Variable Center of Gravity Lifting System

Design for Manufacturing, Reliability, and Economics Report

Team 5

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Abstract

Danfoss Turbocor has asked Team 5 to devise an innovative method to lift their new compressor to the testing height using the existing crane hoist and gantry system. The current gantry system is designed to lift the compressor to a height at which was adequate for previous compressor models, but does not lift the new, taller VTT compressor to the appropriate height for testing. The original request was for Team 5 to develop an offset lifting bar to lift their half ton compressor. However, after conceptualization of numerous designs and continuous consultation with Turbocor, Team 5 has instead proposed to increase the vertical lifting height of the compressor by redesigning the current gantry system and developing a separate lifting bar. Turbocor has been supportive of the team's progress and has assured Team 5 of full financial sponsorship. Team 5 believes that its solution to the problem at hand will be fully implemented at Turbocor after fabrication and prototyping in spring.

1. Introduction

Safety is the most important aspect due to the potential risk to human life. The current method used to lift the VTT compressor to testing position was not only unsafe, but required the use of many engineers and technicians. Turbocor, a company concerned with its employees safety above all else has come to ask Team 5 to devise an inventive method to use the existing crane hoist and gantry system for lifting its new compressor. This will allow Turbocor's employees to safely test each compressor before they go to market.

After the first tour of Turbocor's testing facility, team 5 immediately knew that implementing a solution was going to be challenging given the extremely tight spatial constraints. The team, eager to solve a true engineering problem using their equipped skillset, knowing that the challenge will test them and shape them into engineers ready for the working industry. They are also enthusiastic to work with Turbocor engineers, hoping to absorb every drop of information they receive along the way.

1.1 Background Research

"Danfoss Turbocor Compressors are transforming the commercial HVAC market with innovative technology that redefines lifetime operating costs for mid-range chiller and rooftop applications." [1] Before every compressor is approved for distribution, it must be tested in house by Turbocor on a chiller rig to test for its efficiencies and performance. Turbocor now has a new line of compressors, the VTT line, which is much larger and operates at higher pressures than previous models. Due to the high confidentiality of this compressor, background research has been obstructively difficult. The compressor at hand is shown below in Fig. 1, which has been a primary source of information about the compressor due to this confidentiality.

Presently, Turbocor has implemented a temporary solution that "requires too much manual labor and distracts an engineer from tasks that he could else wise be focusing on." [2] Turbocor is in need of a solution to create safer working conditions and allow the compressor to be lifted in to place safely, requiring less labor to ensure that more engineers can focus on their individual task uninterrupted.

1.2 Need Statement

Danfoss Turbocor requires that each half-ton compressor be tested on the chiller system to ensure quality control. Each time the new compressor is ready for testing, a mechanical engineer must employ the use of a manual chain hoist to lift and install the compressor onto the chiller system. Danfoss Turbocor has sponsored a team of 5 mechanical engineering students to solve this problem. Currently, team 5 is in the process of routinely meeting with Turbocor to discuss project progress. During these meetings, the team presented risk assessments, detailed project specifications, a project plan, and proposed design concepts. After these documents were reviewed, Team 5 proposed an alternative design solution that does not implement the use of an offset lifting bar, but does raise the compressor to a sufficient vertical distance.

1.3 Goal Statement & Objectives

The current problem states that “a better lifting system must be designed and implemented in order to more easily install the compressor for testing." [2] Team 5 has scheduled team meetings as well as sponsor meetings in order to successfully establish a clear and concise goal to establish a firm starting point. The main objective is to increase the lifting height of the compressor. The solution must also have a means to vary the center of gravity to properly lift different versions of the VTT compressor, may they have a change in center of gravity. This new design must completely integrate with the existing equipment in the test room and shall not require a completely new procedure to lift the compressor for simplicity. Finally, this design must minimize all of the safety risks associated with lifting a half ton compressor.

1.4 Constraints

Due to the confidentiality involved in working with Turbocor, there is limited access to vital spatial dimensions in the chiller. Additionally, this prohibits Team 5’s ability of taking pictures and viewing CAD drawings of various compressors in the chiller room to attain dimensions. Turbocor has numerous versions of the new VTT and current TT compressors that are designed to match the proper energy output for a given market. Consequently, the center of gravity in each compressor varies from compressor to compressor. Moreover, the points of lift on these two models are separated by a difference of 18 in. thus adding complexity to the lifting bar design. Therefore, Team 5 is required by Turbocor to produce a lifting bar that can not only lift the current smaller TT compressor and the new VTT compressor but, also account for the slight variation in center of gravity for each compressor. Shown below are the main constraints provided to team 5.

- Must be OSHA regulation compliant
- Primary load capacity: 1200 lb.
- Maximum operating weight (unloaded): 500 lb.
- <$1000 Provided by Danfoss Turbocor
- Extremely constricting dimensions available for compressor/lifting arm movement

2. Design for Manufacturing

Fabrication of the parts required for each component of assembly took place at two different locations, the FAMU/FSU College of Engineering machine shop and Danfoss Turbocor machine shop. Most of the larger parts were machined at the COE machine shop with the water jet cutter. The parts that required water jetting were created with CAD software and exported as a DXF file to for the water jet cutter. For the parts that required multiple steps to manufacture, Turbocor offered to do the machining work. These parts required multi-step drawings with multiple views to assure Turbocor’s machinist properly understood how to machine the part.

2.1 Assembly

Following the completion of manufacturing, all parts for the gantry and trolley were taken to Turbocor to be welded. The lattice of the trolley required a considerable amount of welding. Gussets were also welded on critical points of the trolley to increase the strength. It must also be noted that the water jetted holes on the trolley were intentionally oversized to allow for easy installment of the load bearing bolt. The gantry on the other hand only required eight strips of weld to hold the two I-beams on to the 12” x 24” x 1/2” plates. Also added to the gantry during the welding process were the track guides which were machined out of ¼” A36 Steel. Delrin was added to these track guides to avoid metal on metal friction if the gantry became misaligned on its track. Trolley stops were the final weld addition to the I-beams to prevent the trolley from slamming into the steel plates.

The welds were then checked for homogeneity to assure that there was equal application of weld as well as a void free weld environment. Once the welds were determined to be sufficient by close examination, the welding phase was officially over. Following the welding of the gantry and trolley, the process of mating the trolley to the gantry began and did not require any further assembly at Turbocor. The trolley is able to traverse the lengths of the I-beams by use of the two I-beam trolleys which were purchased from Mcmaster-Carr. These I-beam trolleys came with the necessary bolts, spacers, and washers to bolt on to the trolley and gantry. The process of mating the trolley to the gantry took approximately 1 hour to complete due to the effective yet simple design by Team 5. The addition of the casters to the gantry was the only additional step required, but they were not added until testing was over because they were already certified by Mcmaster-

Carr for a specific load, which exceeded team 5's minimum requirement. Shown below in Fig. 1 is the complete trolley mated to the gantry.

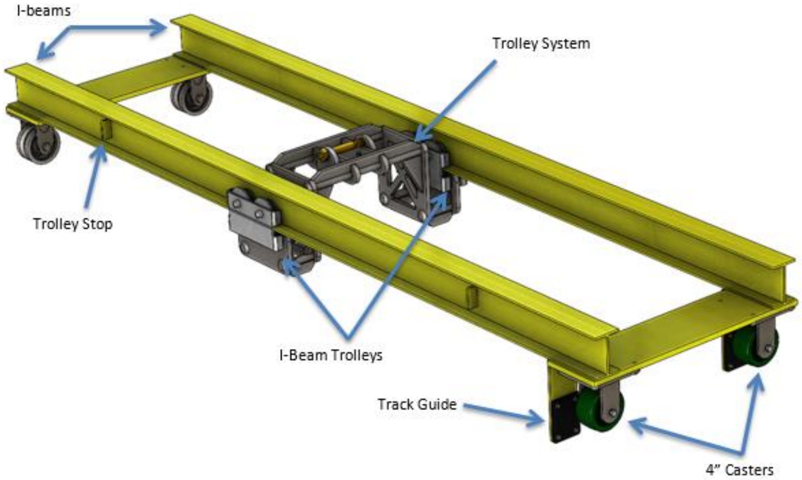


Figure 1 - Gantry and Trolley Assembly showing key components

The assembly of the lifting bar was the last to be completed since it only needed to be bolted together. The U-channel had already been machined at Turbocor to perfectly fit each component, so there were no challenges in bolting the power screw, lifting block, and U-bolts on to the U-channel. There was an addition of two 1/8" steel saddle spacers to the U-bolts to ensure the lowest profile possible. The final assembly step of the lifting bar was to machine down the steel rod at the end of the power screw into a square shape that would fit a 7mm socket. This was done using a mill in the COE machine shop and was done so Turbocor lab technicians would have an easy way to adjust the center of gravity in the lifting bar. Lifting bar shown below in Fig. 2.

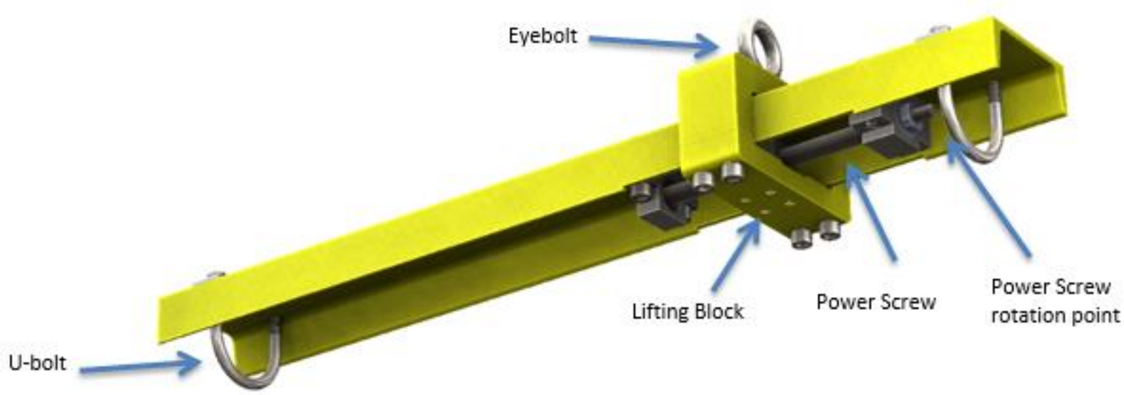


Figure 2 - Assembled Lifting Bar with key components

2.2 Timeline

Table 1 - Team 5 Assembly Timeline

Start Date	End Date	Area	Description
1/16/2015	1/18/2015	Fabrication	Water jet of components by Team 5 at COE
1/19/2015	1/23/2015	Fabrication	Machning of simple components by Team 5 at COE
2/12/2015	2/12/2015	Manufacturing	Welding of gantry and trolley by Turbocor welder
2/16/2015	2/17/2015	Fabrication	Machning of complex components by Turbocor machinist
2/19/2015	2/19/2015	Testing	Load testing of gantry and trolley
2/26/2015	2/26/2015	Manufacturing	Preliminary assembly of Lifting Bar
3/11/2015	3/13/2015	Fabrication	Delrin sheets, U-bolt saddles, bolt alterations
3/17/2015	3/17/2015	Fabrication	Water jet stronger gussets and additional trolley support
3/18/2015	3/19/2015	Manufacturing	New components welded to trolley by Turbocor welder
3/26/2015	3/27/2015	Manufacturing	Assembly of trolley and gantry ready for load test
3/26/2015	3/26/2015	Fabrication	Cut chain to desired length for lifting bar offset
3/31/2015	3/31/2015	Manufacturing	Lifting bar teardown for additional fabrication
4/1/2015	4/1/2015	Fabrication	Power screw machined for compatibility with socket head
4/1/2015	4/1/2015	Manufacutring	Lifting bar completely assembled and ready for load test

During scheduling at the beginning of the spring semester, Team 5 estimated completion dates for every aspect of this design. It was determined that assembly of each component would be completed around mid-March. In reality, all preliminary assembly of components have been completed before mid-March. Team 5 was working ahead of schedule, but revisions to the trolley had pushed this time back to April 1st. The reason there was a need for additional revisions to the trolley assembly is because there was an unanticipated delay in testing. That being said, Team 5 should have allotted additional time to the schedule to cover the time needed to revise parts and assemblies. In summary, Team 5 completed its planned assembly ahead of schedule, but due to unforeseen delays caused by testing, team 5 was two weeks behind. A table of team 5's assembly timeline can be viewed above in Table 1.

2.3 Parts

Team 5's design to increase the lifting height of the VTT compressor hoist is made up of three main components. These components consist of the gantry, trolley, and lifting bar. All three of these components consist of 154 parts in total including nuts, bolts, and washers. A comprehensive list of each part belonging to its respective component can be viewed in Appendix C – Complete Parts List. The Trolley consists of 36 parts, most of which are additional support pieces to the structure of the trolley. If a revision for the trolley was possible, there certainly is room to significantly reduce the amount of parts. This could be done by fabricating a structure with a more efficient geometry. Instead of using round bar with support gussets, team 5 could have used small I-beam shaped steel as the framework for the trolley or a similar shape, eliminating the possibility of deflection at the magnitude of stress which is exerted on the trolley. This was suggested to team 5 by its advisor, Dr. Hollis after the trolley had already been built. If more time and budget was given to team 5, a more efficient trolley with less parts would be implemented. The lifting bar and gantry were designed to be as simple and effective as possible while maintaining lightweight and low cost. Any additional complexities to the lifting bar and gantry would be unnecessary. There could be room to improve the lifting bar, but team 5 has determined that any changes would be too costly.

2.4 Challenges Experienced

Most of the challenges encountered by Team 5 were during the machining and fabrication of various components, below are few of the challenges encountered and how they were mitigated.

Machining – During the machining stage, using the machine shop of the college of engineering was a challenge due to the fact that Team 5 is not the only team trying to fabricate their designs and this was mitigated by getting an early allocation to beat the demand of other teams, also fixing a time for the machinist at the Turbocor machine shop was challenging, therefore the team gives an ample time of notification to avoid disappointment.

Deflection – This was detected during the load testing and it was found that the deflection in the trolley was more than the specified deflection by the FEA analysis. This was mitigated by adjusting the FEA analysis to suit the required deflection which cause the prototype to also be adjusted

Materials lab supervisor – the readiness of the Materials Lab's supervisor often keeps us behind the schedule and that was rectified by doing some other necessary things while waiting on the supervisor's readiness.

3. Design for Reliability

To determine how this device will perform over time, it is necessary to compare the stresses felt by the system to a fatigue curve for steels. The maximum stress that the system will feel is approximately 70 MPa. This system will not cross the endurance limit since it approaches nowhere near the stress needed to cross the endurance limit. Anything under the endurance limit has infinite cycles. Shown below is the fatigue curve of aluminum and steel.

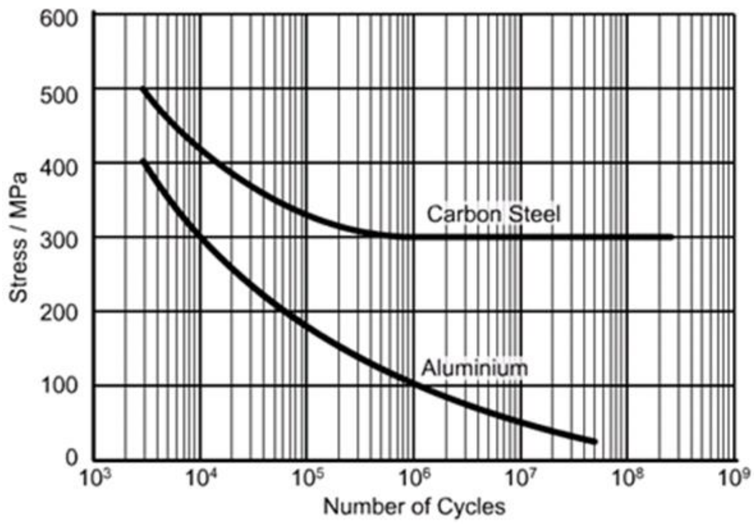


Figure 3 - Fatigue Limit of Steel

The main concerns of reliability are primarily centered on the lifting bar. These modes of failure can be viewed in the FMEA table in Appendix B – FMEA/FEA. Each potential failure mode that received a 10 in severity must be brought to attention. First off, the power screw must not feel any forces in the Z component (vertical) while under load, otherwise it will bend and not be able to adjust to different lifting positions. This can happen if the delrin spacers wear out which are designed to perfectly space the lifting block from the U-channel. The way to address this issue is to periodically check the delrin spacers to see if there has been any wear. To prevent any issues with the mobility of the power screw, it must be greased often to ensure minimal friction.

The Trolley was also a reliability concern in its early stage, but added support gussets greatly augmented the structural integrity of this component. With the first round of load testing, the trolley experienced deflection which was greater than the analysis shown in FEA. To address this issue, team 5 did additional FEA with more gussets added to the trolley. FEA showed that the trolley only experienced .125mm of deflection with the new design, compared to 13mm of deflection from the original design in testing. Satisfied with these results, additional gussets were cut with the water jet and welded to the trolley. This new design proved to be much stronger than the previous rendition, and is no longer a concern of reliability. Additional FEA results can be view in Appendix B – FMEA/FEA.

All of the remaining modes of failure that received a 10 were wear to hardware. This hardware included fasteners, shackles, and rods. Each piece of hardware purchased has a load rating prior to purchase, which has been approved by Team 5. Risk mitigation still must be performed, and to prevent failure, this hardware must be inspected before each time a compressor is lifted to ensure safety to equipment and human life.

4. Design for Economics

The cost of Team 5's solution is approximately $1496.85, which includes all of the materials and hardware. The lifting bar alone costs $608.61 partly due to the expensive ball screw. The gantry costs $402.09, and the large percentage of this cost was the I-beam which is a lot of steel. The trolley costs $486.15. The most expensive part of this component was the trolley hoist which mates the trolley to the gantry. Team 5 has exceeded the budget by $496.85, but Turbocor had agreed to increase the budget after a sufficient project plan had been presented. All of Team 5's financial records can be view in Appendix C – Purchase Requisitions. All of the hardware including screws, nuts, and washers were donated by Turbocor to keep the cost of the project down.

Since Turbocor had its machinists provided for Team 5, the cost has been factored into the Turbocor's financials, and not in Team 5's budget. If this project required Team 5 to source the fabrication to a different company, the cost would have been far greater. Overall, the cost of this project could be reduced in further revisions of the original design, but an effective way to determine which parts can be changed is to implement the lifting system and determine optimal design. A visual representation of the budget breakdown can be seen below in Fig. 4. Each component is composed of any store bought parts, raw material, and hardware. To keep the cost down in future renditions, reducing the amount of store bought material is essential.

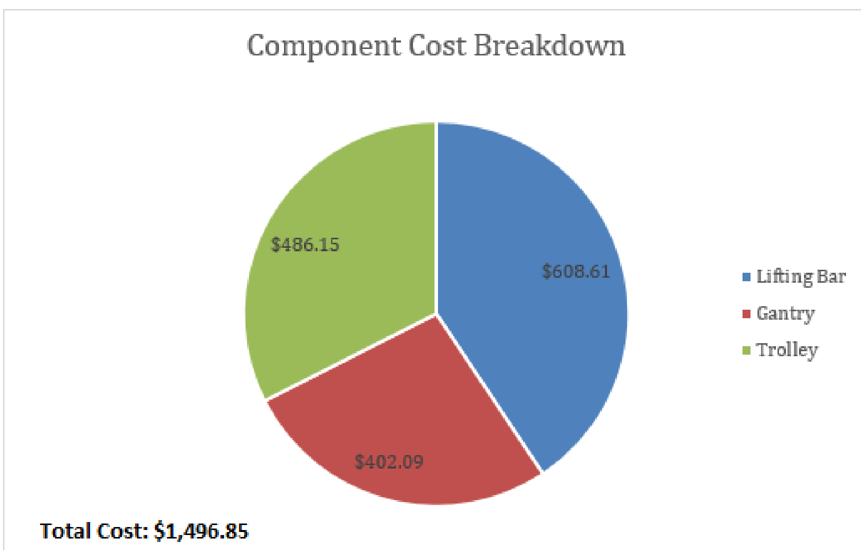


Figure 4 - Cost breakdown of components

4.1 Design Alternatives

Team 5's solution to Turbocor's problem is a unique and custom design. All three components are custom to Turbocor's facilities, but there are similar commercial alternatives to the gantry system and lifting bar. The trolley is a completely custom and unique component which is not commercially for sale. The alternative costs for alternative lifting bars are in the range of $581-$1000. With the most inexpensive option, of the lifting bar made by Vestil, team 5 could have saved ~$27, but it was determined that a custom bar would have the ability to be more compacted than a store bought option. Ultimately, team 5 made the best choice of creating their own design with time, spatial, and budget constraints. Shown below in Figure

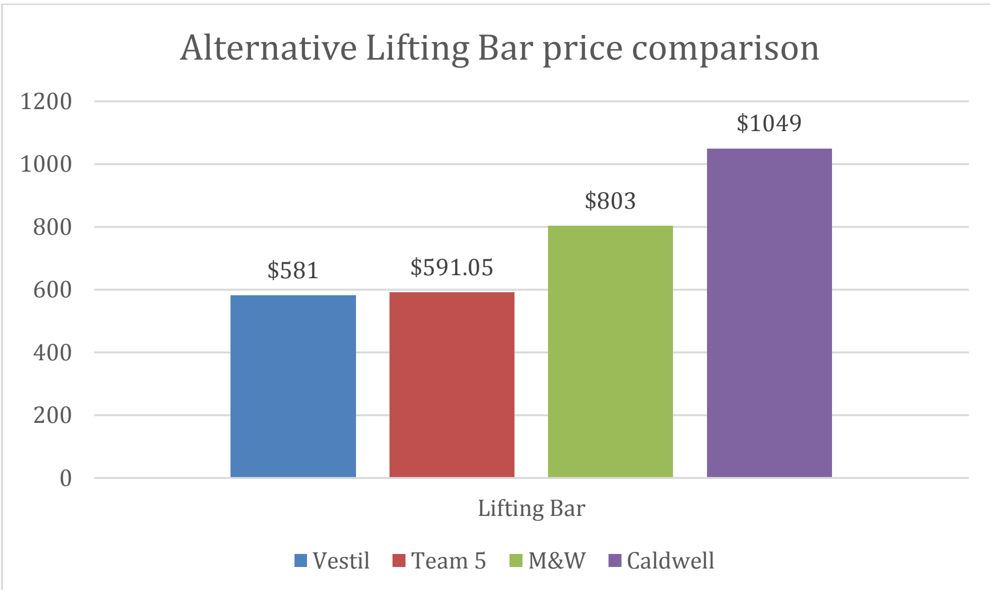


Figure 5 - Lifting Bar cost comparison

5. Conclusion

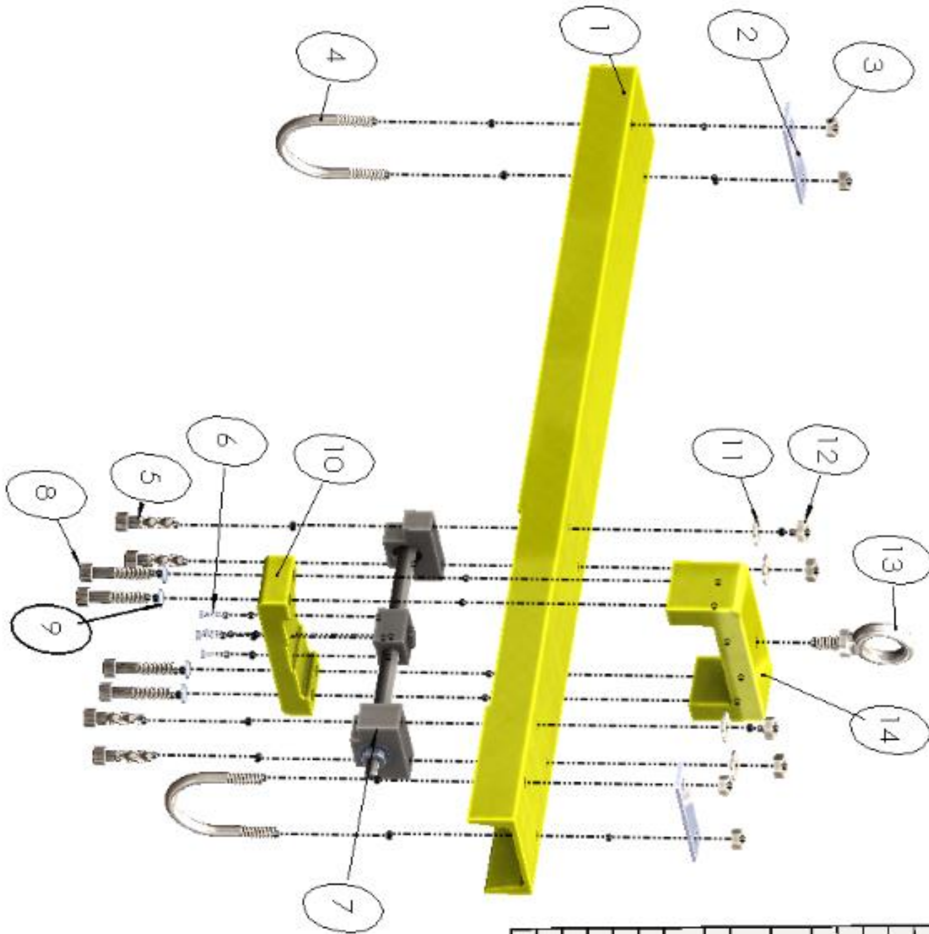
Turbocor is in need of a new lifting system in order to lift the new VTT compressor into place for chiller testing. The current gantry system was sufficient for previous compressors, but is inadequate for the new design. Turbocor had requested that a new, offset lifting bar be designed and implemented with the current crane hoist in order to lift the compressor to the appropriate height. Team 5 had proposed that, in order to safely solve this issue, a new gantry system be designed in order to suspend the crane hoist between the I-beams and also develop a lifting bar that will be able to adjust for a variation in the center of gravity for each compressor. Team 5 plans on implementation of the gantry system into Turbocor by the end of April.

References

[1] "OEM Customers." Danfoss Turbocor Compressors Inc. N.p., n.d. Web. 23 Sept. 2014.

[2] Lohman, Kevin. "Project 5 - DTC Bi-directional Lifting Bar." Www.campus.fsu.edu. Florida State University, 31 Aug. 2014. Web. 26 Sept. 2014.

Appendix A – Exploded View Assemblies



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 6 - Lifting Bar Exploded View

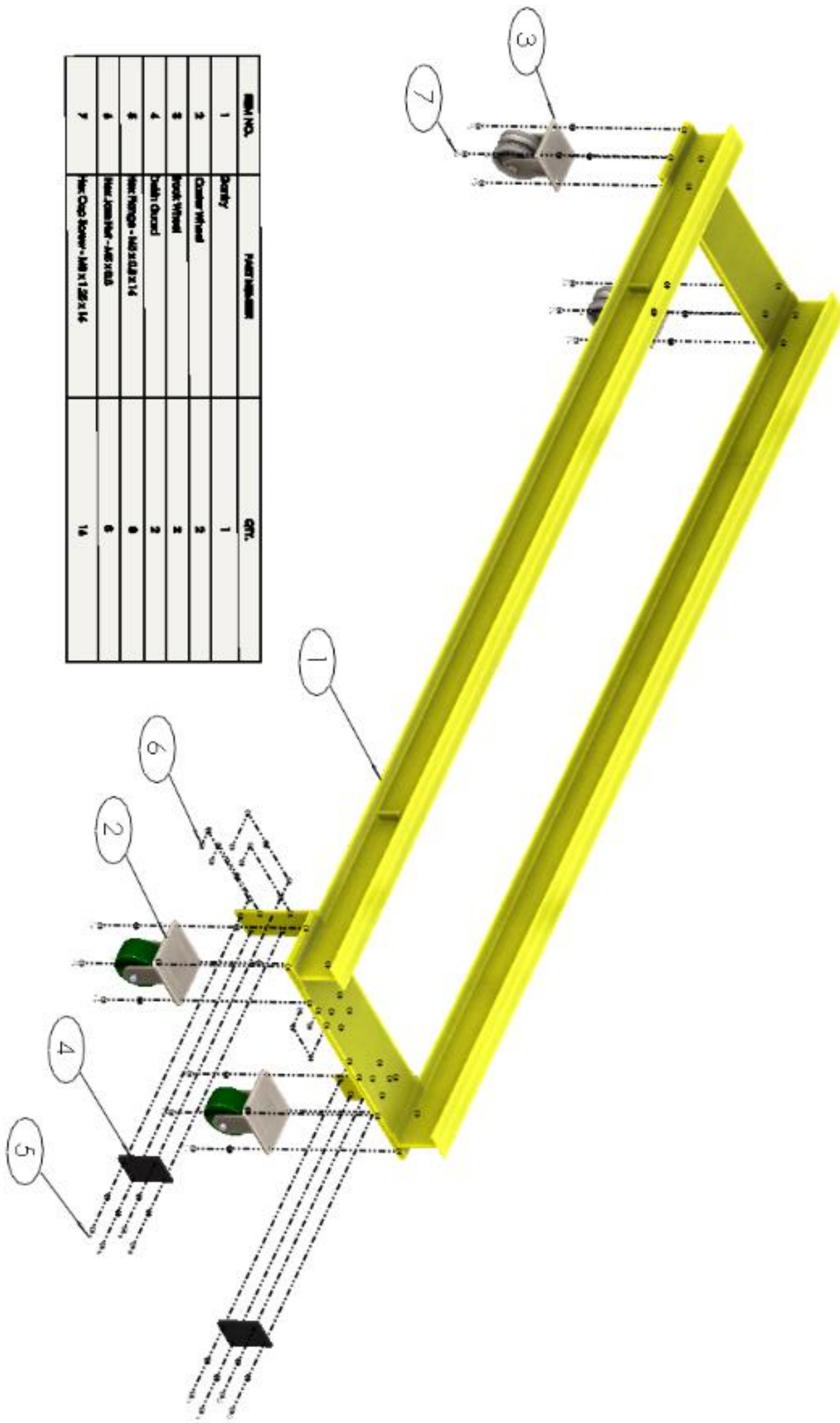


Figure 7 – Gantry Exploded View

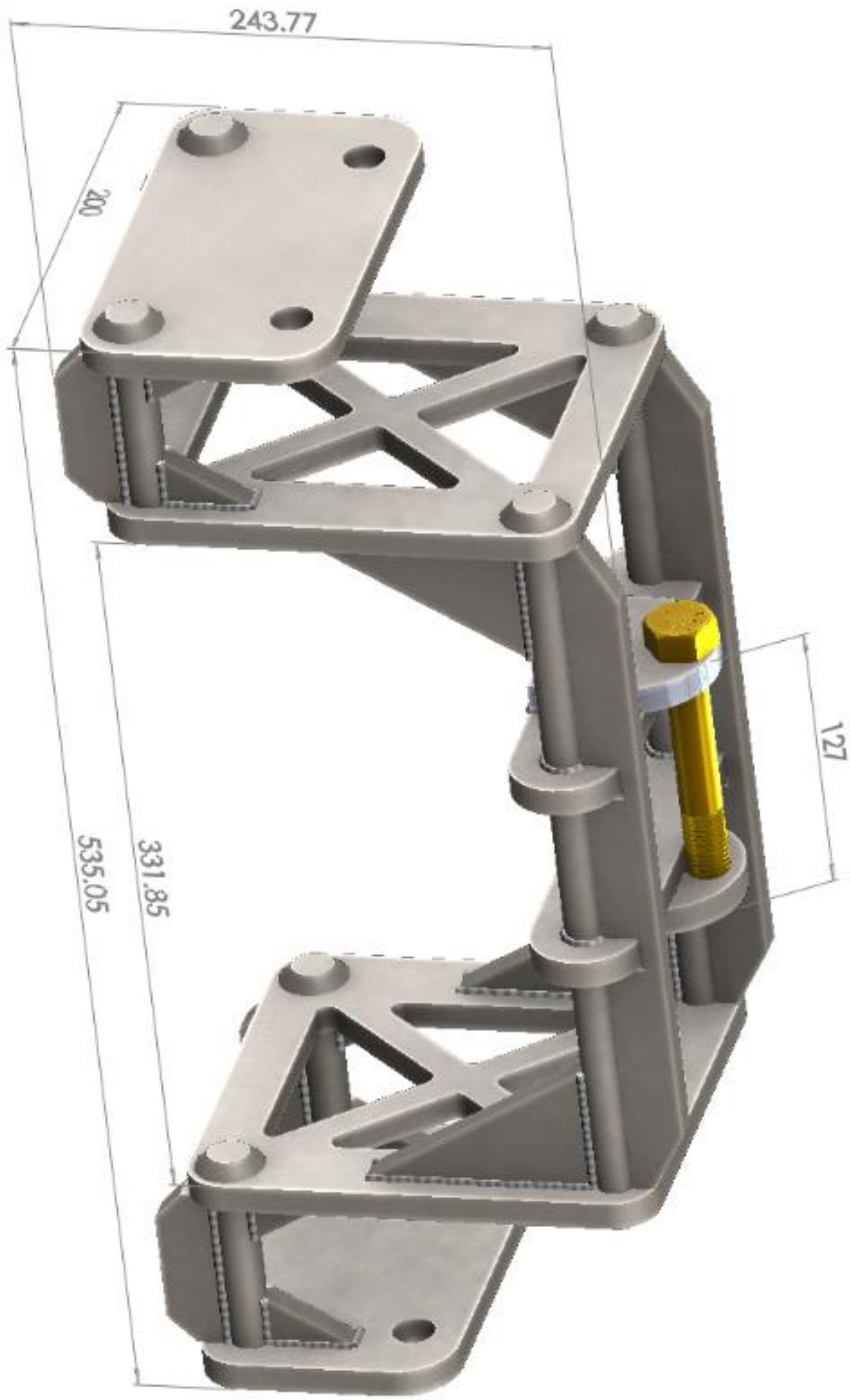


Figure 8 - Assembly of Trolley

Appendix B – FMEA / FEA

Failure Modes Effects Analysis

Team #:	5
Project Title	Bi-Directional Offset Lifting Bar

Key Process Step or Input	Potential Failure Mode	Potential Failure Effects	S E V	Potential Causes	O C C	Current Controls	D E T	R P N	Actions Recommended	Resp.	Actions Taken
What is the Process Step or Input?	In what ways can the Process Step or Input fail?	What is the impact on the Key Output Variables once it fails (customer or internal requirements)?	How **Severe** is the effect to the customer?	What causes the Key Input to go wrong?	How **often** does cause or FM **occur**?	What are the existing **controls** and procedures that prevent either the Cause or the Failure Mode?	How well can you **detect** the Cause or the Failure Mode?		What are the actions for reducing the occurrence of the cause, or improving detection?	Who is Responsible for the recommended action?	Note the actions taken. Include dates of completion.
Loading of Lifting Bar	Deformation of Shackles or U-Bolts	Danger to equipment and operators	10	Overloading or improper use	5	Operator Manual, Hardware strength exceeds max	1	50	Check equipment for signs of wear before and after	Test-Room Operator	
	Yielding of Fasteners	Danger to equipment and operators	10	Overloading or improper use	2	Operator Manual, Hardware strength exceeds max	3	60	Check equipment for signs of wear before and after	Test-Room Operator	
	Plastic deformation of U-Channel	Danger to equipment and operators	10	Overloading or improper use	4	Operator Manual, Material strength exceeds max	1	40	Check equipment for signs of wear before and after	Test-Room Operator	
	Movement of Ball screw during lift	Danger to equipment and operators	8	Improper use, lifting at an angle	4	Operator Manual, Locking mechanism	2	64	Verify proper center of gravity before full lift	Test-Room Operator	
	Ball-Screw Binding	Unability to lift compressor safely	7	Overloading, lack of maintenance	3	Operator Manual, Lubrication	1	21	Maintain Ball screw clean and lubricated	Test-Room Operator	
	Delrin Sheave Cracked	Damage to Lifting Bar	7	Regular Use	4	Operator Manual,	2	56	Replace Sheaves as Needed	Test-Room Operator	
	Ball-Screw Set Screw Tightening	Loss of Ball Screw Adjustability	3	Improper set screw position	3	Operator Manual	1	9	Proper Ball Screw Adjustment According to user	Test-Room Operator	
	Rust	Increased maintenance downtime	2	Lack of Maintenance	1	Paint	2	4	Regular Maintenance	Test-Room Operator	
Loading of Hoist Trolley	Deformation of Rods, gussets, or structural parts	Danger to equipment and operators	10	Overloading or improper use	2	Operator Manual, design	2	40	Testing, Check equipment for signs of wear	Test-Room Operator	Added additional Gussets 3/20
	Cracked welds	Danger to equipment and operators	10	Overload or improper use	1	Stength of materials, and proper weld	4	40	Periodic inspection of lifting equipment	Test-Room Operator	
	Binding of I-Beam Trolleys	Inability to use lift compressor	7	Overloading or lack of maintenance	1	Rated for load significantly higher than recommended	1	7	Regular Maintenance as needed	Test-Room Operator	
	Hardware showing signs of wear	Danger to equipment and operators	7	Overloading	3	Rated for load significantly higher than recommended	2	42	Periodic inspection of lifting equipment	Test-Room Operator	
	Not sitting evenly between Gantry	Potential binding or collapse of trolley	10	Fastener wear, or backing out	3	Locking Fasteners, Threadlock, and Lock washers used	2	60	Periodic inspection of lifting equipment	Test-Room Operator	
Gantry	Binding of Caster Wheels	Downtime to performance maintenance	4	bearing wear	1	casters with sealed bearings	1	4	Maintenance as Needed	Test-Room Operator	
	Shifting track position	Potential derailment of gantry	6	Loose fasteners, improper use	3	V-Tracked casters, derailment guards, and locking fasteners.	2	36	Periodic inspection of lifting equipment	Test-Room Operator	
	Damage to Trolley Stop Plates	Unsafe trolley positioning	5	Improper use	2			0	Periodic inspection of lifting equipment	Test-Room Operator	
	Hardware showing signs of wear	Danger to equipment and operators	10	Overloading	1	Grade 8 fasteners	2	20	Periodic inspection of lifting equipment	Test-Room Operator	
	Deformation of I-Beams	Damage to Gantry	10	Overloading	1	Gantry strength greatly exceeds max hoist load	1	10	Periodic inspection of lifting equipment	Test-Room Operator	

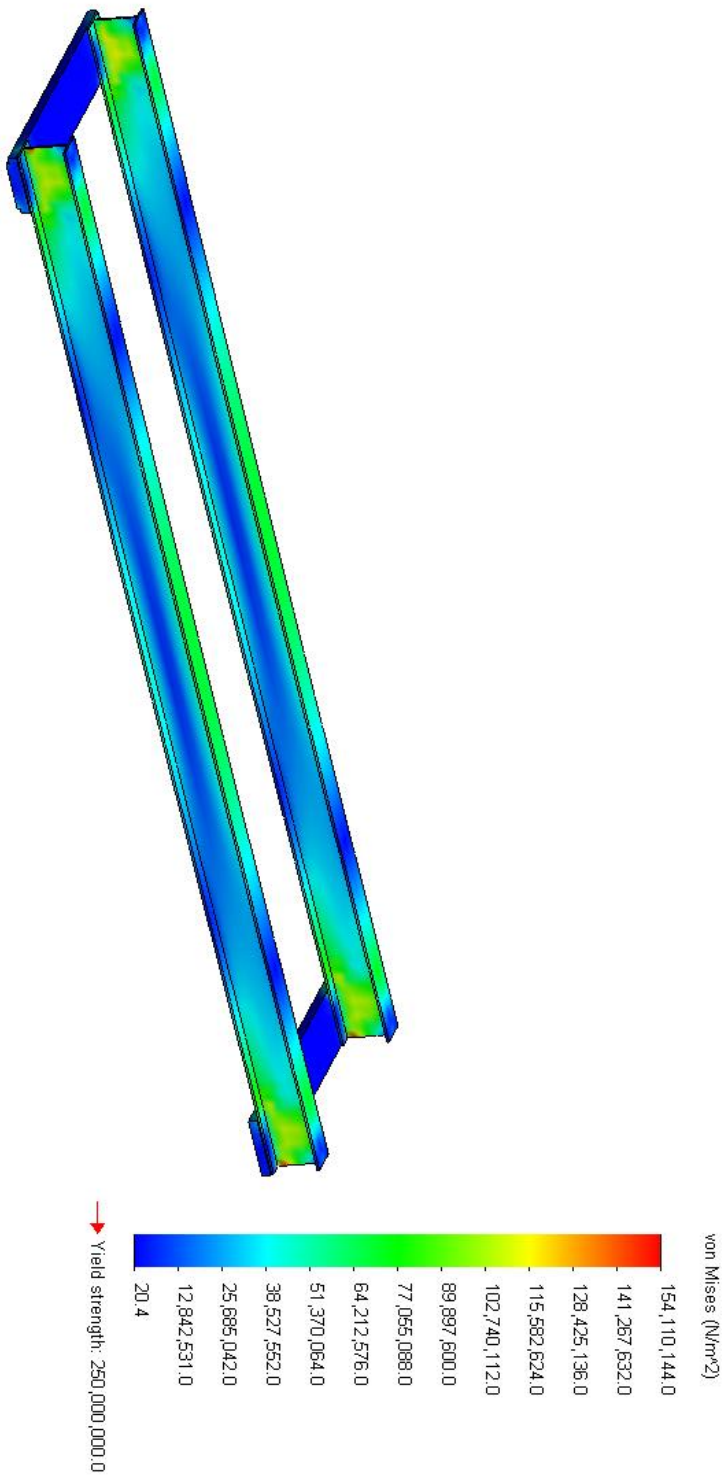


Figure 9 - Gantry FEA

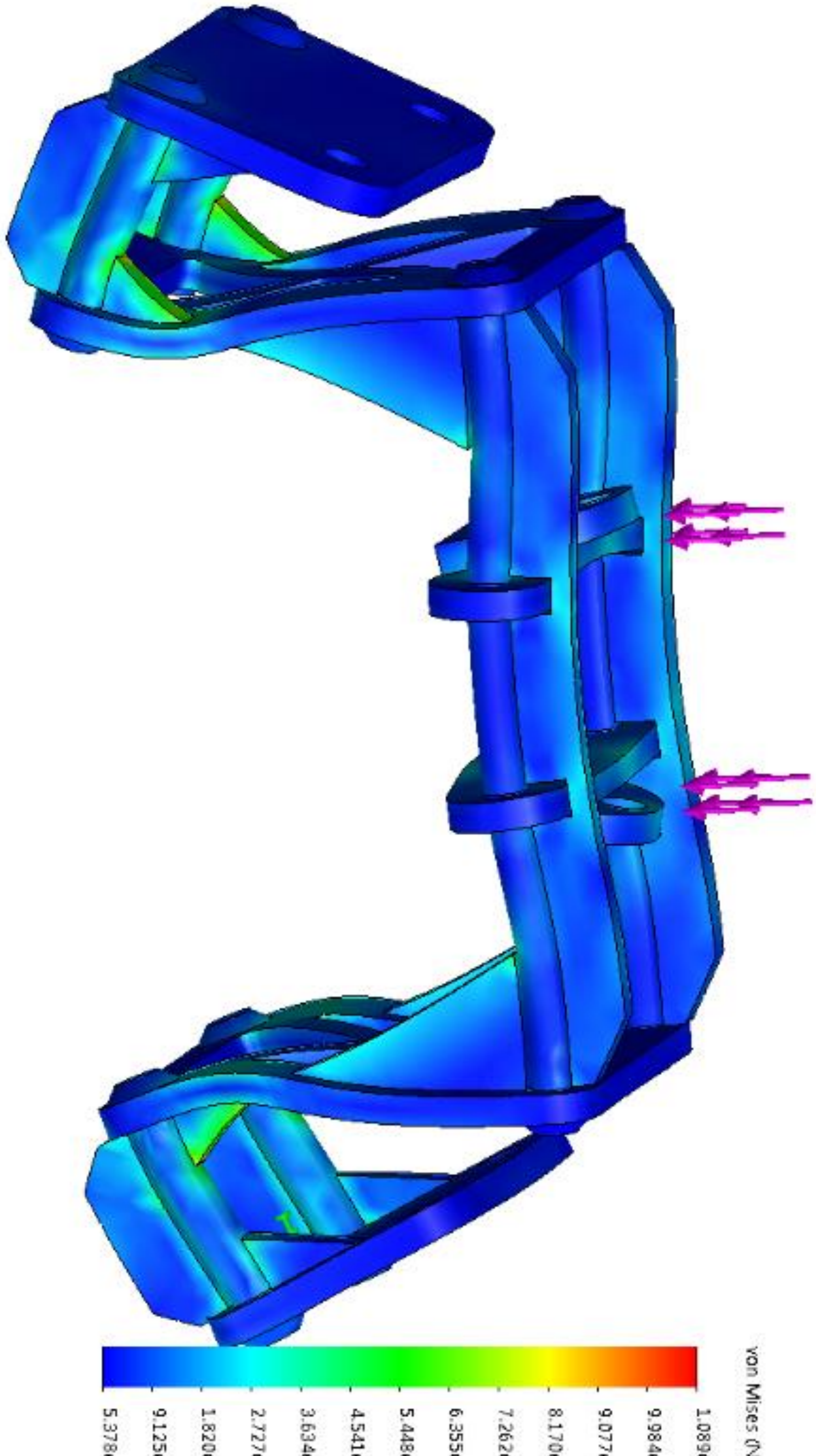


Figure 10 - Trolley FEA

Figure 11 - Lifting Bar FEA

Appendix C – Complete Parts List

Table 2 - Lifting Bar parts list

Adjustable Lifting Bar	
Component	**Qty.**
Eyebolt for lifting - M12 x 1.75, 30 mm eye	1
Lifting Block (2 Piece)	1
3/8" Zinc Chain (2 Links)	1
Block Ball Screw	1
Support Bearing - Fixed Side	1
Support Bearing - Support Side	1
Delrin spacer	2
Loctite	1
U-bolt Shim 1/4" thick	1
Steel Shackle - 3/8" x 1 7/16"	2
U-bolt Saddle 1/8" thick	2
U-Bolt - 3/8" x 16, for 2" pipe	2
M10 x 45mm Socket Cap Screw	4
M10 Lock Washers	4
U-bolt Nuts 3/8"-16	4
M4 x 10 mm Socket Cap Screw	4
M8 x 20 mm Socket Cap Screw	4
M8 Lock Washer	4
M8 Hex Nut	4

Table 3 - Gantry Parts List

Gantry	
Component	**Qty.**
I Beam 4" x 3" x 8'	2
Steel Gantry Caster Plate	2
Guard Delrin	2
4" Track Wheels	2
4" Caster Wheels	2
M4 x 15mm Pan-head Screw Length	8
M4 Nuts	8
M8 x 15mm Socket Cap Screw	16
M8 Nut	16
M8 Lock washer	16

Table 4 - Trolley Parts list

Trolley System	
Component	**Qty.**
Grade 9, 3/4" x 5" bolt	1
3/4" Nut	1
Trolley Plate	2
Round Bar - 19.05 x 369.95	2
I-Beam Trolley	2
Connecting Support	2
Vertical Support	2
Strength Gusset	2
Bolt Support	2
Bottom Gusset	4
Large Gusset	4
Round Bar - 19.05 x 152.4	4
Small Gusset	8

Appendix D – Purchase Requisitions

Table 5 - Component Bill of Materials

Adjustable Lifting Bar					
Component	**Part #**	**Vendor**	**Cost**	**Qty.**	**Total**
Eyebolt for lifting - M12 x 1.75, 30 mm eye	3040T15	McMaster-Carr	$6.63	1	$6.63
Steel Shackle - 3/8" x 1 7/16"	3560T47	McMaster-Carr	11.14	2	$22.28
U-Bolt - 3/8" x 16, for 2" pipe	3043T41	McMaster-Carr	6.33	2	$12.66
4" x 8" x 2" Steel Block (4"x4"X12")block	N/A	Speedy Metals	103	1	$103.00
3/8" Chain (1')		McMaster-Carr	10.64	1	$10.64
Block Ball Screw	BSBR1505-250	Misumi	245.92	1	$245.92
Support Bearing - Fixed Side	BSWE12	Misumi	87.14	1	$87.14
Support Bearing - Support Side	BTN12	Misumi	90.59	1	$90.59
Delrin Sheet, 2" x 12" x 1/8"	8662K13	McMaster-Carr	4.2	1	$4.20
U-channel C4x5.4 (roughly 31 inches)	N/A	Speedy Metals		1	$25.55
Total Cost					$608.61
Trolley System					
Component	**Part #**	**Vendor**	**Cost**	**Qty.**	**Total**
1/2" x 24 " x 24 " Steel Plate	P112	Metals Depot	110.24	1	$110.24
3/4"-10 Hex Nuts (25ct.)	90499A837	McMaster-Carr	9.82	1	$9.82
3/4" x 6' 1018 Round Bar	R134	Metals Depot	20.22	1	$20.22
Grade 9, 3/4" x 5" bolt	90201A660	McMaster-Carr	11.25	1	$11.25
Grade 9, 3/4" x 6" bolt	90201A667	McMaster-Carr	14.28	1	$14.28
Hoist Trolley	3267T62	McMaster-Carr	160.17	2	$320.34
Total Cost					$486.15
Gantry System					
Component	**Part #**	**Vendor**	**Cost**	**Qty.**	**Total**
I Beam 4" x 3" x 20'		Trident	240.00	1	$240.00
4" Track Wheels	8745T89	McMaster-Carr	31.99	2	$63.98
4" Caster Wheels	2453T1	McMaster-Carr	26.63	2	$53.26
1/4" x 12" x 24" Steel Plate guide and bumpers	P114	Metals Depot	31.02	1	$31.02
Delrin Sheet, 3" x 12" x 3/8"	8662K35	McMaster-Carr	13.83	1	$13.83
Total Cost					$402.09
		Total Cost			**$1,496.85**

Danfoss TURBOCOR

PURCHASE ORDER REQUISITION

Vendor: Trident Company
108 Fairbanks Ave, Thomasville, GA 31792

Contact: (229) 225_9965

DATE: 8-Dec-14

DATE REQUIRED:

CAPITAL EXPENDITURE (please tick):

CURRENCY: USD

NOTE: THIS IS NOT A PURCHASE ORDER AND CANNOT BE ISSUED TO SUPPLIER

TURBOCOR P/N	DESCRIPTION	VENDOR P/N	QTY	UNIT PRICE	TOTAL PRICE	PROJECT NUMBER	ACCOUNT NUMBER
	I Beam, 4" x 2.663" x 0.193" x 96"	N/A	2	$ 66.80	$ 133.60		

FREIGHT: A) PREPAID (included)
B) PREPAID & CHARGE
C) COLLECT
D) FIXED AMOUNT amount

TOTAL $ 133.60

Special instructions:

Prepared by: KEVIN LOHMAN (Print name)

Approved by: (Manager)

Approved by: (Director)

PUR-00007F01

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Danfoss TURBOCOR

PURCHASE ORDER REQUISITION

Vendor: McMaster-Carr

Contact:

DATE:

DATE REQUIRED:

CAPITAL EXPENDITURE (please tick):

CURRENCY: USD

NOTE: THIS IS NOT A PURCHASE ORDER AND CANNOT BE ISSUED TO SUPPLIER

TURBOCOR P/N	DESCRIPTION	VENDOR P/N	QTY	UNIT PRICE	TOTAL PRICE	PROJECT NUMBER	ACCOUNT NUMBER
	3/4" Grade 9 Hex Bolt Overall Lg. 6"	90201A667	1	$ 14.28	$ 14.28		

FREIGHT: A) PREPAID (included)
B) PREPAID & CHARGE
C) COLLECT
D) FIXED AMOUNT amount

TOTAL $ 14.28

Special instructions:

Prepared by: KEVIN LOHMAN (Print name)

Approved by: (Manager)

Approved by: (Director)

PUR-00007F01

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PURCHASE ORDER REQUISITION

Danfoss TURBOCOR

Vendor: Speedy Metals

Contact: 866-938-6061

DATE: 8-Dec-14

DATE REQUIRED:

CAPITAL EXPENDITURE (please tick):

CURRENCY: USD

NOTE: THIS IS NOT A PURCHASE ORDER AND CANNOT BE ISSUED TO SUPPLIER

TURBOCOR P/N	DESCRIPTION	VENDOR P/N	QTY	UNIT PRICE	TOTAL PRICE	PROJECT NUMBER	ACCOUNT NUMBER
	4" {A} Sq. A-36 Hot Rolled Steel- By the Inch		1	83.52	$ 83.52		
	Overall Length: 8"	SKU: hs4					
	Price Per inch: $10.44						
	Channel, 5.4 lb/ft A-36 Hot Rolled Steel		1	25.55	$ 25.55		
	4" x 1.584" x 0.184"	SKU: hc4x5.4-36					
	Overall Length: 36"						
	A-36 Hot Rolled Steel Plate		1	$ 53.69	$ 53.69		
	1/2" Thickness	SKU: hp.5-12x24					
	12" x 24" Dimensions						

FREIGHT: A) PREPAID (included)
B) PREPAID & CHARGE
C) COLLECT
D) FIXED AMOUNT — amount

TOTAL $ 162.76

Special instructions:

Prepared by: KEVIN LOHMAN (Print name)

Approved by: (Manager)

Approved by: (Director)

PUR-00007F01

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Danfoss TURBOCOR

PURCHASE ORDER REQUISITION

Vendor: Misumi

Contact: (847) 843-9105

DATE:

DATE REQUIRED: 8-Dec-14

CAPITAL EXPENDITURE (please tick):

CURRENCY: USD

NOTE: THIS IS NOT A PURCHASE ORDER AND CANNOT BE ISSUED TO SUPPLIER

TURBOCOR P/N	DESCRIPTION	VENDOR P/N	QTY	UNIT PRICE	TOTAL PRICE	PROJECT NUMBER	ACCOUNT NUMBER
	Block Ball Screw	BSBR1505-250	1	245.92	$ 245.92		
	Support Bearing - Fixed Side	BSWE12	1	87.14	$ 87.14		
	Support Bearing - Support Side	BTN12	1	90.59	$ 90.59		

FREIGHT: A) PREPAID (included)
B) PREPAID & CHARGE
C) COLLECT
D) FIXED AMOUNT — amount

TOTAL $ 423.65

Special instructions:

Prepared by: KEVIN LOHMAN (Print name)

Approved by: (Manager)

Approved by: (Director)

PUR-00007F01

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PURCHASE ORDER REQUISITION

Vendor: Metals Depot
Corporate Office & Warehouse

4200 Revilo Road, Winchester, KY 40391 USA
1-859-745-2650 Fax 1-859-745-0887

Contact: 1-859-745-2650

DATE:

DATE REQUIRED:

CAPITAL EXPENDITURE (please tick):

CURRENCY: USD

NOTE: THIS IS NOT A PURCHASE ORDER AND CANNOT BE ISSUED TO SUPPLIER

TURBOCOR P/N	DESCRIPTION	VENDOR P/N	QTY	UNIT PRICE	TOTAL PRICE	PROJECT NUMBER	ACCOUNT NUMBER
	Low Carbon Steel Plate, 1/2" x 24 " x 24"	P112	1	110.24	$ 110.24		
	1018 Steel Round bar, 3/4" x 72"	R234	1	20.22	$ 20.22		
	Low Carbon Steel Plate, 1/4" x 12" x 12"	P114	1	18.01	$ 18.01		

FREIGHT: A) PREPAID (included)
B) PREPAID & CHARGE
C) COLLECT
D) FIXED AMOUNT — amount

TOTAL $ 148.47

Special instructions:

Prepared by: KEVIN LOHMAN (Print name)

Approved by: (Manager)

Approved by: (Director)

PUR-00007F01

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Danfoss TURBOCOR

PURCHASE ORDER REQUISITION

Vendor: Mc Master Carr
6100 Fulton Inddustrial Blvd. SW
Atlanta, GA 30336-2853

Contact: (404) 346-7000

DATE: 8-Dec-14

DATE REQUIRED:

CAPITAL EXPENDITURE (please tick):

CURRENCY: USD

NOTE: THIS IS NOT A PURCHASE ORDER AND CANNOT BE ISSUED TO SUPPLIER

TURBOCOR P/N	DESCRIPTION	VENDOR P/N	QTY	UNIT PRICE	TOTAL PRICE	PROJECT NUMBER	ACCOUNT NUMBER
	Eye Bolt, M12x1.75, 30 mm eye	3040T15	1	$ 6.63	$ 6.63		
	Steel Shackle, 7/16" x 3/4"x 1/2"x1 1/2"	3560T47	2	$ 11.14	$ 22.28		
	U-Bolt Pipe, 3/8" x 16, for 2" Pipe	3043T41	2	$ 6.33	$ 12.66		
	Delrin Black, 1/8" x 2" x 12"	8662K13	1	$ 4.20	$ 4.20		
	Grade 9 Hex Bolt, 3/4"-10 x 5"	90201A660	1	$ 11.25	$ 11.25		
	Trolley 1100 lb capacity	3267T62	2	$ 160.17	$ 320.34		
	4" Caster Wheels	8745T89	2	$ 31.99	$ 63.98		
	4" Track Wheels	2453T1	2	$ 26.63	$ 53.26		
	Delrin Black, 3/8" x 3" x 12"	8662K35	1	$ 13.83	$ 13.83		
	3/4"-10 Hex Nuts (Qty 25)	90499A837	1	$ 9.82	$ 9.82		
	Grade 100 Chain - 0.83" x 24"	3410T62	1	$ 10.64	$ 10.64		

FREIGHT: A) PREPAID (included)
B) PREPAID & CHARGE
C) COLLECT
D) FIXED AMOUNT amount

TOTAL $ 528.89

Special instructions:

Prepared by: KEVIN LOHMAN (Print name)

Approved by: (Manager)

Approved by: (Director)

PUR-00007F01

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