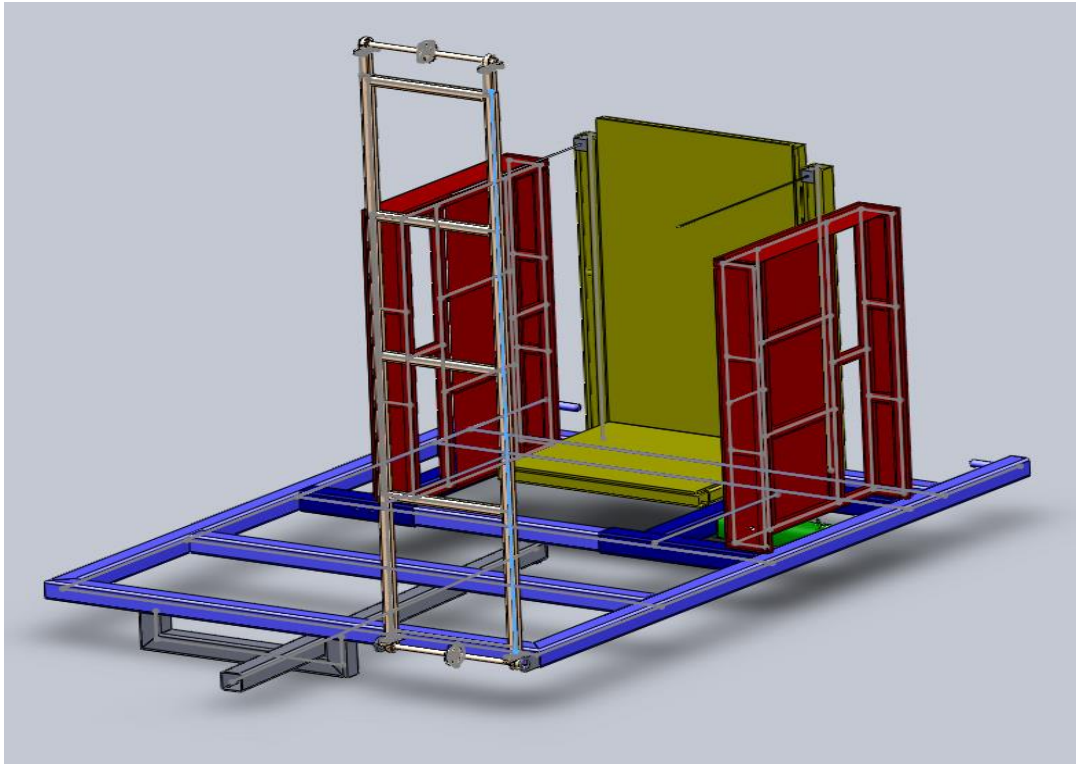
http://www.strapex.com

The Boxel Stack

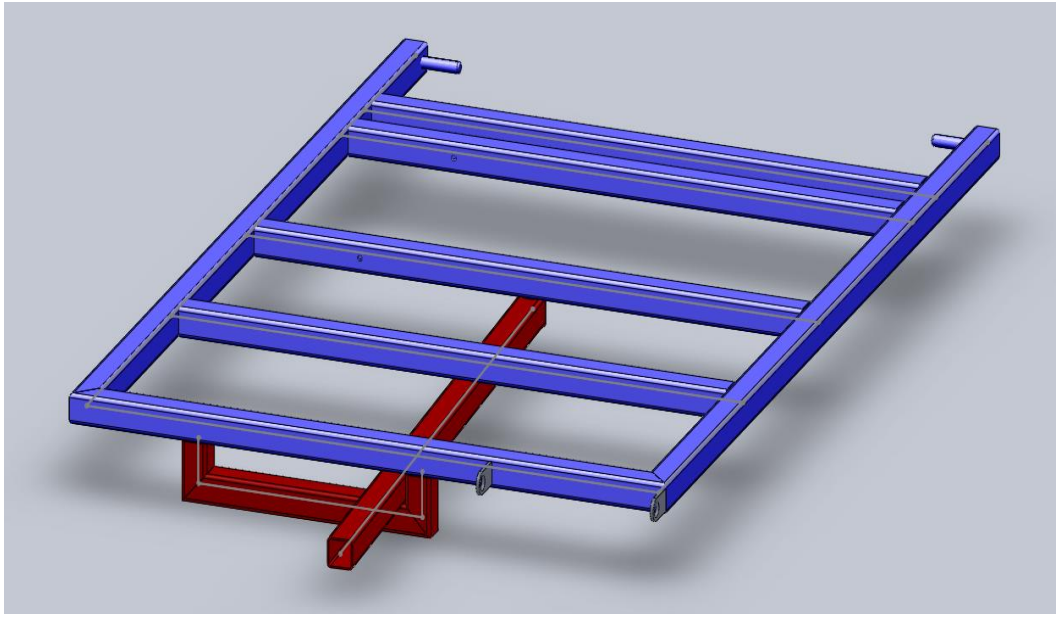
Design Components

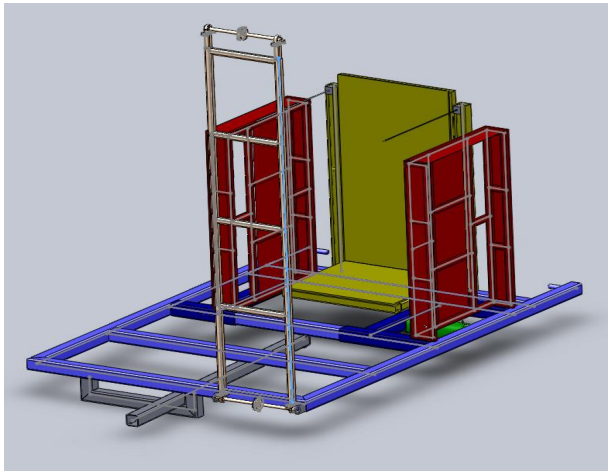
1. Steel Framework

2. Hydraulics

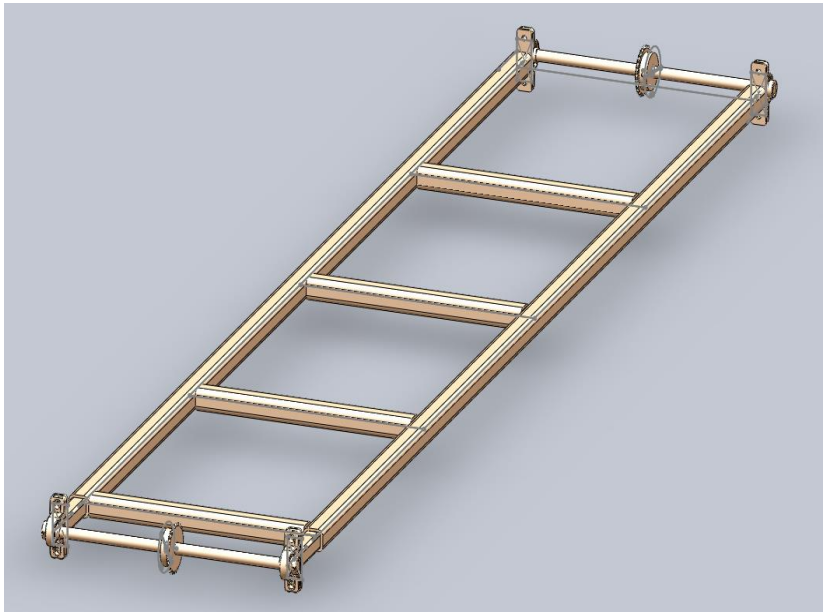


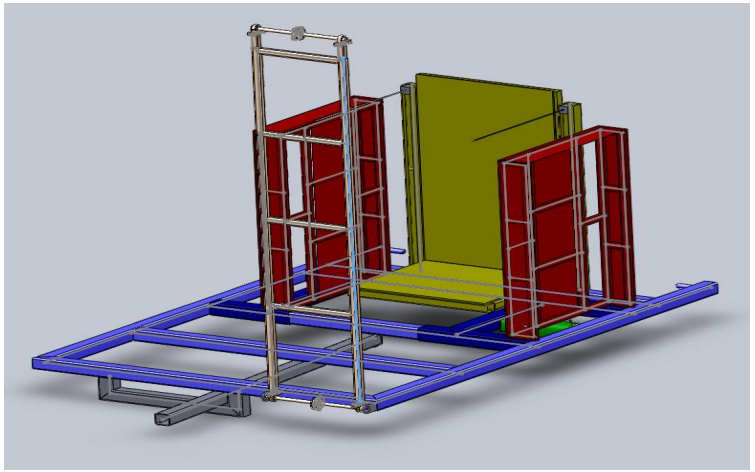
Trailer Frame

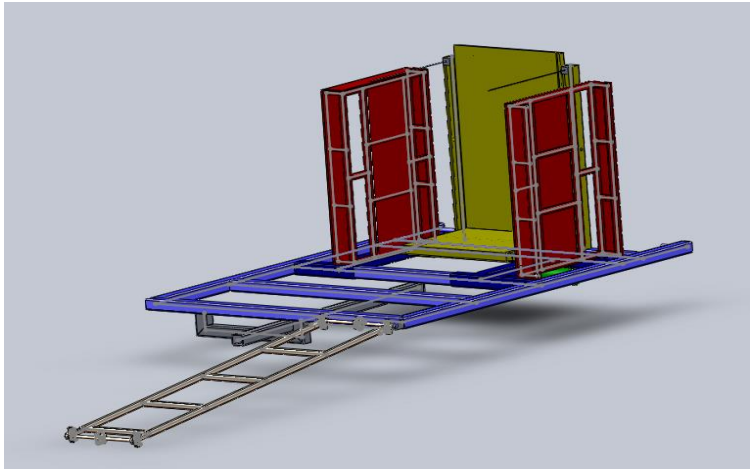




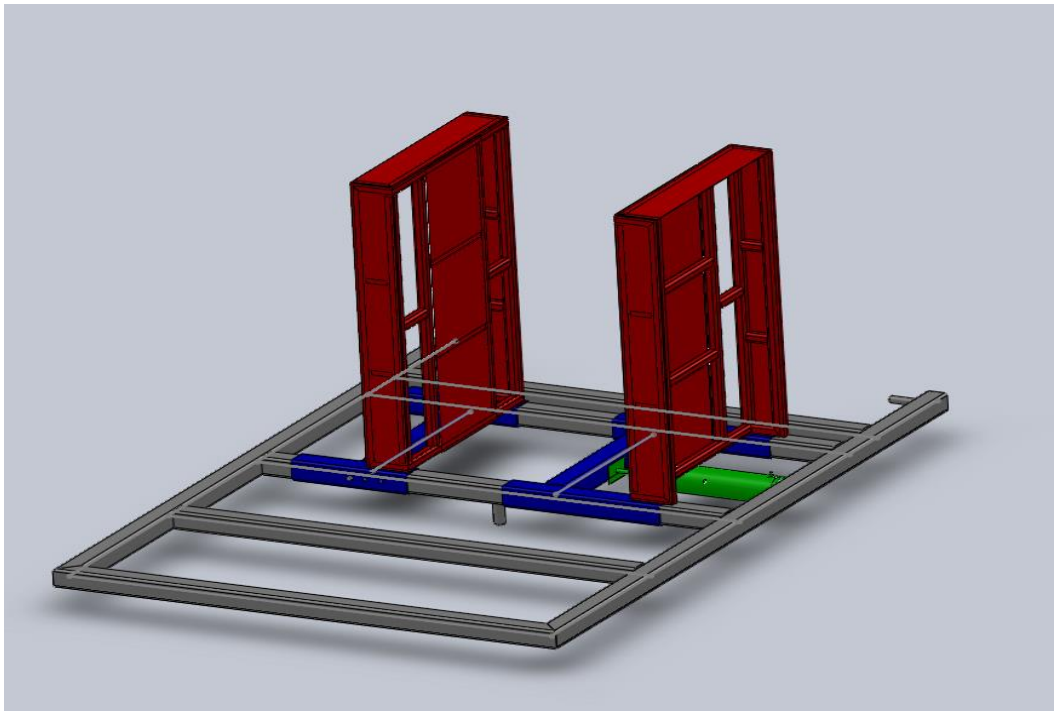
Elevation

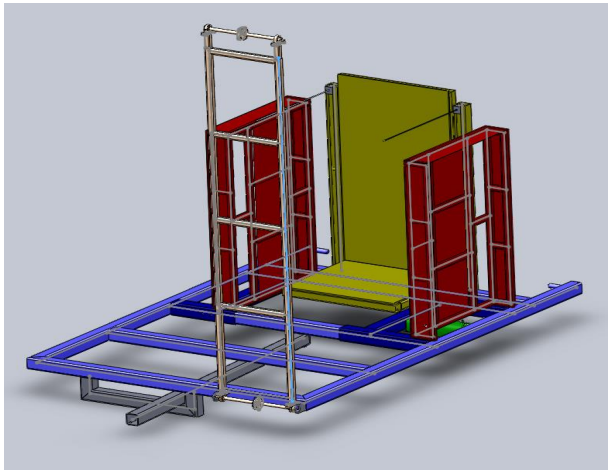




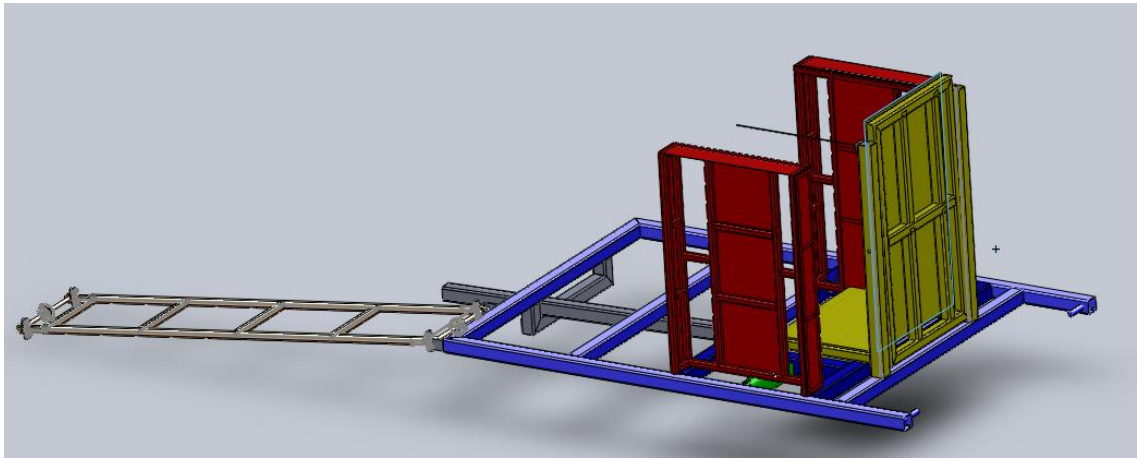


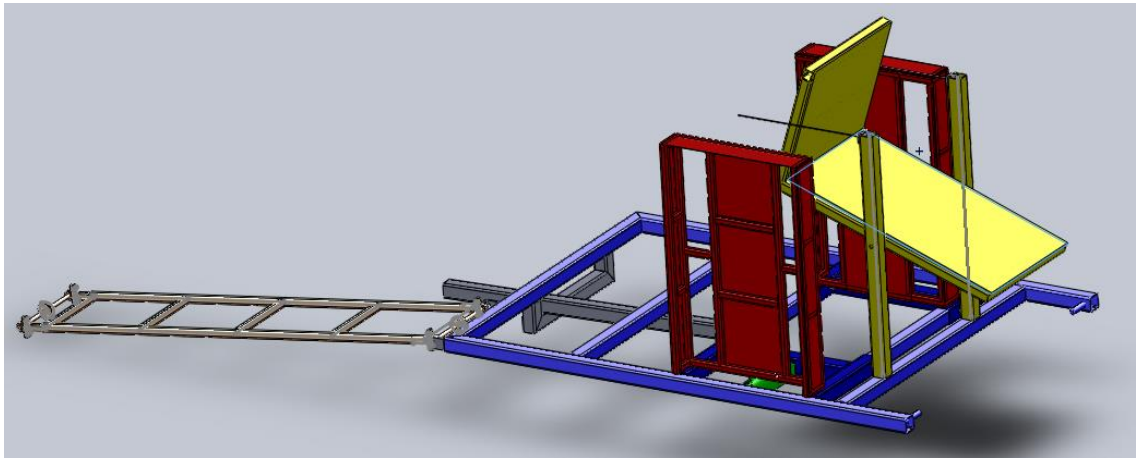
Compression



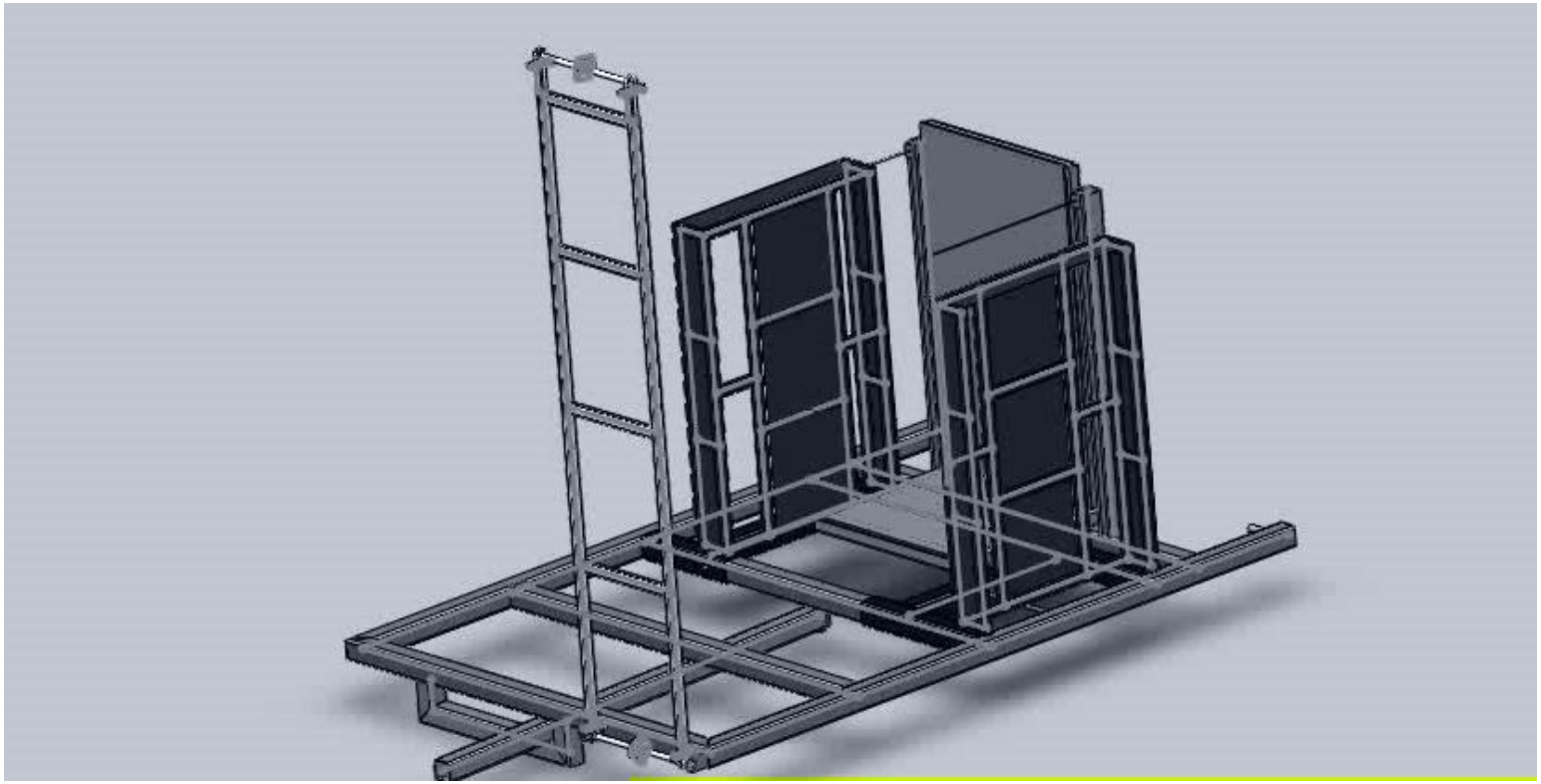


Release





Boxel Bundler Design



Hydraulics Design

Womack Machine Supply

- Tulsa, Oklahoma
  - Jake Martens

http://www.womackmachine.com

Components:

- Spool Valves
- Cylinders
- Motors
- Connections

Target Specifications

Target Design Tractor

- Massey Ferguson Model 4345

http://www.ag1.biz/sidsfarmsupply/mf.htm

Nebraska Tractor Test Lab

- Maximum Pump Delivery Rates
  - Flowrate (Q) ~ 10.2 GPM (gallon per minute)
  - Delivery Pressure (P) ~ 2755 psi (lb/square inch)
  - Hydraulic Horsepower (HHP) ~ 15.4 HP

http://tractortestlab.unl.edu/Massey/Mf4345.pdf

Alternative Hydraulic Power

Foster Hydraulic Power Pack

- Mobile Self-Sustained Hydraulic Power Unit
- Flow Rates and Pressures comparable to the Target Specifications

http://www.fostermfgcorp.com/page/gas/complete_5_13_hp.html

Spool Valves

Mono-block Valve Bodies

- Custom Manufactured to our Specifications
- Wide Range of Operating Options Available
- Low Maintenance
- Operator Friendly
- Adjustable

http://www.princehyd.com/Default.aspx?tabid=46

Cylinders

Double-Acting Single-Ended Tie Rod Cylinders

http://www.princehyd.com/default.aspx?tabid=163#Cylinder

- Cost Efficient
- Low Maintenance
- Wide Range of Sizes Available

Hydraulic Motors

Bi-Directional Gear Motors

- Very Durable
- Few Moving Parts
- Small in Size
- Quiet Operation
- Wide Speed Range

http://www.princehyd.com/Default.aspx?tabid=41

Connections

Custom Steel Lines

- Cost Efficient
- Good for Heat Dispersion
- Durable
- Custom Made

http://www.metal-matic.com/hydraul.htm

Hydraulic Forces

Maximum Pressure (psi)	Bore Size (in)	Maximum Extension Force (lbs)
2,700	1	2,121
2,700	2	8,482
2,700	3	19,085
2,700	4	33,929
2,700	5	53,015
2,700	6	76,341

Stack Forces

- 4” Bore Cylinder ⟶ Force = 33,930 lb
- Stack Area ⟶ Area= 2,000 in^2
  - 50 in by 40 in

$$Pressure = \frac{Force}{Area} = \frac{33{,}930\ lb}{2{,}000\ in^2} = 17\ \frac{lb}{in^2} = 2{,}443\ \frac{lb}{ft^2}$$

Hydraulic system will be design to be pressure limited.

Cost of Manufacturing

Cost of Steel					
Component	**Quantity**	**Price/ft**	**Price/ft^2**	**Unit Price**	**Cost of Good**
Lrg Grd Expanded Metal	x	x	$1.99	$63.70	x
Med Grd Expanded Metal	x	x	$1.67	$53.40	x
Sm Grd Expanded Metal	x	x	$0.95	$30.50	x
4.5'' 4.5'' 0.25'' Steel Tube	x	x	x	x	x
4'' 4'' 0.25''	x	$6.37	x	x	x
2'' 2'' 0.25"	x	$2.80	x	x	x
16ga Sheet metal	x	$1.18	x	$37.60	x
14ga Sheet Metal	x	x	$1.42	$45.35	x
1/4" Sheet Metal	x	x	$4.39	$140.35	x
Shaft Material	x	$1.58	x	x	x
Total Cost					**0**

Cost of Manufacturing

Cost of Hydraulic Components			
Component	**Quantity**	**Unit Price**	**Cost of Good**
P-Clamps	20	$2	$40
Cylinders	4	$200	$800
Multi-Lever Manifold	1	$150	$150
Hydraulic Hoses	x	x	
Necessary Fittings/Couplings	x	$50	50
Motors	2	$300	$600
Total Cost			**$1,640**

Cost of Manufacturing

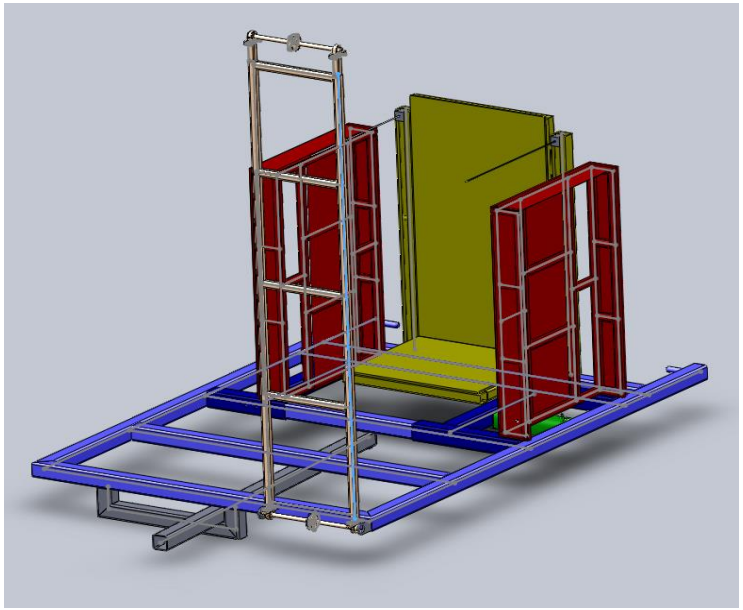
COST OF BANDING			
COMPONENT	QUANTITY	UNIT PRICE	COST OF GOOD
ZPAC ZP26	1	$2,195	$2,195
Plastic Strapping (4200 ft Spool)	1	$80	$80
Battery	1	175	175
Total Cost			**$2,450**

Cost of Manufacturing

COST OF MANUFACTURING - MISCELLANEOUS			
COMPONENT	QUANTITY	UNIT PRICE	COST OF GOOD
Wheels & Tires	2	$59.99	$119.98
Tail lights	2	$29.99	$59.98
Clearance Lights	4	$2.99	$11.96
Spindles	2	$60	$120.00
Electrical Wires 16GA	x	x	x
Bale Chain	1	$60	$60.00
Journal Bearings	10	$10	$100
Bearing Castings	10	$10	$100
Tongue Hitch	1	$20	$20.00
Jacks	1	$35	$35.00
Hub Assemblies (5-Bolt)	2	$22	$44.00
Rollers	10	$15.12	$151.20
Total Cost			**$778.12**

Cost of Manufacturing

ESTIMATED TOTAL COST	
COMPONENT	SUBTOTALS
Steel	~$2,500
Hydraulics	$1,640
Banding	$2,450
Miscellaneous	$778.12
Total Cost	**$7,448.12**



Competitor Comparison

Name	Bale Elevation	Stacking	Banding	Compression	Release	Cost
Boxel Bundler	Ground pick up and/or Baler	Human Operator	Plastic	Hydraulic	Automatic	$16,000
Bale Band-It	Baler only	Mechanical	Steel Strap	Hydraulic	Automatic	$70,273*
Bale Baron	Baler only	Mechanical	Plastic Twine	Hydraulic	Automatic	$62,321**
Arcusin	Ground pick up	Mechanical	Cord	Hydraulic	Automatic	$79,553*

**www.fwr.co.uk* ***www.balebaronuk.co.uk*

Cost of Bale Comparison

PRICES OF BALES*				
Type of Harvest	Price per Unit	Weight (lb)	Price/lb	Price/Ton
Large Round Bale	$35.00	1500	$0.02	$46.66
Small Square Bale	$3.75	67	$0.06	$111.94
21 Bale Bundle	$84.00	1400	$0.06	$120.00
The Boxel Bundle	$60.00	667	$0.09	$179.91

*Information based on current prices of Bermuda grass weighting 66.7Lbs/Bale

Marketing

www.vanguardstoragemodules.com

Marketing

- Trade Shows
  - Southern Plains Farm Show
- Brochures
  - County and State Fairs
- Magazine advertisements
  - High Plains Journal
  - Progressive Farmer
  - Hay and Forage

THANK YOU

For further information, please contact us at
GERRAD.GRAY@OKSTATE.EDU
Cell: 918-650-5797