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Amgen Material Handling

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Abstract

Amgen is a world leading pharmaceutical company that specializes in biotechnology which develops intravenous or injectable biologic medicines. With an outstanding reputation in the field of safety, quality assurance, superior scientific innovation, and continuous improvement in all aspects, Amgen's goal is to serve patients cutting edge medications available in today's market. With this outlook on innovation, Amgen is currently looking into a material handling solution for movement of material between its storage facilities to an IOS9 cleanliness standard laboratory. Such movement includes passing through an airlock which requires the drums containing necessary chemicals for biotechnological production to be cleaned and remain in wet-lock with a specified bleach solution. This process is currently in question since these drums are being handled manually by workers at the risk of injury. With barrels that range from twenty-two to two hundred fifty pounds, great risk is associated with repetitive movement by workers tilting and cleaning these drums, and injury prevention is the main motive for the process change. This manual movement of drums lacks sufficient ergonomics while subjecting workers to injury, and a change must be implemented. A close look will be taken at the current process, and a mechanism will be designed to assist the worker during the new improved moving and cleaning process. Factors including safety, ergonomics, cleanability, timing, and cost will be considered in respective importance. Research on current patents, literature, and competitors' solutions to material handling will be considered in the final design of a mechanism. Devices that were ultimately considered and compared include: electric motor-driven barrel lifters and turners, manual lifting assist devices, and automated systems, all of which would be customized to the company's preference of cleanability, ease of use, and size and power limitations addressed by Amgen.

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Abbreviations

Amgen - Applied Molecular Genetics Inc.

FDA - Food and Drug Administration

FEA - Finite Element Analysis

OSHA - Occupational Safety and Health Administration

REBA - Rapid Entire Body Assessment

QFD - Quality Function Deployment

1. Introduction

The contents of this report are made possible by sponsorship from Amgen. Amgen (an acronym for Applied Molecular Genetics Inc.) is an American pharmaceutical company established in Thousand Oaks, California in 1980. The company's first Cooperate Executive Officer (CEO) was George B. Rathmann, a man who is commonly referred to as "one of the great geniuses of high-tech entrepreneurialism".[1] Starting in a small trailer, Rathmann was able to establish funding for grant experiments in technology, which ultimately propelled the company to new heights. This funding led to the development of a process to produce indigo dye in the E. coli bacteria, sending the company to the front page of Science magazine. With this, the company directed its efforts to curing and treating disease. With this new found success, the company made its Initial Public Offering (IPO) and became a publicly owned company where it continued its expansion. From here, Amgen continued to be a leader in innovation, and was awarded the National Medal of Technology, being the first biotech company to do so.[1] Amgen then began merging and buying up other biotechnology companies, including the developer Immunex (known for developing ENBREL®, located in West Greenwich, Rhode Island, and acquiring its manufacturing plant. Here Amgen continues to expand its disease-fighting innovations and goal of curing and treating diseases today.

With its known reputation as a world leading innovator, Amgen is now looking into some of its manufacturing processes and continues looking into more efficient, safer methods of its current processes. The primary area of interest lies inside of an airlock between Amgen's West Greenwich facility between the warehouse leading into the lab where manufacturing occurs. Being primarily invested in creating injectable medications for patients with serious illnesses, it is crucial to maintain the utmost cleanliness standards. The standards change from IOS8, (a measurement in maximum particles allowed) into an IOS9 cleanliness standard lab which has even more stringent standards of cleanliness. Therefore, barrels holding chemicals and material crucial for manufacturing must be thoroughly cleaned with a bleach solution as outlined by the FDA. This process desperately needs to be redesigned in order to increase the ergonomics of the barrel cleaning process, which would use a maneuverable, cleanable, and easy to use device for the workers who currently move material.

The current process of barrel cleaning is rudimentary, with workers moving barrels by hand, and cleaning all sides (including the bottom) by tilting these barrels and reaching under. The process lacks sufficient ergonomics and exposes the workers to a higher risk of injury, and overall poor working quality which limits the output of manufacturing. With worker safety as the number one concern to the company, this process is currently the weakest link in the manufacturing line. Not only having to move barrels which can weigh in excess of two hundred pounds the addition of strict cleaning standards opens a large amount of risk of injury or possible legal trouble with Amgen if a worker has a hand crushed by one of these drums, or throws out his back attempting to move one. With the help of a newer, more modern process with increased ergonomics, this situation can be avoided. The main goal is to curve this risk as much as possible, while still maintaining cleanliness. The cleaning process will ultimately decide the functionality of this device, whether a hand truck on rollers, or an automated machine. The new design to be presented will maintain the current standards outlined by Amgen and the FDA, while increasing worker safety, and the overall quality of the workplace.

The design that was chosen is a modified hand truck with rollers to allow rotational motion of the barrel while loaded. The limited space in the airlock made it so the mechanism cannot be too large or bulky to move around, while still maintaining the ability to load and unload regularly. (304) stainless steel was chosen in order to give the mechanism an anti-microbial surface (to avoid growth of any life being mold, or microbes which could compromise the medication in the lab being produced.) It is also sufficiently strong to absorb the load of the barrel after tilting. Another important customization of this hand truck is that its orientation would vary from standing vertically before lifting the barrel, and being leaned back to a forty-five-degree angle. This decision was made so the forces required to tip the barrel would be as minimal as possible, while making the barrel have the ability to rotate primarily on its round side. This is important because instead of a worker having to reach under the barrel while someone holds it, they have access to all sides, making the risk of injury negligible. With these additions to a hand truck design, the ergonomics of the cleaning process will be increased and able to keep the worker safer. This report outlines the final design specifications,as well as the factors that ultimately decided the dimensions, orientation angle, material composition, down to roller shapes and material. The addition of one of these customizable hand trucks would lead to a massive decrease in injury related incidents, and is crucial to Amgen so that legal trouble can be avoided.

2. Project Planning

2.1. Design Process

The first step to beginning this project was to create a project plan. A project plan is crucial to follow through the development of a solution to a problem. After the teams were created and introductions were made the project planning began. It was important to be able to set routine weekly meetings that worked around everyone's complex schedules. A meeting with our sponsor from Amgen was scheduled shortly after to go over the course deliverable and obtain a clear and concise definition of the problem that was present.

The team utilized the flow chart in Figure 2.1 to guide us through the design process.[2] After the problem was defined, the team proceeded to conduct research. Research was done first with all members performing a patent search. The team evaluated products that are in production from a variety of companies that handle material handling and barrel moving. Patent searches are an important part of our concept generations for there were components of other barrel tilting and moving devices that could be used to assist a worker at Amgen during the cleaning process. A patent research assignment was completed by each team member. Research was also done on the risk of injuries in a workplace environment, and statistics and evaluations of ergonomics on a worker. This is important as the design of our product which aims to improve the ergonomic rating. This was followed by concept generation and evaluations.

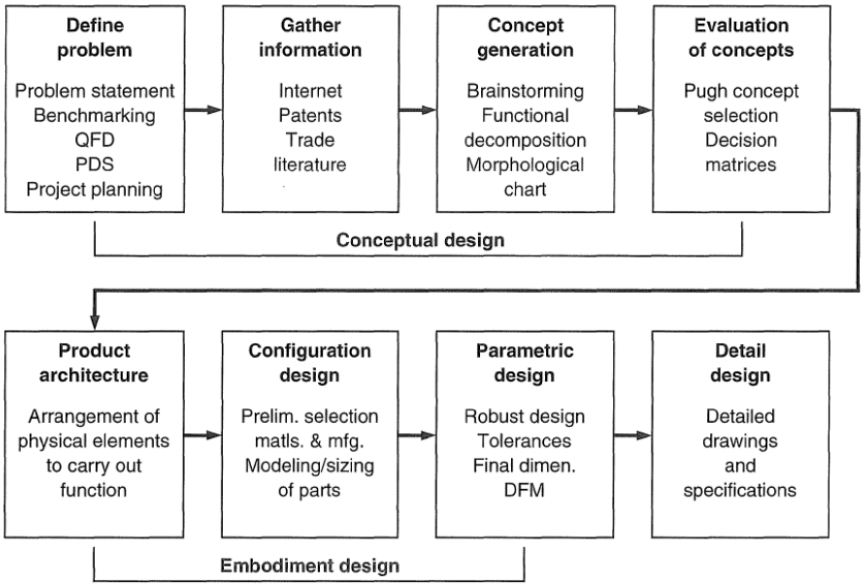


Figure 2.1: DESIGN PROCESS

2.2. Design Organization

Microsoft Office Project served as a way to manage each member's time throughout the two semesters. It is a program that organizes tasks so that the team could plan and visualize the amount of time for specific deadline. Along with dates for deliverables, Microsoft project was used to record important dates, such as meetings with our sponsor, meetings with our professor, and upcoming presentations. With it the team formed a Gantt chart, seen in Appendix A. The project plan was updated as events occurred, changes were made to primary concept components, and individual tasks were assigned. The use of this increased with order delays as well as continuous redesign of the product. Group members worked together on early assignments and later were given individual tasks to assure deadlines were met.Using the chart, the group could shift their focus to assist one another if a task was not complete as the deadline approached. This also kept track of important date such as presentations, poster, brochure, and report dates.

As the team entered the spring semester, the project plan helped in changing dates throughout the semester. Due to uncertainties in order placement, delivery time and expected manufacturing time, dates of certain check points fluctuated. As dates were updated the team could gauge the amount of time to dedicate to build, testing, and redesigning. Important dates such as meetings, presentation, showcase and design report are all included to ensure a completed project in May.

3. Financial Analysis

For this project, safety, reliability, and ergonomics has a heavier weight when compared to the cost that could provide those attributes. The team researched financial areas of this project, such as the cost of a device, manufacturing, and injury claims, especially back injuries, in the work place.

3.1. Cost of Materials

The cost of the device was estimated through the raw materials that would be needed to produce a single hand-truck. The hand truck does not have many intricate parts aside from the rollers and hook mechanism. The rest of the materials required can be purchased through wholesale vendors at standard dimensions.

Table 3.1: Cost of Materials

Materials	Unit Price	Quantity	Price
Corrosion-Resistant 316 Stainless Steal Tub, 0.250" Thick Wall, 2" x 2", 6’ Long	$261.00	4	$1044.00
Machinable 304 Stainless Steel Sheet, 2-1/2" Thick, 6" x 6"	$617.29	2	$1234.58
316/316L Stainless Steel Machinable Sheet, 2" Thick, 8" x 8"	$173.97	1	$173.97
Lightweight Nylon-Core Rubber-Tread Wheel, 5" x 2", Easy-Roll Bearing, for 1/2" Axle, 500 lb Capacity	$15.78	4	$63.12

3.2. Process

Amgen's current process only uses bleach during their cleaning process. The barrels are wiped down thoroughly a ten minute cleaning process called a wet lock. The amount of bleach used in their current process compared to the process using our device would remain the same. The amount needed would depend on the worker wiping the barrel which is about fifteen ounces per barrel.

Table 3.2: Cost of Bleach

Bleach ($/oz)	$0.16
Bleach per Barrel (oz/barrel)	15
Average Barrel per Day (barrel/day)	5
Total ($/day)	$1.85

To perform Amgen's current cleaning process, two workers are required. One worker tips the barrel on its edge while the other sprays and wipes down the barrel, going from barrel to barrel. Using our design concept, only a single worker is required. The device removes the second worker that initially was used to hold the barrel. This saves about twenty dollars a day, which in return, is about the same as the cost of materials for three devices in a years time.

Table 3.3: Cost of Worker

Workers in Process	1
Wage (per hour)	$20
Hours paid per Day	1 hour
Total ($/day)	$20

3.3. Injury Claims Analysis

Manual labor workers in a facility are exposed to risks of injuries, especially back injuries. For this reason, government regulations restrict companies from having their workers perform a task that can lead to injuries. Table 3.4 shows a typical scenario for back injury claims at a work place.[3] The company can lose money in two ways due to a claim. There is a very high percent of settlements for the worker so the company pays out. The second way is through the legal process and lawyer fee which takes, on average, about eighteen months. During this time, OSHA and the FDA can step in to inspect the facility where the infraction took place, and to see the process performed. This can lead to extensive time with no production (no revenue). Amgen's current process uses two workers, there is twice the chance of injures that can result in this high cost.

Table 3.4: Injury Statistics

Workers per Barrel	2
Wage Total	$40/hour
Potential Injury Claim (On Average)	$23,600
Time (Legal Process and Lawyer Fees)	17.9 months
Potential Settlements	74% of cases

3.4. Build Financial Analysis

The Financial analysis was split primarily into two main categories. The first, the build cost of our prototype, was the cost specific to parts needed in order to make a functioning prototype. The second, being the cost of an actual build that would meet the safety standards for workers, as well as for entry into the airlock. The cost difference of the two should be substantial since the final build for Amgen would have to be entirely sealed, completely made of stainless steel, water proof, and equipped with guards to eliminate pinch points for Amgen employees. Our build, will be fabricated from hot rolled steel bars, and the internals will be more exposed so the team can view all moving parts during the testing and operation of the device. Also included in the actual build is that the rollers, wheels, and connections are to all be welded in place to increase the structural integrity, along with an increase in clean-ability. Having the welding done, specifically stainless steel welding, will both require an additional cost of a welder, along with the materials for welding stainless steel. For the prototype, the frame, rollers, and hooks will be bolted on in order for rapid assembly, and proof of dimensions. If the barrel has trouble rolling after being lifted, the bolts can easily be loosened and reattached in the appropriate locations. For our prototype, the final cost of materials came out to be $1,118.09 including the wheels, rollers, frame material, wiring, battery, actuator, and fasteners. For a build of Amgen qualifications and requirements, the cost of materials $2,050. This doesn't include the cost of fabrications, taxes on the parts (exempt for the school build), and cost of hours for a welder, and employees to assemble the lift. Amgen specifically had preference for safety, durability, ease of use, and clean-ability over cost, which ended up raising original estimates of $800-$900 for a manual hand truck, to almost $3,000.00 for a lift-assisted stainless model.

		Initial Build				Finished Product		
Received?	Quantity	Description	Unit Price	Subtotal	Quantity	Description ALL STAINLESS	Unit Price	Subtotal
Yes	1	5 in caster wheels	$69.99	$69.99	1	5 in caster Wheels	$69.99	$69.99
Yes	1	2" x 2" x 11 gage (26 feet)	$193.44	$193.44	1	2" x 2" x 11 gage (26 feet)	$538.20	$538.20
Yes	2	hot rolled steel plate .25" x 8" dia	$9.53	$19.06	2	stainless steel plate .25" x 8" dia	$32.95	$65.90
Yes	1	1 1/2" x 1 1/2" x 11 gage (6 feet)	$30.32	$30.32	1	1 1/2" x 1 1/2" x 11 gage (6 feet)	$96.20	$96.20
Yes	1	bolts .25" x 20 x 3" full thread 100 pk	$22.41	$22.41	1	2" x 2" x 1/8" (2 feet)	$23.26	$23.26
Yes	1	flat washers 100 pk	$4.29	$4.29	1	3" dia 304 stainless steel bar	$145.16	$145.16
Yes	1	hex nuts 100 pk	$6.23	$6.23	1	TPR rubber coaster wheels 2 pk	$6.95	$6.95
Yes	1	2" x 2" x 1/8" (2 feet)	$5.74	$5.74	1	stainless steel hex bolt	$31.51	$63.02
Yes	1	3" dia hot rolled A-36 Steel	$57.50	$57.50	1	bearings (3/4" inner dia, 1.58" outer	$6.37	$38.22
Yes	1	TPR rubber coaster wheels 2 pk	$6.95	$6.95	1	Parrot Beak hook	$180.00	$180.00
In Transit	2	steel hex bolt	$31.51	$63.02	2	fasteners for linear actuator (stainless)	$50.00	$100.00
In Transit	6	bearings (3/4" inner dia, 1.58" outer	$6.37	$38.22	6	bearings (3/4" inner dia, 1.58" outer	$6.37	$38.22
Yet to Order	1	Parrot Beak hook	$180.00	$180.00	1	linear actuator (kinetic load of 550 lbs)	$553.00	$553.00
Yet to Order	1	fasteners for linear actuator	$20.00	$20.00	1	Duralast 12 V 1000 Ah battery	$136.99	$136.99
Yet to Order	1	linear actuator (kinetic load of 300 lbs)	$90.93	$90.93				
Yet to Order	1	12 V 750 Ah battery	$69.99	$69.99	1			
HOURS	20	Work hours of students (not including Dave)	$0.00	$0.00		NEED HOURS		
	4	Work hours of Machinists/Welders	$60.00	$240.00				
			Total:	$1,118.09			Total:	$2,055.11

Figure 3.1: SPRING PROJECT PLAN

4. Patent Searches

Patent searches were a key process before concept generations. To search for material handling devices with a focus on barrel moving since Amgen's material come to the facility enclosed in barrel containers. This search resulted in many modified versions of an ordinary hand truck, all to improve lifting barrels specifically. From these patents, which include and abstract and an image, the team was able to relate real products and generate a useful combination of ideas to create a solution for Amgen.

4.1. Knock down barrel handling apparatus

Patent Number: US 4,335,990
Patent Date: June 22, 1982
Current U.S. Class: 414/457
Current International Class: B62B 1/00

Abstract: "Barrel handling apparatus which includes a cradle having handles, a pair of side rails, and wheels for supporting the side rails is structurally interrelated so as to facilitate knock down of the apparatus to minimize the volume needed in order to package and ship the apparatus. The wheels are removably connected to the side rails. The side rails are removably connected to the cradle. A cross brace is removably connected to the cradle and side rails." [4]

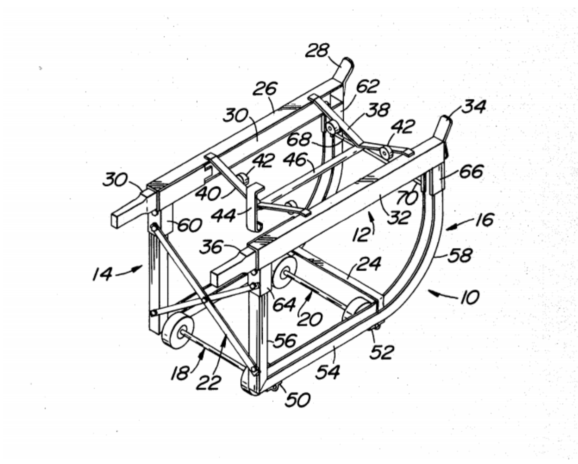


Figure 4.1: KNOCKDOWN BARREL HANDLING APPARATUS

This patent is relevant to to how we came to our primary concept. The apparatus is it to be about the height of the barrel with skis and a adjustable hook to clap down on the barrel. This design also includes rollers so the barrel is able to rotate in the horizontal orientation. this may be intended for barrel pouring but is beneficial in the cleaning process.

4.2. Barrel mover

Patent Number: US 5,042,962
Patent Date: August 27, 1991
Current U.S. Class: 414/452
Current International Class: B62B 3/10

Abstract: "A hand truck particularly adapted for the movement of extremely heavy barrels has a wheeled base platform to which is pivotally attached a barrel holding frame having a forward vertical position and a braced reclining position against the truck. The barrel frame has its pivot point located at a sufficiently forward and low position so as to achieve approximately a ninety to one lever arm from the truck handle to the pivot point. The barrel frame has two lower barrel holding hooks. A pivoted barrel grasper, a lever arm having a pair of offset, facing grabber hooks, is positioned by means of a moveable pivot pin so as to engage the top lip of a barrel. In use, the barrel truck is moved in the erect position adjacent to a barrel; the grasper is positioned so that the grabber hooks enclose the upper rim of the barrel. A downward motion on the lift arm, over the extended lever arm provided clasps the edge of the barrel, lifting it slightly and permitting the bottom support hooks to be slid under the bottom edge of the barrel. The lifting lever arm is then released and a sliding barrel lock hook locks the upper edge of the barrel to the barrel frame. The frame and barrel then may be tilted to a moving position; the separate frame pivot axis creates a large lever arm a single individual, working against a practical handle height, may tilt over a barrel weighing to 1,500 pounds. The barrel frame, when tilted, is supported entirely upon the truck which may then be manipulated to move the barrel to a new location. No strength is required on the part of the individual to support the tilted barrel during the movement process." [5]

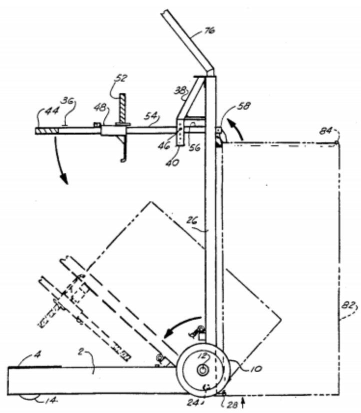


Figure 4.2: BARREL MOVER

This device relates to the problem of forces required to move barrels within the facility. It uses a lever system to reduce the amount of force to tilt the barrel. The barrel also remains in a tilted position so that to assume the center of mass is along the the intersection of the the pivoting point so no forces are required to to support the tilted barrel.

4.3. Hand Truck for Moving Large Drum

Patent Number: US 5,678,976
Patent Date: October 21, 1997
Current U.S. Class: 414/448
Current International Class: B62B 1/26

Abstract: "A pair of rigid, spaced apart arms (30,31)extend outwardly to one side from the upper end of an upright, tiltable frame 20 and a pair of spaced apart wheels 40 extend outwardly to the one side from the lower end of the upright frame for transportably supporting the frame on a flat surface. A rigid lever arm 50 and rest 60 affixed to the frame extend from the other side of the upright frame. The spacing between the arms and wheel supports is predetermined to allow the arms to be engaged underneath the upper rim adjacent the widest diameter of a standard, hot, sealed, 55 gallon drum filled with cooked food products and liquid by raising the lower arm and moving the arms into position under the rim until a restraining strap contacts the drum cylindrical wall. The drum is then lifted by pulling down on the lever arm fulcruming on the wheel support points to swing the bottom end of the drum inboardly while supported at its upper end on the arms until the center of gravity of the drum positioned directly over the wheel support points on the surface and the drum straddled by the wheel supports. The drum may be easily transported in this position, or put at rest by further lowering the lever arm until rest 60 contacts the surface and the center of gravity of the drum is intermediate the three-point surface contact. A single operator performs the entire moving operation without any personnel touching the drum." [6]

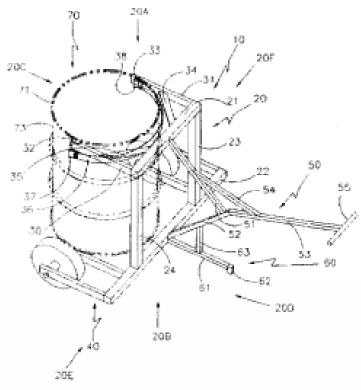


Figure 4.3: HANDTRUCK FOR MOVING LARGE DRUMS

This patent has a unique way of moving barrels unlike a traditional hand truck. The wheels being positioned on the outer side of the barrel allows the the barrel to be lifter directly up. This patent was initially useful in our concept generations for an automated system for the barrel could be placed more precisely.

4.4. Handtruck with foot tilt device

Patent Number: US 9,096,251
Patent Date: August 4, 2015
Current U.S. Class: 414/457
Current International Class: B62B 1/264

Abstract:"Barrel handling apparatus which includes a cradle having handles, a pair of side rails, and wheels for supporting the side rails is structurally interrelated so as to facilitate knock down of the apparatus to minimize the volume needed in order to package and ship the apparatus. The wheels are removably connected to the side rails. The side rails are removably connected to the cradle.

A cross brace is removably connected to the cradle and side rails." [7]

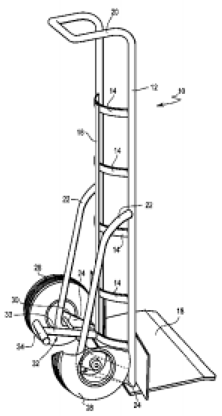


Figure 4.4: HANDTRUCK WITH FOOT TILT DEVICE

This patent, as simple the design, is useful in making a small and easy to use device for Amgen. It addresses the problem of having to move heavy barrels with a common solution and an added advantage.

5. Evaluation of Competition

During the evaluation of different available material handling devices, there was a massive commercial market for the goal of solving similar material handling issues faced by pharmaceutical companies around the world. There is a large array of both mechanical handling mechanisms, as well as electric, hydraulic, and motorized systems designed for attachment to a hand cart. Many of these mechanisms are designed by a few specific companies including: Global Industries, Uline, Grainger and many others.As stated by our sponsor, Chuck Taylor, it is very easy to get lost in all of the commercially available systems out there, but unfortunately, many of these products do not solve the problem of barrel motion while meeting the specific standards outlined by Amgen. A large majority of these products do ease the motion and tilting of barrels, but run on a power source that is unavailable in the airlock, such as gas powered mechanisms or combustion engine attachments. Some other factors that restrict many of these devices is that many of these are simply designed for movement, rather than a cleaning process. Many of these are not made of the specific anti-microbial material that is required to simply be in the airlock, and also contain flat or bowl shaped surfaces where the bleach solution could sit during the cleaning process. Our sponsor has let us know that puddles cannot form on the device, because this could effect the clean-ability of the surface, or potentially effect the integrity of the frame or bearings. With this considerations, all of the competition was eliminated fairly quickly and the solution has been determined to be a custom project. However, in most of the competition, there are significant components of devices that could be included in the projected solution to the Amgen difficulty with barrel movement. Some of these components include frame layouts (with different dimensions based on our specific barrel size and weight) as well as roller set ups that are seen in some of the Uline barrel mixers that have been looked into. With a combination of necessary components found from different devices, the competition ultimately assisted heavily in the formation of our current design. Only our current design is based completely off of the needs of our customer.

6. Specification Definition

The initial problem presented by Amgen was to be able to move barrels of raw medical material while improving the safety for the workers performing the process. This problem was presented with many constraints and requirement that must be met to be approved by Amgen, OSHA, and FDA regulations. Consulting meetings with Amgen provided information so that the team was able to construct a table of design specifications prior to concept generations. These specification are import to maintain and check our concept, device will meet standards and all areas of the problem are accounted for.

6.1. Barrel Sizes

Amgen is a bio medical company that is involved with producing numerous medicines from their facilities. Each medicine is produced from multiple types of raw materials. These materials arrive to their facility in barrels that have variety in dimensions. This is a priority specification that must be addressed in the solution to Amgen's problem. The use of a single device to assist a worker is the cleaning process of the barrel must be compatible with any size barrels. The sizes of barrels and other physical defined dimensions are given in Figure B.1. Amgen is focusing on handling their heavier barrels that have two dimensions. The two barrels a conical and vary in height in about three inches. The device must be able to be adjusted as needed while maintaining a simplistic design to encourage workers to utilize it.

6.2. Environment

While Amgen's facility in West Greenwich Rhode Island is fairly large, the room where the barrels enter is very small. The dimensions are given in Figure B.1 under service environment. This is the room where the barrels must remain wet for ten minutes. The room also has a demarcation line that currently run down the middle of the room to distinguish the "clean" side appose to the "dirty" side. The barrels must remain on the dirty side until the cleaning process is complete, to when they are transported over to a clean pallet. This demarcation reduces the amount of area to where the device can be used. The demarcation line is allowed to be redesigned to accommodate a design and its process. There is power that is available within the room. Punctures within the ceiling of the airlock is not allowed in order to maintain pressure distribution.

6.3. Clean Ability

Amgen works with medical material which poses a large risk for contamination hazards. The reason for the cleaning process of the barrel is to decrease the risk as the materials makes it way through the airlock and through the facility. The device must be easily cleaned or dismantled for cleaning. There is a selection of materials that is allowed within these airlocks. The collection of dirt, and moister is prohibited. Therefore no porous materials are allowed to be used in the cleaning process. Hydraulic device are looked against due to the collection of dirt.

6.4. Safety

Safety is the main focus on this project. Increasing the safety of the workers performing the clean process of the barrels as they enter the airlock. The weight workers are lifting are above OSHA's regulations as of the current process. This project aims to lower the force required by workers to handle the barrels and decrease the probability of injuries during the process.

6.5. Cost

The cost of the device will be is insignificant to achieving the the desired goal for safety the Amgen has stated. For Amgen has already spent a hundred thousand dollars on a machine that is able to move a single barrel at a time but with an over complicated system and multiple attachments for different sizes. This makes the device less likely to be used by the workers. The team aims to create a low cost device that can be used not only by Amgen but other bio medical companies and that will be more appealing to workers as well.

7. Conceptual Design

7.1. Keith Paiva: Concept Generation

1. Two Post Columns:

Figure 7.1: TWO POST COLUMN

A motor driven suspension to lift barrels up. The barrels would be attached to cables in a way such as a collar or clips. this idea helps in making all sides of the barrels are accessible to be cleaned and a way to lift barrels to be transferred. Barrels being suspended does have a risk factor, including if multiple barrels are linked to one another.

2. Barrel Pouring Lift:

This concept is based off existing barrel pouring devices. This is a means of moving the barrel but the accessibility is low. the worker can not get behind

Figure 7.2: BARREL POURING LIFT

the barrel and can not clean area where barrel is held.Also the rotational degree of motion isn't enough. This would be fairly larger than the barrel to reach onto the pallet to obtain the barrel.

3. Ring Clamp :

Figure 7.3: RING CLAMP

This concept would be fastened to the barrel allowing other devices to attach to it. Since there isn't many gripping areas on the barrel for the worker or machinery to grasp the barrel, this concept would be beneficial to be used with another. One down side would be the variety of collars or creating one that can be adjusted easily.

4. single column hoist:

Figure 7.4: SINGLE COLUMN HOIST

Overhead pulley hoist that attaches to barrel to lift to clean and rotate in order to clean side. This would be an individual column mounted in the floor of the room. these columns are able to rotate to transport the barrel. This has a risk of the barrel falling also. Force required by the worker during process would be minimal.

5. Arm Holder:

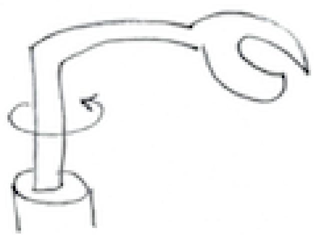


Figure 7.5: ARM HOLDER

A gripping arm that surrounds the barrel of interest. This multiple jointed arm can adjust and maneuver to grasp the barrel. The operator will use a controller to set the size of barrel option and the grip has rollers to rotate the barrel. the barrel will stay in the air with a high friction force apposing gravity. the arm can then transfer barrel over the demarcation line.

6. Cart 1:

Figure 7.6: CART 1

Normal hand truck with stand to lay on side. This would be able to go to the pallet and tilt the barrel down. There would be wheels attached to the rear so that the hand truck is now able to move about the room or to the be delivered to the clean pallet.

7. Cart 2:

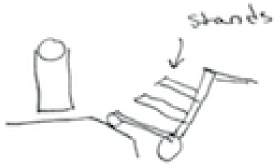


Figure 7.7: CART 2

An incline ramp in the room allowing barrel to be tipped from the pallet height onto cart that has supporting stands. the barrel is now in its tilted position where it can now be cleaned as so a worker is tilting it.

8. Booth cleaning:

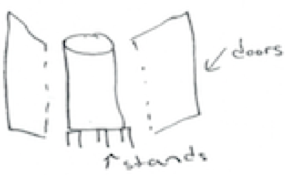


Figure 7.8: BOOTH CLEANING

Barrels would be placed onto thin supporting rods to maximize area seen by nozzles in an enclosure (booth). It would then continuous spray barrel with bleach to clean it during ten minute wet lock period. This a means to improving clean ability but not the movement of the barrel. the booth would need another device to accompany it.

9. Multi-Cart:

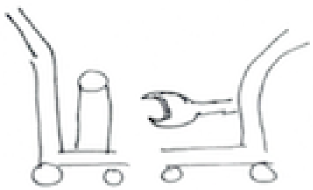


Figure 7.9: MULTI-CART

Carts are equipped with a gripping mechanisms being able to grip onto barrels and allowing them to be transferred between one another or in docking them into a cleaning booth or last semesters lifter.

10. Lifting Cart:

Figure 7.10: LIFTING CART

Cart with raising and lowering devices. This device can be raised to the pallet height so the barrel is placed onto it. Then can be raised or set to an inline to assist for easy cleaning of barrels

11. Lifting Bar:

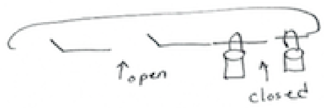


Figure 7.11: LIFTING BAR

A horizontal bar that would go across the room above the where the barrels are placed when the enter the room. Hook ideas to attach to barrels allowing to be suspended as bar moves higher. The idea is be able to lift multiple barrels at once so the cleaning phase occurs to amount of barrels needed that day.

12. To cart pusher:

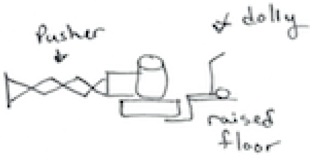


Figure 7.12: TO CART PUSHER

A device to remove barrel from the pallets. This device would simply be the first step to a new process. It would slowly push the barrels of the pallet into a lifter, booth or other devices. No physical effort would be required here.

13. Drum Roller:

Concept based on Knockdown barrel Patent on page 11. Small tilting cart with rollers allowing barrels to rotate leaving all areas of the barrel to be cleaned with Amgen's current process by their workers. The drum roller would utilize leverage to rotate the orientation. Wheels on the back side also

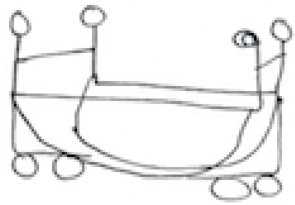


Figure 7.13: DRUM ROLLER

allows this device to be moved about the room.

14. Suction Cup:

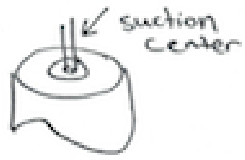


Figure 7.14: SUCTION CUP

Amgen recently acquired a device to assist in lifting barrel by use of suction cup method. The device uses multiple attachments and the controls are far complex. The rate that workers move barrels are also too slow and unpractical compare to the worker waning to slide. Improving this device to a small scale and easier to function.

15. Bar and Cage:

Cage houses a small motor and bar to attach to barrel on its top to lift. Once lifted it is now able rotate barrel. Power supply for the motor can be placed on cart. The electronic components and wiring will need to be securely covered due to the bleach liquid during the process of clean could damage the device.

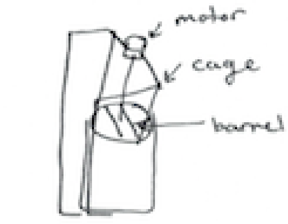


Figure 7.15: BAR AND CAGE

16. Two arm rotate:

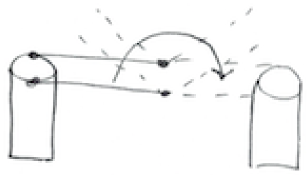


Figure 7.16: TWO ARM ROTATE

Lifts bars with two sets of pins. One at the pivot and other where the barrel is attached to the bar. With a 45 or 90 degree rotation will have the barrel in the air to be cleaned, then continue to the clean pallet over the demarcation line. The pivot point would be on the demarcation line.

17. Entrance slide:

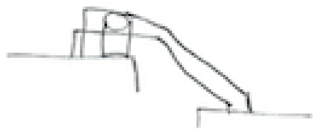


Figure 7.17: ENTRANCE SLIDE

Barrels will enter the room through a slide system. This is to move barrels more quickly and incorporate a cleaning process along with this. This would become a more automated system.

18. Two pole pinch:

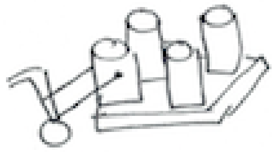


Figure 7.18: TWO POLE PINCH

Two bars connected to a dolly structure. The bars will pinch the barrel allowing the worker to tilt the barrel to clean underneath or moved to a cleaning devices. the bars can come together closer depending on the the diameter of the barrel entering the facility.

19. Claw Crane:

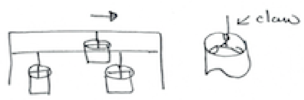


Figure 7.19: CLAW CRANE

A claw style clamp will be lowered to grasp a barrel and continue to lift and translate possibly thorough stages of clean coming to an end on the clean side of the demarcation line onto the clean pallet.

20. Team ‘15-’16 Lifter:

Figure 7.20: TEAM '15-'16 LIFTER

Last year's attempt at the problem involved a lifter to move barrels to a conveyor belt system. The cleaning process is interesting but doesn't address the barrel movement from the pallet to the lifter.

21. Shoot system:

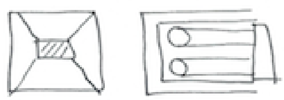


Figure 7.21: SHOOT SYSTEM

utilizing the lifter design from last year. The entire pallet would be placed on the lifter and the barrels will be tipped into the shoot the guides the orientation of the barrels and exit and slides to conveyor system.

22. Conveyor System:

Figure 7.22: CONVEYOR SYSTEM

Once barrels on the conveyor lifting mechanism moves up and down to stop the barrel for intervals during the cleaning process for rollers to pass to next area until cleaning process is completed and barrels exit.

23. Raise Floor:

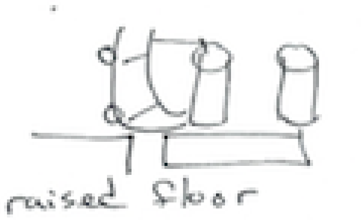


Figure 7.23: RAISE FLOOR

Many dollies are able to lift barrels that are resting on floor rather than a higher position. Raising the floor the height of the floor creating docking stations for the pallets. This makes it easier for trucks and cart more accessible to barrels.

24. Barrel Clips:

Figure 7.24: BARREL CLIP

Clips to attach to barrels, and then supply a point to be suspend. In this position the barrel can rotate and workers can move barrel to clean pallet.

25. Rails:

Lifter would be used to rails. Multiple stoppers to give time to cleaning the barrel. Multiple rails to perform more cleanings at once

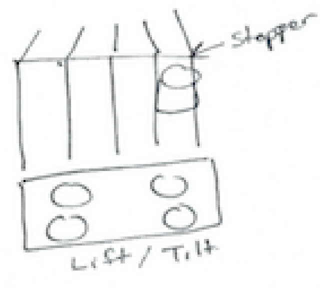


Figure 7.25: RAILS

26. Tumbler:

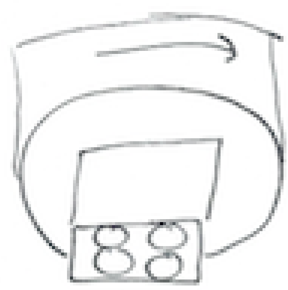


Figure 7.26: TUMBLER

Lifter inserts only barrels leaving the pallet and once the barrels are inserted, the device rotates, applying bleach to the outside of the barrels. This would be a cleaning solution utilizing the previous team's design.

27. Locking Pallet:

Figure 7.27: LOCKING PALLET

Connects to base pallet and locks barrels in an enclosure. When rotated they can rotate inside the enclosure for workers to clean all sides. Lifter would provide the rotation.

28. Side Pallet:

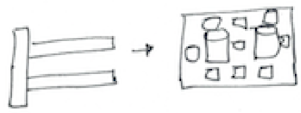


Figure 7.28: SIDE PALLET

A pallet with stands to support barrels in horizontal position. Engages base pallet from side to hold barrels when rotated and can be cleaned with more access available.

29. Barrel spacing roller:

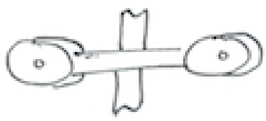


Figure 7.29: BARREL SPACING ROLLER

Spacers to be placed between barrels that will allows barrels to be stacked sideways and rotate to be cleaned. This space can be used with the above concepts.

30. Automation sprayer:

Barrels roll passing sprayers to be coated in cleaning solution and blowers to dry, exits to clean pallet

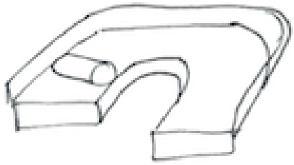


Figure 7.30: AUTOMATION SPRAYER

7.2. Matt Perry: Concept Generation

1. Fork-lift Gripping attachment

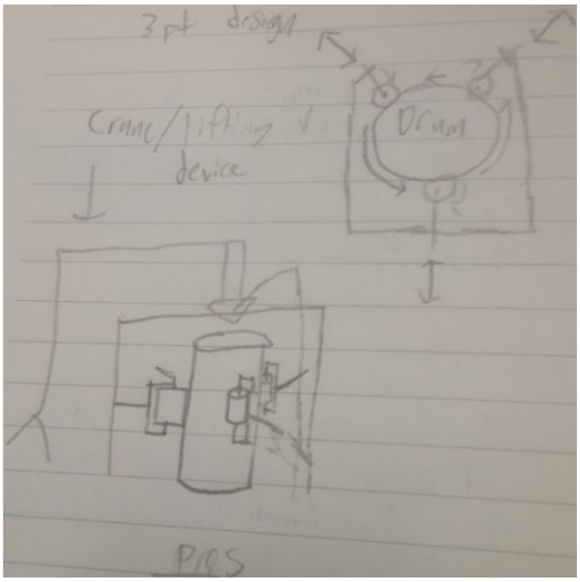


Figure 7.31: FORKLIFT GRIPPING ATTACHMENT

This is a design for a gripper of barrels that could be attached to a forklift or hand truck. This component would both grip and rotate the barrel without touching the top or bottom, making it so all sides can be cleaned while the barrel can be hand rotated.

2. Half-clamp with axis rotator

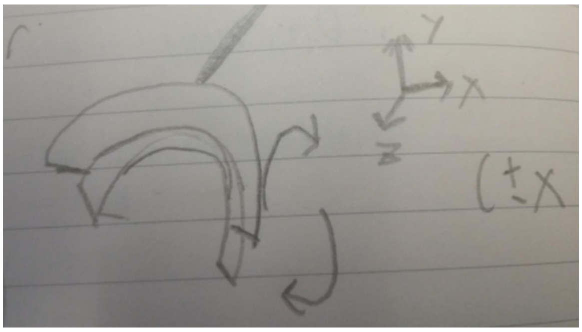


Figure 7.32: HALF CLAMP

This is a model of a potential gripping feature where the barrel would be clamped by half of the barrels diameter. This would allow a rotation so the bottom and top of the barrel are easily accessible for cleaning, would out having to go under the heavy load and risk potential injury.

3. Rolling arm bearing design

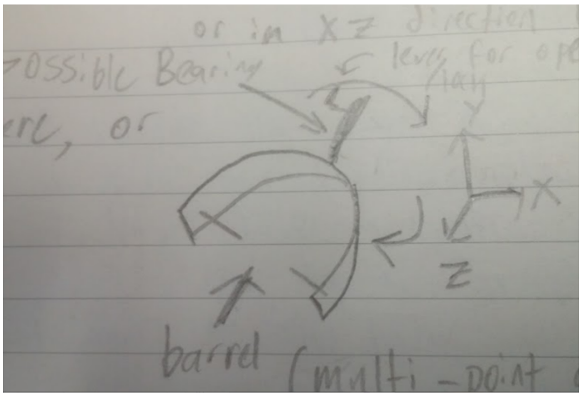


Figure 7.33: ROLING ARM BEARING

This clamp component wouldn't have a frame; instead there would be a bearing in the supporting arm that is free rotating, and allowing cleaners to rotate the barrel as needed for cleaning.

4. Grip method Concepts

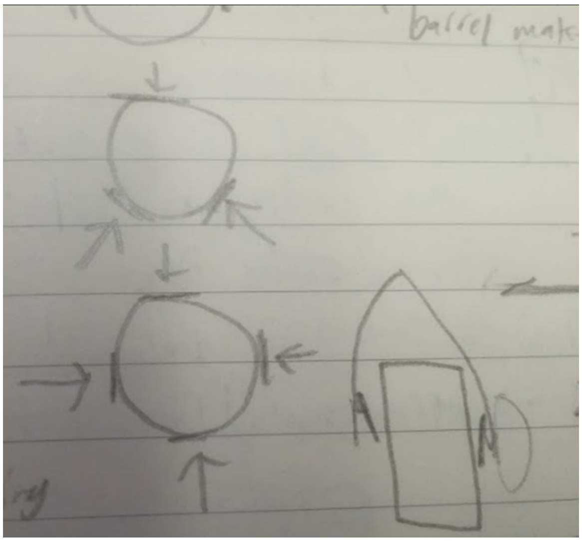


Figure 7.34: GRIP METHOD

These are some different methods for the grippers shown above. Here we have two, three, and four point clamps. Further research would be needed and a compromise would be necessary to maintain accessibility with a low number of points, yet sufficient grip with a larger number of points.

5. Mechanical hydraulic arm assist

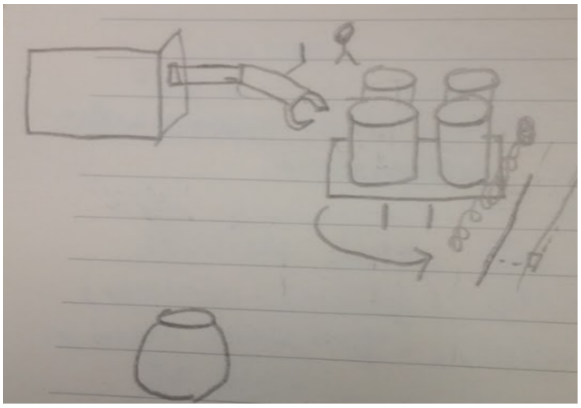


Figure 7.35: HYDRAULIC ARM

Here we have a mechanical hydraulic arm that could assist the user in the actual lifting force needed to lift and tilt the barrels. There would be a manual controller, with a person actually using this device similar to a vice grip with power lifting capability.

6. Round-edge clamp system

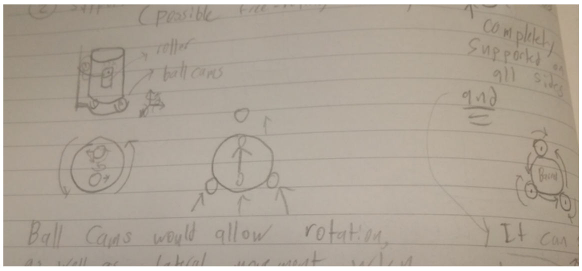


Figure 7.36: ROUND EDGE CLAMP

This idea includes a clamping design on the round edge of the barrel, as well as a bottom support. These bottom supports would be ball bearing cams. This allows both rotation of the barrel as well lateral movement as the barrel is being gripped by the rollers.

7. Adjustable hand-truck with rollers

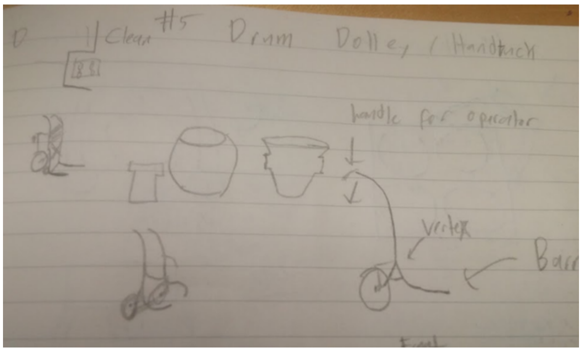


Figure 7.37: ADJUSTABLE HAND TRUCK

This is a hand truck designed for barrel movement with adjustable arms for different sized barrels. This would prevent injury to workers from potential barrel drops because the barrel would be completely supported.

8. Bottom rolling support for hand truck

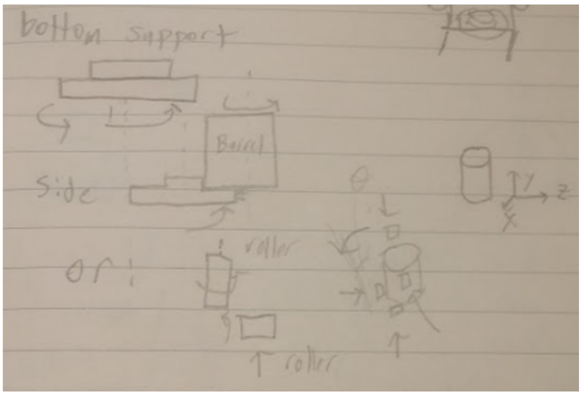


Figure 7.38: BOTTOM ROLLING SUPPORT

Here we have a bottom rolling support which grips the bottom edge of the barrel and allows it to rotate.

9. Hand-truck with both supporting rollers and bottom ball bearing joints

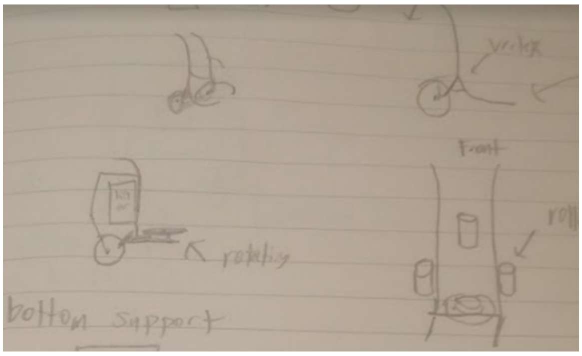


Figure 7.39: ROLLERS AND BOTTOM BALL BEARING

Here we have a hand truck with supporting rollers and rolling bottom pivot making the barrel easier for cleaning and more accessible. Potential draw backs are that physical force is still required, although a favorable mechanical advantage.

10. Cone-shaped grips, which aid vertical placement during rotation

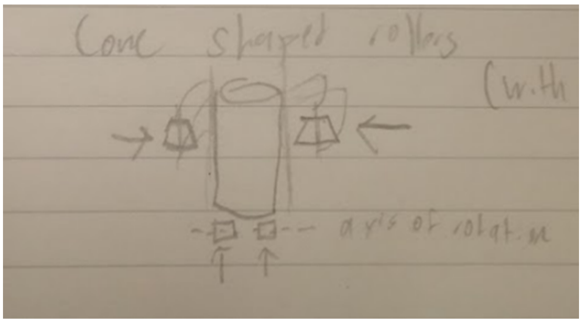


Figure 7.40: CONE SHAPE GRIPS

This is a diagram for cone shaped grips that could keep the barrel from slipping downward because of both the inward and vertical component of the friction applied. This could potentially allow free rolling and completely accessible sides, but grip force could be difficult to come up with without hydraulics.

11. Large spinning lever arm

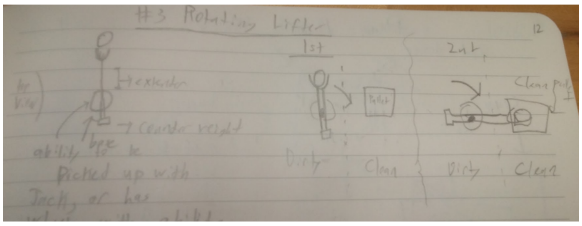


Figure 7.41: SPINNING LEVER ARM

This concept is of a lever arm that would grab the barrel, and spin, bringing the barrel over the line of demarcation separating the two different cleaning standards. This idea is good for movement, however further additions would be needed to incorporate easier cleaning.

12. Demarcation line barrel movement

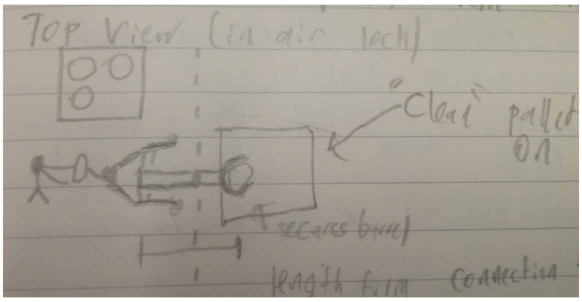


Figure 7.42: DEMARCATION MOVEMENT

This is a potential concept for a technique of barrel movement over the demarcation line after clean barrels are ready for movement.

13. Two man operation design (floor layout)

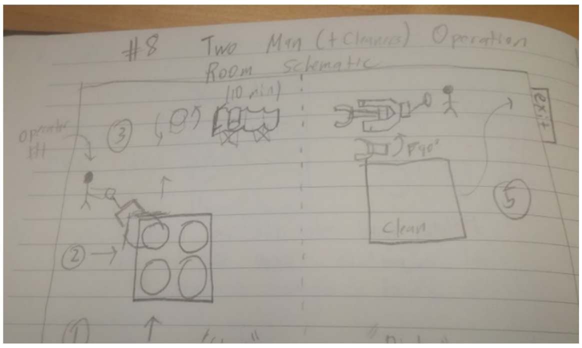


Figure 7.43: FLOOR LAYOUT

This design concept is a floor design for material handling. This line of demarcation would remain constant, while two operators used two different hydraulic pincers to move barrels. The first stage would be entry into the lock using a pallet mover. This would be followed by one of the operators grabbing and rotating the barrel onto a cleaning rack. After cleaning a designating “clean side” barrel mover would grab the barrels off the cleaning rack, and place them on a “clean” designated pallet. This process would eliminate potential injury due to physically lifting and tilting the barrels, and would speed up the barrel moving process.

14. Modified pallet jack

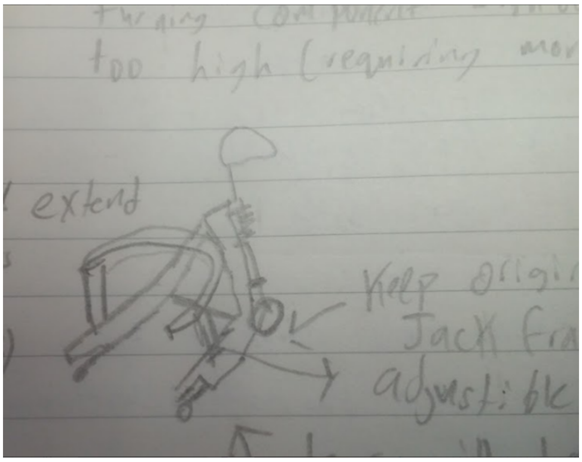


Figure 7.44: MODIFIED PALLET JACK

This idea is similar to the pallet jacks that are currently being used at the Amgen facility. These frames would be altered in order to grab the barrels by the bottom edge and sides. This would make injury negligible with proper training and the employees current comfort ability with pallet movers.

15. Rolling barrel grabber with gear advantage

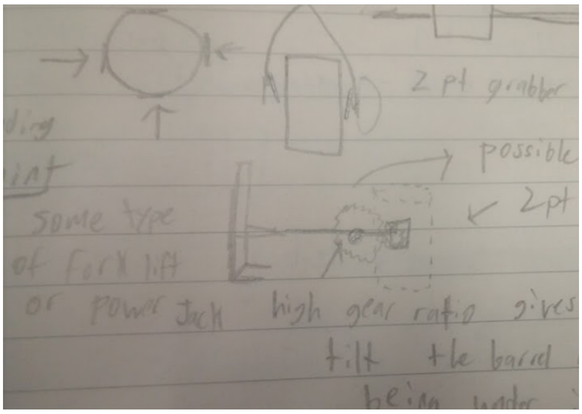


Figure 7.45: GEAR ADVANTAGE

Here we have a barrel grabber that would either roll on wheels, or be attached to a hand truck. This griping device would have a geared axis as well as a rotation axis. The dotted lines represent the location of the barrel. The high gear ratio would be attached to either a steering wheel or lever, and allow the operator to spin the barrel (on an axis toward or away the drawing) with minimal effort, and no actual power source needed. Some potential draw backs are that the gears would need grease, which could potentially compromise the clean workplace environment.

16. Barrel hook actuator

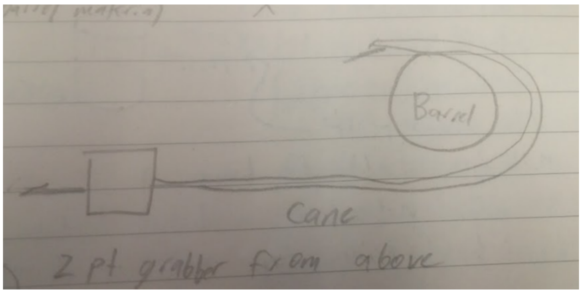


Figure 7.46: BARREL HOOK ACTUATOR

This device is a simple hook mechanism, attached by a gear box that would both extend the hook outward, and spin it 90 degrees so it goes around a barrel. From this point, the hook would be drawn toward the gearbox, dragging the barrel with it.

17. Hydraulic barrel mover (grabber design)

Here we have another option for the hydraulic pallet mover that would have a swinging lever arm on the front. This arm would be extended outward until an operator surrounded the desired barrel, and activated the arm that would move it toward the jack, which could then lift up the barrel effortlessly.

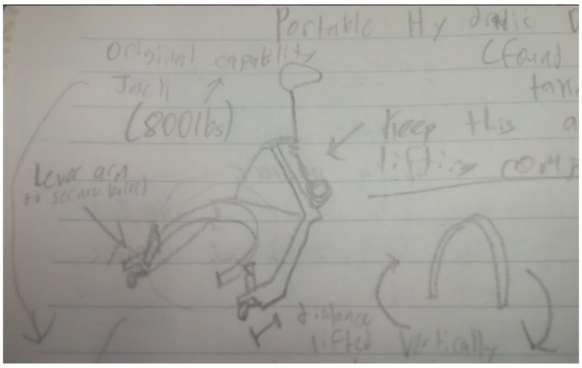


Figure 7.47: HYDRAULIC BARREL MOVER

18. Four point grabbing roller arms

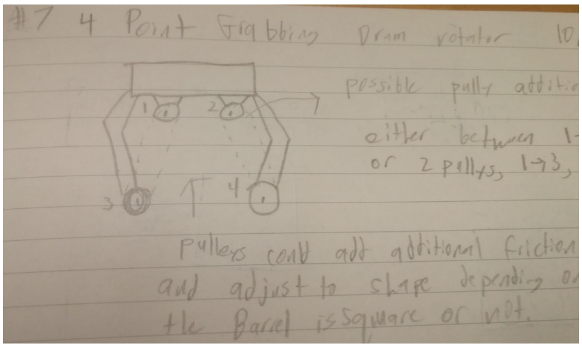


Figure 7.48: FOUR POINT GRAB

This concept is another griping design that would wrap around a barrel without needing an excess of points. The pulleys would be what grips the barrel and allows the barrel to both be lifted, and allow access to all sides for cleaning if it were attached to a rotating lifting arm.

19. Spinning lever arm with extender

Here we have a similar design to the spinning lever arm, but this one would have an extender within the arm to extend the barrel across the demarcation line without touching the floor. This is a decent concept, would workers

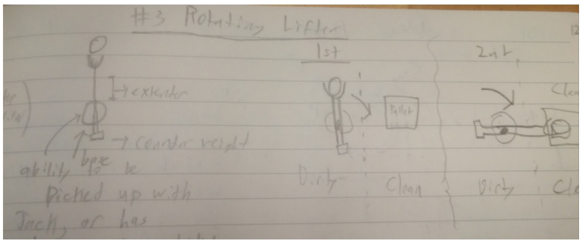


Figure 7.49: SPINNING LEVER ARM

would have to be careful about a large rotating mechanical device in their workplace that could injure someone.

20. Rotation addition to pallet mover

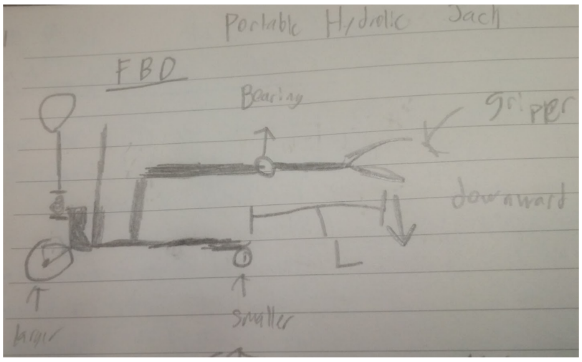


Figure 7.50: ROTATION ADDITION

Here we have another addition to the modified pallet mover; however this one would incorporate a spinning bearing in the center of the lever arm so the barrel can be rotated from its original upright position. Rollers could be incorporated to grab the barrel and move it inward toward the device.

21. Frame addition to the hydraulic lift

Here is a frame concept for the hydraulic lift. This would make it easy to surround a barrel and would grip the barrel at its center of mass. This would minimize resistance as the barrel is spun making it easier for the crew

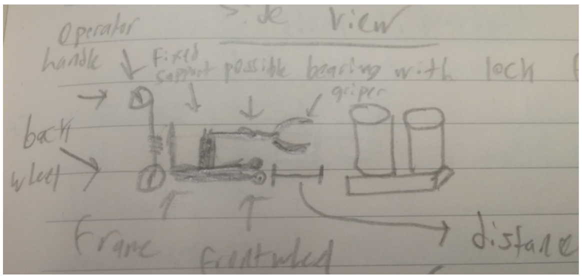


Figure 7.51: FRAME ADDITION

to clean.

22. Patent search barrel lifter

Figure 7.52: PATENT BARREL LIFTER

This is a design found during the patent search. This is a barrel lifter which would greatly reduce the physical work done by crew and decrease potential injury.

23. Mechanical barrel mover

Figure 7.53: MECHANICAL BARREL MOVER

Here we have a metal mechanical barrel mover. This one incorporates an electric power source and rotator. As seen this would work for both metal and plastic barrels, however further modifications would be needed so that the cleaning process would be easier.

24. Global Industries Barrel Lift

This is a barrel lift made by Global Industries (www.globalindustrial.com). This would make it easier for rapid motion of barrels, as it would be easy to keep clean. However the question of accessibility of the sides would not be answered. An addition of rollers to the current grips could allow a user to gain access to the round side of the barrel. [8]

25. Global Industries barrel tilt-assist

Figure 7.54: GLOBAL INDUSTRIES BARREL LIFT

Figure 7.55: GLOBAL INDUSTRIES TILT ASSIST

Also brought to us by Global Industrial is this barrel tilter. With some modification and addition of rollers, this could be a very desirable idea. Not only is this a very simple, yet effective, it is also under 60 dollars per unit. Having a multi unit process could greatly increase productivity and safety. Also the different sizes of the barrels would need to be considered in order for this to be effective. [8]

26. Cylindrical barrel lifting knot

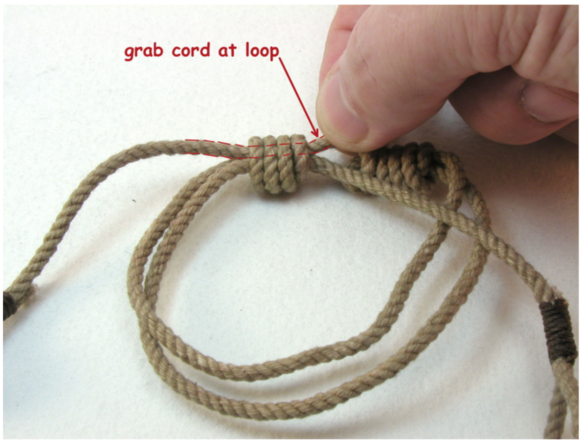


Figure 7.56: CYLINDRICAL BARREL LIFTING KNOT

Here we have a knot designed to grab cylindrical objects. This knot could be used on a larger scale in combination with a hydraulic lift so that the barrels are suspended in air. This would work for all barrel sizes. With initial cleaning of sides, the barrel can then be suspended as workers can clean the top and bottom.

27. Compression gas lift strut

Here we have a compression gas lift strut. This can be combined with the knot idea from above in order to suspend the barrel in air, as it would be if it were on a larger scale with a crane. The miniature version of an industrial crane would be completely mobile and able to fit inside of the room.

Figure 7.57: COMPRESSION GAS LIFT STRUT

28. Global Industries small rolling crane

Figure 7.58: GLOBAL INDUSTRIES SMALL ROLLING CRANE

Global Industries brings another barrel moving solution with this small rolling crane. This would make it so it could collapse and fit into the airlock, and suspend the barrel in mid air for cleaning. [8]

29. Meyer Hydraulics Corporation small hydraulic crane

Figure 7.59: MEYER SMALL HYDRAULIC CRANE

This is a mobile hydraulic crane that is made by Meyer Hydraulics Corporation. This could be a potential winner due to that it is completely metal (one of the requirements), as well as mobile and able to be moved in and out of the airlock while cleaning takes place. This is however, a little on the pricey side starting just short of $5,000.

30. Global Industries barrel rotator with chain attachment

Figure 7.60: GLOBAL INDUSTRIES ROTATOR WITH CHAIN

This Global Industrial device is a barrel rotator. In combination with the crane, this could allow a complete amount of access to the barrel sides. This device has a handle lock making it so the barrel won't move or slip out upon rotation. [8]

7.3. Brandon Fleet: Concept Generation

1. Barrel Raising Pallet Jack Modification:

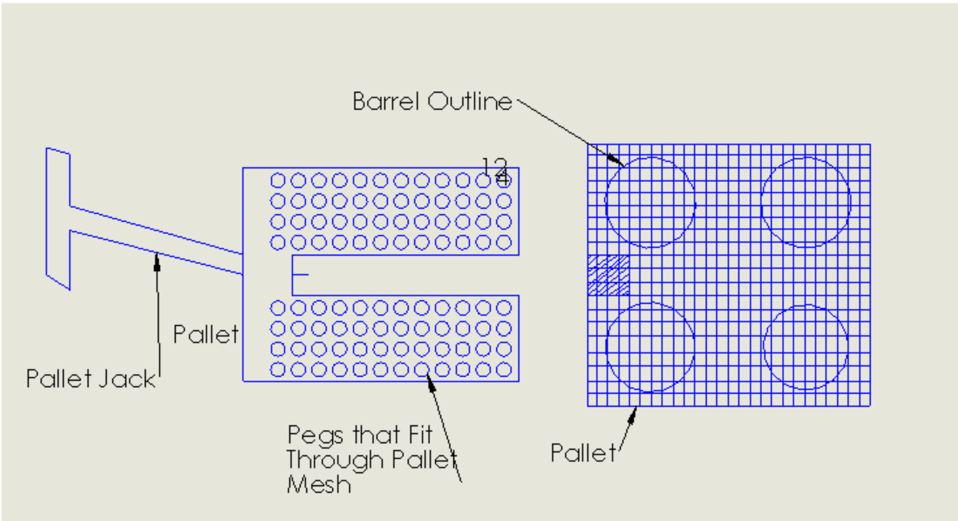


Figure 7.61: BARREL RAISING PALLET JACK MODIFICATION

Two pieces of sheet metal are attached to the forks of a pallet jack. The sheet metal is just narrow enough to fit inside the pallet while avoiding the blocks inside the pallet. Pegs are welded to the top of the sheet metal, and arranged in such a pattern as to pass through the mesh on the top of the pallet. This has the effect of raising the barrels off the pallet by an inch or so, which will allow a forked hand truck's bottom to slide under the barrels, taking advantage of the natural channels in the pegs created by their linear pattern. This will prevent the operator from having to tip the barrel forward in order to slide the bottom of a hand truck style device underneath.

2. Pallet-Jack Peg Modification Adjusted for Normal Pallet-Jack Operation

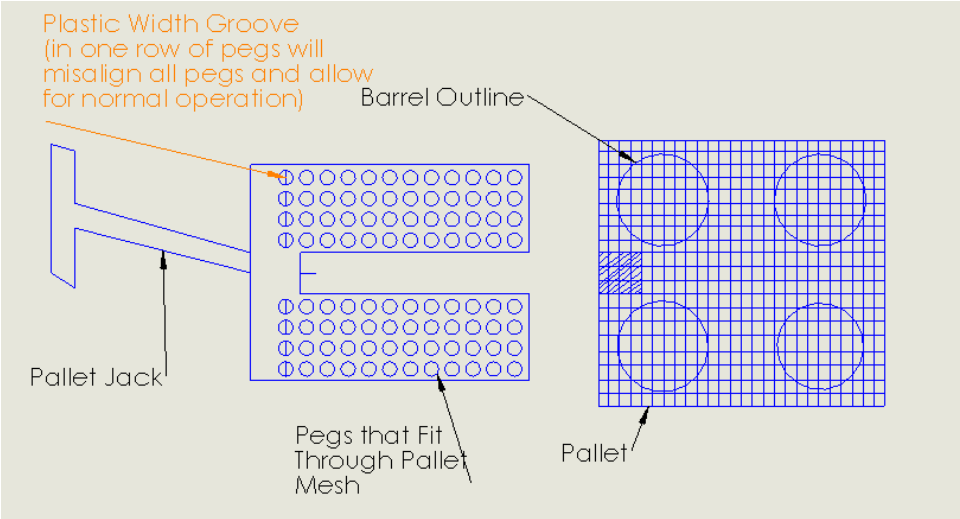


Figure 7.62: PALLET JACK PEG MODIFICATION

By cutting grooves in select pegs, the pallet jack can be locked in such a position as to make contact with the bottom of the pallet at all pegs, so as to allow the pegged pallet jack to function in a traditional capacity, eliminating the necessity of switching between pallet jacks between placement of the pallet and lifting the barrels off the pallet surface in order to be moved.

3. 4 wheel roller system:

Four wheels sit underneath the horizontal barrel on the device in which it is retrieved off the pallet. This will allow free rotation of the barrel, while being as simple as possible to clean. A minimum of 4 points of contact is necessary to fully stabilize the barrel during rolling, but more should not be used to increased difficulty in cleaning. This is advantageous compared to an omni-directional roller system, due to simplicity, cleaning accessibility of all surfaces (with a closed bearing) and its ability to accommodate different sized barrels. A smaller barrel sitting within a 4 wheel cradle will simply

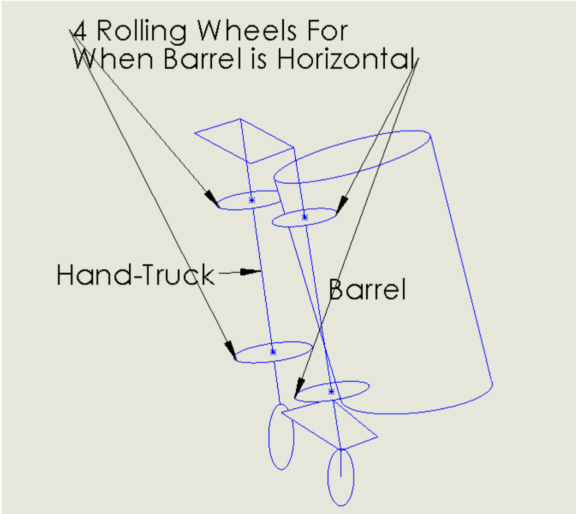


Figure 7.63: 4 WHEEL ROLLER

sit further down into the wheels, provided the radius of the wheels is large enough.

4. Hand-Truck Bottom Modification:

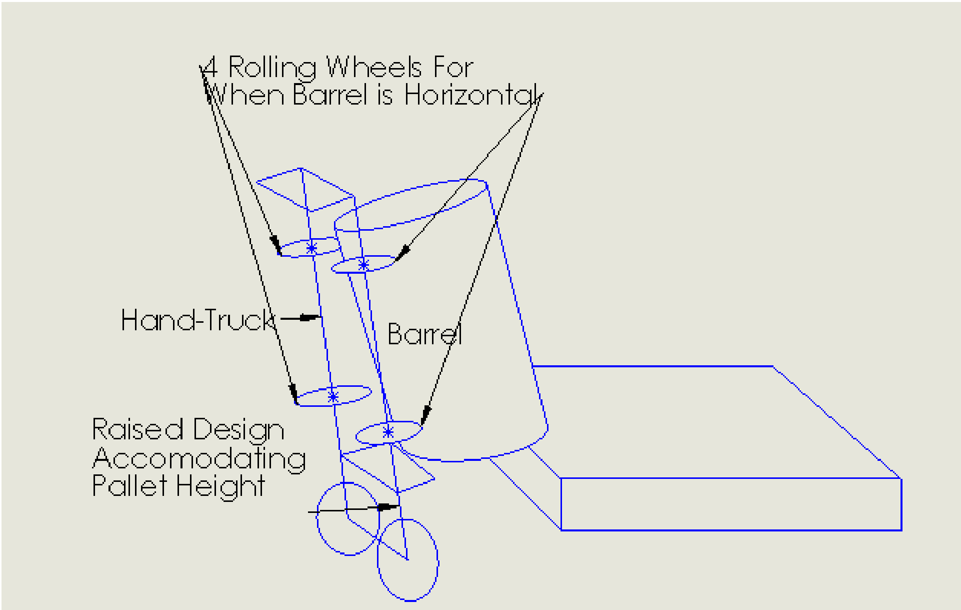


Figure 7.64: HAND TRUCK BOTTOM MODIFICATION

traditional hand-truck would be used, with a modification that puts the base of the hand-truck on the same plane as the pallet. The base of the hand truck would also protrude forward far enough to reach a barrel that is recessed several inches from the side of the pallet, as appears to be the case from photos.

5. Hand-Truck Spring:

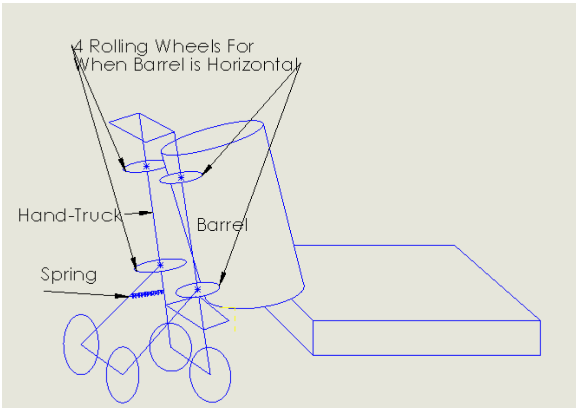


Figure 7.65: HAND TRUCK SPRING

spring could be used to absorb the energy of the lowering action of the hand-truck, allowing the hand-truck to rest horizontally with spring in full compression or tension. The barrel would be cleaned in this holding pattern using the 4 wheel rolling system, and the spring energy would again be used to raise the barrel onto the sterile pallet across the demarcation line. The safe and practical implementation of this device has not been resolved as of yet.

6. Noodle Wheels: (Or Omni-directional).

Research has shown this product exists in other applications, primarily robotics. It would be wheels that are placed around the perimeter of the wheel to allow the wheel to translate left and right as well as rotate forward.

Figure 7.66: NOODLE WHEELS

The outer radius of the smaller translating wheels would have to match the radius of the larger wheel. This outer radius would be the same as the wheel rotates, forming a shape that could be made on a lathe. This would solve the problems that may arise with rear wheels that may translate backwards (to slowly lower the barrel with spring energy). Shopping cart wheels depend on the z axis being perpendicular to the rolling surface (if the z axis is the axis around which the wheels change direction). Wheels that kick out would change this requirement. Two wheels would have to be offset in parallel to avoid bumpiness.

7. Hand Brake:

A bicycle style handbrake could be used on the front wheels to stabilize the lifting and lowering process of a hand-truck.

8. Bleach Misting Chamber:

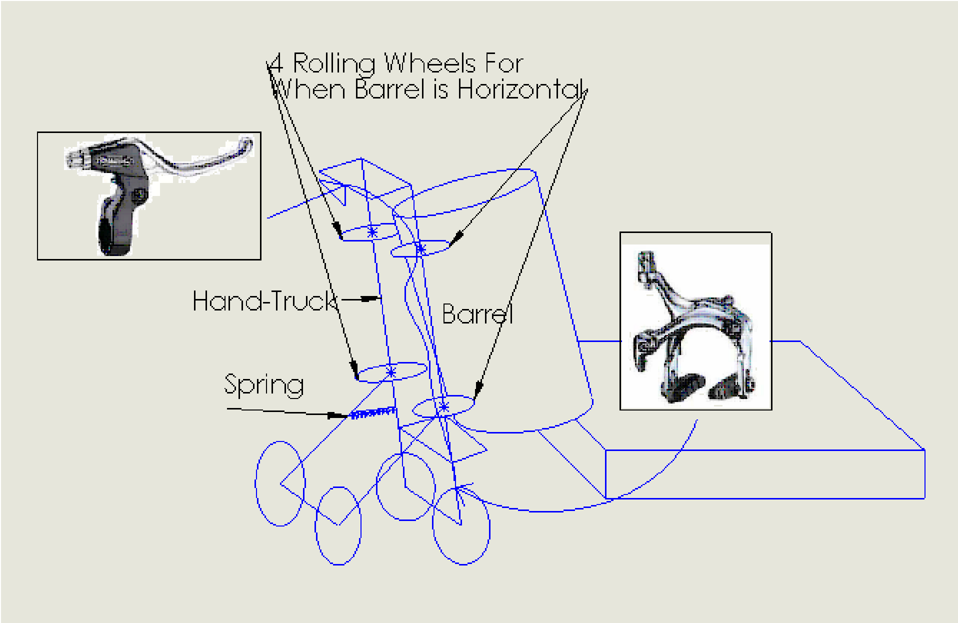


Figure 7.67: HAND BRAKE

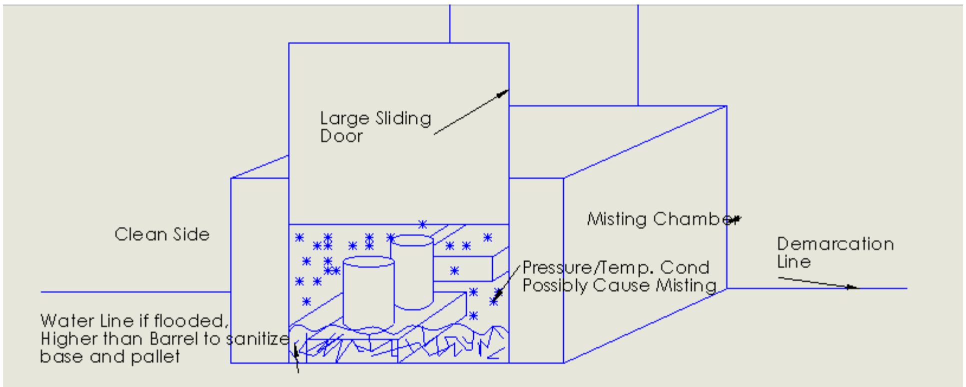


Figure 7.68: BLEACH MISTING CHAMBER

A misting chamber could be used to sterilize the barrels and the pallets concurrently. The pallets would be placed in the chamber through a door on the dirty side. (A large, garage door style door). The barrels could be wiped down standing, but this would not allow for the bottom to be wiped clean of dirt, only sterilized. Following the process, the pallets would be retrieved from a door located on the sterile side, and the previously dirty pallet would now function as a sterile pallet after resting in the misting chamber. Perhaps a flooding of the misting chamber with a bleach water solution to a level that was high enough to drown the pallet (the source of the mist?) and the base of the barrel would mitigate the risk posed by an inability to ever hand-wipe the bottom of the barrel.

9. Massage Chair Concept for Reaching Base of Barrels Within a Misting Chamber:

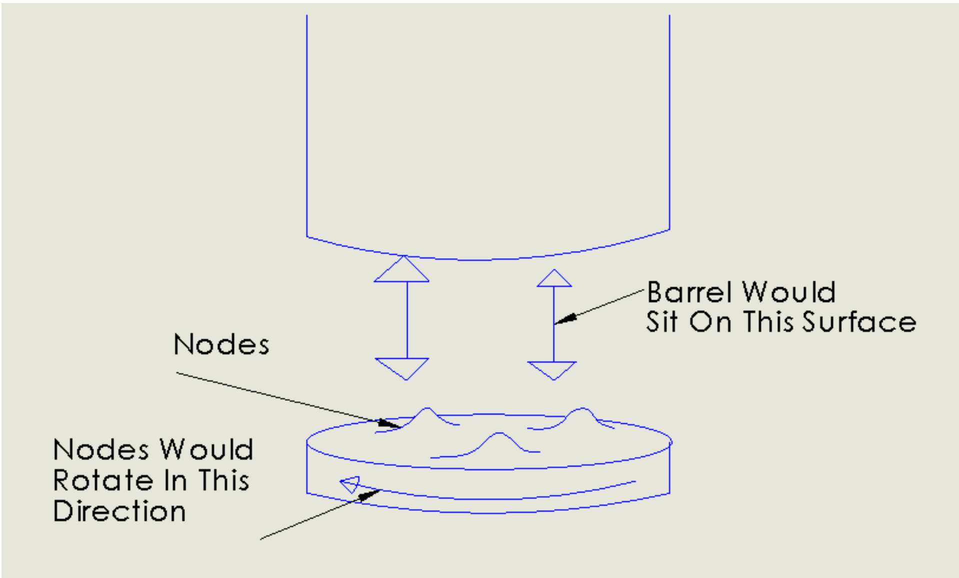


Figure 7.69: MASSAGE CHAIR CONCEPT

Just as the balls inside a massage chair protrude as raised nodes through a (potentially) sealed surface, rotating and exposing the surface of a user's skin to alternating points of contact on the massage chair, (although this is not the primary intent) this concept can be applied to a sterilization chamber idea. If a barrel is placed onto a sealed disk with this same motorized system within a chamber that sterilizes (through mist or otherwise), a (say 3 node at equal height) system may rotate to ensure the entirety of the barrel is being sterilized. Basically, you'd be putting a barrel onto 3 metals balls (or bearings) which rotate and are covered with a skin to protect the electronic components.

10. Pool:

Dump the Barrels in a small (approx. 8 ft D by 3 ft H, raised to comfortable height) sterilization pool. Rotate, clean the barrels as they float. Sterilize the water/control chemical content using appropriate chlorine/filter systems.

11. Merging Pool and Misting Chamber:

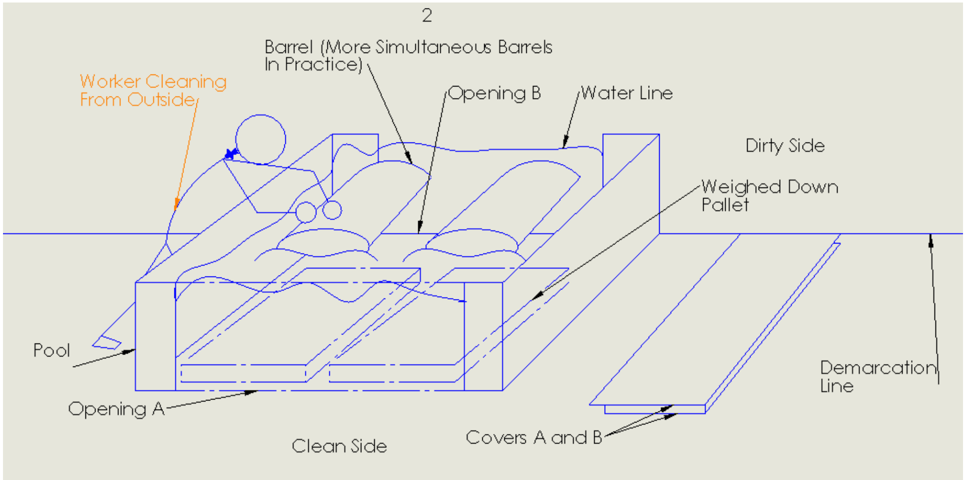


Figure 7.70: MERGING POOL AND MIST CHAMBER

Roll pallets with dirty barrels on them into pen with approximately 4 foot walls which sits on the demarcation line. The pen wall facing the dirty side of the demarcation area is temporarily removed. Once the pallets are placed, (possibly up to four?), the dirty side wall is put in place. (The removeable wall may have a watertight seal around its outside, similar to a refrigerator door, and placed on the inside of the bed to allow the gravity of the water to reinforce the seal). The pen could be flooded with a bleach water solution from a tank next to it, which contains a filter to purify the solution from the last batch. At a certain depth, the barrels will easily turn over and float in the solution. Workers would reach over the outside of the approx. 4 foot wall to clean and spin the sideways floating barrels. When finished, they could once again stand the barrels on the pallets in the solution, which would be just shallow enough to allow this. Then the solution would be once again pumped into the nearby chamber. The opposite wall of the pen would also be removable, and sit on the clean side of the demarcation line. This wall would be removed and the clean and now sterile pallets could be removed by the clean side workers. Pallets would need to be weighed down so as not to float.

12. Hand-Powered Cart the Hovers over Pallet:

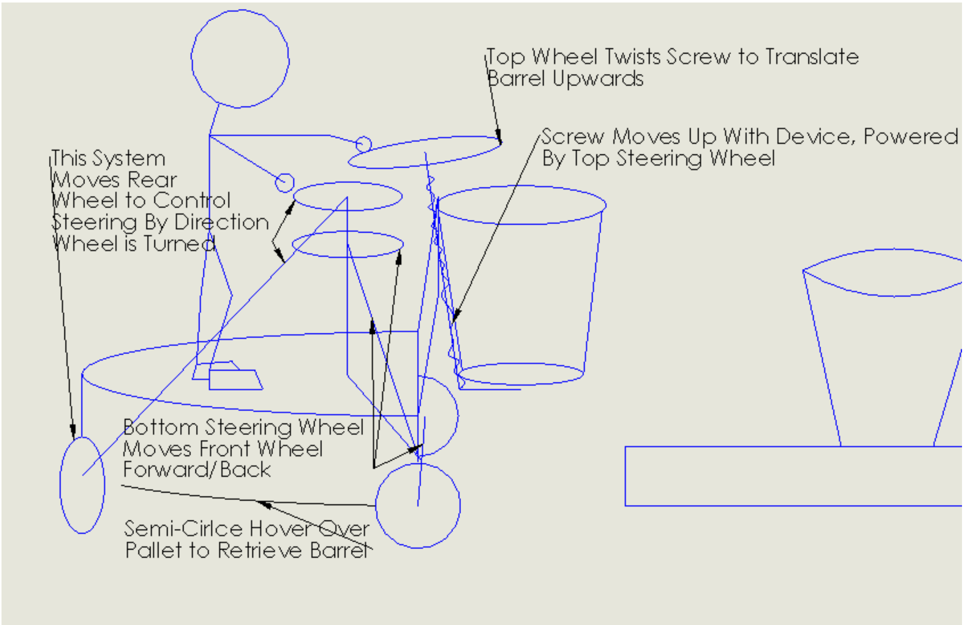


Figure 7.71: HAND POWERED CART

Imagine the spin around toy that toddlers sit on and use a steering wheel to spin themselves around. But make it wider than a pallet, (4 ft), add wheels to the base to lift it above pallet height (so it can roll clean over), make it a semi-circle, with three wheels, and add a steering wheel to the top that can move it forward and back (the baby-toy-analogous wheel rotates the device), and add a 3 foot high horizontal bar that extends the width of the middle of the semicircle cart, which will allow for the translating and positioning of a barrel lifting device. 2 steering wheels would be used to manually move and steer this device to roll over a pallet and up to a barrel, with an operator standing on top of it. A lifting device would translate along the horizontal bar until it is positioned directly in front of a barrel, and a 3rd steering wheel attached to this lifting device would power a barrel lifter, possibly using a screw system similar to a stress testing machine. The barrel would then be turned sideways, as the lifter would rotate on a bearing perpendicular to the floor. The barrels would then be lowered onto 4-wheeled carts, one at a time, and a similar process would be used, utilizing the width of the cart to avoid allowing it to touch the clean side. The demarcation line would have the same square tooth outline that most of our prototypes require.

13. Heating Chamber:

This has since seemed impractical with more research, but an original idea centered around there possibly being a temperature inhospitable to bacteria but safe for the chemical products being used, and the plastic containers/pallets.

14. Modified Lifting Mechanism for Vacuum-Powered Lifter:

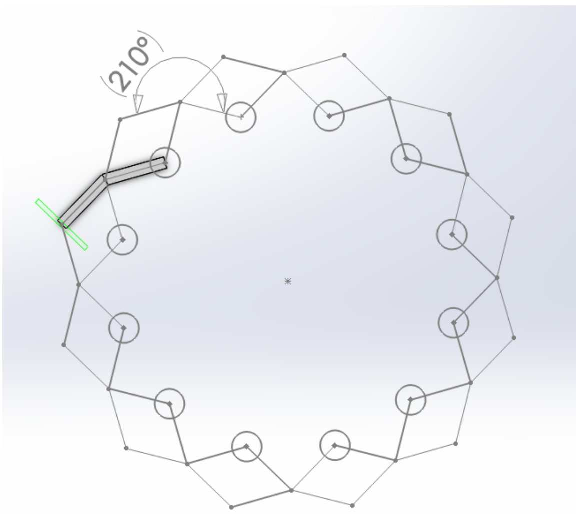


Figure 7.72: MODIFIED LIFTING MECHANISM

Amgen has an enormous robot arm that has a suction cup on the top to pick up barrels by their lid, aided by vacuum-power. The suction cup on this device may be able to be replaced with a device that constricts mechanically along the perimeter of the barrels. The children's toy that amounts to a mechanically collapsible sphere made of small plastic beams (called the rainbow sphere) works using interwoven sets of collapsing beam-contructed circles on a plane. Using one of these circles, and obviously making the device larger and metal, could result in a device that collapses evenly in a circle. If rubber pads were put on the contact points with the barrel, it could accommodate various width barrels and form an evenly distributed frictional force on the outside of the barrel, enough to lift it, which may allow it to be lifted whereas other, two POC robotic lifting devices may have structurally endangered the plastic barrels. This seems potentially more reliable and quicker than suction power.

15. Long Arm attached To A Fulcrum Near The Barrel:

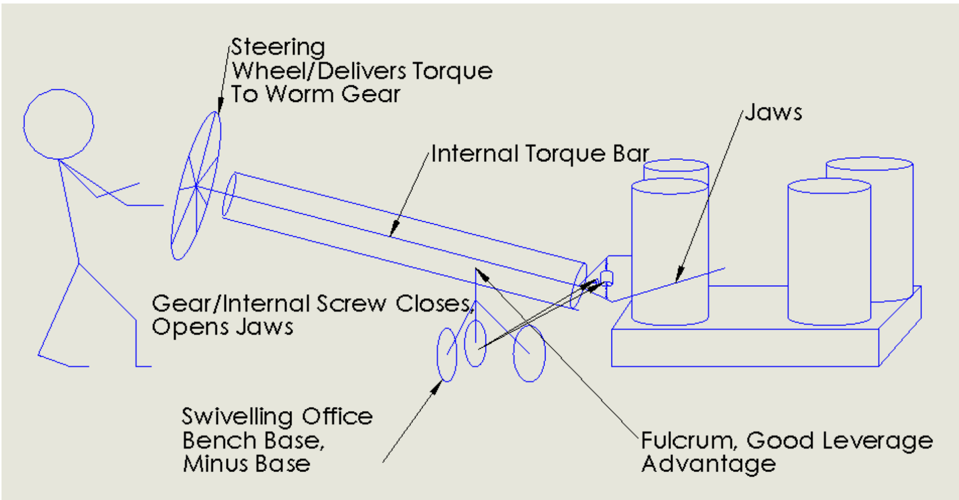


Figure 7.73: LONG ARM

The title sums up most of it. A steering wheel may be placed at the end of the operator side that rotates a torsion bar running inside an outer lever-action bar. This torsion bar could spin a worm gear near the barrel that closes a large clamp around the barrel. The fulcrum would sit on a 3 wheel base (like a swiveling stool with just the wheel base, and a bar protruding upwards and supporting the fulcrum). The lever advantage could be used to individually move the barrels onto rotating carts, and onto clean pallets when they're clean.

16. Pulley Lifting:

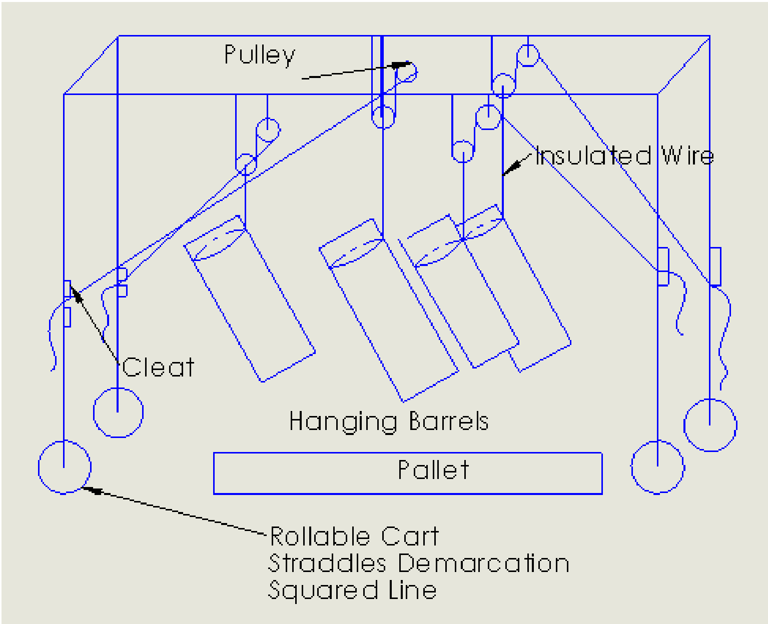


Figure 7.74: PULLEY LIFTING

The dirty pallets containing the dirty barrels could be placed underneath a set of four pulleys. A noose could be placed around each barrel, (or just a loop that constricts with a bearing) underneath a widening section near the top of the barrel or underneath a lip. The pulley would be lifted using enough pulley-wheels to gain an acceptable force advantage. The noose tightens around the barrel as it lifts. Once all 4, (or 3), barrels are lifted off the pallet, the pallet can be removed. Due to how the barrels are hanging from one side, they are now at the same angle as their tipping point. A bottomless cart can now be slid underneath them without having to tip them to this point.

A hook can be attached (as was pictured in our presentation design) and the barrels can be lowered on a 4 wheel bottomless dolly-cart to be cleaned, possibly using a rotational damper. A similar system can be utilized on the clean side, with a three side, square tooth demarcation line setup, but the beams that hold the pulleys over the clean square never touch the clean side. A pulley is wrapped around the barrel (near the top) as it lies horizontally on the cart, and the barrel is lifted until it is off the ground and higher than pallet height. Once all 4 barrels are lifted, a clean pallet can be slid underneath them, and the pulleys can be lowered, adjusting the barrels as they lower so they come down flat on their bottom. Sailing cleats may be used to hold the pulley ropes in place while the barrels are hanging. A non-porous pulley rope would have to be used, possibly a wire surrounded by a rubber like bladder with insulating material to increase the wire thickness and mitigate pinch risks.

17. Winch To Lift Barrels:

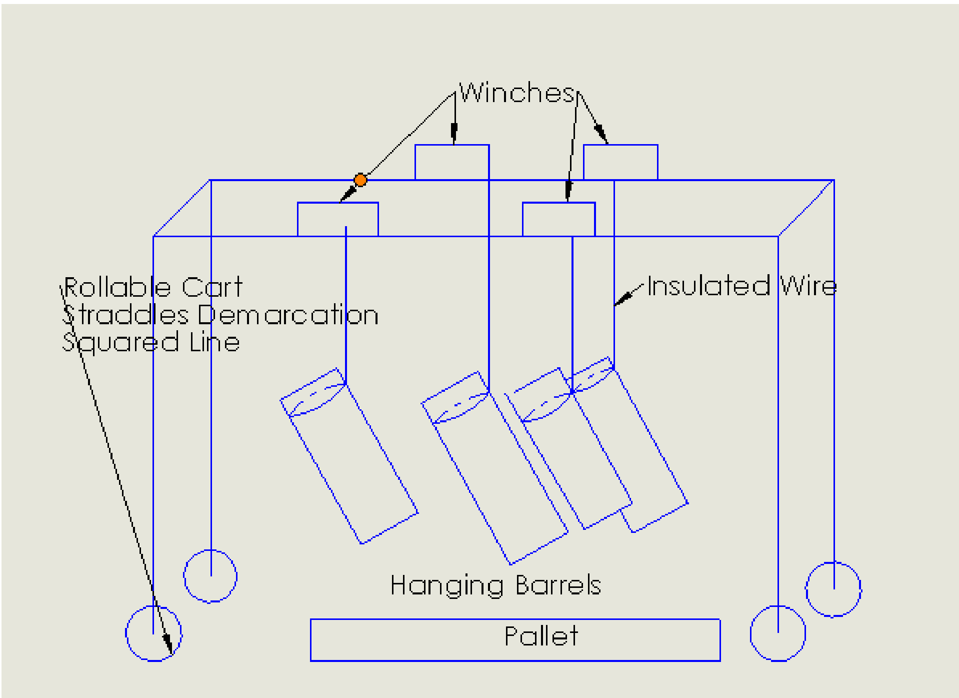


Figure 7.75: WINCH TO LIFT

Same idea as above, but with winch. Concern with this stems from increased pinching risk. An operator lifting a pulley would be immediately aware and responsive of his fingers being pinched in the noose around the barrel and release pressure. A winch is more powerful and potentially non-responsive.

18. Inversion Table:

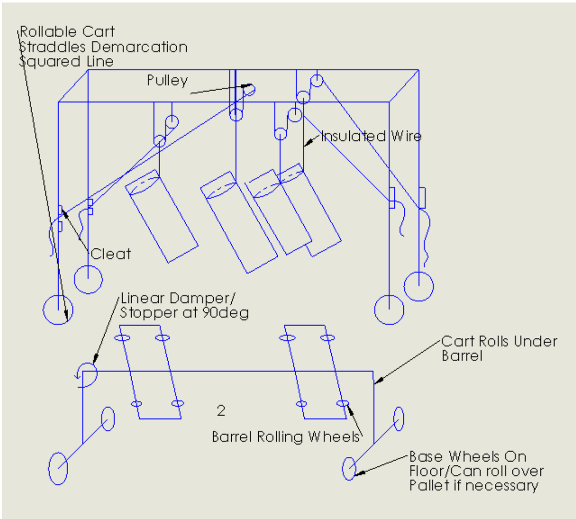


Figure 7.76: INVERSION TABLE

This would be a modification of an inversion table, (the table some use to relieve stress on their backs by lying inverted) except there would be two inversion tables on the same device, and the device would have 4 base wheels in contact with the floor and be wide enough to roll clean over a pallet. This device would once again utilize the pulley/winch from the previous design; once the barrels were hanging, this cart would roll over the pallet, and the barrels would be strapped to the two tables. The barrels would be hanging in the exact right spot to accommodate the spacing and height on the two-table inversion table, due to the placement of the pulleys. The barrels would be lowered until horizontal using the pulley. The contact points for the barrels (and what would suffice for a table) would consist of 4 wheels, as in most other designs. The barrels would remain on these two-barreled, horizontal carts during cleaning, and until they were ready to be transferred to the clean side. If the cart is designed in a particular way, the point of rotation can be designed to be in the approximate center of the barrel, allowing for man power to easily rotate the barrels onto the clean side using dampers and without the aid of clean-side pulleys.

19. Ancient Pig Roaster:

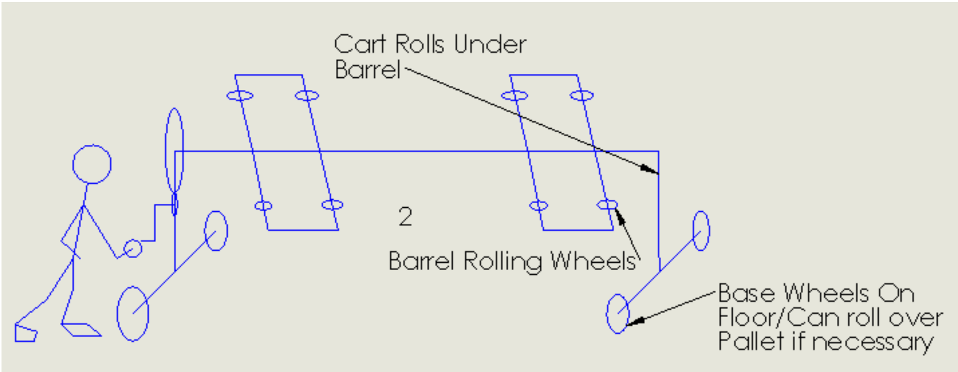


Figure 7.77: ANCIENT PIG ROASTER

This would be similar to the inversion table, but would use a rotating handle on the end to slowly spin the barrels up and down, using gears to achieve force advantage. The tables that rotate would sit above the central, horizontal, rotating beam, (or spit), so rotating them upwards will not require the lift assistance of the pulley system, because this setup will ensure that the barrels never need to dip below the plane of the pallet in order to rotate.

20. Snowboard Strap:

Due to the necessity for clean-ability and speed, a large industrial ladder strap can be used to secure barrels to the back of a wheeled hand-truck. This meets the requirement of non-permeability. If the strap can be tightened enough, perhaps the friction generated by the barrel pressing against

Figure 7.78: SNOWBOARD STRAP

the wheels would eliminate the need for the hand-truck to have a base. The barrel would be tilted horizontally without slipping, ideally. The hand-truck base, or skis, are workable but are preferably avoided due to cleaning complications, especially if the design necessitates that they touch the clean pallet.

21. Hovering Barrels:

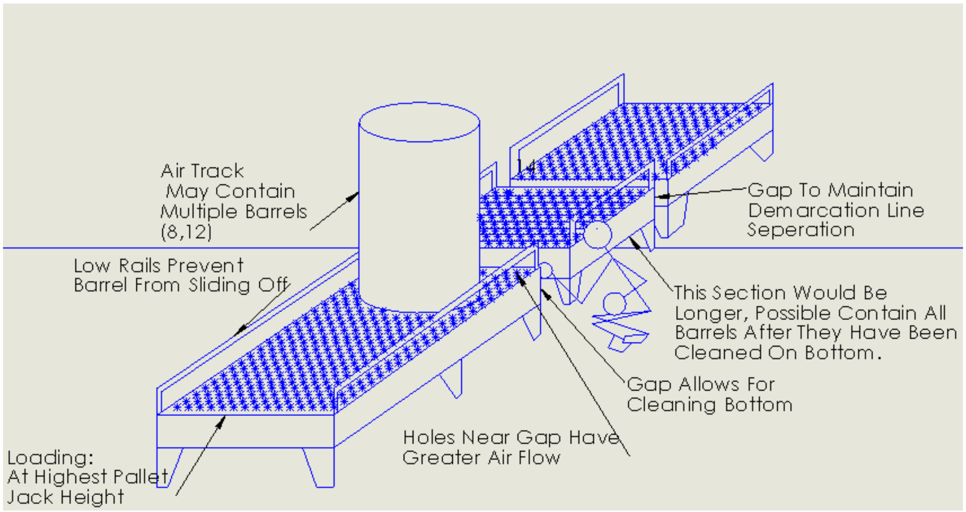


Figure 7.79: HOVERING BARRELS

Barrels would be transferred onto an air-hockey-table-like surface that would function as a long air-conveyor (using another device) The top of this air hockey table surface would be a couple feet in the air, With air moving through the holes in the table. The barrels float upright along this surface, with short bumpers to keep them on the line. There would be a break in the line which would be wide enough for a worker to reach up from the bottom of the table to clean the bottom of the barrel. Increased air pressure near this gap would hopefully keep the barrel hovering. From then on the bottom of the barrel would not be touched, and it would be cleaned and passed along this air track to the clean side. There would be another (1-2 inch) break in the assembly line at the demarcation line, and increased air pressure on both sides near the edge of this break would hopefully allow the barrel to slide over seamlessly.

22. 8 Wheel system:

    An 8-wheel system on the back of the hand-truck for rotating the barrels for cleaning while in the horizontal position, as opposed to a 4-wheel system, with two sets of wheels higher and two lower, adjusted to accommodate the smaller barrels that come stacked on top of each other on pallets. The 8 wheel system would always be on the hand truck, but only the 4 higher wheels would touch the larger barrels, eliminating unnecessary cleaning. The lower and higher wheel setup could work for the small barrels due to their conical shape, and would be used to retrieve the smaller barrels two at a time.

23. Sheet Metal Clamp:

    A sheet metal clamp, modified to grab the top rim of a barrel, and with an enlarged contact surface area so as to prevent damage to the rim, could be used to quickly and temporarily lift a barrel. It works by tightening as weight is applied to it, similar to a sailing cleat.

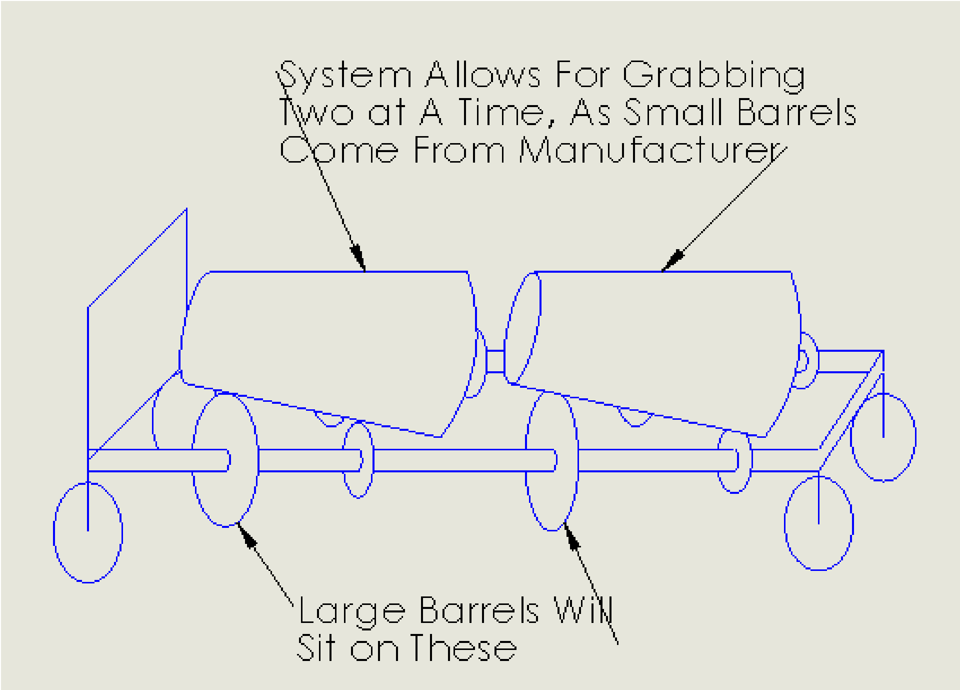


Figure 7.80: 8 WHEEL SYSTEM

Figure 7.81: SHEET METAL CLAMP

24. Pallet Jack With Gears:

A pallet-jack could be modified to be a single piece with one fork (it would be narrower) capable of sliding into one side of the pallet. This surface could be lined with strategically spaced gears (rotating) that are spaced to roll under the pallet with their teeth protruding through the pallet holes as the pallet-jack moves. As the gears move under the pallet, they would gradually snake under the barrel, and a hand-truck base would slide on top of the pallet, offset behind the underside gears that lift the barrel up, to slide under the raised barrel as the gears move forward. When replacing the barrel, and the pallet jack fork component would have to be separable.

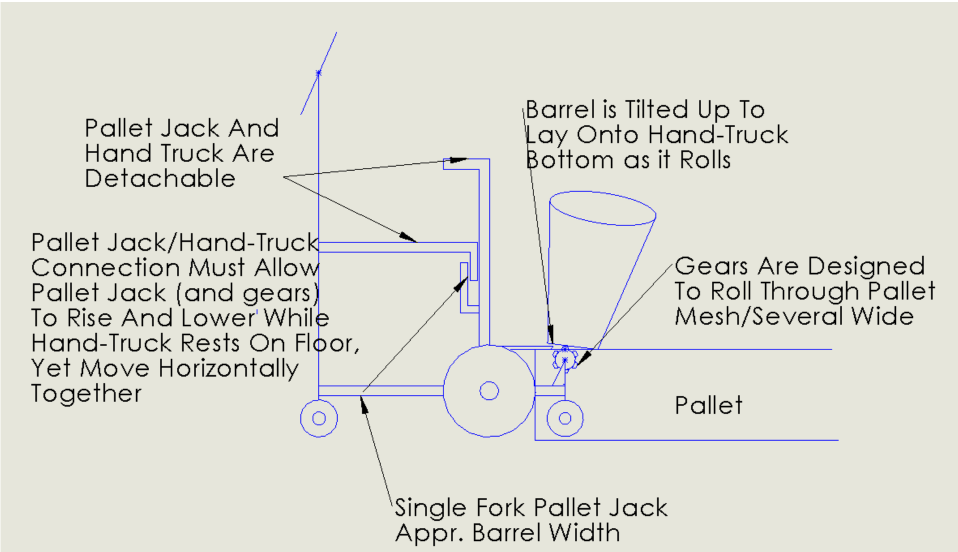


Figure 7.82: PALLET-JACK WITH GEARS

25. Hand-Truck Cart Conversion:

A hook (or pair of hooks for stability) on the back of a hand-truck could hang a cart. The cart would be lifted vertically to grab the barrel with a strap coming from the hand-truck, then lowered to the ground with the hand-truck. Once lowered, the hand-truck component would be separated from the cart, leaving just a simple cart with a barrel on it for the 10 minute cleaning process. The hand-truck would wheel up to and grab another empty cart to retrieve another barrel.

26. Pulley System With Wheeled Bars

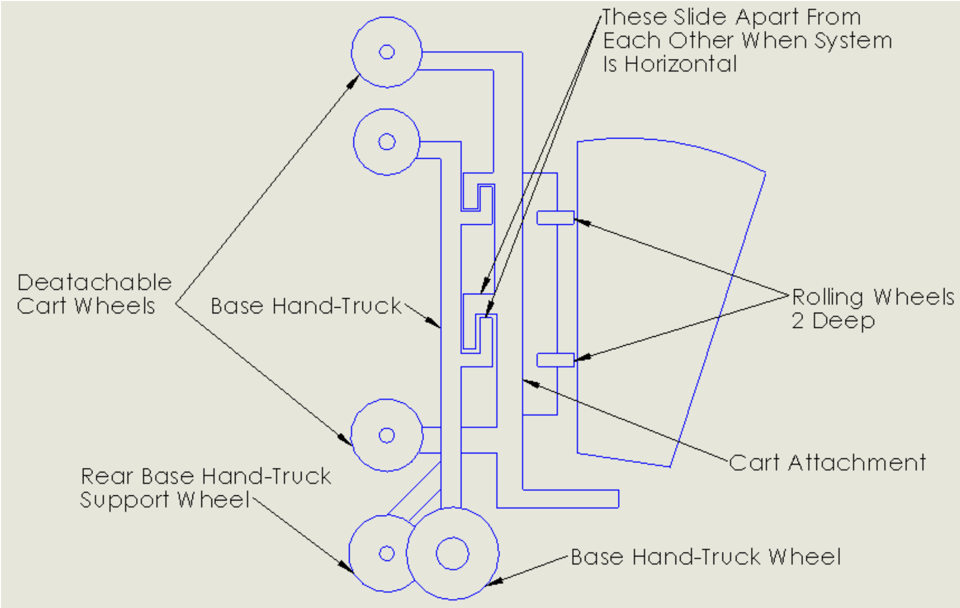


Figure 7.83: HAND-TRUCK CART CONVERSION

paragraph A high cart With 4 pulleys on it could be used to grab 4 barrels, but the noose lifting the barrel could consist of a chain with small metal wheels that allow the barrels to be spun as they hang. (Maybe resembling a meat-rack with barrels instead of dead animals hanging). This would be wheeled forward and hang over the demarcation line. The barrels do not even necessarily need to spin as they hang; the outside of the rim can be cleaned before the noose is wrapped around them.

27. UV radiation

There exists a water sterilization device that uses a safe amount of UV light radiation (some of it is visible) to sterilize water. Perhaps a gun that emits similar light may be employed to sterilize the outside of the barrels. Maybe rolling a pallet over a transparent section of flooring underneath which are UV lights would allow the difficult-to-account-for bottom of the barrels to be decontaminated, if the barrels were moved around a little to let all the light make it through the mesh. This would be a secondary precautionary measure to supplement another cleaning process.

28. Actual Radiation paragraph Giant, sealable microwave that emits safe levels of radiation which don't generate heat. (I believe food microwaves only heat water, not sure if this makes it safe for powdered chemicals?) The setup would be similar to the misting chamber.

8. QFD

A quality function deployment is used to assets the demand characteristics from the customers description. This tool translates these demands into a format that can be used to produce a product that achieves the desire characteristic without the cost of others. A full QFD can be seen in the Appendix C

8.1. Demand Qualities

Table 8.1: Demanded Qualities

Demanded Qualities	Weight
Safety	30
Ergonomics	25
Process Time	20
Quality	15
Cleanability	15
Number of Workers	5
Cost	5

Table 8.1 list the demand quality a respected weights for each. The decisions were based on the design specifications and information from meeting with Amgen.Safety, ergonomics and process time have higher weight due to those are the main focus. A QFD is used to incorporate other qualities such as quality, clean ability, number of workers, and cost from getting over looked and incorporated in the concept generation of a solution.

8.2. Concept Comparison

The QFD can also show relationships between demanded qualities and characteristics. Using these relationships the team was able to determine the relative weight, importance, and max relationships. The team entered leading concepts to perform a visual assessment of each concept potential compared with the demand qualities. The results are compared in the Figure: 8.1 and Figure: 8.2

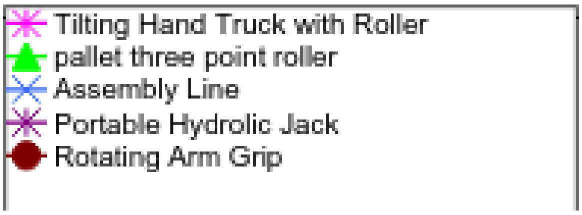


Figure 8.1: COMPARSON LEGEND

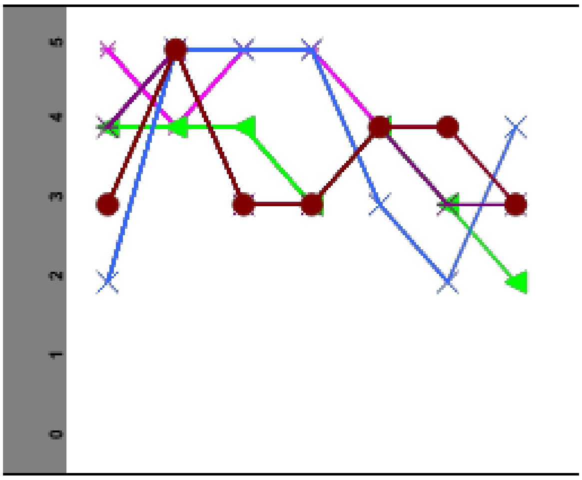


Figure 8.2: CONCEPT COMPARSON

9. Design for X

During the design process, there were a number of factors that were taken into consideration. This section expands the decisions made in designing our concept to achieve Amgen's standards in ergonomics, safety, reliability, maufacurability, and cost.

9.1. Design for Ergonomics

The design for ergonomics was primarily done with the help of the REBA (Rapid Entire Body Assessment) worksheet [9] for employees. This worksheet is commonly used in industry when testing a workers ability to complete required body motions and applications of forces. The assessment is on a scale of risk, as seen in Figure D.1 in the appendix, from zero, up to eleven or higher. This scale is measured by the risk if injury that the worker is exposed to while completing tasks in the workplace. Another consideration is whether these movements take place within the workers power-zone (between knee height and chest height), and this is important to factor into design. A worker has an ability to withstand repetitive force applications in this region, making it important to utilize when it comes to operation a mechanism. The worksheet is completed on a point system with respect to the following areas of the body: Neck, trunk, leg, force, upper arm, lower arm, wrist, and amount of activity. Below is the standard sheet followed by the assessment completed for both the current process of barrel cleaning currently being used, as well as the system using the mechanism for future used.

9.2. Design for Safety

With respect to safety, the largest failure of safety with the current process for barrel movement is due to a lack of ergonomics and assistance with workers lifting the barrels themselves. This lack of safety is the primary factor when it comes to design of the hand-truck with rollers. This hand-truck is designed to be able to tip the barrel using thirty pounds of force at waist-shoulder height of the user (well within OSHA's standard of fifty pounds in this area) as well as a component using the body weight of the user. This ultimately cuts the risk of injury significantly (more than fifty percent). The primary goal is to cut the risk down as much as possible, simply due to the fact that safety of workers is the number one priority of Amgen's company statement. A component that is being looked into is a dampening device to avoid the hand-truck from either slamming down upon the barrel reaching it's tipping point, or slamming forward after the cleaning process is completed. This is currently compensated by keeping the worker away from the barrel all together, but future development of a constant velocity strut could further assist this area.

9.3. Design for Reliability

When it came to keeping the barrel tilting component of the device as reliable as possible, the decision was to limit the amount of as many of the moving parts as possible. The current design is a rigid frame (made of stainless steel) and rigidly attached rollers supporting the back side of the barrel. To ensure the rollers and wheels will perform with longevity, only premium water and bleach resistant bearings will be used within the rollers attachment to the frame. Further, the primary material of the frame and supports is entirely stainless steel which is very resistant to work hardening with repetitive small loads being applied with regularity. One moving part that is required is the sliding translating hook. This hook is also made of steel and will have the same fracture and failure resistant properties that the frame will have. There will be wear on the frame where this hook will slide, but the amount will be small due to the coefficient of friction for metal on metal is minimal.

9.4. Design for Manufacturability

The manufacturability of the device was important when designing the concept. Amgen would need multiple depending on the number of barrels they would like to do on a certain day. All parts with an exception of two was used because they are readily available from vendors in those standard sizes. The majority of the parts can be welded together or fasten using nuts and bolts.

The two components that were conceptually designed were the hook assembly and rollers at the bottom of the dolly. These two pieces need to be custom to the barrel. The lip at the top of the barrel differs from the thousands of designs of barrels and our concept hook will be designed for the specific barrels at Amgen to increase the efficiency of the dolly. The lower set of rollers also must be custom to the barrel. Since the barrel has a conical design the skis were blended with the rollers to be able to reach and sit the barrel on them to allow the barrel to rotate during the cleaning.

9.5. Design for Cost

Amgen came to the University of Rhode Island to present this problem of moving heavy barrels and would like a solution to reducing possible injuries to their workers as the clean barrel full of raw medical materials. Their priority was for safety and the cost to implemented was not of concern. Their previous investment included a hundred thousand dollar machine that isn't being used. The team minimized the the cost of parts and fabrication by using standard size materials. The majority of the cost of this concept, since it is all mechanical is the material and assembly. The materials being used is stainless steel for its durability, corrosion resistance and clean ability. Further improvements will be made to the cost with more in depth analysis to reduce materials and thickness of materials being used.

10. Project Specific Details and Analysis

10.1. Fall Semester Design Details

The center beam that the operator stands on, the welds that hold the rear axle supports to prevent them from moving left and right (into and out of the page), and the top of the main frame right above the top wheel rollers are the intuitive weak points of the design. The top of the main frame consists of two beams that will support what can be assumed to be equal forces, therefore, one beam can be modeled as experiencing a bending moment that is approximately half the total moment caused by the force of the operator pulling the handles perpendicular to the bars. Modeling this as a cantilever beam, and using the appropriate calculations for moment and planar moment of inertia of a hollow square beam, pictured, the maximum force that would be required to be exerted on the handlebars at the 30" position (where the 3 beam supported system becomes 2 in the same plane) to exceed the maximum yield stress in tension or compression of stainless steel (30kPi) with a 1/8" wall thickness is approximately 870lbs per handle, or 1,740lbs total, well in excess of what is required or what the operator is capable of doing. The base of the cantilever, or base of the hand-truck, if modeled as a simple two beam system without considering the larger beam which houses the translating hook attachment welded to the front, (this can be best observed in the 3D color picture, and intuitively appears to reinforce the bottom section of the hand-truck significantly) would allow for a maximum force of 350lbs per handle, which is still safely capable of lifting the barrel, and, equally significant, likely exceeds human potential at that position. The welds on the rear axle supports would have to have a maximum tensile strength capable of resisting the sideways moments caused by the forces that the rear axle may be subjected to, meaning the welds would would have to resist a force up to approximately 12F*4, if F is the sideways force on the kickout bar. This is based on a static analysis that assumes the opposite welds give no resistance to rotation, (the 4 accounting for the 4 welds impacted when the rear axle translates left or right-see diagram). The rear axle (the one you step on) if modeled as a beam with two fixed ends with a point force in the middle (the operators foot), will not yield until it experiences a force of 2,690lbs, obviously well above what is required. The wheels and bearings used will be ones that are bought specifically for hand-truck applications, and should easily meet all weight requirements.

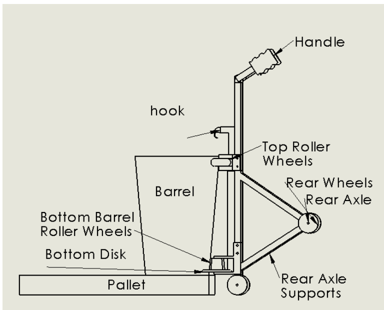


Figure 10.1: HAND TRUCK DIAGRAM

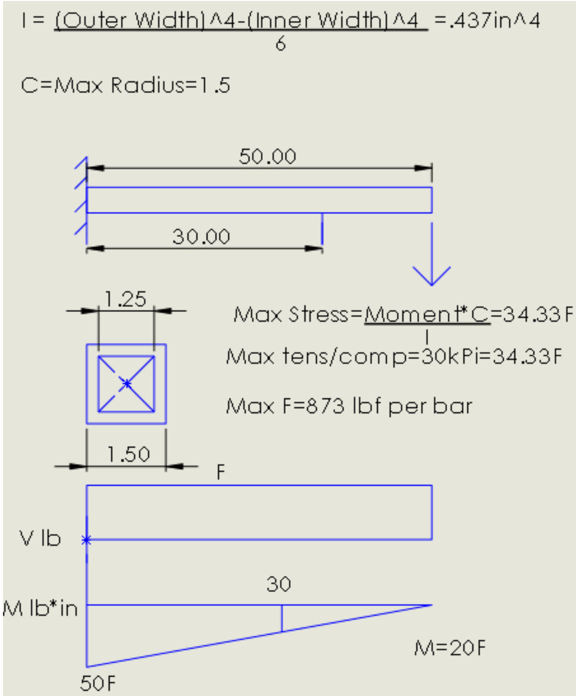


Figure 10.2: CANTILEVER BEAM MODELING FORCES ON HANDLE

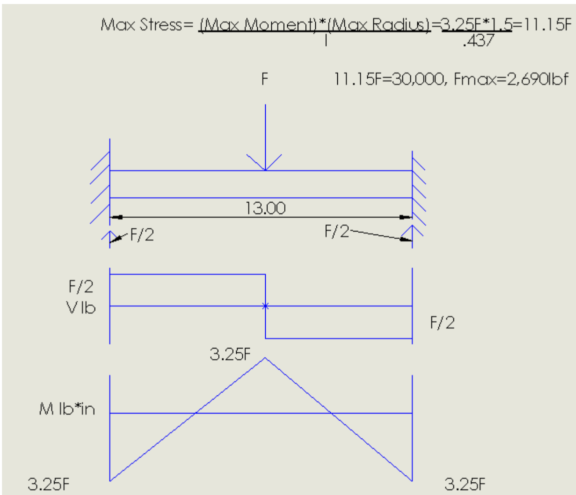


Figure 10.3: BEAM WITH TWO FIXED END MODELING CENTRAL FORCE OF FOOT ON REAR AXLE

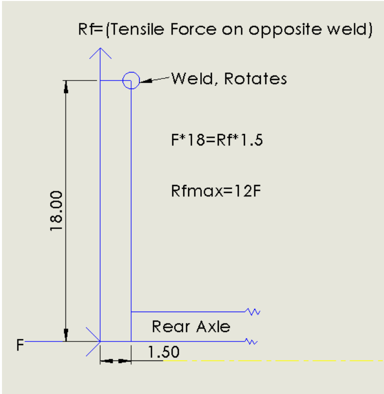


Figure 10.4: SIMPLIFIED MODEL OF WELD TENSILE STRESS FOR VULNERABLE SIDEWAYS MOVEMENT OF REAR HANDTRUCK

10.2. Spring Semester Design Details

For our spring semester build, it was decided to go with a500 steel as the primary metal used in the framing. This was done specifically due to its similar mechanical properties to Stainless Steel, very malleable and easy to machine, and also because its inexpensive. Also for the spring semester build, we decided to focus our efforts on assembly with bolts instead of more permanent welds as to prove dimensional accuracy for the desired angle and force requirements. This helped tremendously because we were able to change locations of joints and crossbars at a moments notice depending on how the barrel handler reacted during testing. Another thing to note is that for simplicity in testing, we went with a 12 Vt wall adapter instead of doing a custom wire job. This was to simply prove the handler's structure integrity, and usability.

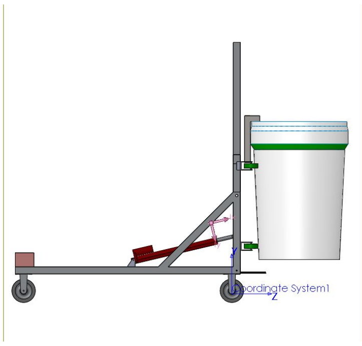


Figure 10.5: SIDE VIEW OF UPRIGHT HANDTRUCK SHOWING CENTER MASS WITH 100 LB BATTERY

Capstone Bill of materials
Team 06

Module: Frame								
Pieces & Dimensions	Thickness	Total Length	Purchase Length	Quantity	Price per purchase length	Total price	Material	Source
2"x 2" Square Tube	1/8"	48in	48in	4	$13.88	$55.52	Steel	Metal Depot
2"x 2" Square Tube	1/8"	31in	48in	2	$13.88	$27.76	Steel	Metal Depot
2"x 2" Square Tube	1/8"	29in	48in	2	$13.88	$27.76	Steel	Metal Depot
2"x 2" Square Tube	1/8"	20in	24in	1	$6.94	$6.94	Steel	Metal Depot
2"x 2" Square Tube	1/8"	16in	24in	4	$6.94	$27.76	Steel	Metal Depot
2"x 2" Square Tube	1/8"	12in	24in	2	$6.94	$13.88	Steel	Metal Depot
Wheel	5"	N/A	N/A	1	$69.99	$69.99	Not Marking	Amazon
TOTAL PRICE OF MODULE						$229.61		

Module: Rotating								
Pieces & Dimensions	Thickness	Total Length	Purchase Length	Quantity	Price per Unit	Total price	Material	Source
Actuator	N/A	18in	18in	1	$169.99	$169.99	Stainless	Amazon
12 Volt Battery	N/A	N/A	N/A	2	$169.99	$339.98	Stainless	Amazon
TPR Rubber Caster Wheels	3in	N/A	N/A	4	$6.95	$27.80	Stainless	Amazon
TOTAL PRICE OF MODULE						$537.77		

Total design projected cost	4 Frames	$918.44
	4 Rotating Materials	$2,151.08
	Total Projected Design Price	$3,069.52

Figure 10.6: BILL OF MATERIALS

A model of the weight distribution shows our strategy for keeping the barrel on the ground. The 1/8in thickness of the bars remains constant in order to keep the cart on the floor, and a 60lb counterweight will keep the wheels on the ground. The 1/8in thickness will be more than strong enough, as was shown last semester and through testing. The actuator will have a 600lb force, be located 7 inches from the barrel pivot point, and have a 12 inch arm. Other pertinent details are shown with annotations on the diagram.

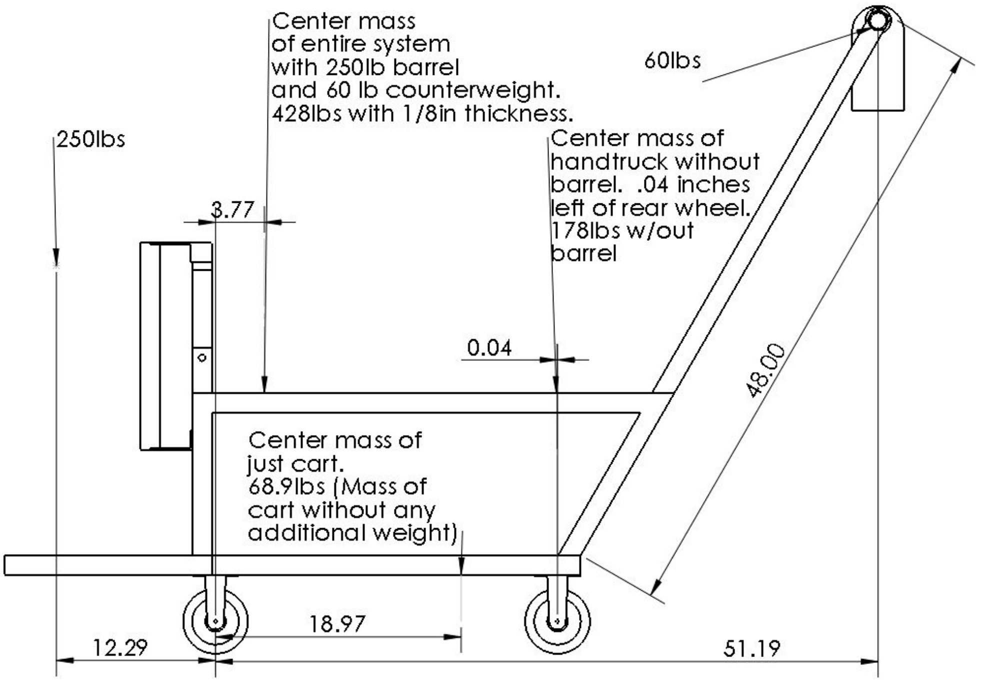


Figure 10.7: SIDE VIEW SHOWING WEIGHT DISTRIBUTION IN DOWN POSITION

11. Detailed Product Design

11.1. Fall Semester Product Details

The frame is made of hollow stainless steel square bars, 1 1/2" outer width, 1/8" thick. All joints are welded. Specific hook design will be determined through testing. Concern arises from hook's ability to damage barrel rims. Bottom Wheels touching floor are plastic, 5", rigid. Kick out wheels are also 5"D plastic. They are either swivel wheels or omni-directional rolling wheels to prevent swaying back and forth, as the current design will frequently require them to leave the floor. Barrel-turning wheels are pictured 30 inches apart, but their distance is modifiable. They are secured to the hand-truck by pins (the holes of which can be observed in the 3D image/the pins are similar to the ones that hold commercial frame tents together), and several hole sets can be drilled to accommodate frequently encountered standardized barrel sizes.

The process used to collect and replace the barrels is pretty straightforward. The steps are:

1. Roll modified hand-truck to pallet containing dirty barrels on dirty side of demarcation line.

2. Tilt hand-truck as pictured, until the bottom plane of the rollers are perpendicular with the plane of the pallet.

3. Tilt hand-truck slightly forward of this plane. Raise, lower, and place hook on rim of barrel.

4. Lean barrel back toward the operator. Moving the back of the hand-truck to a fully vertical position should raise the barrel enough to slide over the .5inch thick bottom disk (see diagram).

5. Step on rear axle. This force will assist the operator in taking the barrel off the pallet.

6. Rear axle wheels will catch barrel past the point of equilibrium. Barrel will remain on hand-truck while being cleaned. Include hook and bottom surface of bottom wheel disks in cleaning process.

7. Replace hook.

8. Roll hand-truck with now-clean barrel to just short of demarcation line in front of clean-side pallet. Tilt hand-truck upwards to replace barrel.

9. Remove hook, repeat process.

Note: several hand trucks will likely be used simultaneously.

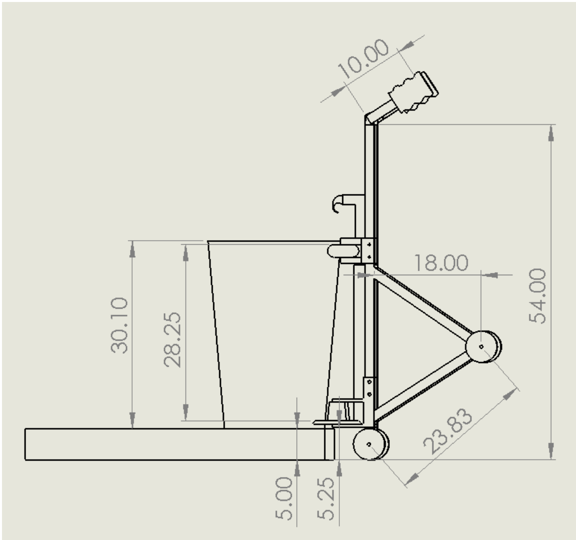


Figure 11.1: HAND TRUCK DIMENSIONS WITH PALLET

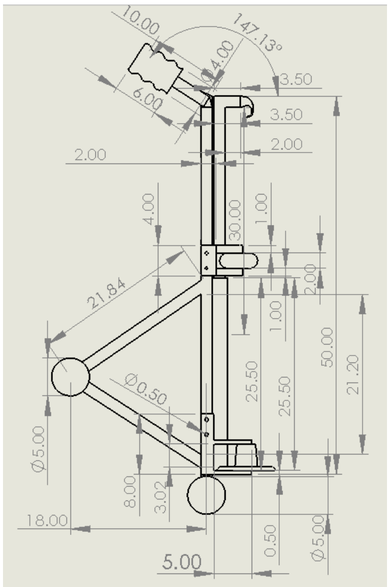


Figure 11.2: RIGHT VIEW

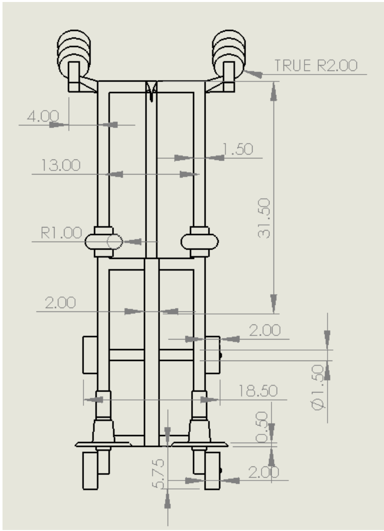


Figure 11.3: FRONT VIEW

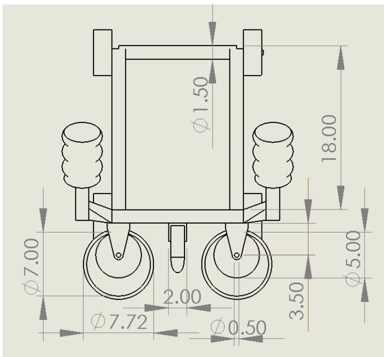


Figure 11.4: TOP VIEW

11.2. Spring Semester Product Details

The route the team decided to go at the beginning of the spring semester was to reduce REBA scores further than our previous concept. The proof of concept still applies to this design, with the changes made to what is applying the force required to rotate the barrel on the dolly. The human input was replaced with an electric linear actuator to perform th task and greatly reduces the REBA score making this new design very beneficial. When considering the location of the linear actuators, the position used by the previous team served to work for our design to main a shorter actuator. Below is are the drawings for the design that was built. The top and bottom piece are single weldments. The tolerance between the swiveling top and the bottom is 1/16 inch on both sides. The wheels are welded straight onto the bars. The sliding hook has a gap of 1/4 inch on all sides, but the final product would be a manufactured hook.

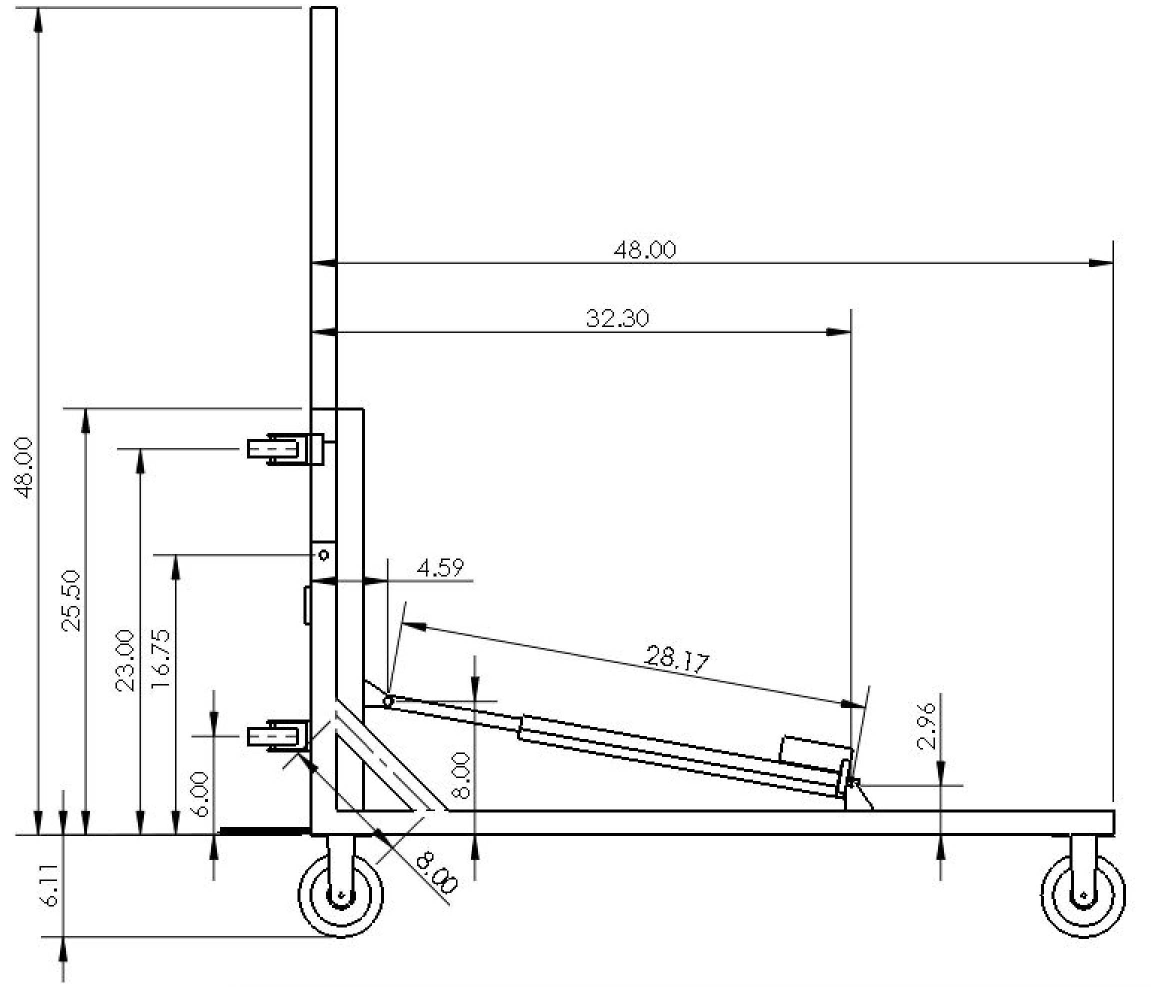


Figure 11.5: SIDE VIEW OF HANDTRUCK WITH DIMENSIONS IN INCHES

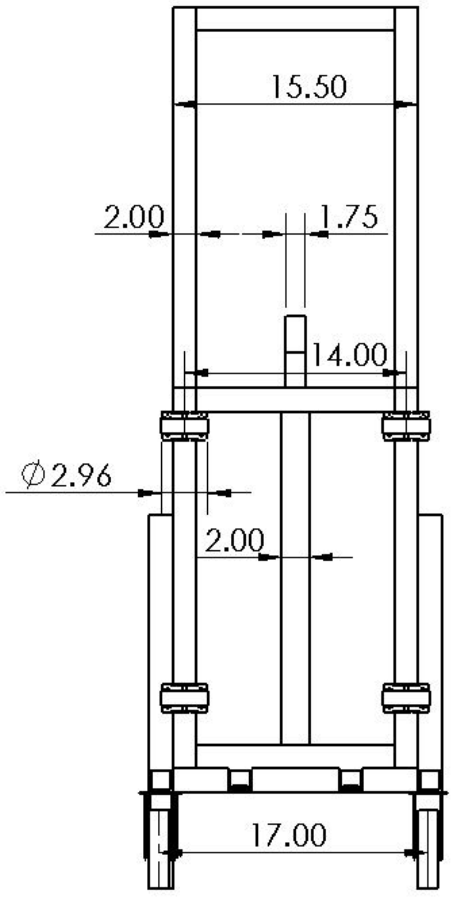


Figure 11.6: FRONT VIEW OF HANDTRUCK WITH DIMENSIONS (INCHES).

12. Engineering Analysis

The device the team aims to create in the spring semester consist of mechanical component and properties. The first approach to analyzing the team's concept was to calculate the forces that would be required by an operator to perform the task. Two free body diagrams were created to determine the minimum forces required to rotate the barrel. This was also done to modify the dimensions and components of the hand truck concept. The second part of our analysis consisted of examining the custom roller design. This component of the hand truck needed to be created to assist in reaching the barrel on a pallet.

12.1. Static Equations

Static moments of equilibrium equations were used to analysis forces on the barrel and hand truck concept. The goal is to minimize the force a worker is required to to use to move a barrel. The only time a worker will use any force is when they are rotating the dolly between its two positions. The worker is no longer required to hold the barrel during the ten minute cleaning process.

On the left in figure 12.1 is the free body diagram for the barrel. The force applied to the barrel is at the top lip of the barrel. This is where the hook mechanism will be able to grasp the barrel. The center of mass was placed at the center of the barrel. This was chosen for a maximum situation for some barrel would not be fill to the top and would then lower the center of mass.

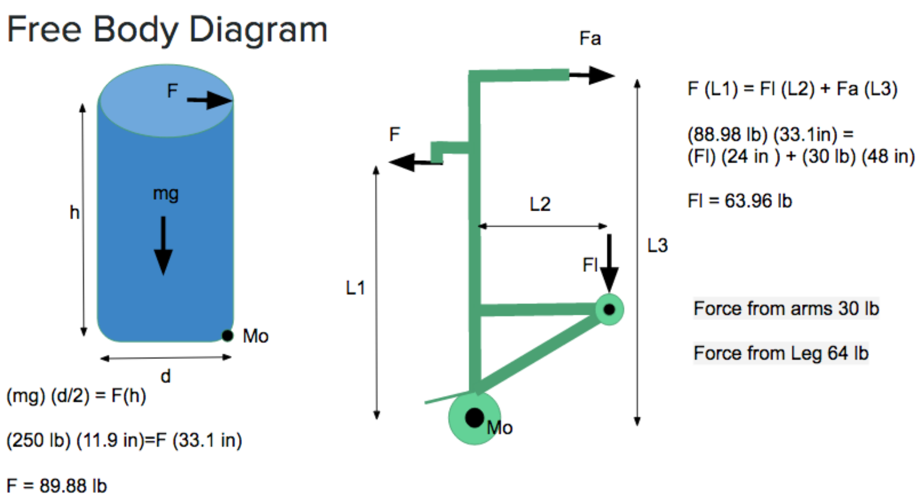


Figure 12.1: FBD OF BARREL AND DOLLY

On the right of figure 12.1 is the free body diagram for our dolly concept. The load required to overpower is at the hook mechanism where its attaches to the barrel. The worker applies loads at two points to counter act the moment induced by the barrel. The two points are at the hand grips and rear wheel axle. The force required will fluctuate between the two points but the intention is to use the workers body weight for the majority of the load. With a thirty five pound force at the grip the worker needs to apply sixty four pound force on the axle which is only a fourth of the average workers weight. The worker has more control over the dolly as well due to the hand grips being a place to moderate the two loads of the barrel and weight applied by the worker to ensure the barrel is lifted and lowered smoothly.

12.2. Finite Element Analysis

The primary focus of the bottom support roller was whether it could withstand the combined force applied from the vertical component of the barrel while its being tilted. Being made of stainless steel, it was tested using a point load of half the weight of the barrel, since at the bottom of the hand-truck frame, there will be two rollers to support the weight of the barrel. With each point load being applied to the weakest part of the roller. This is the bottom edge where support portion begins to angle and thin out to allow the barrel to slide up. With this, a case study was performed in Abaqus, a commonly used force study program.

Knowing the material properties of 304 stainless steel (Poisson's of 0.29, Young's modulus of 203 GPa, Yield Strength of 215 MPa), the geometry of the roller, there was a point load of 125 lbs (half of the 250 lb maximum barrel weight), which would be the highest force exerted on the roller during operation.

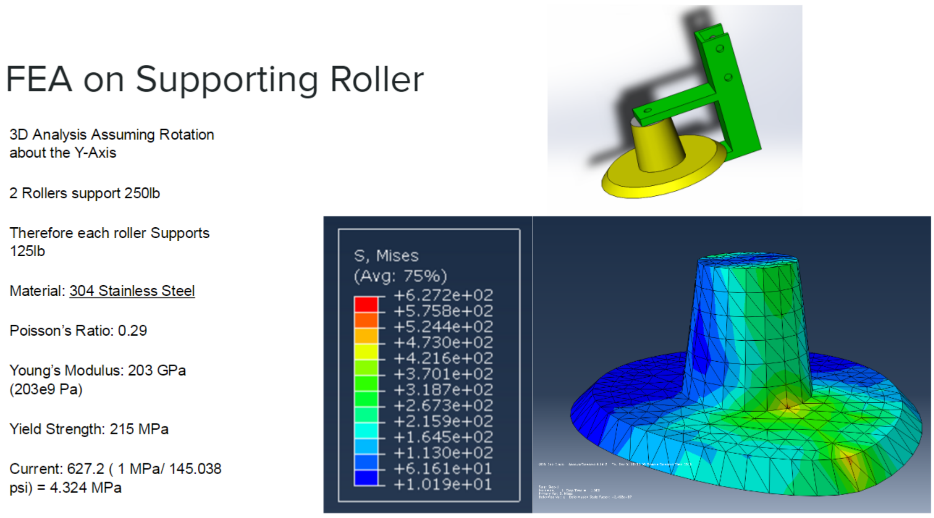


Figure 12.2: ABAQUS ANALYSIS

12.3. Overall Frame Moment

Removing the human interaction with tilting the device, another concern was raise. The potential of the back end of the device to tilt forward due to the weight of the two hundred and fifty barrel past the front wheels of the device. This was resulted with a weight distribution and a calculation of the overal moment to counteract the barrel.

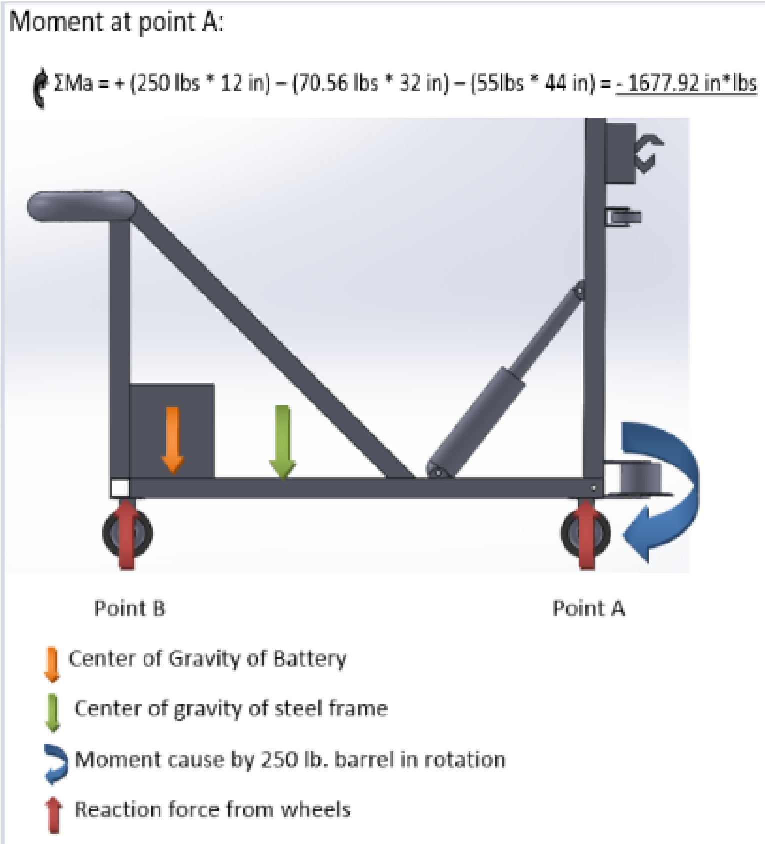


Figure 12.3: FRAME MOMENT ANALYSIS

13. Build/ Manufacture

The build of team 06 design for Amgen material handling problem did not use actual materials intended to be used within Amgen airlock due to keeping overall product cost of the project low, leaving room for resign implementations. The use of of steel rather than stainless steel for similar properties for testing, more affordable actuator and battery with similar output voltage and actuating rates also for testing. The manufacturing will be similar for either sets of materials. The team used a bracket and bolt design to piece the device rather than welding to adjust during redesigning. Welding would have been more time consuming and the time to order more materials were too long to go with that option.

Figure 13.1: BOLTS AND BRACKETS

The actual manufacture of the final design is a simple construct. The structuralist frame will be made of stainless steel and professionally welded. If tubing is used then all opening must be sealed off to prevent containments from entering and reducing the cleaning process of the device. The team constructed custom brackets, since the ones recommended with the purchased actuator did not fit in the end. The team recommends for actual construct, pre-made brackets to secure the actuator to the frame. The the rollers were also mounted to our device with bolts. these as well must be welded to the device to not have any crevices open to can collect dirt. The hook design currently has a tube entering a tube design. In the final version it would have two hooks on the rotation frame. This would be double the security, make the design closed and give a better look to the design.

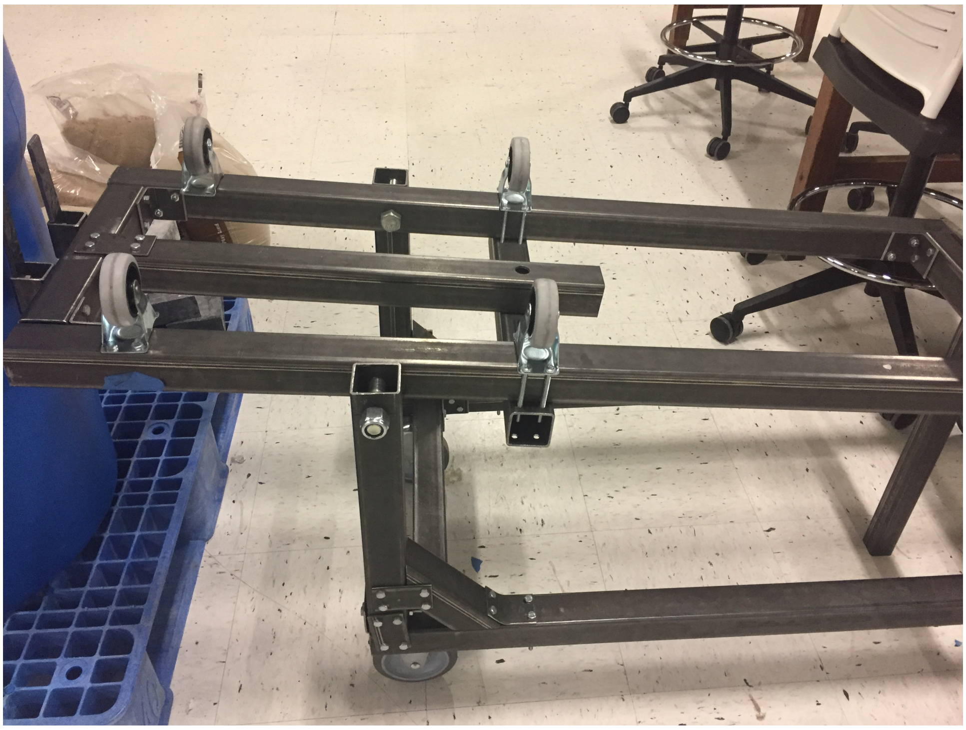


Figure 13.2: OPENINGS IN FRAME

The device would not be mass produced, so the quantities needed would be hand made with professional welders. The construction is cutting, placing and welding. The wiring to the the actuator is a simple positive and negative to the desired controller system then to the twelve volt portable battery. The battery is connected to a battery charger to keep the entire unit as one.

. ANGLE. ANGLE

Figure 13.3: CURRENT CONSTUCT

14. Testing

To ensure the design could be used in Amgen facility for its intended use the team created a test matrix. This was used to identify individual components of the design and to evaluate its performance.

	What to Test?	Results	Test Parameters	Planned Resolutions
Frame	Strength	passed	full motion w/ 250 lb	
Roller	Strength (Abaqus)	Over designed		removed
Roller	Deformation	failed	250 lb load	barrel deformed, more points of contact
Roller	Reliability	passed		
Worker Load	Force of worker in System	N/A		Redesigned
Hook	Movement	passed	250 lb load	
Hook	Stability	passed	Remain in contact during movement	slight movement due to bracket, weld
Shock Absorption	if needed?	not needed		
50lb load	specific load	passed	with strap, and hook	
100lb load	specific load	passed	with strap, and hook	
150lb load	specific load	passed	with strap, and hook	
200lb load 1	specific load	failed	with strap, and hook	tighten actuator bolts
200lb load 2	specific load	passed	with strap, and hook	
250lb load	specific load	passed	with strap, and hook	
250lb load	specific load	passed	without strap, only hook	
Bearings	Upper Bearing rotation	N/A		redesigned
Bearings	Lower Bearing rotation	N/A		redesigned
Movability	Ease of controlled movements	passed		
Actuator	Load Capacity	250 lb - passed	tested up to 250 lb	To be tested higher id possible
Actuator	Time duration of motion	3.45 sec	With Max Load	faster actuator needed
Barrel Simulation	Demonstration Practice	passed		

Figure 14.1: TEST MATRIX

14.1. Pre-Build Tests

The first tests the were an estimation on how our design would move and the actuator capacity using a similar machine designed by Amgen. The machine uses an electric linear actuator powered by a twelve volt battery to lift and and maneuver a pump for maintenance purposes. The actuator was tested by Amgen to a capacity of five hundred pounds. The wheel set up and weight was similar to our design so being able to move around was important when mounting wheels and handle bars to our design. The results were practical for a worker to maneuver and gave assurance to use that specific actuator.

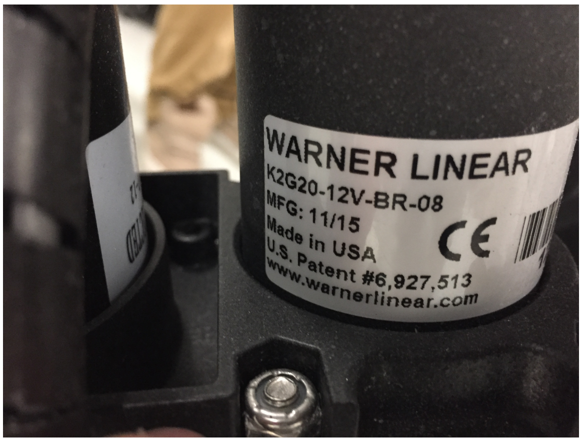


Figure 14.2: ACTUATOR USED IN AMGEN'S DEVICE

14.2. During Build Tests

The team performed tests throughout the manufacturing process to in order to make adjustments as we continued the build. Many of the tests performed were practical tests on performance and functionality. In order of construction, the four small rollers in contact with the barrels were adjusted for maximum contact with barrels. Roll tests were performed with empty barrels with smoothness. With intended force applied to the barrels, they did not bump off the rollers during rotation. The team attached a normal dolly to our frame to get a better idea of the skis to use.

Figure 14.3: FRONT FRAME AND DOLLY

14.3. Device Tests

The rest of the test matrix aimed at overall performance and stability of the design. These tests where performed with a five hundred kinetic load capacity electric linear actuator with a twelve volt plug adapter. The weight of the battery and handlebars with simulated with bricks on the back end of the device.

14.3.1. Load Tests

For safety purposes a strap was used during rotation of the barrel at different loads so that if the hook could not hold the barrel no one would get injured. The testing was done in increments of fifty pounds up to two hundred and fifty pounds. Tests up to two hundred passed, but at two hundred the bracket holding

Figure 14.4: DEVICE

the actuator began to slide along the actuator. This was fixed with tightening the bolts clamping to the actuator. The test was performed again with no signs of struggle. At two hundred and fifty pounds the device handled well with no signs of struggle. After contact with our sponsor, request for a ten to fifteen degree rotation with only the hook was asked, so a final rotating test done with only the hook and no strap was done. This test passed with same results as the ones with the straps so the test was changed to a full rotation, that the device handled well.

Figure 14.5: LOAD TEST POSITION 1

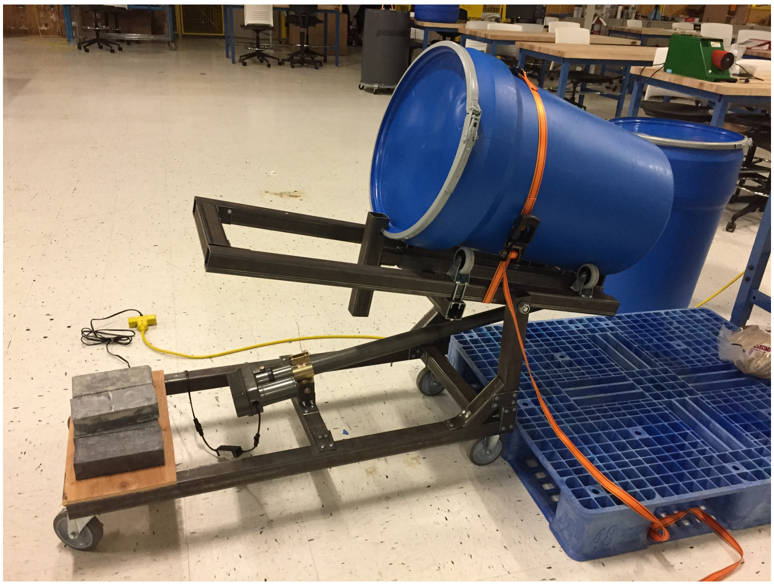


Figure 14.6: LOAD TEST POSTION 2

14.3.2. Additional Components Test

Additional practical tests such as engaging the barrels and securing the hook were tested with repetition in order to find any inconsistency and issues. These were tested with the varied sized barrels. Transporting the barrels with the device was not difficult. Not including handle bars does not accurately show the process but does give a better idea to the degree of freedom the device has to be maneuvered. As Well as rollers again for rotating full weight barrels. When performing this test the barrels began to deform due to weight. Roll-ability was still possible but required some force input. For this, improvements such as implementing larger rollers or more rollers to increase the points of contact with the barrel. This would distribute the stresses on the barrel, eliminating the deformation problem.

Figure 14.7: HOOK

15. Redesign

The team was in redesign since the proof of concept presentation from the fall semester. The leading factor was our REBA scoring of our concept. The score was an improvement from Amgen's current process but aiming to lower this led to a new goal.

15.1. Linear Actuator

To further reduce REBA score would introduce a linear actuator to rotate the barrel rather than a worker as untented in our previous concept. The elimination of the worker's interactions with the barrels weight would lower the REBA and also create a process that could be more consistent. Potential for either an electric or pressure driven actuator could be used within the airlock. Unlike the previous teams pressure driven device, the team wanted to retain the mobility of the original design. The decision was made for an electric twelve volt battery.

Figure 15.1: ACTUATOR DEVICE

15.2. Pivot Point

The reasoning the original designed rotated to a forty five degree angle due to the amount of force a worker would need to apply if it had rotated ninety degrees. The rotation of the original design was at the the front wheels, so this became the the point of rotation when designing the new two-part frames. The actuator would be attached to the top of the rotation frame retaining a forty five degree rotation. With the implementation of a linear actuator required to perform the rotation, the orientation of the barrel can be adjusted. A full rotation of ninety degrees could be achieved now. The previous team had placed their actuator towards the bottom of their device with a raised pivot point. the pivot point was raised fifteen inches above the previous to allow the bottom frame to kick out and reach a ninety degree rotation. The specific height change to the pivot also allowed the barrel to sit higher for Amgen workers to clean the barrels in a natural upright position rather than attempting to bend to reach farther parts.

15.3. Bottom Roller Types

The previous design for the bottom rollers involved a hybrid roller and ski combination. This was and interesting concept for when the barrel was positioned in a forty five degree angle. It would have allowed the barrel to spin with more ease than a separate roller and ski combination. When the design changed to a ninety degree angle rotation of the barrel it was better to have separate components. it would be easier to manufacturer and in ninety degrees the skis wouldn't interfere with the barrel rotation.

15.4. Future Redesign

With limited time on working on this project, additional redesigns can be made to further improvements. The team has developed ways to eliminate existing minor issues that still reside in the product design. The REBA is currently at a two with the lowest value being a one. These are some redesigns based on feedback from

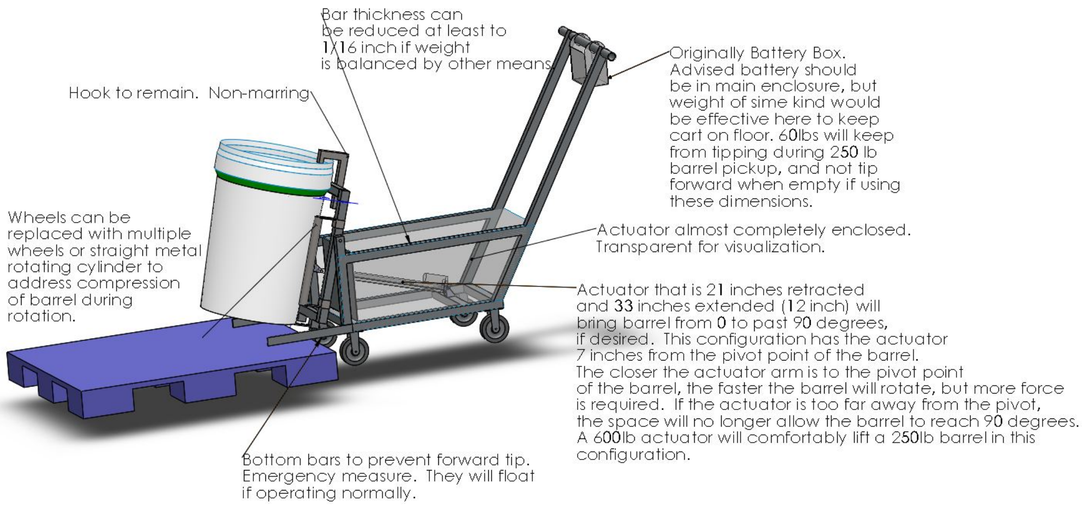


Figure 15.2: REDESIGN FROM TESTING

Mr. Taylor.

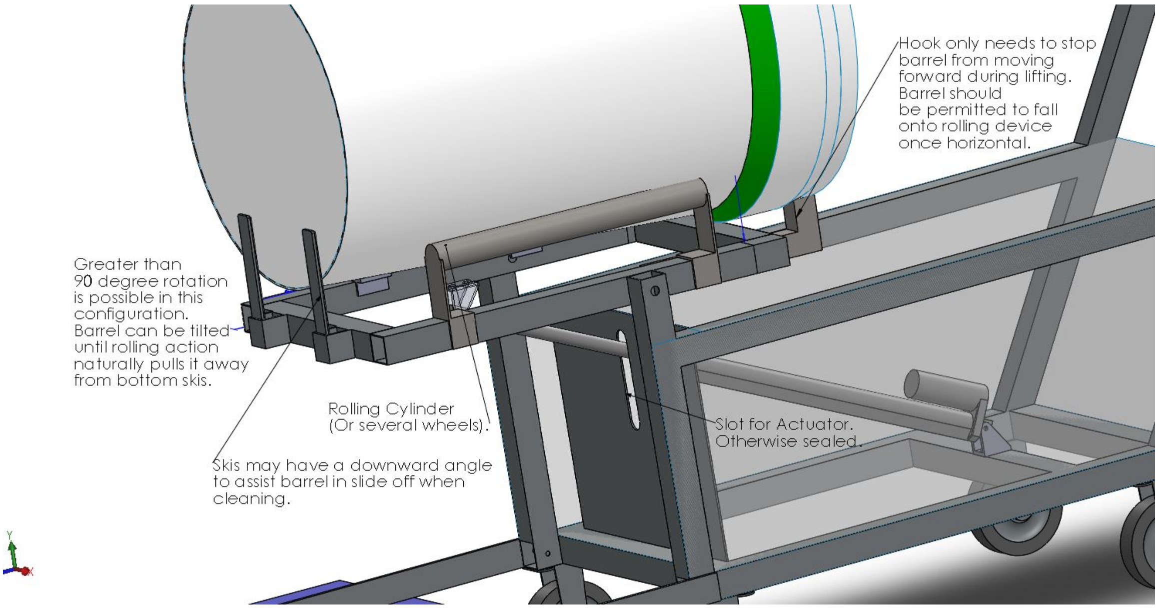


Figure 15.3: REDESIGN FROM TESTING (VIEW 2)

15.4.1. All Rollers

In a latest test concerning the spinning of a two hundred and fifty pound loaded barrel on the set of four rollers failed. The problem that occurred was the barrel began to deform around the points of contact. The barrels integrity wasn't tested prior to the test, so redesign of rollers are necessary. The team aims at two possible solutions. the first is to use more rollers allowing the stresses to be further distributed the barrel. The second approach is to use large cylinder rollers along the frame of the design. This also increase the points of contact with the barrel decreasing is concentrated stresses the current design has.

Since these are spinning components while a worker is engaged with the barrel, safety guards are required. These would be protecting shields to prevent clothing, hanging articles and hands from coming into contact with the roller.

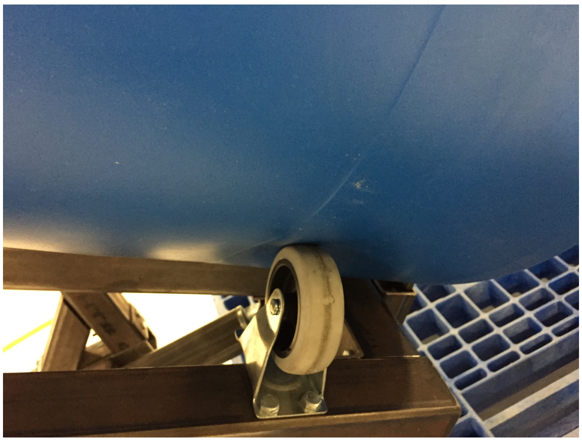


Figure 15.4: BARREL DEFORMATION

15.4.2. Handlebars

Amgen has certain guide lines to the handle bars on their devices. the handle bars would need to follow their guideline and remain in a position that keeps the REBA score of the design as low as it is currently. Some separation from the back wheels are also necessary to avoid any foot injuries since the device has some weight when fully loaded with a barrel.

Figure 15.5: HANDLEBAR CONCEPT

15.4.3. Material Reduction

The amount of material used in the device is over designed. The reduction of materials is possible making the device more compact and less cumbersome than it is now. Extra materials from the front frame remained from the previous design as well as the extra material used in the bottom frame. The design used the materials as the counterweight to prevent the device from tipping forward. This can be shortened using solid weights to reduce the size of the device. The moment would need to be balanced with any reduction to materials.

16. Operation/Assembly/Repair/Safety

16.1. Operation

The barrel lift is designed to be operated by one worker. The operation is to be as simple as possible in order to have great usability and limit the amount of training needed by workers. Operating the lift is a four step process as follows;

1. Push the barrel handler (from behind) up to desired barrel with out breaking the line of demarcation on the floor of the airlock

2. Lift hook straight up and place on the top of the barrel cover and steel ring. While attaching the hook to the barrel, be careful to make sure the hook is firmly attached, and to avoid placing hands and fingers between the barrel and hook.

3. Go to the back of the lift and hold the momentary lift switch and remain at the back of the cart while the barrel is in motion. (note: the switch will be momentary as to force the worker to remain away from pinch points and moving components of the mechanism)

4. Once fully tilted in the upright position (the clean position) move the barrel handle to the desired cleaning location and begin ten minute wet-lock cleaning process wiping all sides of the barrel. Note: avoid placing hands near the frame rollers, to avoid being pinched between the upper frame and the barrel. Also it is fine to remove the hook at this point as long as the

downward tilt switch is not activated.

5. Once the cleaning process is complete, reactivated the hook, move the handler to the "clean" designated pallet, and activate the momentary down tilting switch. At this point, the barrel is sterile, so it is important to avoid contact with walls, employees, and anything other than the frame, and clean pallet.

6. Finally, reach across the handler to the hook, and remove when the barrel is fully lowered at the desired location of the pallet. Here it is also important not to step over the demarcation line to avoid contamination.

7. Finally, restart the process and move the handler to the next barrel.

16.2. Assembly

The assembly that was required for the prototype build slightly differed from the assembly that would meet the specifications at Amgen, for a water proof cleanability these are not met since the prototype build is to prove functionality. On our prototype build, it was decided to bolt the sections of frame together as opposed to welding or permanently affixing the sections together. This was done to prove that the dimensions would be sufficient, and that the could be moved if small changes are required. The actual build would differ with more permanent, stainless steel variant, as well as welds to seal the frame and keep out unwanted water. After the dimensions were proven to be effective, the frame would be sent to Amgen to be welded by their technicians. Unfortunately due to time and scheduling constraints in combination with changes to order forms, we were unable to do this and decided that bolts would be weaker then welds, so if the bolts were effective, the welded version had to be even more so.

However on the actual build with stainless steel, it is desired to keep the bolts in places connecting additional components like rollers, the hook assembly, and caster wheels. This would be to ease repairs using simple available hand tools to keep the barrel handler operating with limited down time for maintenance or repairs.So with a fully welded frame and bolted or fastened additional components, the barrel handler would have both increased structural integrity along with increased interchangeability of parts. Thus being the perfect balance for every day wear and tear, along with guaranteed safety.

16.3. Repair

As over designed as the frame currently, repair to the frame would not exist simply to the fact that 11 gage steel is more than triple the needed thickness of our current frame. However for a redesigned frame with stainless steel, along with 1x1x16 gage steel piping, it is important that the frame is regularly inspected both before and after to make sure that there are no problems with deformation due to regular loading and unloading of 250 pounds. The most likely cause of issue in respect to the frame would be the welded sections. However, since Amgen is very experienced with welding both cold rolled steel and stainless, so this is not considered to be an issue.

In respect to the coasters and rollers, these would be the weaker parts because they hold the entire weight, and are also resting on bearings. With hospital coaster wheels usually being replace within every 2 to 5 years on average, the use of bolts or removable fasteners would increase longevity of each barrel handler, and save money at the same time.

The hook we designed was completely cold rolled steel, which unfortunately charred up the plastic on the barrel. In order to avoid regular replacements or refurbishments of the barrels, rings, and covers, the hook that goes on the stainless version would required a nylon or polymer cover on the hook. This component would be cheap, easy to make and replace, and would be sacrificial as opposed to replacing the barrels and more expensive parts.

Other then that the most likely area where repairs would be regularly needed would be in respect to the actuators power supply, control system, and wiring. Having an electric circuit regularly exposed to water, abuse, and a regular amount of work would make it so these parts would need constant care and inspection both before, and after use as to not waste time of paid employees.

16.4. Safety

Safety of the operator is the most crucial aspect of this design project. Eliminating physical lifting of the barrel drastically reduced the risk of injury to the worker, and after studying average costs of back injuries to workers, along with lawyer fees, settlements, and time wasted, the mechanism we designed would ultimately pay for itself and save the company an average of $50,000 yearly, and costing only $2,500 per unit.

Some additional safety features added to our prototype, was first to make the actuators switch momentary. This is to make it so the operator is forced to stand behind the mechanism at all times during the tilting phase as to avoid injury should there be a malfunction. This is also to keep the operators hands and feet away from the skis and barrel, where a potential pinch point is currently located. Our sponsor was fine with us keeping the current assembly as long as the operator is required to be out of reach, further limiting any issue with pinch points.

Another issue we faced during the testing phase is the location of pinch points between each of the four rollers on the upper frame, and the fully loaded barrel in the upward position. As the operator hand rotates and cleans the barrel, if he decides to reach underneath the barrel (though he should only clean the top half and rotate to avoid bending over), there is potential for a hand or finger to get caught between the barrel and roller. After exploring this issue, it was decided that guards would be placed surrounding the rollers and barrel so they simply are in able to receive any kind of roll-bite or pinch during the cleaning process. So this safety feature was fairly simple to come up with a solution for.

One of the biggest risks faced by an operator using this device, is the motion of the 250 pound barrel, and the possibility of a catastrophic failure with the actuator. There are two solutions to this issue which will be used in unison to further increase the safety of the cleaning process. The first, simply is to keep the operator away from the barrel at all times. If both the hook and skis were to fail simultaneously, the barrel would simply fall in front of the device with the operator completely away from it. The second solution is that the actuator itself could lose power or disconnect from its power supply, and this could make the loaded upper frame fall down with a crash. The solution to this issue is that an actuator with an internal worm gear so that if power is cut during the tilting process, the actuator simply becomes rigid. As long as the force applied by the barrel does not exceed the actuators kinetic force limit (located in the design specs once purchased), the actuator would have to have it's metal worm gears sheared off. Since this would require a force that is exponentially larger then the barrels weight, this is a fool proof strategy to avoiding any failures in the tilting system.

17. Maintenance

Maintenance for the barrel handler would primarily lie with daily inspections of the chassis, electrical circuits, and rollers. With out a long term study on the effects that daily work would do to effect the performance of a barrel handler over time, it would be inaccurate to tell when specific parts would need to be replaced or refurbished. Other then the coaster wheels lasting an average of 2 to 5 years, this would specifically depend on the amount of use they would be getting on a daily bases, and the effect of bleach getting to the bearings. Other than functionality of parts and the electrical system, things like batteries would need to be interchanged once they begin to lose charge a a faster rate. Lastly, the most major necessity to stick by Amgen's strict cleanliness requirements is corrosion resistance. The inspections would need to be detailed to the point of not allowing any contaminants into the airlock. Whether that is residue sticking in the bearings of the rollers, spot rusting on the frame or wires, or battery acid leaks from the connections.

Maintenance is primarily safety orientated, but would also assist workers with avoiding down time with a non working device. Along with avoiding resorting to the previous way of manually moving and lifting the barrels which voids any progress from this report. In addition to this, maintenance is the front line to avoiding any trouble with OSHA or the FDA in respect to their very specific requirements that Amgen must adhere to.

18. Additional Considerations

18.1. Economic Impact

Our product is not designed to increase the process it's facilitating faster or more efficient. It will create additional machinery that will need to be cleaned as well. Its benefit will be in the form of increased safety to the workers, convenience in moving the barrels, and a more reliable cleaning process, the benefits of which we hope will outweigh the drawbacks. The small cost of these product will in future prevent Amgen from law suits of injuries caused from performing their current process.

18.2. Environmental Impact

According to Amgen's website, "The overall aim of our 2020 targets is to protect the environment, improve efficiency, and increase stakeholder value. Our targets are designed to track our progress through deliberate efforts—without influence from growth or contraction in our business." Spills from dropped barrels can contaminate a warehouse, which is always a risk when barrels that are too heavy to be moved easily are handled manually. Our design seeks to mitigate this risk with a linear actuator, which does the heavy lifting while safely securing the barrel. The material that our prototype is primarily made from, stainless steel, is itself an environmentally friendly, and recyclable material. It does not pose a threat to living organisms or the environment, beyond the energy it takes to produce. The battery that powers our design poses a greater cost to the environment, but should be considered acceptable, given the improvement to the safe handling of dangerous chemicals that automation will help facilitate. Batteries which are properly recycled are a diminished environmental risk.

18.3. Societal Impact

The product has a small contribution on societal impact on the small scale. It increases the safety of Amgen workers preventing common injuries such as back injuries when performing the cleaning process. Amgen is a biomedical company innovating and creating new medicine for people with serious diseases. On a larger scale, this product will help Amgen get material safer and more efficiently into their facilities to create more or test for new medicine. The medicine creation rate begins with having those barrels of raw material entering safely and cleaned from contaminants. Amgen is a societal impact already as a company and this product will assist them.

18.4. Political Impact

The political impact of safety, both to the customer and Amgen employees, is always a consideration. The cost of negative publicity related to improperly cleaned equipment can be high. Amgen is inspected regularly and must always be ready.

18.5. Ethical Considerations

The product designed for assisting Amgen employees during the cleaning cycle of their incoming barrel to the facility does not create any ethical issues. Employees are informed and will be given a manual to operate the device to its intended use. There will be voluntary participation for workers who have been hired to perform this job, and does not relate to the product but rather Amgen's hiring contracts. Any possible dangers are to be labeled on the product to make the employee aware of harm such as pinch point labels. Confidentiality consideration does not apply to the product.

18.6. Health, Ergonomics, Safety Considerations

The entire design and system of incorporating a barrel handling device was specific to ensuring workplace safety during the cleaning process. Our sponsor Chuck has let us know that the current system going on in the airlocks is counter productive to Amgen's goal of helping people with their health. With an initial, man-powered improvement of adding a customized hand truck, we were able to significantly cut down risk on the REBA chart of workplace risk assessment from a risk of 11 (very high) to a risk of 5 D.2 (moderate) which was sufficient for the first design period. However, we were successfully able to create a working device that furtherly decreased the risk from a 5, all the way down to a 2 (low risk) D.3 which greatly eliminated almost any physical interaction with the barrels or carts, other then moving the cart around. We were fortunate enough to prove this through testing that physical lifting could be completely eliminated by combining our hand truck deigns with an actuator and outside power source. Along with increasing safety, this device also had massively increase the quality of work faced by the cleaners on a daily basis. through innovation, careful consideration, workplace injury can be an issue of the past, and Amgen would lead competition to an increased quality of life for their employees. With the additional considerations aforementioned in the operation section, things like a momentary switch, keeping the worker from the motion of the barrel, and increased foot room and guards, this device greatly increases safety, ergonomics, and proves that ingenuity can help further society into a safer place.

D.1

18.7. Sustainability Considerations

The sustainability of the product will be dependent on individual parts. With regular maintenance the twelve volt battery will last roughly four years. The actuators lifetime will depend on the amount of use on a day to day cycle. The frame is made of stainless steel which is very durable. It will last fifty years with little wear or tarnish and can stay together if welded properly. The product was designed for maximum life time of performing its intended process.The frame being the largest cost will last through several actuators and battery replacements.

19. Conclusion

After much consideration to a solution for increased ergonomics and injury to workers at Amgen, we as team 6 were happy to achieve our final goal of increasing workplace safety. It's understood that injury to ones workers is a black eye to the companies principle goals in helping with the health of their employees and customers. Through innovation, Amgen is actively increasing innovation in the tech field, and it was a pleasure to be a part of that process and hopefully be of assistance. We as team 6 wanted to thank the following people for our success, and with out these individuals, our progress would not have been close to where we are now. A special thank you to Chuck Taylor, the Lead Engineer who sponsored us, Eli Lamothe, a URI alumni and engineer at Amgen, Alex Desilets, the T.A for capstone, Dave and Jorge, the machinists who guided our build, Professor Taggart, who's knowledge of Finite Element Analysis helped prove our concept, and lastly Professor Nassersharif, who walked us through the design process, and showed us how to to take pride in our work.

20. Further Work

At the end of the spring semester, the team has continued to test and redesign components of our device to fine tune it to Amgen's needs. The device is successful in accomplishing the desired task as it was intended to do. Rather than having a completely manual labor cleaning process, Amgen can reduce the possible injuries that could have occurred with their recent process by using the device team 06 has designed.

Further improvements to the device is to incorporate the future redesign components in the redesign chapters. The main concerns are the handle bars and the the roller contacts. To make this new process work to its maximum efficiency, easy and comfortable handle bars are necessary and must comply with Amgen's regulation standards. The other component is spinning the horizontal barrels. This process needs to become easier with more contacts to the barrel. This can be down by have larger or more contact with the rotating barrels. Additional safety measure must be included such as guards for the rollers to avoid and hands from coming into contact during the spinning process.

21. Acknowledgment

Capstone Team 06 would like to thank individuals at Amgen would made this project possible, especially Chuck Taylor who has helped the team through the development of this project.

The team would like to acknowledge the adviser at the University of Rhode Island who have assisted in the completion of this projection to date, Dr. Bahram Nassersharif

Bibliography

[1] Amgen, *Company*. [Online]. Available: http://www.amgen.com/about/.

[2] L. S. George Dieter, *Engineering design*, 5th ed. McGraw-Hill, 2013, ISBN: 978-0073398143.

[3] M.-N. Research, *Workers' comp back injury*. [Online]. Available: http://workers-compensation.lawyers.com/workers-compensation-settlements-awards/workers-comp-back-injury-how-much-will-i-get-and-how-long-will-it-take.html.

[4] R. F. Apter, "Knockdown barrel handling apparatus", *US Patent*, no. 4,335,990, 1982.

[5] A. M. Lechnir, "Barrel mover", *US Patent*, no. 5,042,962, 1991.

[6] H. Rodriguez, "Hand truck for moving large drums", *US Patent*, no. 5,678,976, 1997.

[7] P. J. Bowden, "Hand truck with foot tilt device", *US Patent*, no. 9,096,251, 2015.

[8] G. Industrial, *Company*. [Online]. Available: http://www.globalindustrial.com/?infoParam.campaignId=T97&gclid=CLPJ-9fL_tACFYiEswodCHMMYw.

[9] D. A. Hedge, *Reba*. [Online]. Available: http://ergo-plus.com/wp-content/uploads/REBA-Worksheet-v-2.0.pdf.

A. Project Plan

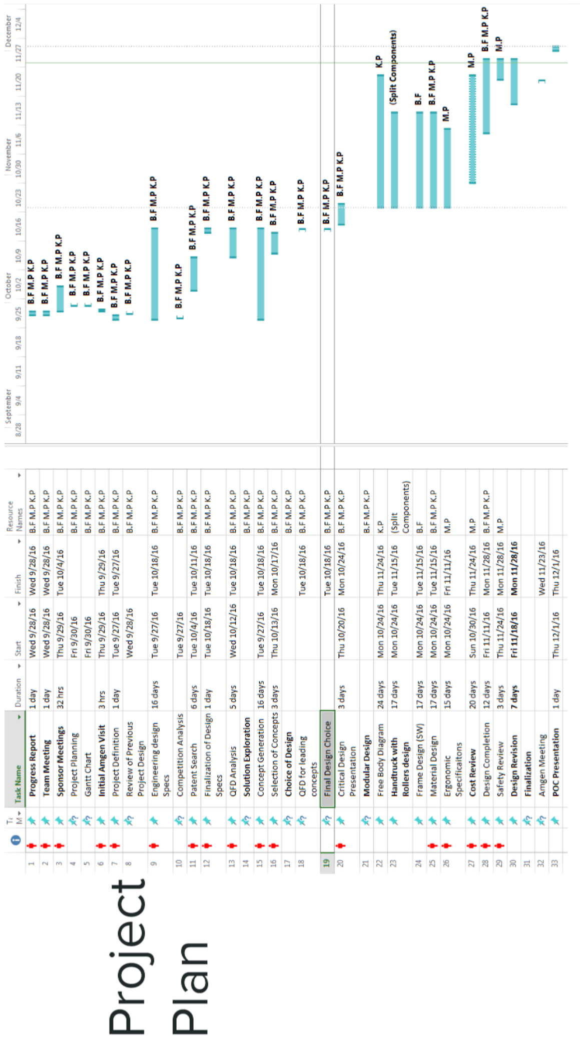
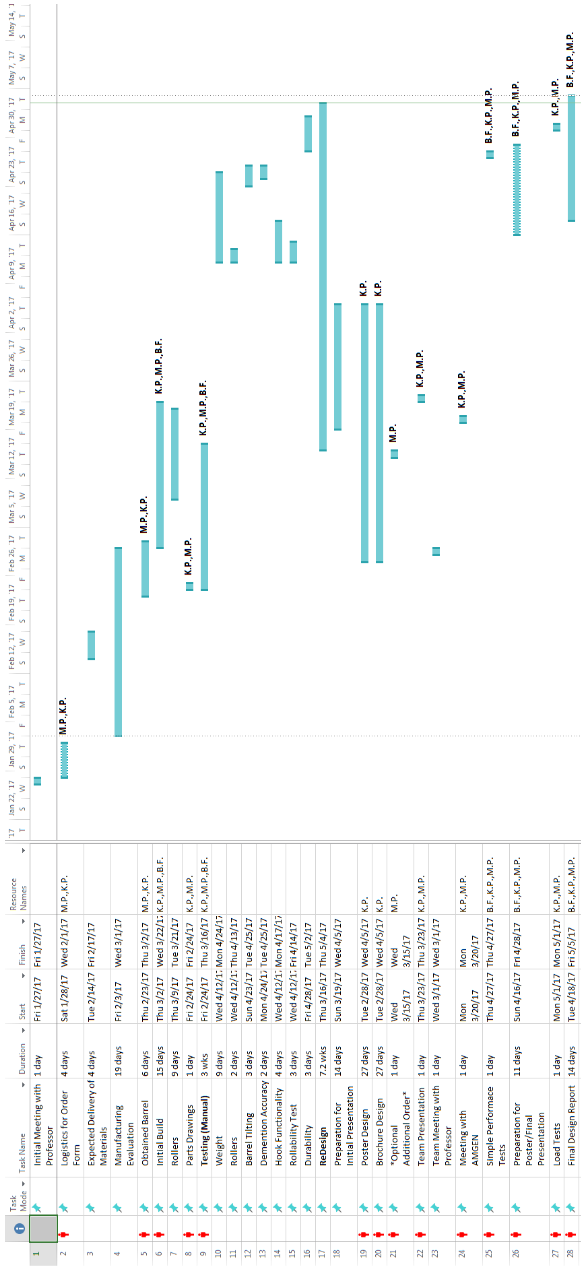


Figure A.1: FALL PROJECT PLAN



	Task Mode	Task Name	Duration	Start	Finish	Resource Names
1		Initial Meeting with Professor	1 day	Fri 1/27/17	Fri 1/27/17	
2		Logistics for Order Form	4 days	Sat 1/28/17	Wed 2/1/17	M.P.,K.P.
3		Expected Delivery of Materials	4 days	Tue 2/14/17	Fri 2/17/17	
4		Manufacturing Evaluation	19 days	Fri 2/3/17	Wed 3/1/17	
5		Obtained Barrel	6 days	Thu 2/23/17	Thu 3/2/17	M.P.,K.P.
6		Initial Build	15 days	Thu 3/2/17	Wed 3/22/1	K.P.,M.P.,B.F.
7		Rollers	9 days	Thu 3/9/17	Tue 3/21/17	
8		Parts Drawings	1 day	Fri 2/24/17	Fri 2/24/17	K.P.,M.P.
9		**Testing (Manual)**	3 wks	Fri 2/24/17	Thu 3/16/17	K.P.,M.P.,B.F.
10		Weight	9 days	Wed 4/12/1	Mon 4/24/17	
11		Rollers	2 days	Wed 4/12/1	Thu 4/13/17	
12		Barrel Tilting	3 days	Sun 4/23/17	Tue 4/25/17	
13		Demention Accuracy	2 days	Mon 4/24/1	Tue 4/25/17	
14		Hook Functionality	4 days	Wed 4/12/1	Mon 4/17/1	
15		Rollability Test	3 days	Wed 4/12/1	Fri 4/14/17	
16		Durability	3 days	Fri 4/28/17	Tue 5/2/17	
17		**ReDesign**	7.2 wks	Thu 3/16/17	Thu 5/4/17	
18		Preparation for Initial Presentation	14 days	Sun 3/19/17	Wed 4/5/17	
19		Poster Design	27 days	Tue 2/28/17	Wed 4/5/17	K.P.
20		Brochure Design	27 days	Tue 2/28/17	Wed 4/5/17	K.P.
21		*Optional Additional Order*	1 day	Wed 3/15/17	Wed 3/15/17	M.P.
22		Team Presentation	1 day	Thu 3/23/17	Thu 3/23/17	K.P.,M.P.
23		Team Meeting with Professor	1 day	Wed 3/1/17	Wed 3/1/17	
24		Meeting with AMGEN	1 day	Mon 3/20/17	Mon 3/20/17	K.P.,M.P.
25		Simple Performace Tests	1 day	Thu 4/27/17	Thu 4/27/17	B.F.,K.P.,M.P.
26		Preparation for Poster/Final Presentation	11 days	Sun 4/16/17	Fri 4/28/17	B.F.,K.P.,M.P.
27		Load Tests	1 day	Mon 5/1/17	Mon 5/1/17	K.P.,M.P.
28		Final Design Report	14 days	Tue 4/18/17	Fri 5/5/17	B.F.,K.P.,M.P.

Figure A.2: SPRING PROJECT PLAN

B. Design Specifications

Name of Product	Airlock Barrel Handler
Basic Functions	Allows for easy handling for barrels containing raw materials for a variety of shapes and sizes through a process designed to assist a rigorous pharmaceutical level of cleaning process.
Special Features	The machine should be designed as a modular system so that it can easily be installed, uninstalled for cleaning, and scaled up for larger than average loads.
Key performance targets	The new process should increase or maintain current efficiency. It should also decrease the risk of injuries to the workers.
Service environment	Room is approximately 4m x 8m. No materials that are porous are allowed to be used in order to meet with cleanliness stipulations.
User training required	Minimal training. Instruction manual and demonstrations.

Figure B.1: PRODUCT IDENTIFICATION

Time to complete project	The project needs to be completed by April 2017.
Fixed project deadlines	Design report is due May 2017

Figure B.2: KEY PROJECT DEADLINE

Physical requirements for product	Maximum load is a 300 lb barrel on a 40"x48" plastic pallet (~1200 lb).
Design variable values that are known or fixed prior to the conceptual design process	Room size~. 8m x 4m x 3m Barrel 1 height x Top diameter-33.1" x 23.8" Barrel 2 height x Top diameter-30.1" x 21.3" Pallet Size- 40"x48"x ~5"
Weight limit of product and lifting capacity	Must be able to transport barrels ranging from 22 to 300 lbs.

Figure B.3: PHYSICAL DESCRIPTION

Target manufacturing cost and price	This project is primarily a safety and efficiency project; therefore there is no target cost and price.
Rate of return on investment	N/A
Capital investment required	$3000

Figure B.4: FINANCIAL REQUIREMENTS

Useful life	15 years
Cost of installation and operation	Operation is simply the cost of worker wage using device.
Maintenance schedule and operation:	The maintenance schedule is explained in a separate table.
Reliability	Able to reach necessary cleanliness with 100% consistency.

Figure B.5: LIFE CYCLE TARGETS

Target Market	Amgen and possibly other biotech companies unless it is kept as a trade secret.
Competing products	There are other products used for barrel handling in industry such as: the Drum Handler ($3239) and the Drum Stacker ($2089). Portable Drum Roller ($1420).These are products do not meet the specifications for the barrels to be easily cleaned.

Figure B.6: MARKET IDENTIFICATION

Are there government agencies, societies, or regulation boards that control the markets in which this product is to be launched?	OSHA and the FDA will be the primary regulatory agencies dealing with our product.
Are there opportunities to patent the process or product or some of its subsystems?	It is unlikely because the current design is a combination of products that have existing patents.
Safety and environmental regulations. Standards. Pertinent product standards that may be applicable	OSHA and the FDA have the necessary regulations. No materials may be used that can absorb water (this may lead to contamination of the factory).
Safety and product reliability. Predictable unintended uses for the product, safety label guidelines, and applicable company safety standards.	Safety and reliability is high. Unintended uses would be by holding incorrect areas and using for objects outside of specified barrels.
Intellectual property. Patents related to product. Licensing strategy for critical pieces of technology.	Apter, Robert F., Carl Apter, and Joseph Soliday. Knock down Barrel Handling Apparatus. R. A. Industries, Inc. (Lansdale, PA), assignee. Patent 06/209,558. 24 Nov. 1980. Print.

Figure B.7: SOCIAL, POLITICAL, LEGAL REQUIREMENTS

Which parts or systems will be manufactured in house?	Frame will be manufactured in house.
Manufacturing requirements. Processes and capacity necessary to manufacture final product.	All metal parts will be stainless steel in the final product, which is easier to clean for use in a clean room. No porous material is allowed. For the prototype, structural steel was used because it will be cheaper, while still mimicking the mechanical properties.
Suppliers. Identify key suppliers and procurement strategy for purchased parts.	McMaster-Carr, SpeedyMetals.

Figure B.8: MANUFACTURING SPECIFICATIONS

C. QFD

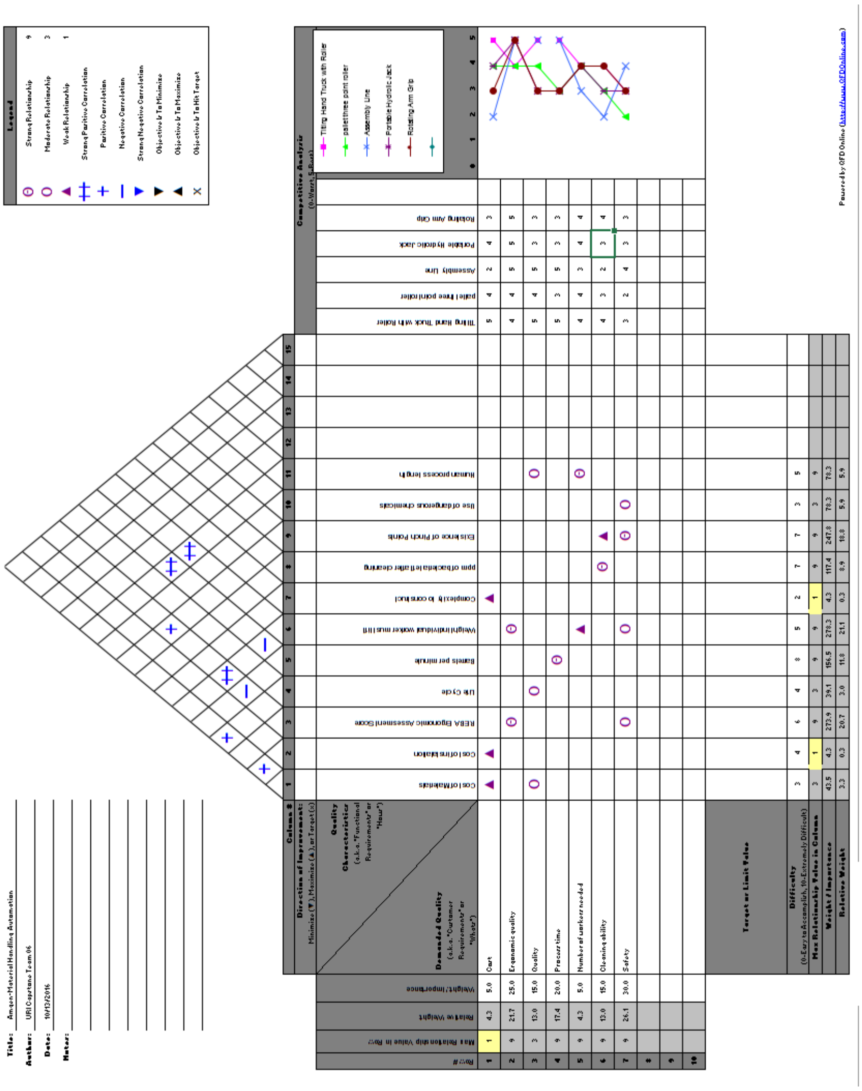


Figure C.1: QUALITY FUNCTION DEPLOYMENT

D. Ergonomics

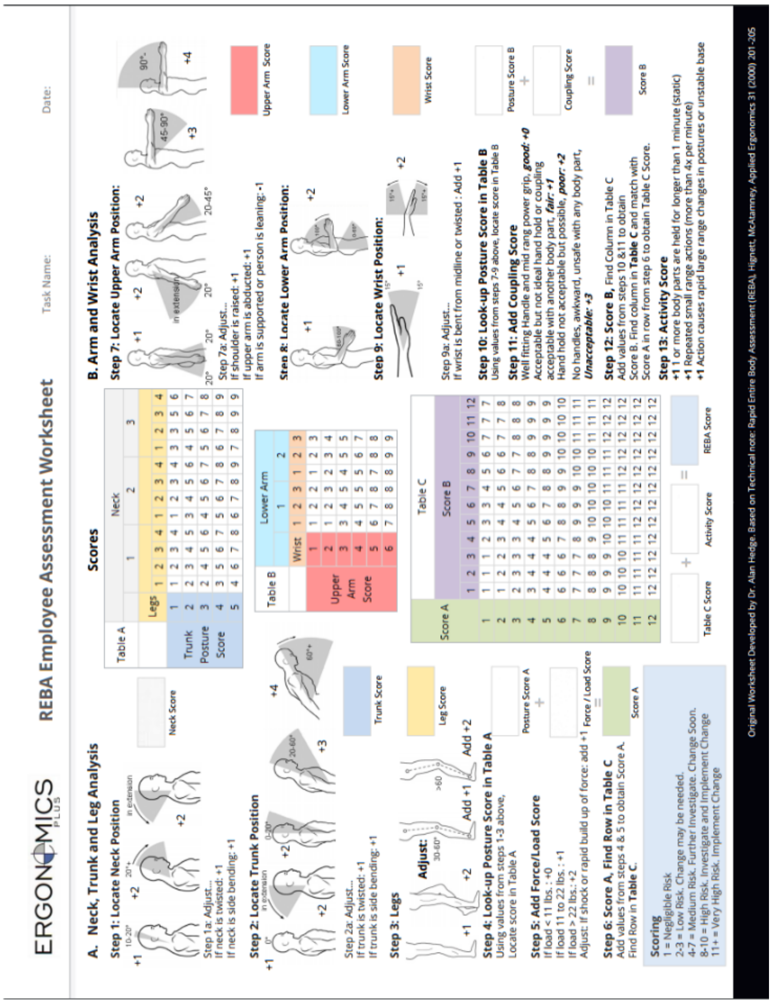


Figure D.1: REBA

Safety and Ergonomics

Ergonomic/Safety Analysis			REBA				
Current Process		(Barrel Tilter Only)					
Part A	Neck, Truck, Legs			Part B	Arm and Wrist		
Step 1	Neck Position		2	Step 7	Upper arm position		3
Step 2	Truck Position		3	Step 8	Lower Arm Position		1
Step 3	Legs		2	Step 9	Wrist Position		2
Step 4	Posture Score		5	Step 10	Posture Score		4
Step 5	Force/Load		2	Step 11	Coupling Score		3
Step 6	Score A		7	Step 12	Score B		7
				Step 13	Activity Score		2
			Table C +	Activity Score =		Total	
			9	2		11	
						Very High Risk	

Ergonomic/Safety Analysis			REBA				
New Process		One User					
Part A	Neck, Truck, Legs			Part B	Arm and Wrist		
Step 1	Neck Position		1	Step 7	Upper arm position		1
Step 2	Truck Position		1	Step 8	Lower Arm Position		2
Step 3	Legs		3	Step 9	Wrist Position		1
Step 4	Posture Score		3	Step 10	Posture Score		1
Step 5	Force/Load		2	Step 11	Coupling Score		0
Step 6	Score A, (Row in Table		5	Step 12	Score B		1
				Step 13	Activity Score		0
			Table C +	Activity Score =		Total	
			5	0		5	Medium Risk

Scoring Guild:	
1	Negligible Risk
2 or 3	Low Risk, Change may be needed
4 to 7	Medium Risk. Further Investigate. Change Soon
8 to 10	High Risk. Investigate and Implement Change
11+	Very High Risk. Implement Change

Figure D.2: REBA ASSESMENT 1

Ergonomic/Safety Analysis			REBA				
Redesigned Process			One User				
Part A	Neck, Truck, Legs			Part B	Arm and Wrist		
Step 1	Neck Position		1	Step 7	Upper arm position		1
Step 2	Truck Position		1	Step 8	Lower Arm Position		1
Step 3	Legs		2	Step 9	Wrist Position		1
Step 4	Posture Score		2	Step 10	Posture Score		1
Step 5	Force/Load		1	Step 11	Coupling Score		0
Step 6	Score A		3	Step 12	Score B		1
				Step 13	Activity Score		0
			Table C +	Activity Score =		Total	
			2	0		2	Low Risk

Scoring Guild:	
1	Negligible Risk
2 or 3	Low Risk, Change may be needed
4 to 7	Medium Risk. Further Investigate. Change Soon
8 to 10	High Risk. Investigate and Implement Change
11+	Very High Risk. Implement Change

Figure D.3: REBA ASSESMENT 2