Variable Center of Gravity Lifting System

Operation Manual

Team 5

Devin Stubbs	drs10f
Coert Maraist	csm11d
Luke Leelum	ljl10
Yoel Bugin	yb12f
Gabriel Omoniyi	goo14

Submitted April 3, 2014

Dr. Gupta

Table of Contents

Abstract ..... **iv**

1 Introduction **1**

2 Functional Analysis **2**

2.1 Project Function 2

2.2 Project Specifications 2

3 Project Assembly **4**

3.1 Gantry and Trolley system 4

3.2 Lifting bar 5

4 Operation Instruction **6**

5 Troubleshooting **7**

5.1 Gantry and Trolley 7

5.2 Lifting Bar 8

6 Maintenance and Upkeep **9**

6.1 Routine Maintenance 9

6.2 Spare Parts and Key Component Replacement 9

7 Conclusion **10**

8 Appendix **11**

Table of Figures

Figure 1 - New gantry and trolley system assembly 4
Figure 2 - Adjustable lifting bar with key components highlighted 5
Figure 3 - Fabrication drawing of the gantry 11
Figure 4 - Exploded view of the Gantry 12
Figure 5 - Fully assembled gantry with dimensions 13
Figure 6 - Trolley with dimensions 14
Figure 7 - Adjustable lifting bar with dimensions 14
Figure 8 - Exploded View of Lifting Bar 15

Abstract

Before an operator should ever utilize a piece of equipment, they should be familiar with the equipment and be comfortable with operating it. Specifically, he/she should understand how the equipment works, the proper way in which to use it, and the possible failure scenarios. Once understanding how the equipment could fail, the operator needs to know the steps to take to prevent failure and how to approach the situation if a failure were to occur. The operator should also be aware of the manner in which routine maintenance should be performed and ways to prolong the life of the equipment. For productivity and ease of maintenance, certain spare parts and components should always be readily available. The operator must always maintain safety of themselves and others around them at the upmost importance when operating equipment.

1 Introduction

In order to increase the lifting position of the VTT compressor in chiller 3, Team 5 developed a gantry, trolley, and lifting bar. The gantry and trolley are designed to suspend the crane hoist between the two I-beams and increase it's vertical position by 150 mm. The lifting bar is designed to be adjustable in order to have the capability to lift all of the VTT compressor models. It is also lower profile than the current lifting bar (about 50 mm shorter). In total, the gantry, trolley, and lifting bar increase the lifting position of the compressor by about 200 mm. It is crucial that the operator understands how each component works and is familiar with how to regularly maintain the equipment. Prior to any operation of the equipment the operator needs to inspect each individual component and ensure everything is in working order and that all fasteners are properly installed. It is very dangerous and potentially deadly if not every component is properly installed and working as intended. If the operator notices any issues with the equipment prior to utilizing it, he/she must fix the issues before any operation. If the issue cannot be easily fixed, the operator should report the incident to the appropriate supervisor. If the equipment is in use when a failure occurs, the operator needs to avoid injury in any way possible. If possible, the operator needs to return the compressor to the ground and report the incident to a supervisor. Never stand beneath the compressor while the compressor is being suspended by the crane hoist.

2 Functional Analysis

This section will be useful for familiarization of the different components and assemblies. It is vital that the operator understands how the mechanism works and the manner in which it is intended to be implemented prior to using any aspect of the design.

2.1 Project Function

Turbocor requires that each of their compressors be tested on a chiller rig for quality control purposes. One of their chiller rigs, Chiller 3, was not adequately designed for testing the new, larger VTT Compressor. The current gantry and crane hoist cannot lift the compressor to a sufficient height in order to secure the compressor into testing position. The newly designed gantry and trolley system will increase the vertical position of the current crane hoist by approximately 150 mm, thus increasing the lifting height capability. The newly designed lifting bar is approximately 50 mm shorter in vertical height than the current lifting bar, which will also allow for an increased lifting height. Due to 12 different compressor models having varying centers of gravity, the lifting bar will also be adjustable as to allow it to be useful for each compressor model. By implementing the gantry, trolley system, and lifting bar the lifting height of the compressor will be increased by approximately 200 mm in Chiller 3.

2.2 Project Specifications

Increasing the vertical position of the crane hoist is fairly straightforward. First, I-beams had to be appropriately spaced out in order to allow for the crane hoist and trolley assembly to fit between them. Center to center distance of the two I-beams measures 49 cm. It was crucial that the overall width of the new gantry did not exceed the width of the current gantry as to prevent any unforeseen spatial issues. The length of the new gantry is the same as the current one (2316 mm) as to allow it to use the current gantry track system and reduce cost. Due to the low ceiling height in the chiller rig, the I-Beams could not be greater than 101.6 mm. Half-inch plate is used in order to connect the I-beams and 4 separate casters, which have a combined load rating of 3000 lb, support it. The trolley rig is suspended from each I-beam by two separate I-beam trolleys rated at 1100 lb each. By using gussets, a truss like design, and hardened steel it was possible to increase the vertical position of the crane hoist and produce a load rating of 2000 lb.

Design and implementation of the lifting bar is slightly less straightforward as the gantry and trolley system. For strength and stability of the lifting bar, a 790 mm C4x5.4 channel was used as the structure of the lifting bar itself. For simplicity, U-bolts and D-shackles are used for connecting the compressor to the lifting bar (1200 lb load rating for each U-bolt and over 3600 lb load rating for the D-shackle). It is crucial that the two U-bolts are spaced exactly 687.6 mm apart as that is the distance between the lift points on the compressor. Two links of high strength 3/8” chain were used in order to offset the position of one of the D-shackles per the design of the compressor. In order to prevent tear out of the U-bolts, saddles were machined out of 1/8” steel. Adjustability of the lifting point of the lifting bar as to account for various compressor models was produced by implementation of a power screw and lifting block. The Power screw is rated at over 5 kN for a dynamic load and almost 11 kN for a static load, sufficient for the half ton compressor. The lifting block is milled from 49 mm thick steel, is bolted to the ball screw, and wraps around the lifting bar. To reduce friction between the channel and lifting block surfaces, 1/8” delrin sheet is held in place by hex screws. Adjustments to the position of the lifting block will be possible by using a ratchet or wrench and simply turning the power screw in order to translate the lifting block in the desired direction. An eyebolt is connected to the lifting block so the crane hoist is able to lift the compressor.

3 Project Assembly

This section will outline the way in which the various designs can be assembled. Correct assembly of each component is crucial to ensure that each assembly performs the way in which it was intended. Refer to the Appendix for exploded views and dimensionalized renderings.

3.1 Gantry and Trolley system

Prior to any assembly, welding must be performed on the gantry and trolley. The trolley itself is completely welded. A weld assembly drawing can be found in the Appendix and a 3D rendering with important components annotated can be seen below in Figure 1. The I-beams must be welded to the ½" steel plate with their center-to-center dimensions being exactly 49 cm. Prior to welding ensure that each steel plate has 8 M8x1.25 holes drilled and tapped for installation of the casters. Track guides must then be welded onto the gantry as to prevent the gantry from possibly jumping off the track. Each caster is bolted to the gantry by 4 M8 washers and bolts, 15mm in length. Delrin sheet is bolted to each of the track guides by 4 M4 bolts, nuts, and washers. Using the proper amount of spacers and washers, the I-beam trolleys must be bolted onto the I-beams with the welded trolley already in place. Ensure that each bolt in the assembly is tightened down snug.

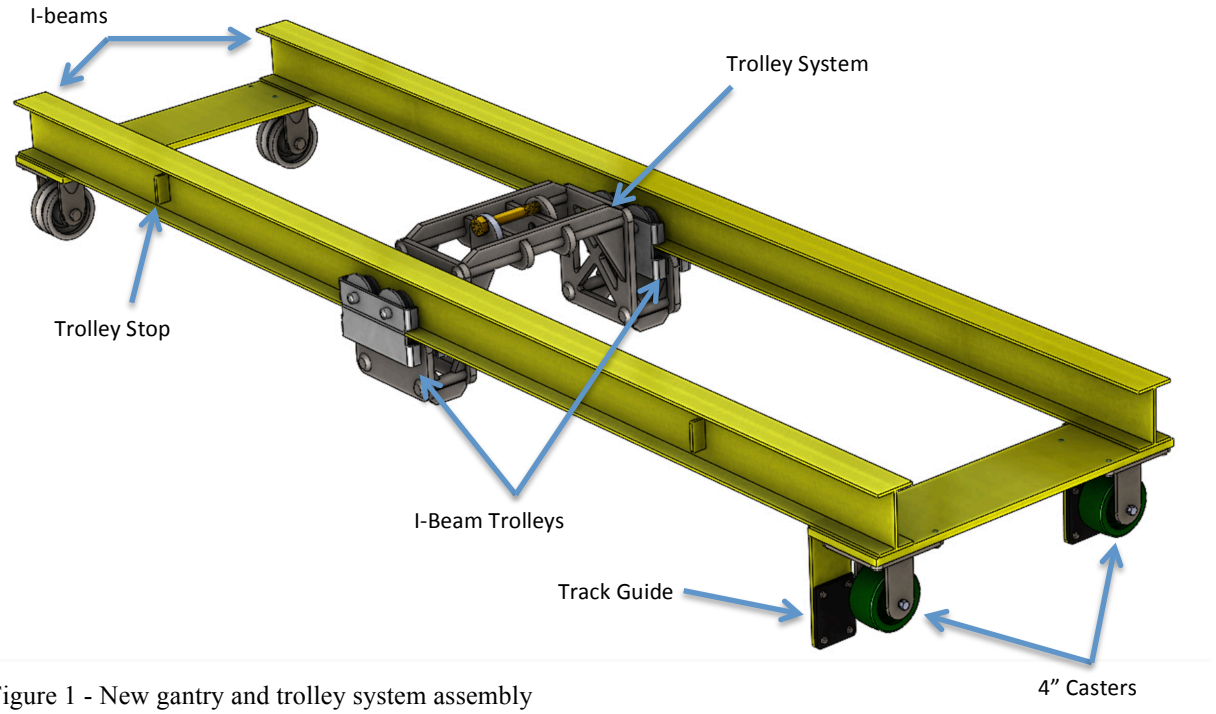


Figure 1 - New gantry and trolley system assembly

3.2 Lifting bar

The lifting bar was designed in such a way that it simply bolts together. The assembled prototype is pictured below in Figure 2. First, the ball screw is bolted to the channel by using 4 M8 bolts, 40 mm in length. To prevent them from coming loose, lock washers are used between the nut and the lifting bar surface. The delrin sheets for the lifting block must be installed next. These are held in place by 2 M3 x 10mm screws each. Next, bolt the bottom half of the lifting block to the ball screw by using 4 M5 x 15mm machine screws, with each screw having a lock washer to prevent them from loosening. The top half of the lifting block is bolted to the bottom half using 4 M10 x 45mm bolts, with each bolt using a lock washer. Attach the eyebolt to the top of the lifting block by screwing it into place until it is snug. On the side with the lifting block, slide the U-bolt into place and using the saddle and two 3/8" lock nuts tighten the U-Bolt into place. Slide the other U-bolt into a link of the 3/8" chain and then install the U-bolt in the same manner as the first one. Then install the D-shackle onto the chain and on the other U-bolt and the lifting bar is ready for use.

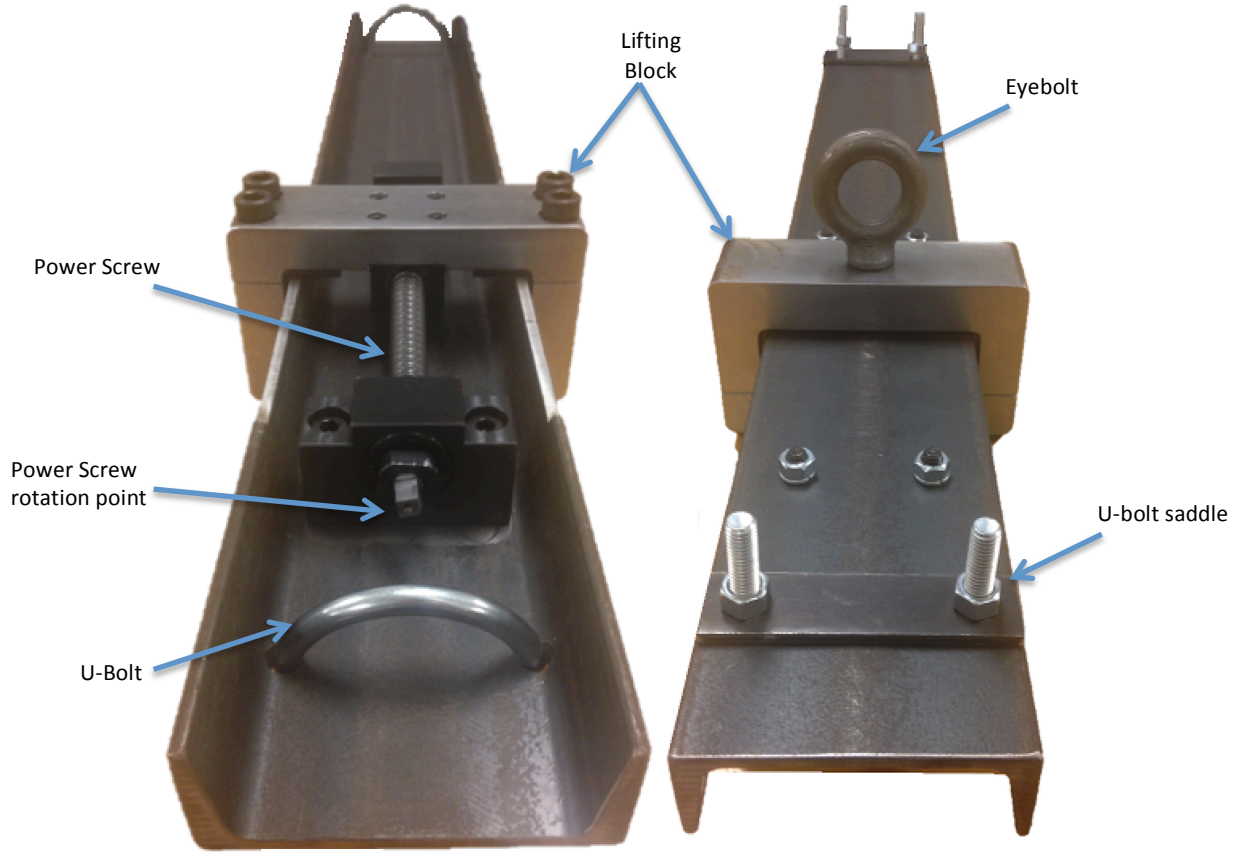


Figure 2 - Adjustable lifting bar with key components highlighted

4 Operation Instruction

Prior to operation of any components ensure that all components are properly assembled and are in proper functioning order. Check that all screws and bolts on the lifting bar are securely fastened and all stationary components are not able to move. Likewise, make sure that all components intended to move are in fact moving in the way they should be. Check for any tears or flaws in the materials that could result in catastrophic failure once the lifting bar is put under load. Inspect the gantry and trolley is in working order as well. Check that the nuts holding together the I-beam trolleys are very tight. Ensure that the gantry is properly seated on the track and there are no obstructions. Once all components have been inspected it is possible to then begin implementation of the lifting bar. NEVER stand beneath the compressor.

1. Traverse the lifting block into the correct position for the corresponding compressor model to be lifted by using the ratchet and socket combination in order to rotate the power screw. Do not make adjustments to the lifting block while the lifting bar is experiencing any load.
2. Connect the lifting bar to the compressor by using the D-shackles. Make sure the side of the lifting bar without the chain is connected to the volute side of the compressor.
3. Using the crane hoist switch, bring the chain down to position and attach the hook on the chain to the eyebolt on the lifting block. Ensure the hook is fully engaged as to prevent sudden dropping of the compressor.
4. Slowly raise the chain using the crane hoist keeping a close eye on the compressor. If the compressor begins to be raised at an unnatural angle return the compressor to the ground and adjust the lifting block so the compressor is lifted perfectly horizontal.
5. Carefully raise the compressor using the crane hoist. Keep a close eye on the lifting bar, trolley, and gantry system. Make sure there isn't any severe deflection. If there is any concern of failure at any point, unload the crane hoist completely and return the compressor to resting position on the ground. NEVER stand beneath the compressor.
6. Once the compressor is raised to sufficient height, carefully manipulate the position of the compressor into testing position. Ensure the feet of the compressor are properly resting on the supports located on top of the chiller rig.
7. Secure the compressor in place on top of the chiller using the provided bolts.
8. Once the compressor is properly bolted in place, release all tension from the crane hoist and unfasten the D-shackles as to remove the lifting bar from the compressor.
9. Carefully lower the lifting bar to the ground so the crane hoist is no longer under load. Unhook the crane hoist hook from the lifting bar.
10. Use the crane hoist controller to return the hook back to its original position so there is no remaining chain hanging from the crane hoist.
11. Return the Lifting Bar to storage location.

5 Troubleshooting

Due to the multiple components all to be used in unison, there are several points of failure that the operator needs to be aware of while using this design. It's imperative that points of failure are understood by the operator prior to use as to prevent any avoidable hazards. In all cases of failure, the operator should safely remove the load seen by the component and report the incident to an adequate supervisor.

5.1 Gantry and Trolley

The gantry is a vey sturdy design and any failure will most likely not be due to material composition, but due to fasteners and the track in which it rolls on. The most important point of failure the gantry may be subject to is if the gantry were to jump off the track. Best-case scenario: the track guides catch the gantry and the hazard is averted. Be sure to exit the chiller rig if this is to happen. Catastrophic damage could result if the gantry is loaded with a compressor, jumps off the gantry track and the track guides do not catch the falling gantry. This is a very severe condition and it is imperative that all operators inside the chiller pay close attention to the behavior of the gantry on the tracks and exit the facility if there is any concern of the gantry jumping the track.

Issues can also arise from the I-beam trolleys rolling along the I-beams. As long as the trolley bolts are fastened properly, the trolleys should hug the I-beams and there should be no issues. However, if the operator notices any unnatural movement by the trolleys, he/she should stop what they are doing and immediately tighten the trolley bolts so it is secure once again. Due to all of the welds and contact surfaces on the trolley itself, there is risk of material fatigue and failure. Thus, the operator should always be aware of this and keep a close eye on the trolley while putting it under load by supporting and/or lifting the compressor. The operator should make sure there isn't severe flexing of the trolley or any noticeable defects. If the operator is suspicious of the structural capability of the trolley at all he/she should immediately unload the compressor and contact the proper supervisor. It is up to the operator to make sure there is always a nut on the trolley support bolt. If there is a nut missing, it is important the operator furnish the bolt with the proper nut before using the gantry/trolley in any way.

5.2 Lifting Bar

The lifting bar's greatest point of failure stems from the ball screw. Just like with any design, points of failure are exaggerated at moving components. If failure is to occur at the ball screw, the hefty lifting block will prevent the compressor from crashing to the ground but the lift position could be compromised and the half-ton compressor could possibly become a 1000 lb swing. If any failure to the power screw occurs, the operator should try to avoid any contact with the compressor. If possible, safely lower the compressor back to the ground. Operation of the power screw may also be impeded by the nut used to keep the power screw in the proper place. This nut has a set screw that keeps the nut in a set position so the power screw's position between the two bearings is constant. The operator must inspect this setscrew and ensure it is properly torqued down to prevent improper motion of the power screw. If this setscrew is not properly installed, motion of the power screw could be disrupted or the power screw could jump out of the thrust bearing and cause catastrophic results. The operator must immediately tighten the setscrew if it is found to be unsecure. Debris in the power screw could also cause binding and so any debris should be removed as to remedy/prevent binding.

Failure may also occur at the U-bolts due to tear out. This failure is relatively avoidable if the operator carefully inspects the lifting bar prior to loading the compressor. If failure were to occur at the U-bolt, it would occur without notice and in a catastrophic manner. If this were to occur, the operator needs to avoid any contact with the compressor if possible. The situation is no longer safe enough to approach and if possible, use the crane hoist controller to lower the compressor to the ground if not already on the ground. The eyebolt could also possibly tear-out from the threads holding it in place. In this case, the compressor will drop straight down. It is because of this, no operator should ever stand under the compressor.

If the lifting bar is loaded past its capability, there will be noticeable deflection in the lifting bar. If this were to occur, binding in the power screw could occur. Binding in the power screw could also weaken the strength of the block ball bearing and cause failure at the power screw. Bending of the lifting bar will also change the characteristics of the load being applied to the U-bolts and could enhance tear-out failure or produce deformation in the U-bolts. If any noticeable bending occurs in the lifting bar, immediately unload the bar and report such occurrence to the proper supervisor.

6 Maintenance and Upkeep

In order to promote longevity, regular maintenance should be performed on the components. Also, for fluid operation there should always be select spare parts and components at hand ready for replacement.

6.1 Routine Maintenance

The operator should routinely inspect the condition of the lifting bar and all of its components. He/she should be keeping a close eye on the condition of the power screw, power screw bearings, delrin sheets, lifting block, and U-bolts. If any of these components require replacement, replace immediately. The power screw should always have a sufficient amount of grease reducing the wear and tear. The operator should also look out for any debris on the power screw. This could cause serious issues inside the bearing block and so all debris should be removed immediately. It is imperative that any unpainted surfaces be monitored for corrosion and any corrosion be taken care of and the part must then be oiled to prevent further corrosion. All painted components should be regularly inspected to check for deep scratches that could lead to rust and these scratches should be painted over.

6.2 Spare Parts and Key Component Replacement

Due to the inclusive nature of this design, there are not many components that are designed for replacement. Components such as the U-bolts, eyebolt, and hardware could be replaced depending on usage and condition. One component that will absolutely be replaced is the delrin guides that sit between the lifting block and the channel. These delrin sheets are there to reduce friction and will wear down with age. It is not yet understood how often these components will be replaced. However, delrin is relatively inexpensive and so if noticeable wearing of the delrin is visible, each sheet should be replaced immediately. This will require the removal of 12 cap screws and so the operator should have M8, M3, and M2 hex keys nearby for regular use. The delrin sheets are approximately 20x49mm in dimension and are 1/8” thick. More than enough material was provided to Turbocor in order to replace these parts several times.

7 Conclusion

Turbocor was unable to easily lift their VTT compressor into testing position. In order to increase the lifting capability of their compressor, Team 5 developed an improved gantry and trolley system to increase the vertical position of the crane hoist. Team 5 also developed a lifting bar that has a lower profile than the current lifting bar and can be adjusted for different compressors possessing a range of centers of gravity. The new gantry has lower profile 4" I-beams to allow plenty of clearance from the lower ceiling of the chiller rig. The I-beams are also spaced out further in order to suspend the crane hoist between the two; all while have the same wheel-to-wheel dimensions as the current gantry. The trolley system uses ½" steel, ¾" steel rod, and two I-beam trolleys to increase the crane hoist position by approximately 150 mm. The lifting bar utilizes a power screw for finite adjustment of the lifting point position in order to life all 12 models of the VTT compressor. It also has a lower profile than the current lifting bar by about 50 mm, and thus Team 5 was able to achieve an increase in lifting height of approximately 200 mm.

It is of the upmost importance when utilizing this equipment that all hardware, fasteners, and components are properly installed and or in proper working order. It is the operator's responsibility to check the equipment prior to use and if any issues are noticed these issues need to be solved immediately. If during operation the operator notices a problem with the equipment or if any failure occurs of the equipment, the operator is to avoid any injury if possible. He/she is to then safely return the compressor to the ground, if it is possible. The operator needs to then exit the chiller and notify the appropriate supervisor. Before operating any of the equipment the operator needs to be familiar with the operation instructions and troubleshooting. Safety is of the upmost importance and so if any time the operator feels to be unsafe or in danger, he/she should vacate the chiller rig immediately. Never stand beneath the compressor when it is being suspended by the crane hoist.

8 Appendix

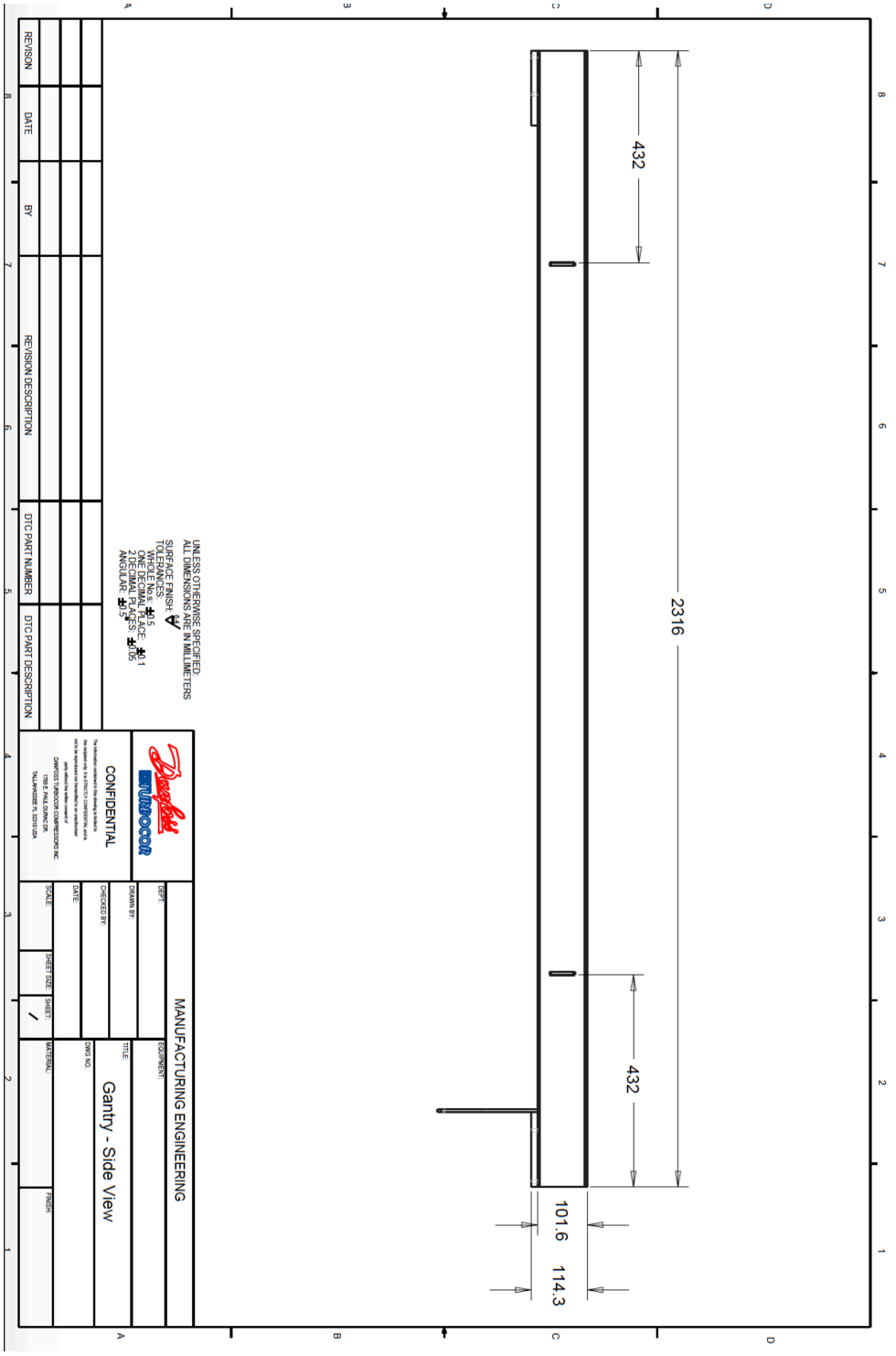


Figure 3 - Fabrication drawing of the gantry

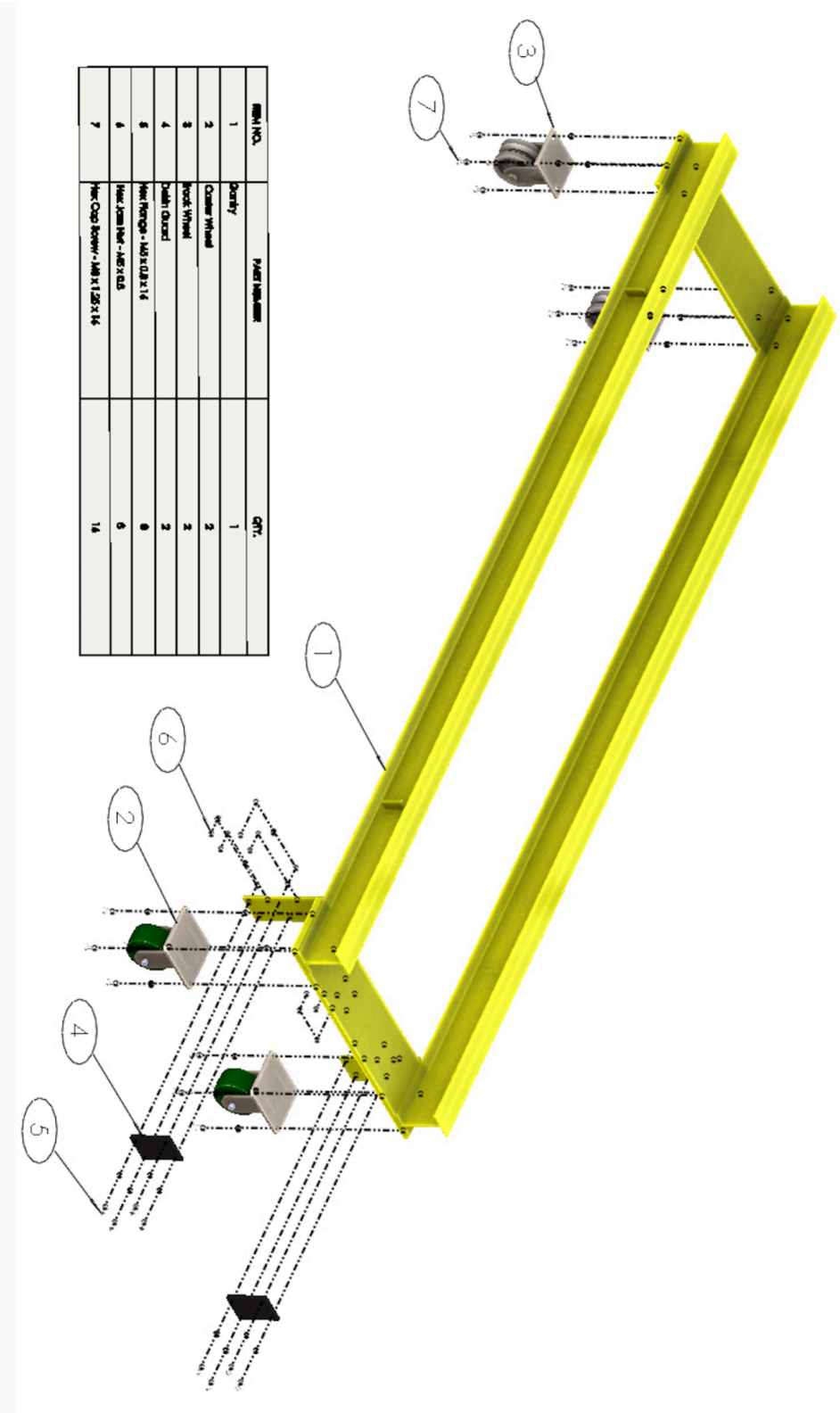


Figure 4 - Exploded view of the Gantry

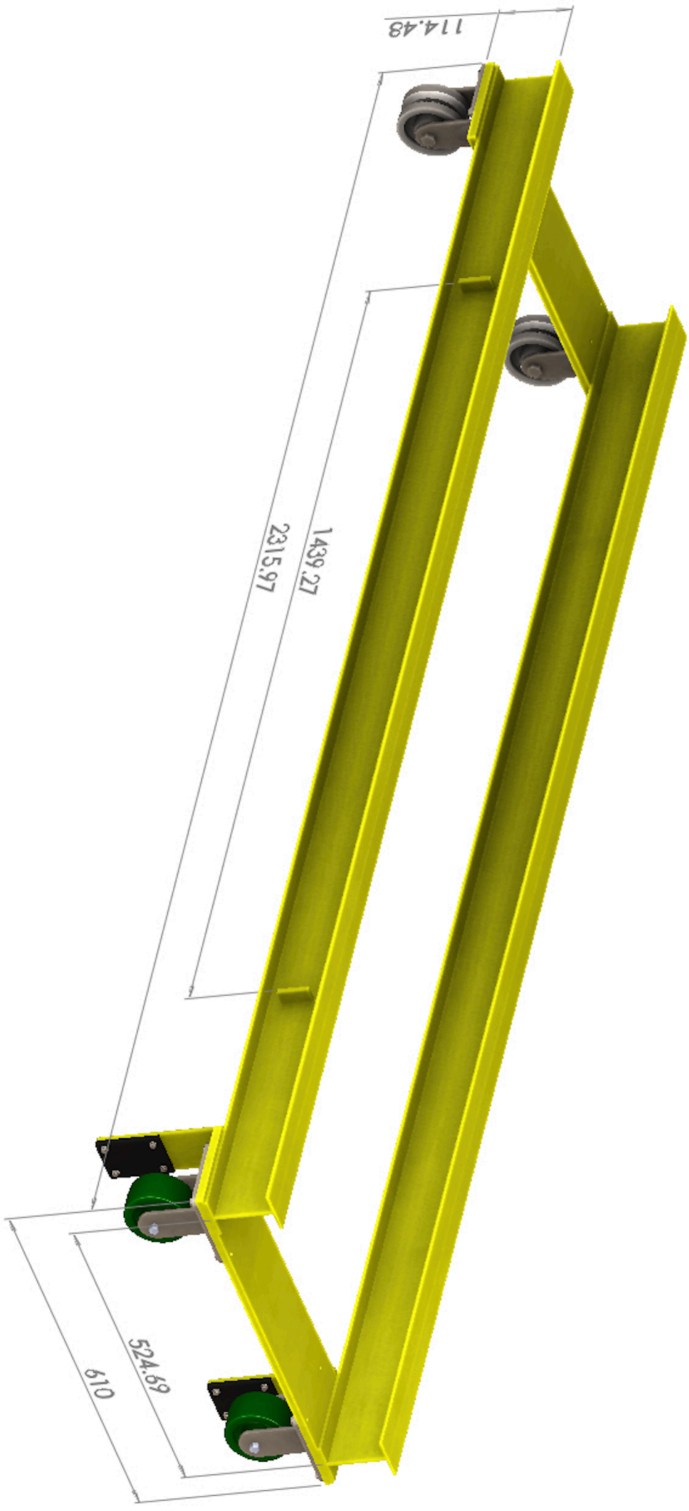


Figure 5 - Fully assembled gantry with dimensions

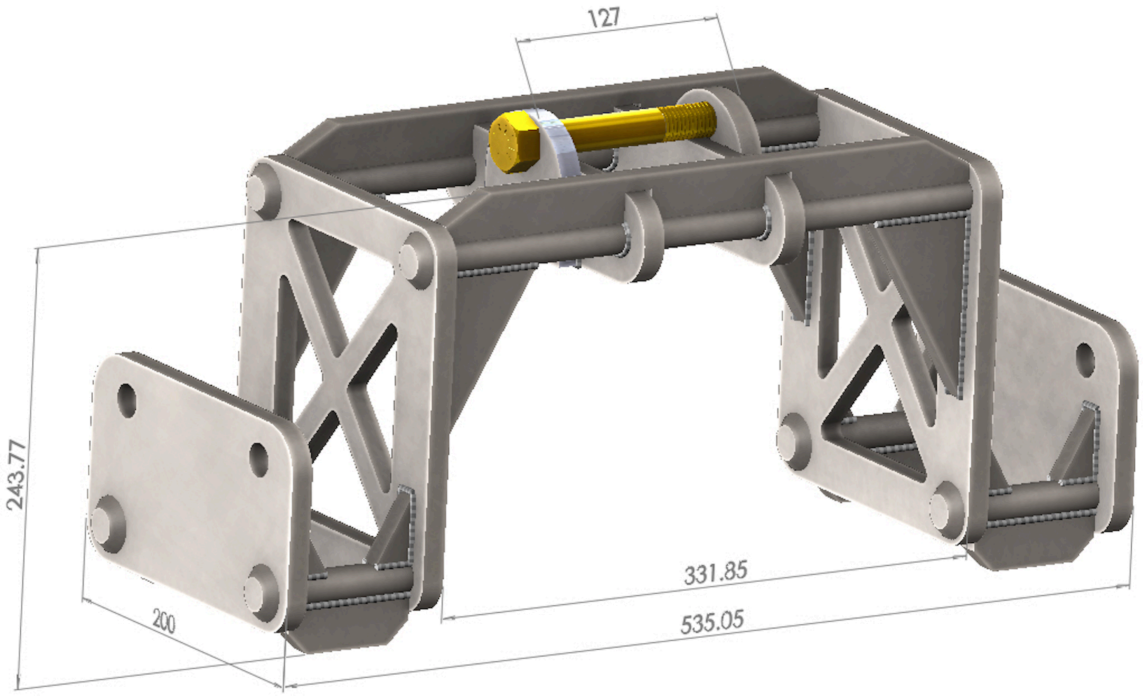


Figure 6 - Trolley with dimensions

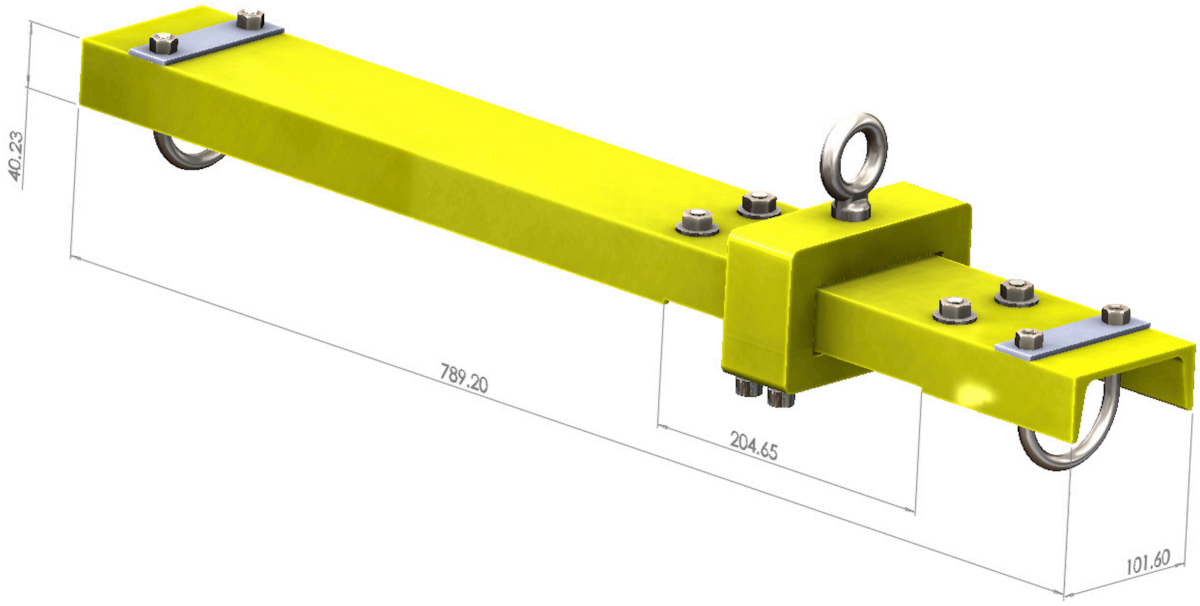
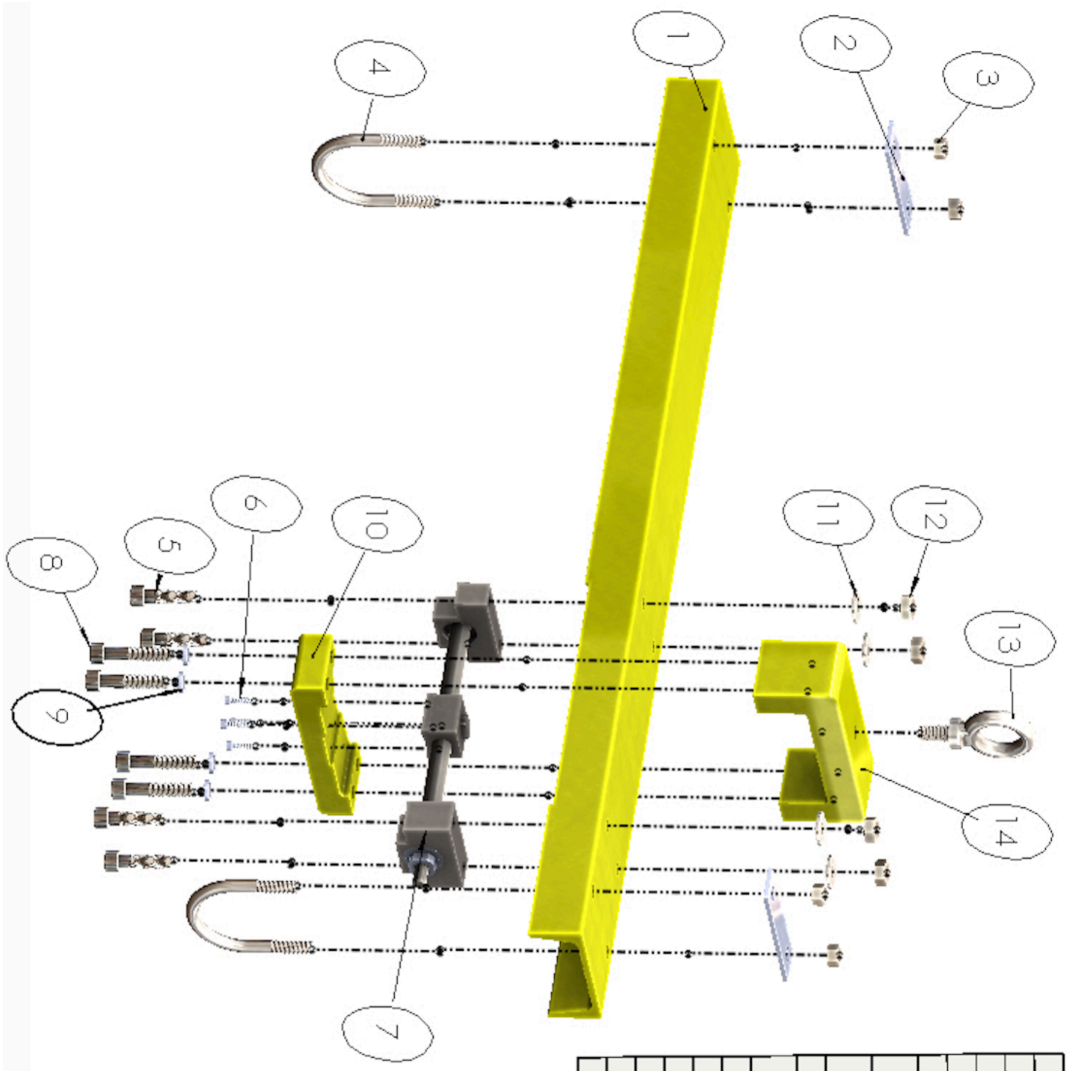


Figure 7 - Adjustable lifting bar with dimensions



ITEM NO.	PART NUMBER	QTY.
1	U Channel	1
2	U Bolt Saddle	2
3	3/8" Locking Nut	4
4	3/8" U-Bolt	2
5	Socket Cap Screw M8 x 1.25 x 20	4
6	Socket Cap Screw M4 x 0.7 x 10	4
7	Ball Screw Assembly	1
8	Socket Cap Screw M10 x 1.5 x 45	4
9	Locking Washer M10	4
10	Lift Block Bottom	1
11	Locking Washer M8	4
12	M8 Locking Nut	4
13	Eyebolt M12 x 1.25	1
14	Lift Block Top	1

Figure 8 - Exploded View of Lifting Bar