A Solution for Commodity Field Hauling with Self-Unloading Semi-Trailers

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A SOLUTION FOR COMMODITY FIELD HAULING
WITH SELF-UNLOADING SEMI-TRAILERS

by

Lee Wilkerson

A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of
Master of Science

School of Technology
Brigham Young University
August 2006
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A SOLUTION FOR COMMODITY FIELD HAULING
WITH SELF-UNLOADING SEMI-TRAILERS

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Master of Science

Commodity hauling of bulk goods is a growing enterprise that has expanded from hauling agricultural products to hauling many other bulk products. Commodity trailers are used to haul agricultural products from storage facilities to processing plants. These trailers are designed for highway use but are frequently required to work in field conditions as well. In many cases this environment overstresses these trailers and results in permanent irreparable damage.

In addition to the structural problems of these trailers, the current systems for unloading the bulk produce from these trailers have serious inadequacies. While functional, the currently used chain and non-chain driven belt discharge devices are expensive and often problematic, requiring frequent maintenance and replacement. Furthermore, the discharge device also causes damage to the produce.
This thesis provides innovative solutions to these two key problems and introduces a completely new trailer design that can be used for both field and road conditions. The main chassis of the trailer has a framework of ribs supported by two I-beams. This unique rib design combined with the main I beams act as large vertebra, which results in a rigid underbody that maintains flexibility and strength. Special consideration was taken while creating this design to account for dynamic loading on soft muddy soils or uneven surfaces while still maintaining the desired lightweight trailer characteristics.

In addition to the improved trailer frame and body design, a simple and effective device for unloading bulk products was constructed. The new design—a belt-over-chain system—is actually two separate systems performing one job in unison with different characteristics and speeds. The system works by means of a hydraulic orbit motor that actuates the drive chains into motion. The weight of bulk commodities on the chain presses the unattached conveyor belt against the chain and cross-members, creating friction, which advances the conveyor belt.

This thesis solves two of the problems associated with hauling bulk produce from the field to the storage facility and sets the groundwork for improving the hauling capabilities used to move commodities from the field. Finally, this thesis introduces a new commodity self-unloading trailer for hauling produce, which has a belt system that preserves quality and a body design that provides trailer longevity.
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CHAPTER 1: INTRODUCTION

Bulk self-unloading trailers are the primary means of moving produce from storage facilities to processing plants throughout the United States and Canada. Commodity hauling of bulk goods is a growing enterprise that has expanded from hauling agricultural products to hauling refuge, chemicals, wood chips and many other bulk products. Many of these trailers are used both in the field and on the highway. This dual-use requirement places specific constraints on the design of these trailers.

1.1 STATEMENT OF PROBLEM

Current commodity trailers are manufactured in a lightweight configuration for highway use. Almost all of these trailers are uni-bodies, and the dynamic loading they undergo from field use results in structural fatigue and ultimately in failure. Also, the majority of commodity trailers currently use chain driven, flap-belt discharge systems.

These systems, which are highly promoted by competing manufacturers, are expensive to manufacture and require frequent maintenance including replacement of rubber belt flaps. An alternative to a chain driven system, is a non-chain driven solid belt system that relies on the tension between two hydraulic-powered drive rollers to
move the belt system. However, this design has also proven problematic, requiring frequent adjustment and replacement due to the elastic fatigue of the belt, which causes slippage during wet, icy, or cold winter conditions.

1.2 PURPOSE OF THESIS

The primary purpose of this thesis and research is to develop a dual-use trailer that has both the lightweight characteristics for economic highway travel and the structural strength for withstanding dynamic loading of continual field and off-road use. A second objective is to design a new hybrid belt system that will have the benefits of both a solid belt and a chain driven system. Additionally, the new belt system minimizes damage to produce during the unloading process. The combination of these two objectives will produce a bulk self-unloading trailer superior to current products available on the market.

1.3 METHODS USED

Previous experience and actual industry use of these trailers provided the necessary background and foundation for this research. Three initial prototypes were built and tested for desired field and belt characteristics. From six different field tests on three new prototypes, a trailer with the desired functions evolved. This thesis study was used to design and engineer a completely new fourth trailer. The testing was conducted under worst-case field conditions. Trailers were loaded and measured to note flexing and overall performance, both on and off the field. The tests involved measuring asymmetric flex, as well as overall bridge flex. The trailers were loaded to standard, legal load limits and then further tested for overload trials, which would be actual figures used in real world scenarios out in the field. In Alberta, Canada, further
dynamic load tests were conducted, which severely stressed the structural integrity of the new trailers and displayed the improved capabilities of the new design.

Two fully functional, hybrid belt system prototypes were designed and built. Each system was evaluated in a loaded and non-loaded environment; unloading parameters were measured, as well as overall performance. The data for belt speed, time to unload, and angle of trailer wall were measured. The belts were also evaluated to see if they met specific requirements involving produce handling and preservation. In this test, the number of damaged potatoes in hundred pound samples from the trailer loads was evaluated. These are the six parameters that were tested:

- Asymmetric twist testing
- Sag in the trailer bridge under normal and over load conditions
- Belt speed
- Time to off-load
- Wall incline on trailer body and belt size
- Number of damaged potatoes in hundred pound samples from the trailer load

Visual inspection, timing, and measuring were used to assess the improvements and changes in each test and prototype.

1.4 DELIMITATIONS

The data collection on the structural integrity and belt systems of the new trailer design extends back six years. While certainly appropriate for research, such as this study, actual trailer life is even longer. This lack of very long-term data makes it difficult to determine the ultimate lifetime of the system. Furthermore, long-term
maintenance and wear issues have not yet been observed and will require further research and observation. The latest model of this generation of trailer was produced in 2005 and will not give a data history or have time to display its improvements over the prior three prototypes. This trailer incorporates all of the lessons learned from the research and has the potential to prove a great success. The drawings and plans are included in this thesis in Appendix B and can be referred to as a reference or can be used to replicate the new trailer design. It could take up to four years of continual use to obtain reasonable observations that could benefit further research and development and lead to new improvements to this trailer generation.

1.5 SUMMARY

This research has shown it is possible to design a trailer suitable for both field and highway use. The complete testing of the prototypes also suggested the manufacture-ability and feasibility of the design and has also demonstrated its superior characteristics when compared to the current trailers offered by other major manufacturers. The newly designed trailer is capable of both off-road and on-road operations while preserving and minimizing payload damage.
CHAPTER 2: LITERATURE REVIEW

There are two primary styles of bulk commodity haulers. Most are the uni-body style manufactured by Western Trailers, Star Inc., Red River Manufacturing and IMCO Inc. The second type is the “Eagle Bridge” style manufactured by Trinity Trailers. Both involve using the uni-body of the trailer as the main load-bearing device for the vehicle.

Currently, there are only two discharge devices available for produce-hauling commodity trailers. The first is the chain driven flap system, used by most major manufactures. The second is the chainless solid belt system used exclusively by Spudnik’s trailers.

FIGURE 2-1 CHAIN DRIVEN BELT SYSTEM USED BY MOST MANUFACTURERS (TRINITY TRAILERS)
FIGURE 2-2 SOLID BELT USED BY SPUDNIK TRAILERS (SPUDNIK)

FIGURE 2-3 SOLID BELT USED BY SPUDNIK TRAILERS (SPUDNIK)
2.1 UNI-BODY STYLE BODY TYPE

The uni-body style of commodity trailer is by far the most widely used and oldest of current body types used in commodity hauling. The design was originally intended for highway use with lightweight structural members and a very thin skin (0.095-0.125 in.). Star Transport Trailers Inc., based in Sunnyside, Washington, began the first manufacture of commodity haulers in the early 1970s. These trailers were comprised of two lightweight steel side walls with small internal struts to create the slope and floor of the trailer. The original trailers were designed with a solid belt system with a single driver on the rear of the trailer and boards that covered the belt (H. Waller, personal communication, Feb.12, 2005).

To further decrease weight and increase payload of these trailers, many manufacturers have gone to a combination steel/aluminum construction, with the longitudinal and cross members composed of steel and the skin of the trailer and other components composed of aircraft aluminum. The weight reduction involved with aluminum trailers is significant; however, the decrease in strength and rigidity limits these trailers primarily to highway work.

Unfortunately, many farmers in a pinch will use these trailers for field work and in doing so permanently damage the side walls, top rails, and even the entire uni-body, rendering the trailer nearly worthless. Uni-body trailers suffer from the obvious weakness that they do not have an underlying backbone that can handle extreme loading situations and the continual dynamic loads during field use. Some manufacturers have now begun to confront this problem by attaching a light pseudo-
frame to the underside of their trailers. Another adaptation has been to extend the skin of the trailer side so that it runs the full height of the trailer.

While both of these modifications do increase the overall strength and rigidity, even with these modifications, this trailer type is best suited for highway use and generally should not be taken into the field. The extended wall modification increases strength and trailer capacity, but it renders the trailer incapable of being loaded on the field by a potato combine. IMCO Inc., Red River Manufacturing, and Western Trailers have manufactured more exclusively with aluminum in the last few years, but the trailers produced are only suitable for highway use. These trailers are easier to keep clean and are corrosion-free because of the aluminum, but stress cracks easily form due to the aluminum structural parts.
FIGURE 2-5 ALUMINUM – STEEL CONSTRUCTION (WESTERN TRAILERS)

FIGURE 2-6 STRUCTURAL CRACKS ON MAIN FRAME MEMBERS (RED RIVER)
The newly designed composite aluminum steel trailers are also unsuitable for the field because they have had problems—from asymmetric twist, which cause aluminum members to undergo structural damage, to main members.

A major factor that leads to failure in an uni-body design is that it can be difficult to clean after being used on salty or muddy roads. The salt stays in the space between the outside wall and the underside of the sloping floor. This leads to accelerated corrosion and compromising of the trailer’s structural integrity, which will eventually lead to a catastrophic structural failure.

![Figure 2-7: Areas of Corrosion in a Standard Uni-body](image)

The aluminum versions of these trailers help prevent corrosion but do not give the trailers the dynamic loading capabilities that steel allows for with continuous flex. One other version of a corrosion-free trailer is the stainless steel trailer built by Trinity. Stainless steel trailers in these configurations help prevent corrosion from the road and the sometimes-corrosive payloads. This version of trailer is expensive for the common farmer or commodity hauler. Stainless steel trailers are usually purchased only by specialized haulers who can justify the additional expense.
FIGURE 2-8 SIDE WALL FCORROSION COMPROMISING UNI-BODY (STAR TRAILERS)

FIGURE 2-9 SIDE WALL FCORROSION COMPROMISING UNI-BODY (STAR TRAILERS)
2.2 EAGLE BRIDGE STYLE BODY DESIGN

The Eagle Bridge body type was developed and produced, beginning in 1975, by Trinity Trailer Manufacturing, Inc.

![Eagle Bridge Exoskeleton](image1)

![Eagle Bridge Trailer](image2)

FIGURE 2-10 EAGLE BRIDGE EXOSKELETON TRAILER

FIGURE 2-11 EAGLE BRIDGE (SIDEVIEW)

This innovative design involves a steel body type similar to the uni-body style but with added diagonal members or inverted trusses on both sides of the trailer. The Eagle Bridge, or inverted truss, gives the trailer a level of flexibility not available in conventional trailers, while also allowing for considerable axial twist and flex.
A representative of Trinity Trailer Manufacturing, Inc. spoke about the steel construction of their trailer. He commented that with conventional trailers, the axial twisting that is ever present in fieldwork will cause cracking of the aluminum skin over time, and this limits the trailer to a finite service life when exposed to field conditions. With the Trinity design, the all-steel construction eliminates this problem completely. (Note that steel does not have a finite fatigue life and will theoretically last forever.) In fact, Trinity Trailers now offers their trailer in an all-stainless steel model, which provides superior strength and corrosion resistance. This trailer type has been adapted to many applications within the commodity hauling industry (Trinity Trailers, personal communication, June 22, 2006).
Once again, as with the uni-body style body type, Trinity Trailer’s Eagle Bridge trailer does have a few major deficiencies in fieldwork. Even though it does significantly improve on the conventional body type, it still does not address extreme loading conditions, such as a trailer being in a completely stuck condition in a wet and muddy field. These conditions are not atypical in a potato harvest during the autumn months. The forces then required to extract the trailer from the stuck condition can easily exceed the nominal tensile and shear forces on the trailer by a factor of three to four.
Without a strong backbone to counteract these tensile forces, the Eagle Bridge trailer can easily be warped or pulled out of shape or alignment. The bridge system is engineered to take on heavy loading in the downward dimension of the truss, but trusses were not engineered for a tensile pull in shear. A sounder framework is required to accommodate direct pulls in soft and muddy soils with loaded trailers that weigh upward of eighty thousand pounds.

Other problems that arise with the Trinity truss system occur when welds are broken in the truss system. The trailer is then weakened and could fail, which would destroy the trailer permanently. Stress cracks or weld cracking on the truss system can lead to catastrophic failure. During field situations with the main truss system close to the ground in the center of the trailer, it is common for a Trinity trailer to bend or rub
the main part of the frame on the ground or on other foreign objects that could ruin the trailer’s integrity.

![Figure 2-16: Trailer exoskeleton damage from rubbing object (Trinity Trailers)](image)

Having the main truss system exposed near the ground and on the exterior of the trailer makes this design somewhat vulnerable to frame damage that could render the trailer unusable until repaired.
2.3 SPUDNIK NEW BELT AND TRAILER DESIGN

In the last five years, Spudnik Equipment Company has made an effort to increase its manufacturing from standard potato handling equipment to self-unloading potato semi-trailers. Spudnik designed a new trailer with an uni-body box design. The selling point of the new trailer design was its belt system, which they advertised would handle potatoes more gently and cause less percent damage (Spudnik Trailers, personal communication, June 22, 2006).
The new trailer design works well in moderate to fair conditions but has a reputation of failing in the wintertime or in rainy conditions. When the drives for the belt are lubricated by rain or ice, the belt fails. The trailer body is steel and has a tendency to collect mud on the underside between the slope and the side wall, which leads to corrosion and shorter trailer life.
2.4 COMMODITY TRAILER DEVELOPMENTAL HISTORY

Stacking and handling commodities in burlap sacks, baskets or small wooden boxes was used in the early 1900's for moving commodities. The bags and boxes would be hand lifted onto trucks or wagons and then unloaded, again by hand, at the destination. This method was changed in the 1940s when the first potato truck beds emerged (D. A. Smittle et al., 1974).

These truck beds were unloaded with a system that used potato hook and latch chain covered with removable boards. The boards were removed by hand as the potatoes unloaded, thus they were called board pulling truck beds. Hook and latch chain beds never reach lengths of over twenty-six feet. The next improvement on truck beds was the use of a rubber belt. These twenty-foot field beds were so effective that they are still being used today.
Star Transport Trailers Inc. of Sunnyside, Washington began the first manufacturing of commodity haulers in the early 1970s. Star trailers had been manufacturing twenty-foot potato beds for many farmers in the Columbia Basin (H. Waller, personal communication, Feb. 12, 2005). They took some innovative ideas and designed the first semi-trailer beds based on their experience from truck bed manufacturing. These trailers were comprised of two lightweight steel side walls with small internal struts to create the slope and floor of the trailer. The original trailers were designed with a solid belt system with a single driver on the rear end and boards that covered the belt. This was called a board-pulling trailer because a worker had to be inside the trailer bed as it was being unloaded in order to pull the boards sequentially until the trailer had been unloaded.
Since then, the uni-body system has undergone minor evolutionary changes; however, the basic concept remains the same. The latest self-unloading trailers now use chain-driven belt systems and the solid belt system designed by Spudnik.

2.4.1 SELF-UNLOADING TRAILER BELT HISTORY

In the 1950s and 60s, potato trucks were designed with pull boards and potato chains as the unloading system. These were the boards that had to be pulled over a moving conveyor belt by a worker as the truck was unloading. In the early 1980s, the first real self-unloading trailer was born when the first chain-driven flap belt was produced by Star Trailers, Inc. (H. Waller, personal communication, Feb.12, 2005). This trailer pulled the belt-covered chain beneath the load of potatoes. As the belt and chain pulled, it would slide under the payload in the front of the trailer and would unload from the rear of the trailer forward. This new belt system was effective in that
it no longer required additional workers to unload the trailer by pulling boards. The disadvantage of the new belt system was that the potatoes at the front of the load were bruised and damaged as the belt chain system pulled underneath the load (R. C. Brooks, 1993; D. Corsini et al., 1999). Another problem with the new system was the heavy chain required to pull the entire load was very expensive, and the manufacturing—with many rubber flaps—was expensive and time consuming to assemble. The flaps were all attached separately and would often be ripped from the chain by a loading device or a rock caught in the chain system.

Spudnik designed its new belt system to get away from the expensive and time-consuming production of the flap system. Their new system with a solid belt was less harmful to produce during the unloading process. The problem it had was that it would slip if the drive rollers got wet or icy. This slipping caused this new trailer to gain a reputation of not being reliable for unloading, and it therefore lost the trust of customers and is no longer in production.

2.4.2 SELF-UNLOADING TRAILER BODY HISTORY

The first self-unloading body designs emerged from board-pulling trailers with low side walls and was only forty-five feet long. These trailers were constructed with an uni-body design where the side walls carried the load. In the mid 1970’s, one of Star Trailer’s employees started Trinity Trailer Manufacturing, Inc., and a new design emerged called the Eagle Bridge (H. Waller, personal communication, Feb. 12, 2005). This new design had an exoskeleton that carried the load of the trailer and payload. It was a more flexible trailer with new lightweight characteristics.
In the early 90s, IMCO Inc. and Western Trailers began manufacturing an all-aluminum body style with high side walls, wider belts, and a steel pseudo-underframe. These trailers were more over-the-road trailers, designed strictly for commodith hauling. Some other manufactures, such as Red River Manufacturing, had created an aluminum trailer for hauling commodities. These trailers had an aluminum unibody super frame style that was lightweight but expensive to build because of the excessive aluminum. The problem with the all-aluminum trailer built by Red River is that cracks appeared in the support members due to the aluminum design.

2.5 TRAILER DESIGN FAILURES

Through the many years of research and attempts to create the most capable commodity trailer, many lessons have been learned from expensive and costly field trials. Some of the failures have been the Spudnik attempt to create an all-round trailer for field, highway, and unloading. This trailer was expensive to manufacture because of the double drive system and was not an improvement in the body design. The final problem was the unreliable belt system.

2.5.1 TRAILER BELT FAILURES

When potato trailers were first developed, the most trying part of the belt design was to find a drive system to handle the torque required to turn the belt with extreme loads on it. On the belt’s initial break-free point, it could require up to fifty thousand foot pounds. According to Star Trailers, it was difficult to find hydraulic orbit motors and pumps that could produce the necessary output to run the trailer’s belt systems. So initially, the problem with belt systems was hydraulic drive mechanism failure.
Secondly, the pintal chain that drove the belt had to be further developed to be strong enough to pull the entire load.

As the trailers evolved, the hydraulic and chain systems improved and became capable of handling the loads placed on them. With the development of large chain belt systems, two problems emerged: (1) the flaps covering the chain would wear out or get torn off, and debris and dirt would then go down into the chain system wearing the chains out, and (2) the wavy surface created by the chain rubber flap system bruises produce because of the rolling motion as it unloads. The chain rubber flap design creates an uneven unloading surface, which can be somewhat destructive to produce when unloading.

Spudnik has designed a way to deal with eliminating the flap chain design by using a thick non-flexible belt stretched between two main drivers on the front and the
rear of the trailer. This surface for unloading is even and easy to create airtight seals on the belt joining the sides of the trailer; however, the belt has been known to slip in wet and icy conditions. When a belt slips and an unloading trailer is in sequence to unload at a process plant, it poses a serious problem. Therefore, the trailer belt design is ineffective.

![Figure 2-24 Deficiencies in the New Spudnik Belt Design](image)

**FIGURE 2-24 DEFICIENCIES IN THE NEW SPUDNIK BELT DESIGN**

### 2.5.2 BODY DESIGN AND STRUCTURAL FAILURES

Many of the body design failures are a result of unchecked corrosion, which destroys the integrity of the trailer by weakening the outer skin. These structural failures are in part to blame on the trailer’s body design, which makes it very difficult to clean road salt and mud from the trailer’s inner structural wall and side wall.
FIGURE 2-25 TRAILER CORROSION WHERE SIDE WALL AND OUTSIDE PANEL MEET HOLES (STAR TRAILER)

FIGURE 2-26 BOLTS SHEARED OFF FROM TRAILER FRAME TWIST IN NORMAL OPERATION (RED RIVER)
As shown in figure 2-26, other structural designs include the use of aluminum and steel in areas where more flex is required and structural cracking results. In some instances bolts are sheared from the constant flex of the members involved.

2.6 OTHER WORK ON FIELD HAULING

Spudnik, in the early 90s, designed a field trailer forty feet in length with a larger chassis under it. It had a flat-belt design like a regular twenty-foot, self-unloading field bed. This trailer was not successful because it was very heavy and expensive. Because of its weight, it was not profitable to be used on highway hauls to the potato processor and became designated only for harvest. In order to justify costs, a trailer must usually be used for highway transport as well as field use (D. Hunt, 1995).

2.7 SUMMARY

Since the 1970s, commodity hauling has made many innovative advances that have improved the ability of our nation to haul bulk products. These innovations have led to the ability to produce more tons per acre and operate larger farms because of the ease in transportation and ability to move more goods. Many of the farm innovations in transportation of bulk products have been adopted by other commodity production, such as chemicals, wood chips, and salt. The newly designed trailers are capable of effectively hauling any commodity on highways and roads; however, since the transition to commodity hauling, the agricultural emphasis in commodity hauling has diminished.
Many current trailers are built with lightweight aluminum and thin steels that are not capable of the off-road and field use needed by farmers. Most farmers cannot afford a trailer fleet for road hauling to the processor and a second fleet designated for field hauling (H. P. Smith and L. H. Wilkes, 1976; D. Hunt, 1995). A farm-use trailer needs to be re-engineered for field and highway use that meets the agricultural needs of hauling in America.
CHAPTER 3: METHODOLOGY

3.1 BACKGROUND AND EXPERIENCE

Growing up as the son of a potato farmer, I had many opportunities to solve problems related to farm machinery. Many of the inefficiencies I worked on led to bottlenecks within the farm operations. One of the main bottlenecks of a potato operation is getting the crops harvested and stored an orderly and timely manner. Weather is always a major threat that could slow a harvest operation and even destroy crops, which would be left in the ground due to wet and muddy or even freezing conditions (A. B. Smit et al., 1998; H. Symington and A. Collings; 2002; P. Hogg, 2004). Therefore, the need to have effective machinery and the capability to quickly harvest crops in the fall is critical to the success of a farm. The transportation of the potatoes to the storage facilities was always a weak spot in the production chain. The trucks would commonly get stuck in poor weather conditions and fail to keep up with the high production potato combines.

One common problem is that most field potato trucks in the potato industry are designated, meaning they are usually only used for hauling potatoes from the field to the cellar once every harvest season (D. Hunt, 1995). These trucks, therefore, tend to have more maintenance issues and problems from being stationary for ten months out of the year until harvest.
It would be advantageous to use potato trailers, which were already in use for hauling from storage facilities to processors. The new generation of potato trailers has generally been large—up to fifty feet long with two to three, and sometimes four, axles. They have twice the capacity of a normal twenty-foot field truck. The two major limitations found in larger commodity haulers are that they were built with light materials for highway hauling and that the commonly used chain-driven flap belts frequently damage and bruise fresh produce. When potatoes are being put into long-term storage, levels of bruising are measured. These levels are an important consideration that directly affects the storage life of a crop (W. Sparks, 1957 & 1977; J. A. Schoenemann, 1986).

In the 1997 crop year, the farm I worked on was unable to harvest a significant amount of crops due to poor fall weather conditions. The loss we suffered led to my interest and further research and development of an optimum field commodity trailer. My idea was to design a trailer that would be effective in both field and highway use and would be capable of operating on rough field conditions. Another key consideration was developing a field trailer with a solid belt system, like the one commonly used in twenty-foot unloading field beds. These lighter belt systems cause significantly less damage to the produce being unloaded (J. A. Schoenemann, 1986).

### 3.2 NEW IDEAS AND INNOVATION

In 1998, the first rough ideas and drawings were drafted to create a new field prototype. Information and body styles were studied from five self-unloading potato trailer manufactures. All of the designs were constructed with an uni-body system.
with some kind of exoskeleton frame. None of the trailers on the market were
designed with a strong frame for heavy field and off-road use.

Based on the requirements to pull a loaded potato trailer in the mud, it was
necessary for the chassis be designed with a main I-beam structure; this would allow
for a direct tension force in excess of a hundred thousand pounds when being pulled.
Ribs were used to create an exoskeleton to support the side walls and allow for
dynamic loading and continual longitudinal twist. These ribs would also create the
rigid structure required to hold the payload and allow for strength and flex at the same
time. The I-beams combined with the chassis would act as a large vertebra, creating
strength and flexibility. This system would also allow the truck to pull directly on the
trailer axles through the two major I-beams.

3.3 CREATING NEW TRAILER PROTOTYPE DESIGNS

With new design techniques and ideas, over a four-year period, three prototypes
were designed, built, and tested to provide statistics and further understanding for
optimizing the new trailer design. Each trial was an improvement based on the
lessons learned from the preceding trial. In this thesis these trials will be referred to
as Trailer 1, 2, and 3, respectively. In this chapter, the description of each trailer and
the trial tests will be described in chronological order, and diagrams and pictures will
accompany each trial.

3.3.1 EXPERIMENTING AND DISCOVERY OF NEW BELT DESIGN

Other earlier belt designs had used either a solid rubber belt or a chain system
covered with rubber flaps. This new trailer needed the benefits of both systems. It
needed the direct pull of a chain-driven belt system and the flat surface created by a solid, rubber belt system. This trailer was built with an eighteen-inch belt that had a chain-over-belt design.

The belt system in the new trailer was first developed by attempting to attach the rubber belt material to the chain carriage.

![FIGURE 3-1 UNDERLYING CHAIN HARNESS DIAGRAM](image)

The chain system was constructed with cross members every six inches that created a floor and a structure to fasten a flat rubber belt. The belt was then fastened to every cross-member with two-inch carriage bolts. The system was worked on by trial and error until a condition was found where it would work. The most effective method in creating a new belt-over-chain composite design was to try different techniques to have the chain turn the belt. The first technique attaches the chain to the belt with a series of bolts. The second technique to create a belt-over-chain design
allowed the belt and chain to remain unattached and see if they would work by friction. This would allow two systems, doing the same operation, to work within one system.

3.3.2 TRAILER 1 PROTOTYPE FEATURES

The first prototype was built with the new style of ribs combined with a container chassis to form the underlying framework. Now that a frame system with main chassis beams had been roughly designed for the new trailer, a new belt design needed to be created. Trailer 1 was designed with the new rib design in conjunction with a container chassis as the main I-beam chassis. The ribs were attached with welds on the lower leading edge and stitch welded to the sheeting, creating the body and container of the trailer. The trailer had an eighteen-inch wide belt with the belt-over-chain system. Other features included the take-up for the belt assembly,
designed to be outside the trailer body and positioned in the front of the trailer. This made the take-up bearing and assembly easy to access and created a step in the front to climb into the box of the trailer or a standing place to talk to the loading crew as they loaded the trailer with a telescopic piler.

![Figure 3-3 Front Belt and Chain Take-Up with Step](image)

Trailer 1 was pulled out of a muddy field on three occasions with a D-6 crawler tractor. The trailer was put under extreme stress when being pulled out. Because of the I-beam chassis, it did not experience any body or frame damage. The direct pull was estimated at fifty thousand pounds of force.

Trailer 1 was then further tested by overloading it with seventy-five thousand pounds of produce. These larger-than-normal loads, were evaluated for sag. The trailer was then tested for off-load speeds.
3.3.3 TRAILER 2 PROTOTYPE FEATURES

Trailer 2 was built a year later with a wider belt of thirty inches. It had an underlying chain harness to hold the belt used earlier in the Trailer 1 trial.
This trailer had a wider box, of 102 inches, and was designed in the same fashion as Trailer 1 with a container chassis as the main frame with ribs of one and a half inch by one-eighth inch square tubing. The set of axles (or bogies) was moved to the front of the trailer to improve turning capability.

![FIGURE 3-6 TRAILER 2 WITH BOGIES MOVED FORWARD](image)

This trailer was designed with a low-profile configuration, which allowed for potato combines to more easily load the trailer and reduce bruising. The lower profile configuration also improved the visibility of the driver operating the potato combine. This improved loading and visibility in the field, which greatly reduced the distance the potatoes would fall from the stinger on the combine to the floor of the potato trailer or the pile of potatoes on the floor.

Further evaluation of this trailer occurred in southern Alberta, Canada, in the same manner as the first prototype. It was tested in a month of field trials during the 2000 fall crop. Other improvements on this trailer included the wider belt and lower profile configuration. It also had a new ladder design for climbing the rear of the trailer in order to tarp the load.
After this trailer had been completed, Star Trailers Inc. bought the belt system. They felt like the new belt system had potential for improving commodity trailer unloading systems by reducing damage to commodity, wear on belt system, and ease of manufacture-ability.

### 3.3.4 TRAILER 3 PROTOTYPE FEATURES

The Trailer 3 prototype was designed to be 102 inches wide and 48 feet long, with a 32-inch belt and a more heavy-duty chassis and suspension. This trailer was designed with its own chassis, constructed out of 10-inch beams that had 5-inch flanges. The beams were 40 feet long, and the neck of the trailer had 4-inch H-beams that extended to the fifth wheel plate. This trailer was designed for field use, which
would include overloads and harsh conditions. The features that allowed for heavy overloads were the 30-inch walls and the large I-beams supporting the trailer frame.

A new feature that was introduced to this trailer was a semi-bent ladder that would allow for easy access to the inside of the box and to the tarp connections. It also included the newly designed belt take-up that was positioned outside of the potato box for easy cleaning and servicing. This trailer was tested and evaluated in southern Alberta, Canada. It proved to be very effective both in the field and on the highway. It is still in use today.
3.4 BELT TESTING

Belt testing means evaluating the overall performance of a trailer unloading, including the speeds to unload and how the load comes off the trailer, which involves sequencing and load movement characteristics. This also includes the belt assembly wear patterns and the stresses on the drive assembly on initial break-free and continuous run.

3.4.1 BELT SPEEDS

The belt speeds were measured by sticking colored tape on the belt and then timing the revolution speeds. Trailer 1 had an electrical gear reduction system, which only had one set belt speed. The succeeding two trailers had hydraulic motors and
pumps, which allowed for variable speed on the belt system. The hydraulic systems on the two trailers were set at maximum hydraulic fluid displacement and then measured.

3.4.2 BELT WIDTHS

Belt widths were simply measured and then evaluated for their effects on load movement. These widths were evaluated on how they affected the load movement process while unloading.

3.4.3 WALL ANGLE

The wall angle and width of the belt were measured on each trailer. These two factors play a major role in unloading speeds and in overall performance of trailers. Evaluation of how these affected the trailer unloading performance was documented and noted. These features were noted for how the loads were visually displaced off the trailers. Then comparisons were made between the trailers on how these parameters affected performance. The amount of commodities left in the container portion of the trailers was documented and evaluated based on different wall angles.

3.4.4 UNLOADING SPEEDS

Time to unload trailers was taken by a stopwatch. These were performed on level surfaces with similar potato type and conditions.

3.4.5 PERCENT PRODUCT DAMAGE

Percentage of damaged potatoes per load was evaluated by running loaded potato trailers directly into a washing process system. Potatoes were visually inspected and
determinations were made using hundred pound samples of potatoes, with approximately two hundred potatoes per hundred pound sample.

### 3.5 ASYMMETRIC TESTING

Asymmetric testing was accomplished by pulling a loaded trailer at a 45-degree angle to harvested potato rows. As the trailer was pulled across the furrows, it would flex in opposing corners. This flex was measured to determine the flexibility of the trailer as it crossed uneven ground. To evaluate for cracking and tearing, measurements of flex were taken by an individual riding in the trailer. A small measuring device with a red laser was used to measure the difference in corners. This was mounted with a clamp and set so that opposing corners could be measured for the difference in twist.

#### 3.5.1 90-DEGREE TEST

The final step of asymmetric testing was to back the potato truck on rough ground at a 90-degree angle and evaluate the neck flex of the trailer in the same manner as measuring opposing corners.

### 3.6 BRIDGE TEST

Bridge testing was accomplished by putting two clamps on the main chassis I-beam of the trailer from rear to front and stretching a fishing line between them. This line was aligned with the bottom channel of the I-beam. The trailer remained stationary and was loaded with a potato piler to 65,000 lbs. and 75,000 lbs. Once loaded, the fishing line was checked at its fastened ends, and the sag was measured.
CHAPTER 4: RESULTS AND DISCUSSION

4.1 BELT-OVER-CHAIN SYSTEM ANALYSIS

Following completion of the new belt-over-chain system, it was evaluated for operation and performance parameters. It was first operated in order to conduct a test trial, which would verify the belt’s alignment and bearing settings. It was discovered that after three revolutions the belt began to bind and build tension. Noises were heard from the increase in tension of the belt and the chain attempting to move at different speeds. The belt was loaded with potatoes and was operated to evaluate its performance while unloading. After eight full-belt revolutions the belt and chain seized and came to a compete stop.

In order to relieve the seized chain, carriage bolts were unfastened from the chain and taken out. The trailer was still full of potatoes so the belt was turned on again in order to unload. It was discovered that the trailer was still capable of unloading the produce without the rubber belt attached to the chain. After this discovery, the bolts were unfastened one cross member at a time until they were all taken out. It was discovered that the chain and belt ran exceptionally well when disconnected from each other and allowed to operate independently. The belt would move forward from the friction of the weight of the produce on top of it. When the
belt had emptied its load, it continued to move because the weight of the belt on top created enough friction to continue moving the belt forward.

Each time it was tested, Trailer 1 unloaded without a flaw. The loads were approximately 65,000 pounds each. The belt system worked well with allowable belt and chain adjustment being made up on the return side of the belt and chain system.

With the belt on the outside circumference and the chain on the inside of the end spool drive, the assembly needed to be adjusted for the different speeds of the belt and the chain. This adjustment was necessary because the speed of the belt was greater than that of the chain on the end spool drive assembly. The speed differences were discrete, and therefore only a small change in speed between belt and chain was necessary. This change takes place continuously on the return side of the belt and chain where there is no load. For every foot of forward motion, there was
approximately a sixteenth of an inch noted between the belt and chain systems.
Without the allowance for speed change in a belt-covered chain system, the chain
would cease or destroy its components after the change in speed differential grew.
Therefore, it is impossible to attach rubber to the chain-driven system that forms a
continuous loop in both belt and chain. The newly discovered system was actually
two separate systems working together in unison and forming a newly designed belt-
over-chain unloading system.

The Trailer 2 prototype proved to work under the same principles as the first
trailer. Its unloading speeds were faster by approximately five minutes, and it
incurred less bruising than the previous trailer by approximately 15%. The new belt
system worked effectively in a 30-inch configuration. However, the slope of the
trailer had a negative effect on the system, not allowing the total load mass to move
as a unit and creating too great a force placed on the slope, which produced excess
friction.

After experiencing excessive moisture from the highway between the belt and
chain, Trailer 2 had a field trial failure while unloading during the third unloading
trial. This failure was mitigated by wetting the loaded side of the belt system with
water, which allowed it to slide and continue the unloading.

Figure 4-2 shows the Trailer 2 belt-over-chain design with a 30-inch chain system.
4.2 BRIDGE TESTING

Bridge testing was done on the commodity trailers to evaluate the sag of the trailer under a load and under an overload. The trailers were designed to have a one-degree arch, which increases the strength and reduces sag.
This was done initially by using winches to pull an arch in the chassis before the ribs and skin where attached to the trailer. The arch was set to the desired degree, and then the ribs were attached following the sheet metal. Once the sheet metal was secured by stitch welding, the arch would stay in the chassis and body of the trailer for its lifetime.

<table>
<thead>
<tr>
<th>Trailer</th>
<th>Weight (lbs.)</th>
<th>Sag (Inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>65,000</td>
<td>1/32</td>
</tr>
<tr>
<td>1</td>
<td>75,000</td>
<td>1/16</td>
</tr>
<tr>
<td>2</td>
<td>65,000</td>
<td>1/16</td>
</tr>
<tr>
<td>2</td>
<td>75,000</td>
<td>1/8</td>
</tr>
<tr>
<td>3</td>
<td>65,000</td>
<td>1/64</td>
</tr>
<tr>
<td>3</td>
<td>75,000</td>
<td>1/32</td>
</tr>
</tbody>
</table>

The new frame design of this commodity trailer had very little sag. This result comes from the large beams that are created from the side walls of the trailer in conjunction with the main chaises I-beams. Trailer 3 had the least sag because of its 30-inch box wall design along with slightly heavier main chassis I-beams. The increase in wall height made a significant change in the flex, twist, and sag of the new trailer style.

4.3 ASYMMETRIC TESTING

Asymmetric testing was used to simulate the continual twist a field commodity trailer would undergo in a field or off-road situation. It was found that the new rib I-beam design would allow for continual twist and maintain integrity over time. The main chassis and framework of ribs were found to create a rigid underbody with
special characteristics of flexibility and strength. The trailer’s rib design allowed the new commodity trailer’s main skeleton to act as a large vertebra, which permits significant flex and twist while maintaining strength and durability. The ribs were designed to create rigidity at the main I-beam and less rigidity toward the leading edges, allowing for ample horizontal wall flex but almost immeasurable vertical wall flex. These ribs were found to extend the strength of the chassis I-beam all the way to the leading edge of the trailer, thus creating a bridge. The bridge is comprised of two major beams that support the load of the trailer.

### TABLE 2 ASYMMETRIC TEST RESULTS OF THREE COMMODITY TRAILERS

<table>
<thead>
<tr>
<th>Trailer #</th>
<th>Depth of Furrows</th>
<th>Distance</th>
<th>Speed of Truck</th>
<th>Opposing Deflect</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Avg. 10”</td>
<td>200’</td>
<td>5 mph.</td>
<td>Avg 8”</td>
</tr>
<tr>
<td>2</td>
<td>Avg. 10”</td>
<td>200’</td>
<td>5 mph.</td>
<td>Avg 9”</td>
</tr>
<tr>
<td>3</td>
<td>Avg. 10”</td>
<td>200’</td>
<td>5 mph.</td>
<td>Avg 6”</td>
</tr>
</tbody>
</table>

Asymmetric tests were taken on the field by driving the trailer at a 45-degree angle across the harvested potato furrows. This created an uneven surface that caused the trailer’s opposing corners to flex as the trailer was towed. A Stanley measuring laser was used to measure the displacement in opposing corners.

During the test, trailers 1 and 2 were noted to have more flex in the neck of the trailer than in the rear. These trailers also had lower profile boxes with side walls of 24 inches. The lower wall allows for more flex than the 30-inch wall, which makes the container portion of the trailer more rigid. This is understood because of
the thinner I-beams used in the front trailer hitch assembly. Trailers 1, 2, and 3 did not experience any cracking or metal tearing as a result of the test. Minor binding noise was noted, which was believed to have come from the welded sheet metal directly in the corners of the trailer. Trailer 3 had less flex during the test because of the additional height of the walls on the box portion of the trailer design.

**FIGURE 4-4 WELDING SOLUTION**
Figure 4-4 it illustrates the correct way to attach the ribs to the main chassis I-beams. The correct weld is approximately half the width of the flange of the I-beam and is centered on the I-beam. This weld application allows for the I-beam to flex in the flange portion of the I-beam.

Two years after each trailer’s initial testing, the trailers were examined for cracking on the welds of the main I-beams where the ribs were attached. There was no weld cracking or metal bending noted on any of the trailers. The inside corners of the trailers were examined for weld cracking and metal fatigue. Trailer 2 had some metal fatigue on the front of the trailer in the welded corners, but it did not have any weld brakes or weld cracking.

The trailers were also examined for weld breaks on the chassis and box portion of the trailers. Trailer 1 had some weld cracking on the top leading edge, where two leading-edge, 2-inch by 2-inch by 1/8-inch tubing had been butt welded together. In Trailer 3, this problem was resolved by using a 40-foot, 3-inch by 3-inch by 3/16-inch tubing. The joint of this tubing to complete the 48-foot length was placed at the rear of the trailer and was reinforced with side fisher plates.

Trailer 1 avoided the problem of the leading edge having cracks in the welding because it had an inverted angle iron 2-inch by 2-inch by 1/8-inch stitch welded parallel to the leading edge.

4.3.1 ASYMMETRIC TESTING OF TRAILER NECK

The trailers had to be designed so that under a loaded condition the truck pulling the machine could pull at a 90-degree position. This pulling situation puts
enormous twist on the trailer because the three axles are spread over a 12-foot length and the trailer actually has to drag the first and last axle.

The three trailers were tested in soft soil, and it was found that they performed well.

<table>
<thead>
<tr>
<th>Trailer</th>
<th>Displacement of Opposing Corners</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11”</td>
</tr>
<tr>
<td>2</td>
<td>12”</td>
</tr>
<tr>
<td>3</td>
<td>8”</td>
</tr>
</tbody>
</table>

These tests demonstrate that the more rigid the trailer portion of the box is, the less flex is experienced under a 90-degree pulled or pushed position.

One negative trial took place with Trailer 2 following a 90-degree test. The farmer using the trailer claimed that the neck of the trailer suffered a minor bend to the overall longitudinal symmetry of the trailer, particularly in the neck portion. After measuring opposing corners, it was discovered that bending was not measurable. The trailer was unconnected from the truck, and it still did not measure a bent neck or chassis. From the eye, it did appear to have a slight bend to it when connected to the truck. This potential bend was not the result of the standard 90-degree test but was a result of the truck operator releasing the clutch in a quick and abnormal manner. This mistake during the test placed additional twist on the trailer far beyond what would be considered operational.
4.4 BELT SPEED TESTING

This test was done in order to create a baseline for optimum belt speeds. The speed of the belt is directly related to the time it takes to unload a commodity trailer. Testing the speed of the belts also helped evaluate the amount of potato bruising verses the speeds used. In commodity trailers and most unloading devices, the speed at which the unloading device is operating is usually considered directly related to the speed at which the machine or device will unload. However, this is not true in commodity trailers; a belt can be running at a very slow rate, yet the trailer will unload upon one revolution of the belt system. This is because the entire payload will move at the belt speed. This is possible because trailer boxes are lined with UHMW or HMWPE. This material is a type of slippery plastic that is mechanically attached to the trailer bed and acts as a type of bed liner.

The following are the measured speeds of the three trailers tested for one complete belt revolution: Trailer 1, 110 seconds; Trailer 2, 180 seconds; Trailer 3, 210 seconds. The first trailer had a narrow but fast belt. This trailer had the longest unload times; whereas the third trailer had the slowest belt, which was wide and would move the entire trailer load in one mass toward the dumping end of the trailer.

Based on the speeds of the belts that were tested, it was found that belt speed does not necessarily improve overall unloading capabilities and speeds.

4.5 WALL ANGLE AND WIDTH OF BELT

Wall angle and width of belt have the greatest affect on a trailer’s unloading capabilities. As the belt width increases to 24 inches or greater, the entire load in a commodity trailer will move in a mass. At less than 24 inches, the belt system mined
the commodity and caused damage due to scuffing and bruising. If the belt is more than 36 inches in width commodities, like potatoes, will fall from the belt system in masses and cause substantial bruising. This was observed both visually and from hundred pound samples counted for bruising. The optimum belt width seems to be between 30 and 36 inches. This range of width is most favorable for produce hauling and still allows for the hauling of other commodities, such as wood chips and rubber cuttings for playgrounds.

![FIGURE 4-5 BELT SIZE GRAPH](image)

Trailer unloading can be improved by lining the trailer with a plastic material such as HMWPE or UHMWPE. This creates a smooth, slippery surface that allows the load to move with minimal resistance. In my research I found a new way to attach this material. The method for attachment was using a three-eighths carriage bolt with a one inch head. After stretching a 50-foot piece of plastic material over the
length of the trailer, these bolts were placed four inches apart and 2 inches from the cut edge of the material. A technique that improved attachment was countersinking the bolts into the plastic by heating the head.

Side wall angles are of equal importance to unloading capabilities. Side walls approaching 30-degrees leave too much material or produce on the sides following an unloading. These side wall angles also create excess friction because there is not enough of the payload putting pressure on the belt system. As the side angle approaches 50 degrees, too much weight is placed on the chain, which over burdens the drive system and prematurely wears out the chain and its underlying wear points. The optimum degree used on the side angle, based on the findings of these three experiments, would be between 40 and 45-degrees.
If a trailer was designed with a wider belt, it would be correct to favor a steeper side wall to increase trailer volume. If a trailer was designed with a narrower belt, it would be correct to favor less steep side walls, which would most likely be used for produce. This would bring down the height of the side wall in the final assembly and allow for easier side loading in the field. The less steep side wall puts a smaller force on the produce on the bottom of the pile and in direct contact with the belt system.

From visual inspection of unloading Trailer 1, it was found that potatoes would first unload directly from the back of the trailer. This resulted in the belt skidding along the produce for the first five minutes of unloading, causing damage to produce in direct contact with the belt system. After five minutes, the trailer continued to unload from the back with 1/3 of the output yield coming from the front of the trailer. This resulted in potatoes being scrubbed under the entire pile.
toward the unloading end of the trailer. In the last third of the unloading sequence, the middle of the trailer would unload from the center outward, concluding with potatoes being left on the side because of the 35-degree slope.

For ease of loading, the slope on Trailer 1 was initially used to try to minimize the height of the trailer’s leading edge from the ground. This angle was designed at 35-degrees. It worked well for loading because of the improved visibility into the trailer box. This improved visibility allowed for placement of the potato combine stinger, so as not to hit and damage the potatoes piled in the truck while loading. The 35-degree angle, however, had a negative effect on unloading. It slowed down the movement of the commodity being hauled and cause belt mining of the produce and left produce and dirt buildup on the sides of the trailer following unloading.

The belt size used on Trailer 1 was 18 inches, which was only effective for saving money on material and chain size. The belt was too slow because it was incapable of unloading the produce as a mass. The belt system had to run at faster speeds, which led to more wear, which shortened the life span of the trailer belt system. An 18-inch belt is not effective for unloading a 45-foot commodity trailer.

The slope on Trailer 2 was left at 35 degrees because that angle allows a visual of the pile inside the trailer, which improves produce quality. The trailer, however, was designed with a 30-inch belt to improve unloading capabilities. Increasing the belt size and maintaining a 35-degree slope created a trailer that had a low profile, which was optimum for field loading and visibility. The trailer unloaded in a fairly uniform manner and was capable of unloading in a timely manner as well. The 35-degree
side walls prevented some produce from unloading. If the commodity to be unloaded were fairly round in shape, then the trailer would be clean after unloading.

Trailer 3, constructed with a 32-inch belt and 45-degree side walls, was capable of unloading consistently every time. The entire load moved together toward the back, and there was little or nothing left in the trailer body after it had unloaded. Unloads usually took 10 to 12 minutes, depending on receiving capability. The trailer connected to the truck PTO unloaded in less than 10 minutes, depending on truck RPM and oil displacement. The load was consistently emptied before the belt could make more than two complete revolutions.

4.6 TIME TO UNLOAD

It was discovered that the time to unload a trailer was based on multiple factors, including belt speed, belt size, and side wall angle type on the bed liner in the trailer box. In the first prototype, a field trailer was designed with some of the worst unloading characteristics. This trailer on average unloaded in 18 minutes. However, many of the field strength characteristics were first implemented in this field trial and served as building blocks for further development of the future trailer design.

<table>
<thead>
<tr>
<th>Test #</th>
<th>Time (Closest Minute)</th>
<th>Load (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>18 min.</td>
<td>65,000</td>
</tr>
<tr>
<td>2</td>
<td>14 min.</td>
<td>65,000</td>
</tr>
<tr>
<td>3</td>
<td>21 min.</td>
<td>65,000</td>
</tr>
<tr>
<td>4</td>
<td>19 min</td>
<td>65,000</td>
</tr>
<tr>
<td>5</td>
<td>19 min</td>
<td>65,000</td>
</tr>
<tr>
<td>Average</td>
<td>18.2 min</td>
<td>65,000</td>
</tr>
</tbody>
</table>
Factors besides the mechanical device that affect unloading speeds include mud, dirt, rock and moisture content. Another factor is the shape and size of the potatoes.

Trailer 2 on average would unload in 13 minutes; this was a definite improvement over Trailer 1, but in an unloading crunch, it was still not fast enough. This trailer’s unloading times improved when unloading red potatoes, which are more round in shape. If the trailer was loaded from the field with additional contamination of dirt or rock, it slowed the unloading process by a couple of minutes because of material left on the side wall slope of the trailer.

Trailer 3 would unload on average in 10 minutes with no material left in the trailer body. This trailer would unload in as fast as 8 minutes when using the PTO from the truck pulling it. When unloading at faster speeds, it was noted that some produce would strike the back cross brace between the door and stinger door. This is because the load did not have sufficient time to fall through the opening but ended up being pushed against the back door brace because of excessive unloading speed.

4.7 PERCENT OF DAMAGED PRODUCE

In commodity hauling, percent of damaged produce only applies to produce (A. Baritelle, et al., 2000; W. Sparks, 1977). Other products hauled, such as gypsum, salt, wood chips, rubber, alfalfa cubes, etc., cannot be substantially harmed by the belt system or the speed of loading or unloading. However, consideration should be given to hauling produce with commodity trailers because almost all commodity haulers at some time will be required to haul produce, such as potatoes, sugar beets, carrots, grains, and apples. In the field experiments the percent damage was as follows:
As shown in the results of Table 5, trailer 1, with a narrowest belt and low side wall angle, had the highest produce damage. The narrow belt causes an increase in damage because of the increase of the belt speed to make up for less volume than a wider belt. However, these damage results overall do not include the damage that would be saved by having a low-profile trailer in the field. (A low profile trailer allows the stinger from the harvesting machine to reach closer to the inside of the trailer, which results in less produce damage.) Based on the new belt design, we assumed that trailer 2 would have the least produce damage, however it still had a low side wall angle, which caused undermining from the pressure of the load and resulted in more damage than expected. Trailer 3 had an optimal side wall angle and belt size, and therefore had the least amount of damage because the load moved as one mass.

### TABLE 5 PERCENT PRODUCE DAMAGE

<table>
<thead>
<tr>
<th>Trailer</th>
<th>Samples</th>
<th>Loads</th>
<th>Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9</td>
<td>3</td>
<td>11%</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
<td>3</td>
<td>6%</td>
</tr>
<tr>
<td>3</td>
<td>9</td>
<td>3</td>
<td>4%</td>
</tr>
</tbody>
</table>
5.1 CONCLUSIONS

Commodity hauling is a growing enterprise with many potential areas of improvement. Since the first self-unloading semi-trailers in the early 1970s, commodity hauling has moved from hauling produce almost exclusively from cellars to processing plants to hauling a host of commodities, including produce, bulk chemicals, and a variety of bulk materials. This thesis has measured and evaluated two areas within commodity hauling: improving self-unloading belt systems and designing a better field trailer chassis and body design for hauling off-road. Three prototypes with innovative changes were built, tested, and evaluated in order to create a baseline for a new off-road trailer design. Trailer parameters were evaluated for belt operation capabilities and for trailer off-road performance. From these findings, drawings, and settings the following conclusions have been recommended for generating the most capable off-road trailer design:

- A chain-over-belt design is more effective than a belt flap design because of savings in manufacturing time and materials. The system has potential to have less maintenance issues and have a longer lifetime.
This new belt design has turned out to be an invention that relates to a chain-driven belt apparatus for moving agricultural products and other bulk flow materials. Due to this invention, a new device for moving bulk flow material is provided. The new device includes and idler sprocket assembly and a drive sprocket assembly. The drive sprocket assembly is engaged with a motor, which turns the drive sprocket assembly. It is designed with an endless loop of two parallel drive chains and an endless loop of rubber belting on the outside circumference of the chain, but these two loops are not attached. The drive sprocket assembly drives the chains, which moves the belt. Spacer bars are positioned perpendicularly and are attached to the endless loop drive chains. A conveyor belt is loosely fitted on the endless loop drive chains, covering the chains and leaving slack in the conveyor belt. Sloped side walls are used to direct the bulk flow material onto the conveyor belt. In the method of the invention, the motor powers the sprocket assembly, which drives the chain harness; this provides a carrier for the belt loop which moves forward unattached while maintaining the capability to make speed adjustments between the belt and chain. The weight of the bulk flow material presses the conveyor belt against the chains and cross-members, creating friction, which moves the conveyor belt. Speed adjustments are made up on the return side of the belt. The belt and chain are two
separate systems performing one job in unison with different characteristics and speeds.

- The chain-over-belt apparatus has been evaluated for damage to produce. It has been determined that for the same size chain in the same or a similar trailer there is a 10% reduction in damage to produce. This system is less likely to cause bruising and cracking in produce such as potatoes. This new belt design has various applications and possibilities in industrial settings where commodity movement of bulk materials is required to pull large loads, such as in the mining or soil sorting industry. The new design was purchased by Star Transport Trailers, Inc. in exchange for a 2001 potato trailer valued at $50,000. Refer to appendix A for further patent claims and description of the belt design.

- From the asymmetric testing, it was found that a trailer with a higher side wall is more rigid. From the tests done on the three commodity trailers, it was concluded that a commodity field trailer needs to continually have eight inches of flex for opposing corners of the rear and front of the trailer. When the new trailer design was compared to a Trinity trailer for asymmetric flex, it was found that the trailers flexed continuously on average for the same side wall configuration. The trailer 90-degree test found that a Trinity trailer flexed up to 12% more. This makes sense because there are no I-beams in the neck or chassis of a Trinity trailer. I-beams are only placed where the axles are attached. Flex and overall brute pulling strength are inversely related.
As the flex increases, the strength and weight of trailers decrease.

There are compromises to be made on strength versus flex due to the increased steel structure and thickness of metal sheeting. For a field-use trailer from the study, it is recommended to use a 10-inch I-beam at 19 lbs/ft for the main chassis. The main chassis I-beam should be high quality, cold rolled steel. For the neck, a four to six inch H-beam is recommended. The tubing to build the trailer skeleton should be two-inch square tubing at 0.125, and sheeting should be 0.1196 (11 gauge) or a minimum of 0.1046 (12 gauge). The inside vertical wall should be sprayed with industrial polyurethane, which increases the wall strength and restricts the sheet metal from bowing or bending. If these basic specifications are used with quality materials, the trailer built according to the new design will be capable of continuous dynamic loading.

- Based on the results of the bridge test, it was noted that as the vertical side wall of the trailer increases in height, the trailer has less sag and more rigidity. However, as the side wall is increased in height, the visibility into the box portion of the trailer is reduced. This configuration leads to bruising produce because of the combine operator’s reduced visibility, which results in the combine stinger striking or dropping the potatoes more than 10 inches. As the upper side wall of the trailer is increased in height, the overall weight of the trailer increases. Some commodities are very light, like cotton and bulk
styrofoam. For these situations, Trinity trailers has used aluminum extensions, which bolt onto the trailer side walls. From the findings, a trailer that is designated more for field hauling would be built with 24-inch side walls, and if multi-use field trailers were needed, they would have aluminum extensions. Trailers that are highway and off-road trailers would be built with 30-inch side walls, thus increasing the trailer’s ability to have move volume, which would allow for hauling a wider variety of commodities.

- From this study, it was initially thought that the faster a belt runs on an unloading device, the faster the machine will unload. This is not the case with commodity trailers; the desired operation is to have the belt run slowly, with enough torque to pull the entire load as one mass. The narrow belt running at fast speeds was not as fast at unloading as a wide belt pulling twice as slow. The belt speed for a 30-inch to 36-inch belt should have variable speeds with a maximum speed of 180 seconds for one belt revolution. The trailer should be lined with UHMWPE or HMWPE to improve unloading speeds.

- Side wall angle and belt size are among the most critical considerations when designing a commodity trailer, whether it is a field or highway version. The side wall angle should fall between a maximum of 50 degrees and a minimum of 40 degrees. The optimum angle found in this research was 45 degrees. In a field trailer consideration, 40 degrees would be preferred for increased visibility and for the low
profile configuration that can be achieved. Belt width is a parameter that affects the life of the belt and drive system. The wider the belt, the faster it deteriorates. As the belt size approaches 38 inches, produce begins to fall in more than 1000 lbs. increments. Therefore, the belt system should be kept between the 36-inch maximum and 24-inch minimum. This allows the load to move as a mass and minimizes wear on the chain and belt. For optimum field use, a 36-inch belt would be used, allowing for the transport of potatoes, sugar beets, and a host of other commodities. This width will not limit the trailer’s ability to haul other commodities of a non-produce nature. The other advantage to a wider belt is it increases the volume of the box portion of the trailer.

- Finding the optimum time to unload is a result of three other trailer design parameters, which are belt speed, wall angle, and belt width. In the field trials, it was discovered that a trailer with a 36-inch belt, 45-degree side wall angle, and 200-second belt revolution speed would consistently unload in 10 minutes. These unloading trailer times are consistent with those of Trinity trailers. Other unloading speeds were realized through using the truck PTO. With a truck running the hydraulic orbit motor, unloading speeds of less than eight minutes were achieved. Unloading in eight minutes or less put undo strain on the trailer’s working components, and, in most cases, the receiving devices were not capable of such heavy off loads.
In most transportation organizations, the fact that some of the material being hauled will suffer damage or potential loss is always a consideration. In commodity field trailers, damage to produce is a critical component of effectiveness (R. C. Brooks, 1993; D. Corsini, et al., 1999). The trailers with the new belt design had 10% less damage than a standard chain flap trailer. Having a lower side wall in a trailer design reduces damage by an estimated 5%. An optimum field trailer would have a new belt-over-chain design with 24-inch side walls. These parameters would improve the quality of produce being hauled to the processor and to storage facilities.

For the purposes of this thesis, the optimum field commodity trailer would contain the parameters listed in the conclusions and recommendations drawn from the field trailer findings in chapter four. Determining the amount of field use a trailer will experience during a season is an important consideration to the design. In Appendix B, AutoCAD drawings outline the commodity trailer characteristics that would be most favorable for field use. The drawings contain the blueprints to manufacture or replicate the findings of this thesis.

5.2 RECOMMENDATIONS AND FUTURE RESEARCH

The parameters developed by this research have generated a baseline for developing a field-use trailer and for preparing for future research. There are two main focuses in developing an ultimate field trailer: a belt design that requires little maintenance and a payload and body design that have strength and flexibility. These two objectives have been met in this thesis, but they could be further refined. The belt system could be further developed, and the body style could be redesigned to
be lighter. The following items are further research and improvements that could be studied:

- The next step in the design of the belt apparatus is to create a chain harness that has only three independent chains made of pintal chain stalk with attachments. This system would allow for fewer parts and easier manufacturing. This would put less weight on two chains and allow three chains to do the work, hence improving the lifetime of the trailer-belt system.

- The act of using three separate belts with attachments to carry the weight of the load could be tested. This new system could then be implemented with separate belt and chain take-ups on the front of the trailer. This would allow the operator to adjust the belt and chain separately, which would improve the way the system works on the return side of the belt-and-chain system.

- One important aspect of developing the new belt system involves doing further research to discover the best belt thickness. This could be accomplished by a series of experiments. A thinner belt helps keep the weight of the trailer down and helps minimize the cost of the belting.

- Developing a side door on the front left-hand 20 feet of the trailer is something that a lot of farmers have shown interest in, but has not been developed in semi-trailers. This door would allow for better visibility when initiating the piling of produce from the front of the trailer in the
field. It would also help eliminate unnecessary bruising when beginning to field load a self-unloading trailer.

- Further development on cutting back the weight of the trailer could be done by experimenting with beam sizes and sheeting width, which could possibly cut down on as much as 1,000 pounds. These types of experiments are difficult to do because of the magnitude of the experiments and the cost involved (G. C. Misener and C. D. Mcleod, 1987).

- Trailers could be tested for actual breaking points, being pulled on by a bulldozer when loaded in soft soils. Again, this kind of experiment was beyond the scope of this thesis because of the cost. This experiment would give data on catastrophic failure as a result of a direct pull in soft soils. It would reveal the actual weak and breaking points of trailers. This kind of experiment would be the equivalent to test crashing cars.

- Other research that could benefit this new trailer design would be to use aluminum in the skin of the trailer attached with heavy riveting to the steel rib system. This type of application could help the trailer to remain light and have fewer corrosion issues.

The new field commodity trailer designed in this research has the ability to become an asset to field commodity hauling. This new trailer and belt design has the potential to become commonplace on potato and sugar beet farms. The new capability of having a trailer that provides reliable highway use and field hauling will allow farmers to justify purchasing a commodity trailer. The baseline parameters of
the new trailer design provide a foundation for further research and development in commodity field hauling. The current potato operations in the United States and Canada have a need for this new generation of commodity trailer. The final step in this research would be to manufacture trailer designed in this thesis and eventually provide a superior product for farmers throughout North America.
REFERENCES


APPENDICES
ABSTRACT

A device for moving bulk flow material is provided. The device includes an idler sprocket assembly and a drive sprocket assembly. The drive sprocket assembly is engaged with a motor, which turns the drive sprocket assembly. Endless loop drive chains are functionally engaged on the idler sprocket assembly and the drive sprocket assembly. Spacer bars are positioned perpendicular to and attached to the endless loop drive chains. A conveyor belt is received loosely on the endless loop drive chains, covering the endless loop drive chains and leaving slack in the conveyor belt. A method for moving bulk material is also provided. According to the method, the motor turns the drive sprocket assembly, advancing the drive chains. The weight of the bulk flow material presses the conveyor belt against the chains, creating friction, which advances the conveyor belt.
CHAIN DRIVEN BELT DISCHARGE APPARATUS AND METHOD

TECHNICAL FIELD

This invention relates to the field of material handling equipment. More specifically, the invention relates to a chain-driven apparatus for moving agricultural products and other bulk flow materials.

BACKGROUND OF THE INVENTION

In the agricultural industry, it is common to load agricultural products such as potatoes into a trailer for transport from the field to a storage facility. Most conventional agricultural trailers are open on top, so that produce can be loaded easily by automated picking equipment. There are various means known for emptying the contents of an agricultural trailer. One common method is to employ a chain driven belt to carry the contents to the rear of the trailer, where they are discharged out a rear gate. In a typical arrangement, a conveyor belt affixed to a pair of endless drive chains extends along the floor of the trailer. The chains are received by a pair of freely turning sprockets at the front end of the trailer, and a second pair of sprockets at the rear end of the trailer. The second pair of sprockets are turned by a motor, pulling the upper run of the drive chains from the front of the trailer to the rear, and the lower run of the drive chains from the rear of the trailer to the front.
While functional, the currently known chain driven belt discharge device is problematic. When used to unload agricultural products such as potatoes, which are mixed with dirt, mud, and/or rocks when harvested, the chain drive can be damaged by debris which slips under the belt and becomes caught in the chain. Attempts have been made to avoid this problem by using a belt made up of a plurality of relatively lightweight overlapping flaps. Each flap is affixed to the chain drive at the flap leading edge, and its trailing edge is unattached. A spacer bar affixed between the drive chains supports each flap. The flaps form a flat surface on the upper run of the chain drive. As the belt is advanced to the rear of the trailer and the produce is offloaded, each flap rotates around to the lower run of the chain drive. The unattached trailing edge is free to hang vertically from the chain drive. Thus, any debris which may have entered the belt drive apparatus is free to fall through to the ground without causing damage to the chain drive. While somewhat effective at reducing problems associated with rocks, dirt and mud damaging the chain drive, the flap-belt device is expensive to manufacture, and adds unwanted weight to the trailer due to the many spacer bars required. Additionally, the flap belt device requires more maintenance than a conventional conveyor belt design.

Another problem with the currently known chain driven belt discharge device is that when the belt becomes worn or damaged, it must be detached from the chain drive for replacement. This process can be time consuming, especially when the belt has been affixed to the chain drive every 12 to 18 inches. To avoid this problem, attempts have been made to use a relatively thin belt that relies on tension between two or more rollers to hold it in position. However, such a design has been proven to
be problematic, requiring high maintenance and frequent replacement to keep the belt in position.

It would be advantageous, therefore, to have a chain driven belt discharge device which does not require that the belt be affixed to the chain drive or held in place by tension between two rollers.

It would also be desirable to have a chain driven belt discharge device which is relatively lightweight.

It would further be desirable to have a chain driven belt discharge device which permits relatively rapid and simple change of worn or damaged belts.

**SUMMARY OF THE INVENTION**

According to the invention, a device for moving bulk flow material is provided. The device includes an idler sprocket assembly and a drive sprocket assembly. The drive sprocket assembly is engaged with a motor, which turns the drive sprocket assembly. A first endless loop drive chain and a second endless loop drive chain are parallel to one another, and functionally engaged on the idler sprocket assembly and the drive sprocket assembly. Spacer bars are positioned perpendicular and attached to the endless loop drive chains. A conveyor belt is received loosely on the endless loop drive chains, covering the endless loop drive chains and leaving slack in the conveyor belt. According to an aspect of the invention, sloped side walls are provided to direct the bulk flow material onto the conveyor belt. In the method of the invention, the motor turns the drive sprocket assembly, advancing the drive chains. The weight of the bulk flow material presses the conveyor belt against the chains, creating friction which advances the conveyor belt.
BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a perspective view of an embodiment of the chain driven belt discharge apparatus;

FIG. 2 is a cut-away perspective view of an embodiment of the chain driven belt discharge apparatus;

FIG. 3 is a side view of an embodiment of the chain driven belt discharge apparatus;

FIG. 4 is a perspective view of an alternative embodiment of the chain driven belt discharge apparatus; and

FIG. 5 is a cut-away perspective view of an additional embodiment of the chain driven belt discharge apparatus.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

The chain driven belt discharge device 10 of the present invention is shown generally in FIGs. 1 through 4. As shown in FIGs. 1 and 2, the chain driven belt discharge device has a first end 11 and a second end 12, and is adapted for receiving bulk flow articles such as potatoes 14 or other agricultural produce (not shown). In a preferred embodiment, the chain driven belt discharge device is incorporated in a trailer 57 for bulk flow articles (See FIG. 4). In alternative preferred embodiments, the chain driven belt discharge device stands alone or is incorporated in other types of equipment, such as packing lines and the like.

The chain driven belt discharge device 10 consists of a frame 16 of typical design, and a floor 17. A first idler sprocket 18 and a second idler sprocket 20 are mounted on an idler sprocket shaft 22, spaced apart from one another at a distance d,
forming and idler sprocket assembly 24. The idler sprocket assembly is mounted proximate the first end 11 of the chain driven belt discharge device in a way that allows the idler sprocket assembly to turn freely. A first drive sprocket 28 and a second drive sprocket 30 are mounted on a drive sprocket shaft 32, spaced apart from one another at distance $d$, forming a drive sprocket assembly 34. The drive sprocket assembly is mounted proximate the second end 12 of the chain driven belt discharge device, and is functionally engaged with a motor 38. In a preferred embodiment, the motor is a high ratio hydraulic powered motor, such as model number TF0195, manufactured by Parker. Other types of drive means are also contemplated, such as an electric or gas powered motor or a power take-off (PTO).

A first endless loop drive chain 40 is engaged on the first idler sprocket 18 and the first drive sprocket 28. A second endless loop drive chain 42 is likewise engaged on the second idler sprocket 20 and the second drive sprocket 30, as shown in FIG. 2. The first endless loop drive chain and the second endless loop drive chain are parallel to one another and move in concert when the drive sprocket assembly 34 is turned by the motor 38. Each of the endless loop drive chains is comprised of a plurality of links 50. In a preferred embodiment, the endless loop chains are 3” link drive chains, such as part number D667KC manufactured by Drives.

A plurality of spacer bars 44, each having a first end 46 and a second end 48 are provided for maintaining the parallel position of the first endless loop drive chain 40 and the second endless loop drive chain 42 at approximately distance $d$ apart from one another. The spacer bar first end is fastened to a link 50 in the first endless loop drive chain, and the spacer bar second end is fastened to a link 50’ in the second
endless loop drive chain, so that the spacer bar is perpendicular to the first and second endless loop drive chains. In a preferred embodiment, the spacer bars are fastened in place with rivets (not shown). Other fastening means are contemplated, such as screws, spot welds, bolts and the like.

A conveyor belt 52 having a width approximately equal to or slightly greater than distance $d$, is provided as shown in FIGs. 1 and 3. In a preferred embodiment, the conveyor belt is made from flexible rubber. Alternatively, the conveyor belt may be made from other, similar materials. A belt made from fabric and rubber has been used successfully. The conveyor belt is sized to be received loosely over the endless loop drive chains without fasteners. The conveyor belt is longer than the endless loop drive chains, so that an amount of slack 54 remains in the belt when it is installed and while functioning. In a preferred embodiment, sloped side walls 56 are provided to direct bulk flow articles onto the conveyor belt 52. The width of the belt allows the belt edges 53 to contact the sloped side walls of the apparatus, thus minimizing dirt, mud, rocks and the like from sliding beneath the belt and causing damage to the endless loop drive chains.

In the alternative preferred embodiment shown in FIG. 5, at least a pair of runners 74 and 74' extends the length of the chain driven belt discharge device 10, directly beneath and substantially parallel to the first endless loop drive chain 40 and the second endless loop drive chain 42. In this embodiment there is no floor, such as the floor 17 shown in FIG. 2. This arrangement allows dirt, rocks, mud and other debris to fall away. The runners and the spacer bars 44 support the drive chains.
Preferably, the runners are made from a high molecular weight plastic to provide a low friction surface upon which the drive chains can slide.

In use, bulk flow articles are loaded onto the conveyor belt 52 of the chain driven belt discharge device 10. A switch (not shown) actuates the motor 38 to turn the drive sprocket assembly 34. As the drive sprocket assembly turns, the first endless loop drive chain 40 and the second endless loop drive chain 42 advance from the first end 11 toward the second end 12, in a rearward direction 70. The weight of the bulk flow articles presses the conveyor belt 52 against the drive chains, creating friction between the conveyor belt and the drive chains. The spacer bars 44 support the conveyor belt. As a result, the loaded conveyor belt advances around toward the second end 12 of the apparatus without being fastened to the drive chains. As the bulk flow articles are discharged off the second end 12 of the apparatus, the conveyor belt continues around the drive sprocket assembly and back toward the first end 11 of the chain driven belt discharge device in a return direction 72.

In a preferred embodiment, the chain driven belt discharge device 10 is incorporated in a typical trailer 57 for bulk flow articles, as shown in FIG. 4. The trailer has a front wall 58, a rear wall 60, and opposing parallel side walls 62, each having a top edge 64 and a bottom edge 66. The side walls are sloped such that the distance between the top edges is greater than the distance between the bottom edges. In a preferred embodiment, the bottom edges of the side walls meet the trailer floor (not shown). In an alternative preferred embodiment, neither the trailer nor the chain driven belt discharge device has a floor. A pair of runners (not shown) are provided to
support the drive chains in the manner shown in FIG. 5. The sloped side walls allow the contents of the trailer to slide onto the conveyor belt 52.

The first end 11 of the chain driven belt discharge device 10 is located proximate the front wall 58 of the trailer 57. The second end 12 is located proximate the rear wall 60 of the trailer. In this embodiment, the idler sprocket assembly 24 is positioned proximate the front wall 58 of the trailer. The drive sprocket assembly 34 and the motor 38 are positioned proximate the rear wall. The rear wall has a discharge gate 68 for allowing the contents of the trailer to be emptied.

In use, bulk flow articles are loaded into the trailer 57. The articles are directed to the conveyor belt 52 of the chain driven belt discharge device 10. A switch (not shown) actuates the motor 38 to turn the drive sprocket assembly 34. As the drive sprocket assembly turns, the first endless loop drive chain 40 and the second endless loop drive chain 42 advance from the first end 11 toward the second end 12, in a rearward direction 70. The weight of the bulk flow articles presses the conveyor belt 52 against the drive chains, creating friction between the conveyor belt and the drive chains. The spacer bars 44 support the conveyor belt. As a result, the loaded conveyor belt advances toward the second end 12 of the apparatus at the rear wall 60 of the trailer without being fastened to the drive chains. As the bulk flow articles are discharged from the trailer through the gate 68, the conveyor belt continues around the drive sprocket assembly and back toward the first end 11 of the chain driven belt discharge device near the front wall 58 of the trailer in a return direction 72.

In compliance with the statues, the invention has been described in language more or less specific as to structural features and process steps. While this invention
is susceptible to embodiment in different forms, the specification illustrates preferred embodiments of the invention with the understanding that the present disclosure is to be considered an exemplification of the principles of the invention, and the disclosure is not intended to limit the invention to the particular embodiments described. Those with ordinary skill in the art will appreciate that other embodiments and variations of the invention are possible, which employ the same inventive concepts as described above. Therefore, the invention is not to be limited, except by the following claims, as appropriately interpreted in accordance with the doctrine of equivalent.

CLAIMS

What is claimed is:

1. A device for moving bulk flow material, the device comprising
   a first end and a second end;
   a first idler sprocket and a second idler sprocket, joined by an idler sprocket shaft, to form an idler sprocket assembly, located proximate the first end;
   a first drive sprocket and a second drive sprocket, joined by a drive sprocket shaft, to form a drive sprocket assembly, located proximate the second end, the drive sprocket assembly being functionally engaged with a motor for turning the drive sprocket assembly;
   at least a first endless loop drive chain and a second endless loop drive chain, the first endless loop drive chain including a plurality of links, and sized to be functionally engaged on the first idler sprocket and the first drive sprocket, and the second endless loop drive chain including a plurality of links,
and sized to be functionally engaged on the second idler sprocket and the second drive sprocket;

the endless loop drive chains spaced apart from and parallel to one another,

a plurality of spacer bars, each having a first end and a second end, each spacer bar positioned perpendicular to the endless loop drive chains and attached at its first end to a link of the first endless loop drive chain and attached at its second end to a corresponding link in the second endless loop drive chain, the spacer bars being distributed along the endless loop drive chains; and

a conveyor belt, the conveyor belt forming a circumference greater than the circumference of the endless loop chains, such that the conveyor belt is received loosely on the endless loop drive chains, covering the endless loop drive chains and leaving slack in the conveyor belt.

2. The apparatus of claim 1, wherein the bulk flow material is agricultural produce.

3. The apparatus of claim 1, wherein the belt is formed of reinforced rubber.

4. The apparatus of claim 1, wherein the motor is an electric motor.

5. The apparatus of claim 1, wherein the motor is a hydraulic motor.
6. The apparatus of claim 1, further comprising

   a plurality of runners, each runner positioned beneath and parallel to a
   drive chain.

7. The apparatus of claim 1, further comprising

   a pair of sloped side walls, each having a lower edge, for directing the
   bulk flow material onto the conveyor belt; and

   a floor extending from the first end to the second end, the width of the
   floor being defined by the lower edges of the sloped side walls.

8. The apparatus of claim 7, wherein the conveyor belt has a width approximately
   equal to or greater than the width of the floor.

9. A trailer for bulk flow articles, the trailer comprising:

   a front wall, a rear wall, opposing parallel side walls each having a top
   edge and a bottom edge, the side walls being sloped such that the distance
   between the top edges is greater than the distance between the bottom edges,
   and the rear wall having a discharge gate therein;

   a floor which extends from the front wall to the rear wall along the
   bottom edges of the side walls, the width of the floor being defined by the
   lower edges of the side walls.
a first idler sprocket and a second idler sprocket, joined by an idler sprocket shaft, to form an idler sprocket assembly, located proximate the first end;

a first drive sprocket and a second drive sprocket, joined by a drive sprocket shaft, to form a drive sprocket assembly, located proximate the second end, the drive sprocket assembly being functionally engaged with a motor for turning the drive sprocket assembly;

at least a first endless loop drive chain and a second endless loop drive chain, the first endless loop drive chain comprising a plurality of links, and sized to be functionally engaged on the first idler sprocket and the first drive sprocket, and the second endless loop drive chain comprising a plurality of links, and sized to be functionally engaged on the second idler sprocket and the second drive sprocket;

the endless loop drive chains spaced apart from and parallel to one another,

a plurality of spacer bars, each having a first end and a second end, each spacer bar positioned perpendicular to the endless loop drive chains and attached at its first end to a link of the first endless loop drive chain and attached at its second end to a corresponding link in the second endless loop drive chain, the spacer bars being distributed along the endless loop drive chains; and

a conveyor belt, the conveyor belt forming a circumference greater than the circumference of the endless loop chains, such that the endless loop belt is
received loosely on the endless loop drive chains, covering the endless loop drive chains and leaving slack in the conveyor belt.

10. The apparatus of claim 8, wherein the bulk flow material is agricultural produce.

11. The apparatus of claim 8, wherein the belt is formed of reinforced rubber.

12. The apparatus of claim 8, wherein the motor is an electric motor.

13. The apparatus of claim 8, wherein the motor is a hydraulic motor.

14. The apparatus of claim 8, wherein the conveyor belt has a width approximately equal to or greater than the width of the floor.

15. A trailer for bulk flow articles, the trailer comprising:

   a front wall, a rear wall, opposing parallel side walls each having a top edge and a bottom edge, the side walls being sloped such that the distance between the top edges is greater than the distance between the bottom edges, and the rear wall having a discharge gate therein;

   a first idler sprocket and a second idler sprocket, joined by an idler sprocket shaft, to form an idler sprocket assembly, located proximate the first end;
a first drive sprocket and a second drive sprocket, joined by a drive sprocket shaft, to form a drive sprocket assembly, located proximate the second end, the drive sprocket assembly being functionally engaged with a motor for turning the drive sprocket assembly;

at least a first endless loop drive chain and a second endless loop drive chain, the first endless loop drive chain comprising a plurality of links, and sized to be functionally engaged on the second idler sprocket and the second drive sprocket;

the endless loop drive chains spaced apart from and parallel to one another,

a plurality of spacer bars, each having a first end and a second end, each spacer bar positioned perpendicular to the endless loop drive chains and attached at its first end to a link of the first endless loop drive chain and attached at its second end to a corresponding link in the second endless loop drive chain, the spacer bars being distributed along the endless loop drive chains;

at least a pair of runners, each runner positioned beneath and substantially parallel to an endless loop drive chain; and

a conveyor belt, the conveyor belt forming a circumference greater than the circumference of the endless loop chains, such that the endless loop belt is received loosely on the endless loop drive chains, covering the endless loop drive chains and leaving slack in the conveyor belt.
16. A method for unloading agricultural produce from a trailer, the method comprising the steps of:

   providing the trailer with a chain driven belt discharge system, including an idler sprocket assembly, a drive sprocket assembly, at least a pair of endless loop drive chains functionally engaged with the idler sprocket assembly and the drive sprocket assembly, a plurality of spacer bars for maintaining a distance between the endless loop drive chains, a motor functionally engaged with the drive sprocket assembly, and a conveyor belt loosely engaged on the endless loop drive chains;

   activating the motor to turn the drive sprocket assembly and advance the endless loop drive chains;

   allowing the weight of the agricultural produce to press the conveyor belt against the endless loop drive chains, thus creating friction which causes the conveyor belt to advance with the endless loop drive chains;

   discharging the agricultural produce out a discharge gate of the trailer.
APPENDIX B. AUTOCADE DRAWINGS OF 2005 TRAILER
2005 Prototype - Body Skin
2005 Prototype - Rib Design