VHDM Connector Production Line Efficiency Improvement

Major Qualifying Project Report

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Abstract

While working in China for Amphenol TCS, the group was given a goal to increase the efficiency of the VHDM Power Module line from 114% to 140%. In order to achieve such a goal, one must first gain the necessary knowledge about the production line and where the current problems exist. Once this is achieved the technique of lean manufacturing can be implemented throughout the production line to reduce the bottleneck times and increase the efficiency and product output.

Acknowledgements

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We would like to thank all of the employees at Amphenol TCS especially Sky Wang and JunChuang Qi for their help and guidance. Finally we would like to thank our advisors Professor Rong from Worcester Polytechnic Institute and Professor Gao from Huazhong University of Science and Technology for all their help and guidance with the completion of this project.

Authorship

All members of the team helped with data collecting and analysis, design of the tools, and the writing of the paper. Clinton McAdams and Michael Pagonis were responsible for the formatting of the paper and the Background sections. Wu Jianbo, Liu Fei, and Fang Xiaowen served as translators for the group and were responsible for the CAD models of the tools, and helped with all sections of the paper. Michael Pagonis focused on the Methodology, Conclusions, and Solutions sections while Clinton McAdams focused on the Background, Data, and Results sections. All members also took part in multiple presentations at Amphenol TCS and at HUST.

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Nomenclature

CAD- Computer Aided Design

WPI- Worcester Polytechnic Institute

HUST- Huazhong University of Science and Technology

VHDM- Very High Density Metric

TCS- Total Connectors Solutions

1 Introduction

The Amphenol Corporation was founded in 1932, and since that timeAmphenol has become the world's third largest connectors company, having sales of $447 million in fiscal year 2007. Amphenol is a leader in high-speed, high-density connection systems and backplane systems. Amphenol has been active in China since 1984. Unlike the branches in the United States, the branches in China focus on product production. The product that this project focuses on is the VHDM Power Module. VHDM is a connector that plugs into backplanes and daughter cards. The VHDM Power Module is very flexible because it can have two pin or three pin combinations and can be combined with other VHDM connectors.

The problem statement given to the group was to improve the current efficiency of the VHDM line from 114% to 140%. In order to achieve this goal the team had to combine the knowledge gained about Lean Manufacturing along with the skills already gained in the field of Mechanical Engineering. Along with the goal from the company, the team came up with other goals to achieve. The team would like to decrease the cycle time as well as increase the production output. The team also needs to find other problems with the line and create solutions for them.The team would also like to increase the line balance rate, and make the process easier for the workers.Upon completion of the project, the team hopes that the solutions recommended and given to the company can be incorporated into the current VHDM line to improve the efficiency as well as all other objectives.

2 Background

The following is a description of research required for completion of the project. Each section contains information that was required for completion of the project. Research was gathered to gain more knowledge about the techniques of lean manufacturing and the Amphenol TCS Corporation.

2.1 Amphenol TCS

Amphenol was founded in 1932. Amphenol TCS is the leader in high-speed, high-density connection systems, designing and manufacturing the industry's leading high-speed, high-density connectors and backplane systems. Amphenol TCS solves system design challenges with integrated interconnect solutions for application in the networking, communications, storage, and computer server markets. Amphenol is the world's third largest connector company employing over 27,000 people worldwide. In 2006 Amphenol had $2.5 billion in net sales. Amphenol has been active in China since 1984. The China branch focuses on design, manufacturing and marketing of electrical, electronic and fiber optic connectors, coaxial and flat-ribbon cable, and interconnect systems[1].

2.2 VHDM Power Module

While working with Amphenol TCS the team was given the task of focusing on the VHDM Power Module production line. The VHDM connector family consists of both backplane

[1] Amphenol Corporation, High Performance Connection Systems from Amphenol TCS, 03 2008 <http://www.amphenol-tcs.com/>.

and daughter card connectors. All of the VHDM connectors can be built to many different specifications and can be combined with each other. These features make it an extremely flexible product. See Appendix D for technical drawings and a picture of the VHDM Power Module.

2.3 Lean Manufacturing

This project will have a focus in the area of lean manufacturing. Lean manufacturing is the optimal way of producing goods through the removal of waste and implementing flow. Lean manufacturing is focused on getting the right things, to the right place, at the right time, in the right quantity to achieve perfect work flow while minimizing waste and being flexible and able to change. More specifically for this project,lean manufacturing techniques will be used to decrease non-value added activities, or decrease the risk to the customer.

2.4 Continuous One Piece Flow

A major lean manufacturing technique is continuous one-piece flow. Continuous one-piece flow is a technique used to manufacture components in a cellular environment. The cell is an area where everything that is needed to process the part is within easy reach, and no part is allowed to go to the next operation until the previous operation has been completed. The goals of one-piece flow are to make one part at a time correctly all the time to achieve this without unplanned interruptions to achieve this without lengthy down times[2].

2.5 "5S"

Amphenol TCS needs to produce as much product as possible with the least amount of waste and with the smallest down times. To reach this goal Amphenol applies the "5S" technique. "5S was invented in Japan, and stands for five Japanese words that start with the letter 'S': Seiri,

[2] Superfactory Ventures LLC, One Piece Flow, 2007, April 2008 <http://www.superfactory.com/topics/one.htm>.

Seiton, Seiso, Seiketsu, and Shitsuke." Translated into English 5S means Sort, Set in order, Shine, Standardize, and Sustain. "5S is a structured program to systematically achieve total organization, cleanliness, and standardization in the workplace. A well-organized workplace results in a safer, more efficient, and more productive operation." [3] 5S is a way for the company to improve the quantity and quality of product output while implementing flow and reducing waste.

[3] Silicon Far East, The 5 'S' Process: Seiri, Seiton, Seiso, Seiketsu, Shitsuke, 2004, 04 2008 <http://www.siliconfareast.com/5S.htm >.

3 Methodology and Summary

The objective of this project is to increase the efficiency of the VHDM Power Module line from 114% to 140%. This objective will be accomplished by using five primary steps. The first step is to define the problem at hand. The next step is to gain as much knowledge of the current production line as possible, and then collect all the necessary data from the line to be analyzed. Once all the data is collected, the next step is to analyze the data and find some preliminary solutions. Next, the solutions are improved on until the final step, which is to take the solutions and put them into practice. After these five steps are completed the goal of improving the efficiency of the line can be accomplished.

3.1 Define the Problem

One of the most important parts of the project is to first define the actual problem to which the team must find solutions. The company gave the team a goal to raise the VHDM Power Module line's efficiency from 114% to 140%. Along with the goal given to the team from the company, the team also came up with its own set of goals that included making the production line run more smoothly with less down time and increasing product output along with the line balance rate.

3.2 Information on the Line and Data Collection

The next step was to learn as much as possible about the production line the team will be working on. In order to do this the team had an engineer JunChuang Qi show them the VHDM line. Jun Qi showed the team each step of the process and explained what happened at each station. The line has six steps and a total of ten workers, one of which is the head of the line and makes sure the line is running properly. The first station on the line consists of four workers who insert the pins into a fixture. Station two has two workers and their job is to put the plastic caps on top of the pins in the fixture. Next, they pass the fixture to station three where there is one worker. Station three is where the caps are pressed firmly onto the pins by a press-fit machine. The press-fit machine is powered by compressed air. The worker then pulls the six connectors out of the fixture and passes the connectors to the next station and at the same time the worker also passes the empty fixture back to stations one and two. After the connectors are passed to station four, they are packed into a tooling tube that holds 54 connectors in one tube. After the connectors are packed into a tooling tube they are then dumped out into the printing mould that holds 16 connectors. The printing mould is put onto a conveyer belt that passes under a printing machine that puts a label onto each connector. The printing mould is then removed from the conveyer belt and the 16 connectors are dumped out onto the table to the next station. Station five has one worker who takes the connectors on the table and packs them into the final tube. Once the final tube is filled with 54 connectors the top of the tube is stuffed with a small pink insert and then taped. Next the tube is passed to station six where one worker inspects the packed connectors under a magnifying lamp to make sure there are no defected connectors. The worker then passes them to the worker from station five who labels them with barcodes and packs them into boxes to be shipped.

The team then started to time each step of the process. The team also took videos on each step and of the whole line. The team timed each step in two different ways. One way was to time how many tubes or in some cases how many fixtures could be finished in five minutes. From this time the team could figure out how many pieces per hour were completed at each station. The other way timed how long it took to complete an individual connector at each station. For example, one member would time how long it took to put in all the pins into the fixture at station one and then pass it to station two. Another example would be the time it took for the station three workers to take a fixture, press it, and then pull out the connectors and then divide that number by six because there were six connectors on the fixture. Using these two methods for timing the team had enough data to start analyzing and developing preliminary solutions.

3.3 Analyze Data and Preliminary Solutions

Correct analysis of the data collected was essential for the simple fact that if analyzed incorrectly the team could potentially suggest wrong solutions to the company. After analyzing the data, the team quickly found that the main problem with the production line was the dumping of the connectors out onto the table after station four. The team found out that the bottleneck of the line occurred at station four, the printing station. The printing station had the least amount of pieces per hour and also had the highest time to complete one individual connector. The team believed that if a tool could be made to dump the connectors directly into the final tubes it would dramatically reduce waste time and increase output.

The team then found out that station three, the press-fit station, took the second longest amount of time and the second lowest amount of pieces per hour. The thought was to design a tool that can take out all six of the connectors from the fixture at once, instead of the worker pulling them out one at a time by hand.

The last problem the team found was that the way the fixture was passed from station three to station one. With the way the fixture is currently passed there is waste time and the station two workers need to pass the fixture to the station one workers. If this could be eliminated it would reduce the wait time and increase output. The team came to the conclusion that if the layout of the tables could be changed it would increase the efficiency of the process.

3.4 Improving Solutions

Now that the team knew what the problem areas were, it was time to think about how the preliminary solutions could be turned into something concrete that the company could actually use.

The team took the preliminary solutions for the printing station and brainstormed. The team came up with a tool that can take the printing mould and dump those connectors directly into a final tube. The design is very simple but very useful.The team came up with two ideas for the press-fit tool. One idea was very similar to the printing station tool in which a cover clamps down onto the fixture, which then releases the connectors into a tooling tube. The other idea is to have two spring claws attached to two handlebars with a ramp in the middle to have the pieces slide down them.

The solution for the passing of the fixture was to change the table layouts. One design was to have two tables in an "L" shape in which the fixtures are passed in a circular motion. The second idea was to combine two tables and put the tables together to make one large table. In this case the fixtures will be passed in a square, eliminating congestion.

3.5 Put into Practice

The team was able to put one of the solutions into practice. The tool for problem one, the printing station, was actually built and brought to the company to be tested. The tool was built at the HUST Engineering Training Center. The team then tested the tool at HUST with the connectors that were given to them.

Once at the company, the team put the tool into practice right away. The tool was set into place and the team showed the printing station worker how to operate it properly. The worker was give one full day to get accustomed to the tool. The next day the team took the same times and calculations as during the first visit, except this time the tool was in place.

The press-fit tools were not built, but there are CAD drawings for them. The table layouts were not implemented either, but the company has the size requirements and ideas so if they would like to implement the new layouts they will be able to do so.

4 Data and Analysis

After being introduced to the VHDM Power Module production line the team started working on the project. Much of this work was collecting data and taking notes, pictures and videos of the production line. Time data was taken with stopwatches. Some initial data needed to be thrown out because the workers on the line would speed up when they knew they were being recorded. Eventually the workers adjusted to the team recording them and worked at a normal pace and each set of data was taken ten times.

4.1 Details of VHDM Power Module

The team collected data on every station involved in the production of the VHDM Power Module. Some stations were broken down into more than one step to determine what part of the station was causing the most issues.

Table 1 and Table 2 show the original times for the production line. On the chart and graph all times are shown in seconds. Time/Panel is the time to complete one fixture, board per is the amount of connectors the worker has in his or her fixture, headcount is the amount of workers each station requires, unit C/T is the cycle time, STD time is the standard or average times, board is the average time to complete one connector. Times for stations one and two were determined by timing how long it took for each worker to complete 20 panels then averaged. Stations three four five and six were timed for 5 minutes and the amount of panels finished in that amount of time was recorded.

Table 1 Original Production Times

Station	Workers	Time/Panel	Board Per	Headcount	STD Time		
					Panel	Unit C/T	Board
Inserting Contacts	1	31.13	6	4	29.95	4.99	1.25
	2	26.12					
	3	29.13					
	4	27.71					
Assemble Plastic Cover	1	15.18	6	2	16.08	2.68	1.34
	2	15.45					
Press-Fit	1	9.39	6	1	9.39	1.56	1.56
Printing	1	24.23	14	1	24.23	1.73	1.73
Packing and Label	1	62.39	54	1	62.39	1.16	1.16
Final Inspection	1	42	54	1	42	0.78	0.78

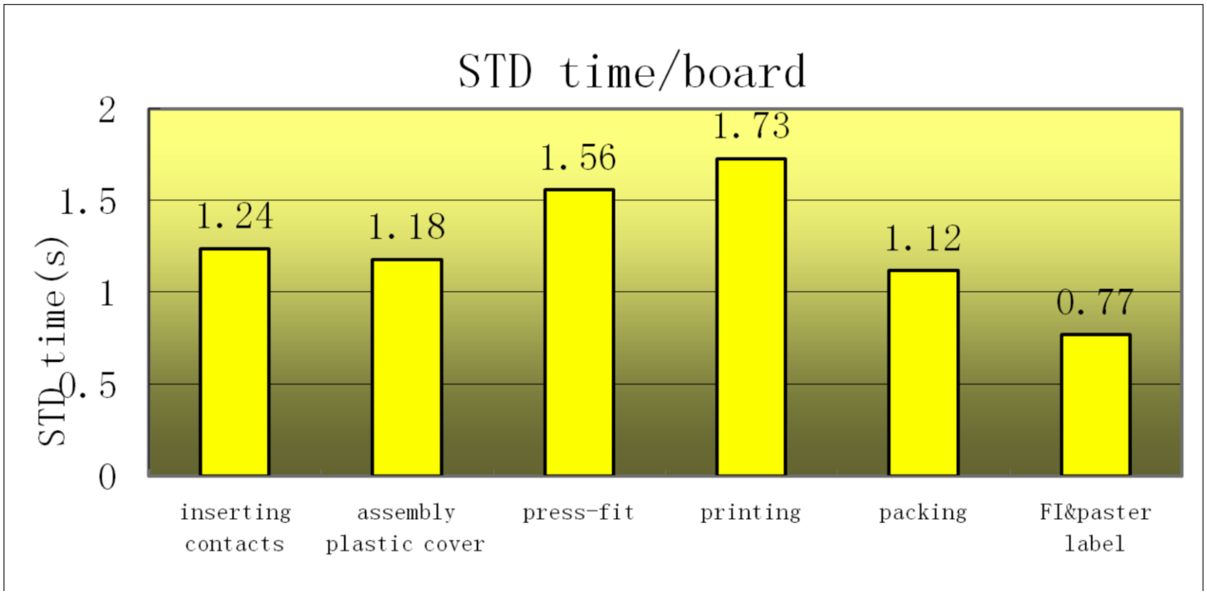


Table 2 Standard Time per Board

After analysis of the chart it was determined that the bottleneck was located at station four, the printing station, with additional issues at the press-fit station. With this knowledge the team returned to the production line to gather more detailed information on these stations.

4.2 Analysis of Station 4, Printing

The team determined that the printing station could be broken down into two steps, loading the tooling tube and printing of the connectors. Times to completely fill an empty tooling tube and to empty and print a tube were recorded. Table 3 shows these times.

Table 3 Station 4 Printing

Station 4 Printing		
Load tube completely (sec)	**Completely unload, print, dump out pieces (sec)**	**Total (sec)**
47.53	33.81	
45.75	31.78	
48.02	34.03	
46.41	31.53	
45.59	33.42	
46.32	32.76	
45.1	33.67	
47.25	33.26	
43.42	32.87	
45.62	33.39	
46.101	**33.052**	**79.153**

With this data it was found that on average it took 0.85 seconds per piece to load into the tube and .612 seconds per piece to print and unload. In other words 58% of the time was used to load the tooling tube. After a meeting to discus the results the team determined the loading of the tube to be a non-value added function and would be the focus of the project.

4.3 Analysis of Station 3 Press-Fit

After analysis of the bottleneck station the team turned their focus to the press-fit station. The team broke the press-fit station into three steps to gather more detailed information. The first step was grabbing the fixture and placing it onto the machine. The second was to press the connectors. The third was unloading the machine, remove the pieces and return the fixture to stations one and two. Table 4 Station 3 Press-Fit shows that the most time is in the third step. With further analysis it was found that step one took an average of 0.36 seconds per piece, step two took 0.25 seconds per piece, and step three took 0.99 seconds per piece. This translated into 59% of the time spent on removing the connectors and returning the fixture to the former stations.

Table 4 Station 3 Press-Fit

	Station 3 Press Fit			**Total (sec)**
	Grab and Put on (sec)	How long to press (sec)	Take off, unload, pass back (sec)	
	2.47	1.44	5.12	
	1.75	1.37	4.84	
	1.47	1.4	4.97	
	1.53	1.5	4.38	
	2.63	1.47	7.09	
	2.09	1.47	6.25	
	2.28	1.47	6.19	
	2.31	1.47	7.16	
	2.78	1.47	6.63	
	2.5	1.47	6.48	
Average	**2.181**	**1.453**	**5.911**	9.545

4.4 Other Observations: Stations 1 and 2

Along with the printing station and press-fit station the team felt the need to solve some problems with the passing of the fixture from station three to station one. Station two had the third highest cycle time and station one had the fourth. The problem with the way the fixture is passed is that it requires the help of station two and this slows down their working ability. The team was unable to take more times on this problem because the company switched from making the VHDM Power Module to a different connector.

5 Solutions

After collecting all the necessary data from the VHDM production line, the team was able to figure out the three main problems of the line. Now that the problems were known the team compiled a list of ideas and thoughts that may be solutions to the problems. The solution to the printing station bottleneck problem is a tool that the worker can use to directly pour the connectors into the final tubes. The solution to the press-fit problem is two tools that would remove all six connectors at once from the fixtures. There are two solutions to the problem of the passing of the fixtures from the press fit station back to station one. The first solution is bigger tables that are placed in an "L" shape, making the flow more cellular. The second solution is to place two table back to back, creating more work space and square flow.

5.1 Thought Process Behind Printing Station

The bottleneck of the VHDM production line was located at the printing station, and this is verified by the data the team collected. The team knew exactly where changes needed to be made at the printing station; after the connectors are printed they are dumped out onto the tube and then re-packed. The team immediately came to the conclusion that some sort of tool needed to be made to help the worker pack the connectors into the tube either faster or directly. The team knew that the simpler the tool the better.This is because the more complicated the tool is the more time it would take to use the tool, thus not making a great impact on the station. The team took all the measurements of the printing mould and the size of the connectors. The next step was to think of how the worker could pack the connectors directly into the final tube. One of the first thoughts was to have a sort of slide at the end of the conveyer belt where the printing mould would slide off and the connectors could then be packed into the final tube 16 at a time. The problem with this idea is that it still takes to much time to pour the connectors into the final tube for the simple fact that it would be hard for the worker to pour the connectors into the final tube because there is no guide for the connectors to follow. The second problem is that the worker would then need to pass the printing mould back to the previous worker, which still takes too much time. The team knew that the key to reducing the waste time was to have the connectors from the printing mould poured directly into the final tube. The team then took this knowledge and thought about how the mould could be poured directly into the tube. The solution was to build a tool that can hold a final tube while at the same time the connectors can be poured out from the printing mould. The tool the team designed consists of a cover, shaft, and a base (see Figure 1 for detailed CAD drawing). Now that the team had its final solution, CAD drawings with accurate dimension were made. These drawing were then given to workers at the HUST Engineering Training Center who built the tool for the team. After the tool was built it was tested repeatedly to make sure that it worked before the team headed back to the company to show them the tool.

5.1.1 How the Tool Works

The key to the tool is the simplicity of it. There are three main parts to the tool. The first is the cover and base, which holds the final tube and acts as a guide for the printing mould. The second is the shaft, which allows the tool to rotate on an axis. This rotating allows for the connectors to slide down the printing mould directly into the tube for packing. The worker simply takes the printing mould off the conveyer belt then puts the printing mould in the tool.

Once the mould is fully inserted into the toolit is rotated and the connectors slide down the printing mould and into the final tube.

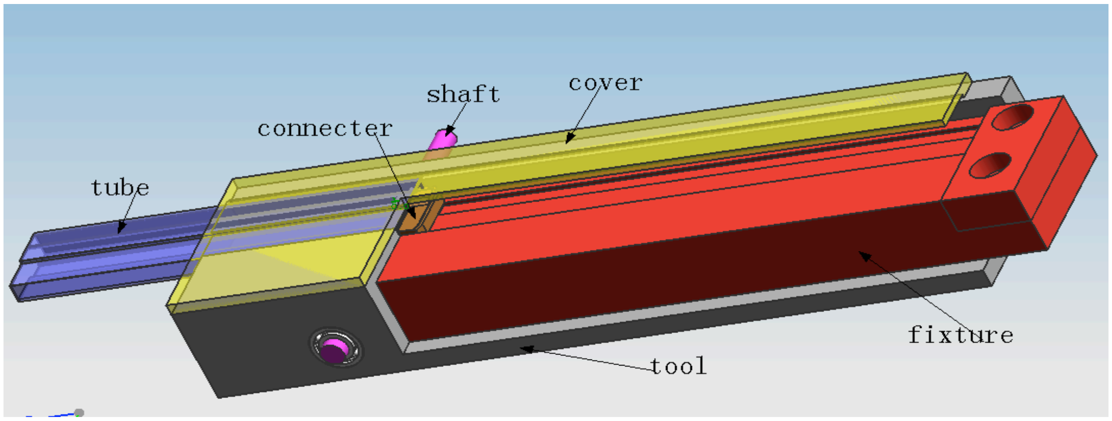


Figure 1 CAD Drawing of Printing Station Tool

5.2 Thought Process Behind Press-Fit Connectors Removal

The team already knew that the printing station was the bottleneck of the line, however, with the application of the printing station tool the bottleneck was now at the press-fit station. The problem with the press-fit station is that it lives and dies with the press fit machine. The worker at this station can only work as fast as the machine can press the caps onto the pins. There lies the problem; there really are not a lot of things that can be done to help speed up production of this station. The team first thought about taking the worker from the pre-packing station and having them help the press-fit worker. The idea was that after the caps were pressed onto the pins, the pre-packing worker would remove the connectors from the fixture and then directly pack them into the tooling tubes. The problem with this solution and why it didn't work is for the simple reason that it takes to much time to take each connector out and pack them into the tooling tube and then pass the fixture back to the press-fit worker who then passes it back to stations one and two. Instead of decreasing the pre-packing time it increased it as well as increasing the press fit cycle time. The next thought was to design a tool that could remove all six connectors at one time. This would make it easier for the press-fit worker to pull out the connectors and pass them to the pre-packing worker while also passing the fixture back as well. The team came up with two preliminary tool designs. One of the designs is specific for the VHDM production line while the other design is more flexible and could possibly be used on other lines as well. The first design, which is specific for the VHDM line, is similar to the tool designed for the printing station. The tool has a cover, base, and a link (see Figure 2 for detailed CAD drawing). The second tool, which could potential be used on other lines, consists of a base, a slide, springs, and two fingers (see Figure 3 for detailed CAD drawing).

5.2.1 How the VHDM Specific Tool Works

The VHDM specific tool works similar to the tool for the printing station. The links on the tool are the key parts. The links are what closes the cover on top of the fixture and releases the connectors. The fixture is pushed into the tool, the links snap and the cover closes on top of the connectors, which are then pulled out of the fixture. The cover is released and the connectors slide down the base and into the tooling tube. This tool allows the worker to take all six of the connectors out at once and at the same time pack the tooling tube directly with the connectors.

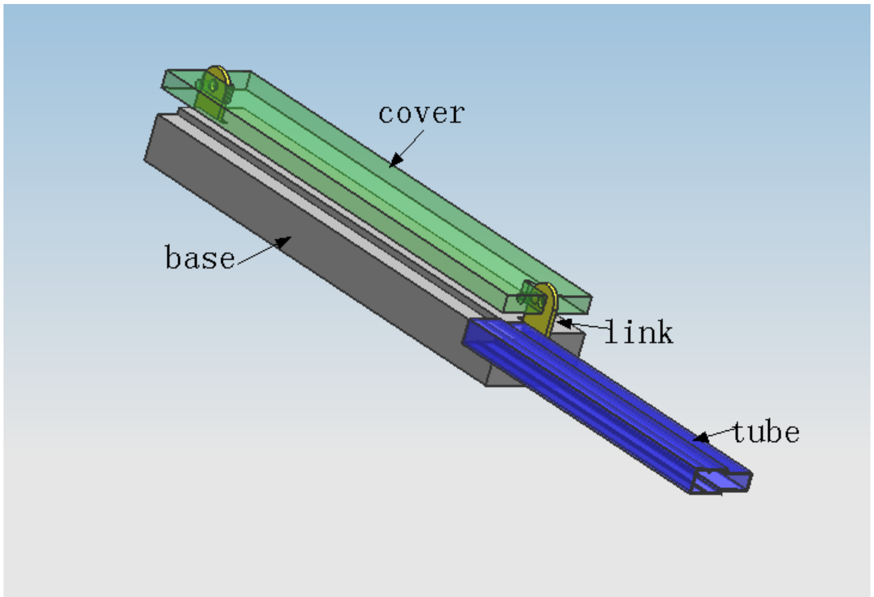


Figure 2 CAD Drawing of VHDM Specific Tool

5.2.2 How the General Tool Works

The second tool, which could potentially be used on other lines, is even simpler than the VHDM specific tool. The key parts of this tool are the springs and fingers. The fixture is placed between the two fingers. The fixture is then pressed down as far as the fingers allow until the connectors are pulled out. The fixture is then released and the connectors slide onto the table. This tool is very simple and has great flexibility because it can be used to pull out other pieces on different lines, not just the connectors from the VHDMline.

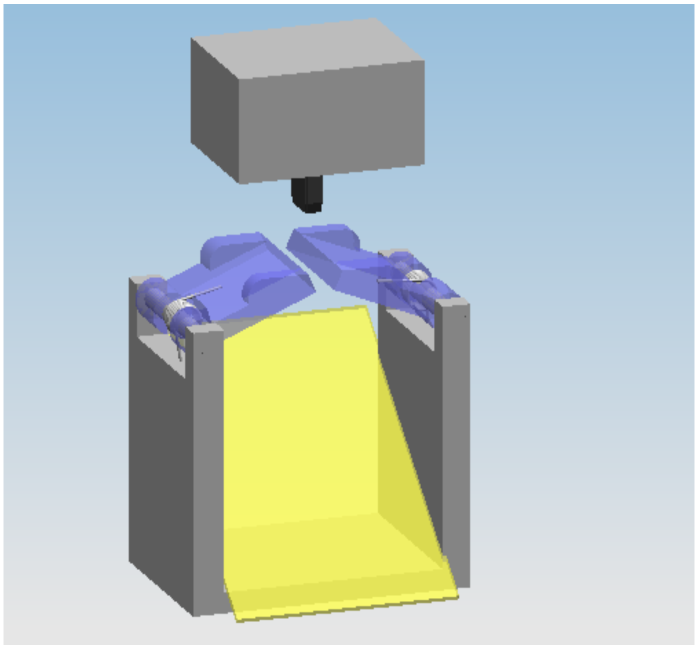


Figure 3 CAD Drawing of General Tool

5.3 Thought Process Behind Returning Empty Fixtures to the First Station

The first and second stations are not necessarily where a major problem lies, but there is still some problems. After looking at videos and watching the stations work the team noticed a problem, after the press-fit worker removes the connectors from the fixture, the fixture is then given to the station two workers who then have to pass the fixtures to the station one workers. This is a problem because the fixtures sit in the middle of the table and cause an erratic flow. The team realized that if there was a circular or constant flow, then the production of these stations would increase and the cycle times would decrease. The team decided that the best way to improve flow would be to change the layout of the tables where the first three stations are located. The team thought about the problem and came up with ideas. The problem with most of the solutions is that the current tables are 80cm by 180cm and do not allow for a lot of flexibility. Most of the ideas had much better flow, but because of the small size of the tables, the room needed for a worker to work comfortably, and the size of the press-fit machine, most of them would not work. The team then decided a potential solution would require larger tables. The idea was to use a table that is 122 centimeters by 184centimeters and have it connected to a regular sized table in an “L” shape. The idea is that the “L” shape will create a more circular flow and because the table is bigger it will allow the workers to work more comfortably. The four workers at station one would be on the left side of the larger table. The two workers at station would be at the top of the table. The press-fit worker would be at the intersection of the “L” where the two tables meet and station four worker would sit at the bottom of the table (see Figure 4). The only problem with this idea is that the team was not sure whether the company would want to invest in new tables.

The team also came up with a second solution that uses the current tables. The idea was to put two of the 80 centimeters by 180 centimeters tables back to back essential creating one larger table that is 160 centimeters by 180 centimeters. This idea would create flow that is in a square and also give the worker more room to work. Three of the station one workers would be at the top of the table. On the left side of the table, the fourth station one worker would sit along with the two workers for station two. On the bottom the press-fit worker and station four worker would sit (see Figure 5). The team thought that the company may like this idea better because they would not have to buy a new table and use tables that are already in use, however the one draw back of this design is that the company would have to make a small hole in the tables where the press fit machine is to make room for the wires.

5.3.1 How the “L” Shaped Layout Works

The idea behind the “L” shape table is to give the workers more room to work while implementing a constant flow of the fixture from station to station. The station one workers at the left side will pass the fixtures to the top of the table to the station two workers. They will then pass the fixtures in a diagonal downward direction to the press-fit worker. The press-fit worker will then pass the fixture down to the bottom of the table where the station four worker is, who will then pass easily pass the fixtures back to station one workers who are close in proximity. The "L" shape layout will create a more circular and constant flow while eliminating the congestion in the center of the table that already exists. This layout will also to help create more cellular workstations.

5.3.2 How the Back-to-Back Layout Works

The back-to-back layout might be more favorable to the company because the tables needed do not need to be purchased. The back-to-back layout will create a constant flow that is in a square while also increasing the amount of workspace for each worker. The station one workers at the top of the table will pass the fixtures to the station two workers who are to the right of them. The station two workers will then pass the fixtures to the press-fit worker at the bottom of the table. This worker then passes the fixtures to the right where the next worker is. This worker will then pass the fixtures up to the station one workers. The back-to-back layout will create a better flow and allow the fixtures to be passed from station to station without any congestion.

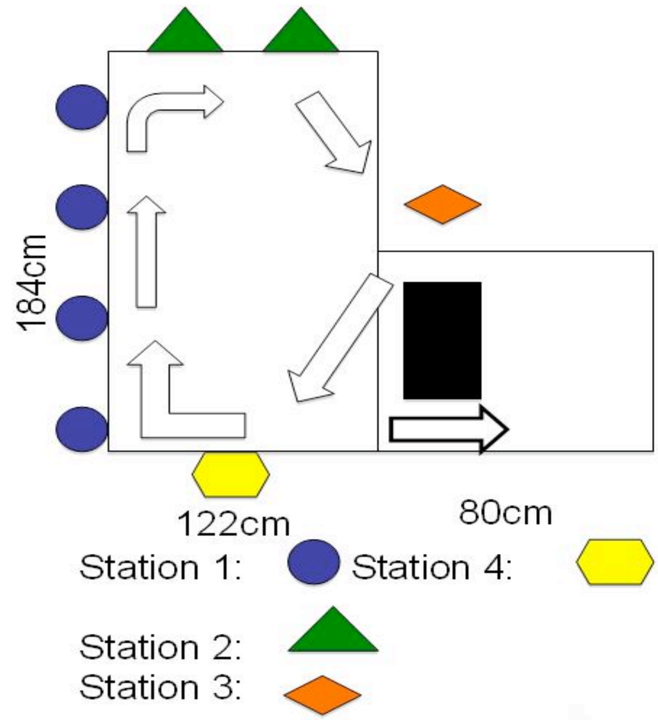


Figure 4 "L" Shape Layout

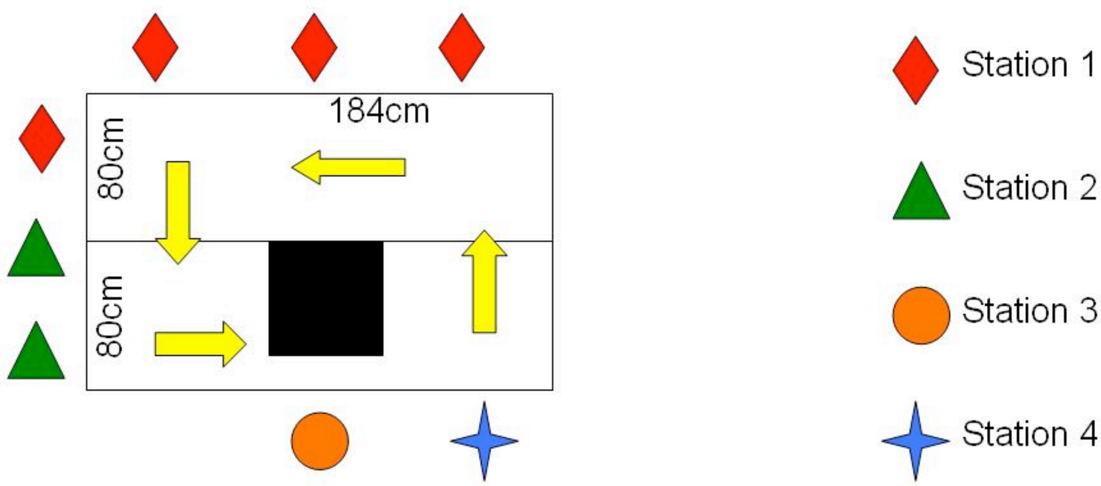


Figure 5 Back-to-Back Layout

6 Results

The goal of this project was to improve the VHDM Power Module line efficiency from 114% to 140%. With the solutions presented in section 5 the team has exceeded this goal. The team has also achieved its goals of increasing the line balance rate and increasing production output.

6.1 Printing Station Tool Results

The printing station tool was the only tool the team was able to implement, but this one tool increased production. Table 5 shows that with the tool, the packing and printing stations times decreased by a combined total of 0.79 seconds per connector. That translates to a 27.3% decrease in time in those two stations.

Table 5 Standard Time With Printing Tool

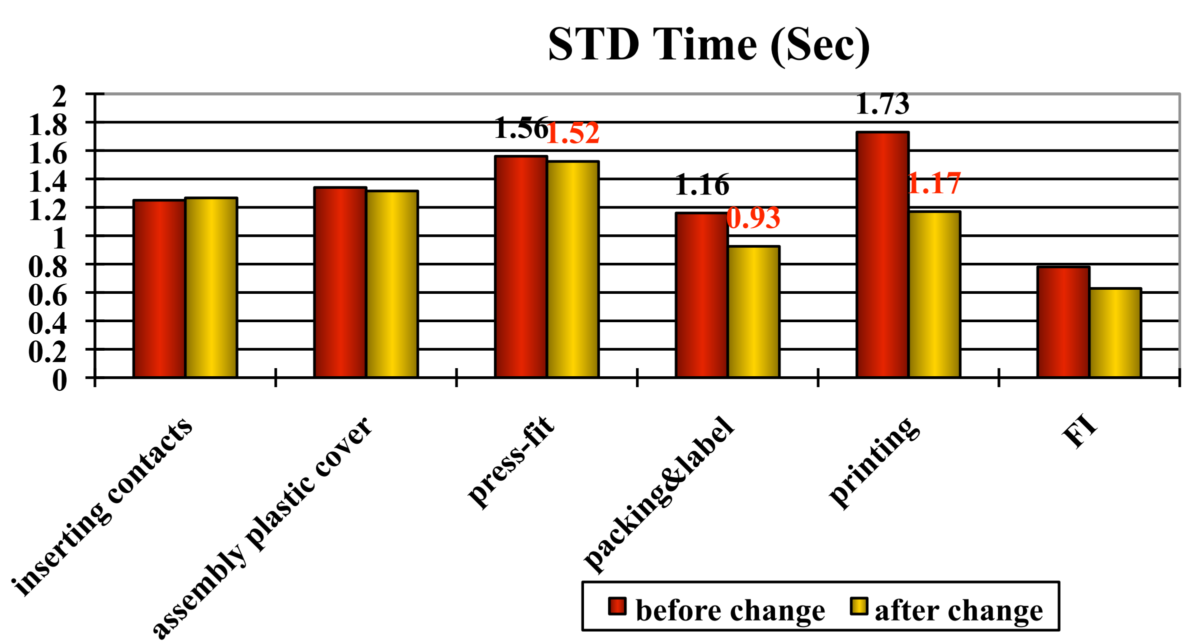


Table 6 Print and Packing Stations Times

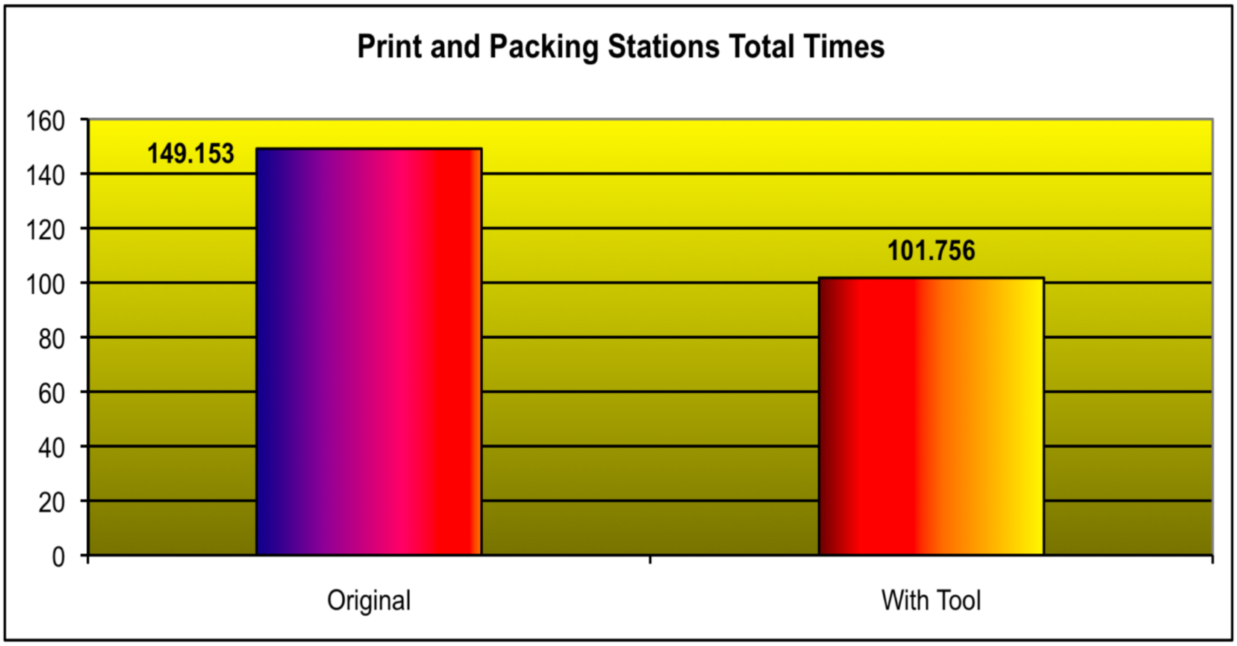
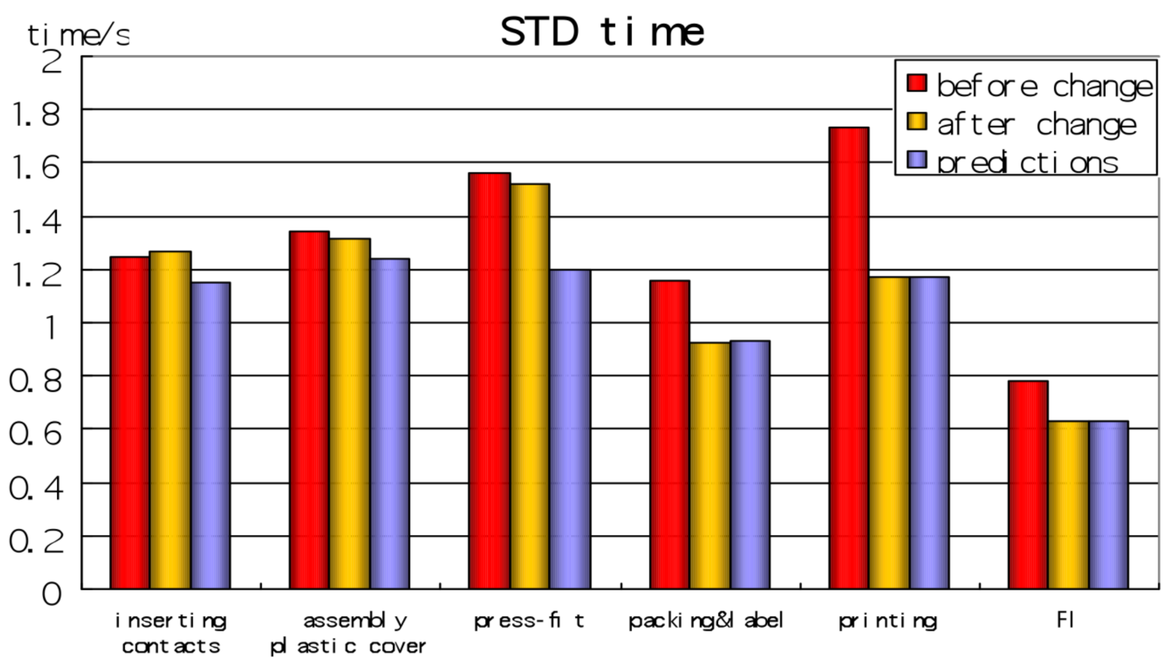


Table 6 shows the amount of time, in seconds, it takes to print and pack one tube. With the addition of the printing tool the time to print and pack 54 connectors decreased from 149 seconds to 101 seconds. That is a 31.8% increase in production in these two stations. With these facts the team calculated the new line effiency to be 129%. See Apendix A Equation 1.The team was pleased that one tool could increase the total effincecy by 15%. The team also calculated the new line balance rate. This was found to be increased from 74.62% to 79.28%. See Apendix A Equation 2 and 3. This was also exciting to the team to see the line balance rate increase by nearly 5%.

6.2 Predicted Results

Due to the fact that the team could only take data on the printing tool the following data is predicted. The prediction for the press-fit station was made by removing the extra time required to pull out the connectors one at a time. This decreased the standard time by 0.38 seconds per connector. This approach was also taken for stations one and two. With these predictions the station one and two standard times reduced by 0.10 seconds respectively. Table 7 shows the original, current and predicted cycle times.

Table 7 Predicted Standard Times



With the addition of a new table lay out, the press-fit tool and the printing tool the team calculated the new efficiency to be 158.7%. See Appendix A Equation 6. This exceeds the goal of 140% set forth in by Amphenol. The team also calculated the line balance rate to be 89.6%.

See Equation 4 in Appendix A. Both of these results pleased not only the team but the advisors at Amphenol TCS also.

6.3 Other Results

Along with the above results the team would like to note that with the addition of the VHDM specific tool the need for the station between the press-fit and printing stations would no longer exist. This would mean the line would be able to operate at an efficiency of higher than 158.7% with one less worker. Thisresult would be in the best interest of Amphenol TCS the team believes. This is because Amphenol TCS will no longer need to employ that worker yet they will be producing more connectors then they did with the extra employee.

7 Future Recommendations

After the implementation of the printing station tool the team noticed that the tool had a major effect on the line. It increased production while decreasing cycle time. The team also feels strongly that the suggested solutions to the press-fit station and to stations one and two will also dramatically affect the production line. While solving these three problems was the team's main goal, the team also came up with a few recommendations to the company that could also be of great use.

7.1 Full Use of Workers

While working on this project the team sometimes had trouble collecting data. The problem occurred at the first two stations. Station one is supposed to have four workers while station two is supposed to have two workers; this is not always the case. After the team implemented the printing station tool the group members tried to take new data and production output for an hour, however this could not be accomplished because there were only three workers at station one, and eventually the number decreased to only two workers. The team believes that the company should take full advantage of the work force it has. By this the team means that there should be a set number of workers at each station every day. The team was told there would be ten workers working on the VHDM line, however this was not always true. The team suggests that the company either use four workers all the time or three workers all the time at station one, instead of an inconsistent amount of workers. The team feels strongly that by using the same number of workers each dayAmphenol TCS will get a much more consistent production output on a daily basis.

7.2 Extend Press-Fit General Tool to Other Lines

Amphenol has many more lines than just the VHDM line. The team noticed that many of the other lines have very similar production processes as the VHDM line. The major similarity is that nearly all productions lines have a station where connectors need to be removed from a mould. The team believes strongly that the general tool that was designed to pull out all six connectors after the press-fit could be used on multiple production lines. The tool can easily be adjusted to pull out different pins or connectors from other line. If the tool can increase production output and decrease cycle time on the VHDM line, the team feels that it can also have this effect on other product lines.

7.3 "Think Outside the Box"

The team consisted of Mechanical Engineers and Mechanical Design majors. Amphenol TCS is predominantly Industrial Engineers as well as some Mechanical Engineers. The team was given a project that was based on Industrial Engineering and lean manufacturing and turned it into a Mechanical Engineering project. The team believes that Amphenol TCS and its employees need to think "outside the box" on a more consistent basis.This is means that the engineers at Amphenol TCS should be more willing to explore solutions outside of the Industrial Engineering field. The team was able to come up with three tool designs because of a combined Industrial Engineering knowledge with Mechanical Engineering knowledge. The team believes that some problems are better solved with a Mechanical approach and feel that Amphenol TCS should explore more solutions to all of its problems.

7.4 Incentives for Workers

After being at the company for just one day the team came to the conclusion that the workers at Amphenol work very hard. The workers only get 20 minutes for lunch and don't get any other breaks besides to go to the bathroom. The team feels as though some sort of small incentive should be given to workers if they meet a certain output goal. This goal should be higher than the required daily, weekly, or monthlyoutput. If this goal is reached some sort of reward should be offered. Some ideas of incentives are work retreats, time off, longer breaks, or monetary. With this in place it is believed that production and moral would increase.

8 Conclusion

The team was given a goal from Sky Wang of Amphenol TCS to increase the efficiency of the line from 114% to 140%.The team then found three major problems with the line and started to find the best solutions for these problems. The printing station is where the bottleneck of the line occurred and was the main focus of work. By designing and implementing a toolthe efficiency of the VHDM production line increased from 114% to 129%. The printing tool also increased the printing station output of pieces per hour from 2,184 to 3,240. The tool increased the packing stations production from 3,240 to 4,536 connectors per hour. With the printing and packing stations combined the printing tool increased output in these two stations by 31.8%. The printing station tool also decreased cycle times in the printing and packing stations. Prior to the addition of the tool it took 1.7 seconds to complete one connector at the printing station and 1.1seconds to complete one connector at the packing and labeling station. With the addition of the tool the printing station is currently 1.1seconds per connector, and the packing and labeling station is 0.85seconds per connector.

The team also found solutions to the press-fit problem and the returning of the fixtures to station one. The conclusion was made that if Amphenol TCS introduced the VHDM specific tool at the press-fit station, then one worker can be removed from the production line without negatively effecting efficiency or output. With the press-fit tool and printing station tool in place and the addition of a new table layout, the efficiency can be raised from 114% to 158.7%, which is above the 140% goal. The addition of these ideas would also decrease the time to complete one connector in every station. The press-fit station would become 1.2 seconds per connector from the original 1.5seconds per connector.

In conclusion the team was successful in its efforts to help Amphenol TCS increase efficiency on the VHDM Power Module line. Along with an increase of efficiency the line balance rate was increased and product output was increased. A solution has also been suggested to reduce the work force while still keeping the efficiency at or above 158%.

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Appendix A: Equations

Amphenol's equation for efficiency

$$Efficiency = \frac{Actually\ rate\ of\ production}{Standard\ rate\ of\ production} \times 100\%$$

$$= \frac{CT \times Quantity\ built}{(Actual\ working\ time + over\ time - PM / Change\ over\ time) \times 3600}$$

PM=Periodic Maintenance, CT=Cycle time

Equation 1: Efficiency with printing tool only.

$$\frac{19.6282}{15.2} \times 100\% = 129\%$$

Equation 2: Original line balance rate.

$$\frac{12.91}{17.3} \times 100\% = 74.62\%$$

Equation 3: Line balance rate with printing tool only.

$$\frac{12.05}{15.2} \times 100\% = 79.28\%$$

Equation 4: Predicted line balance rate.

$$\frac{11.11}{12.4} \times 100\% = 89.6\%$$

Equation 5: Original efficiency.

$$\frac{19.682}{17.3} \times 100\% = 114\%$$

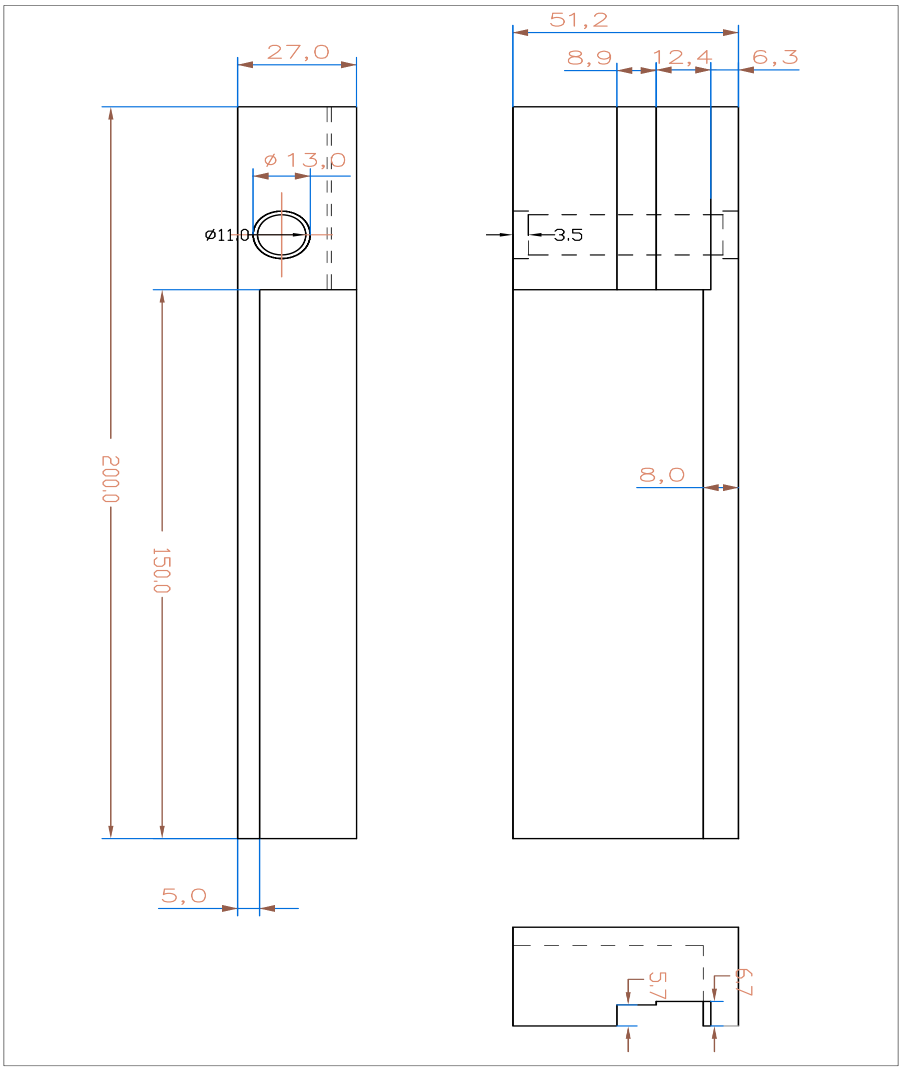
Equation 6: Predicted efficiency:

$$\frac{19.682}{12.4} \times 100\% = 158.7\%$$

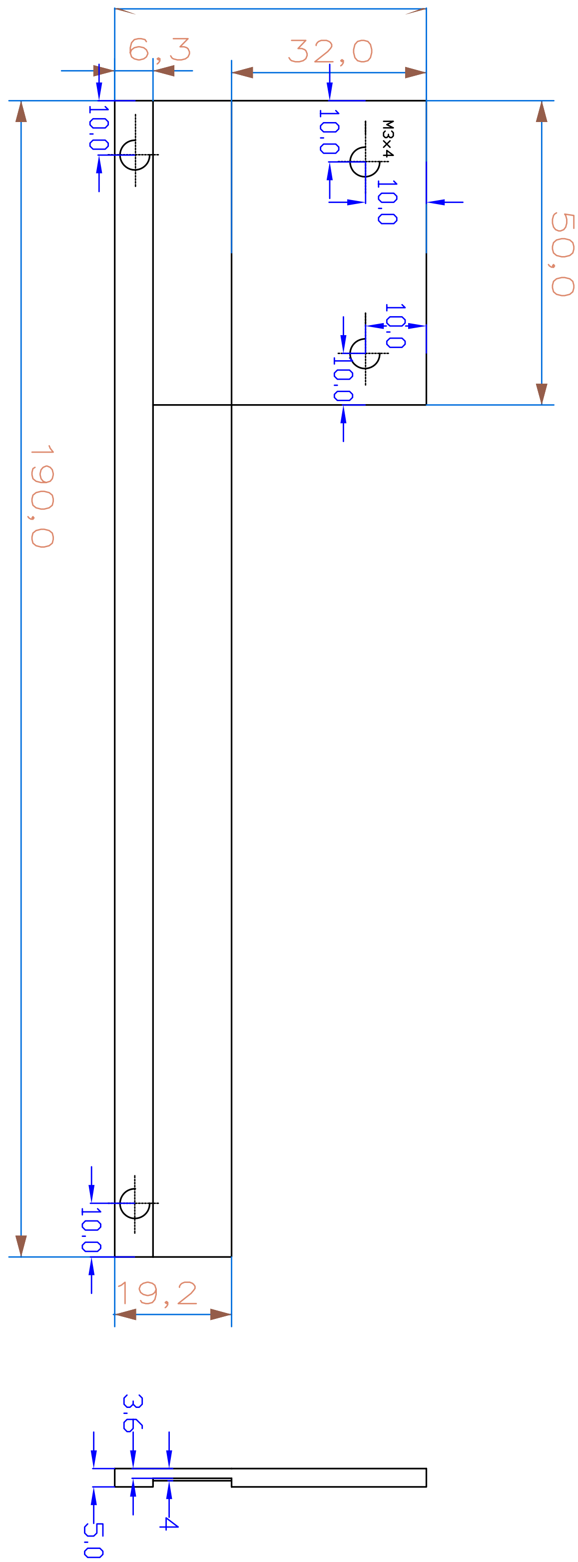
Appendix B: CAD Drawings and Pictures of Printing Tool

All measurements in millimeters.

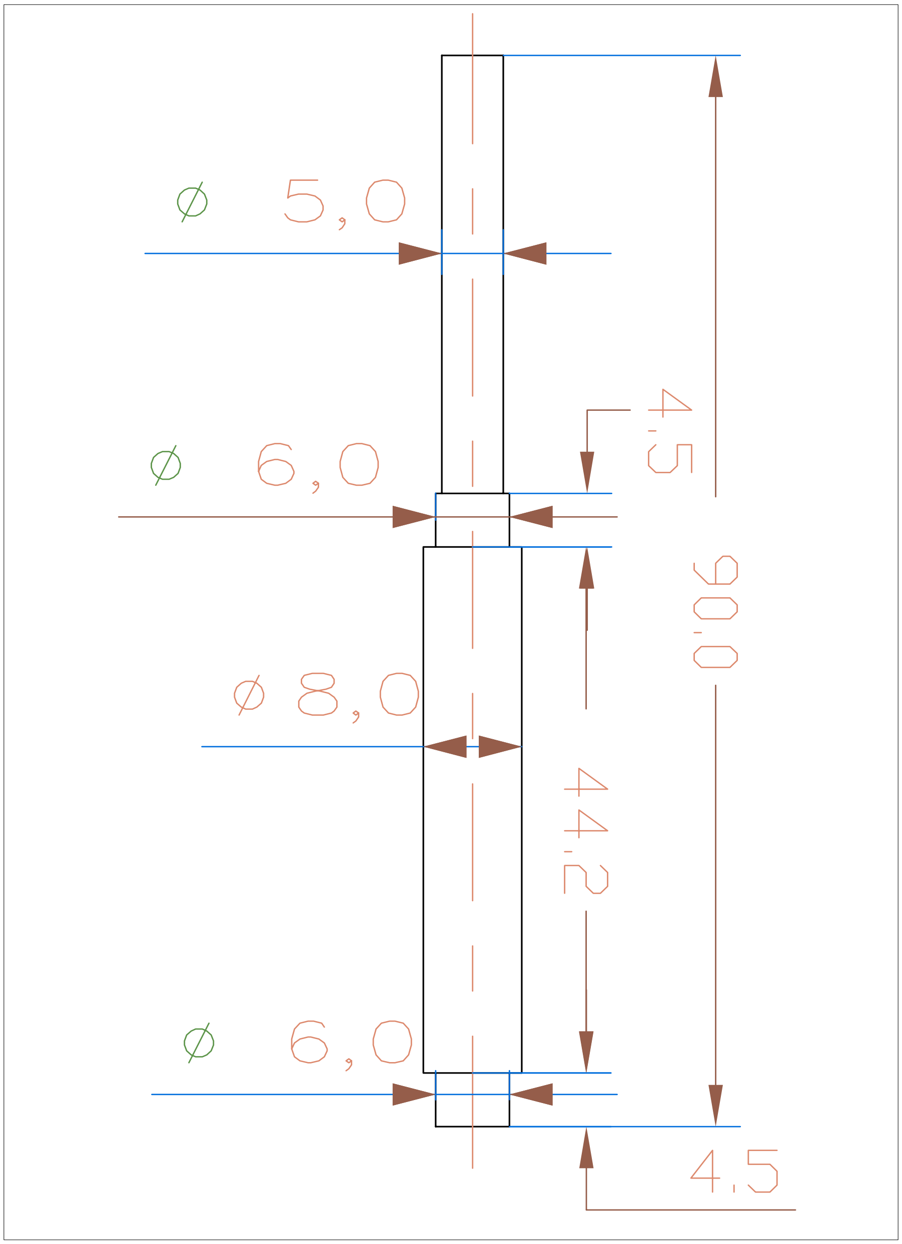
Body of Tool



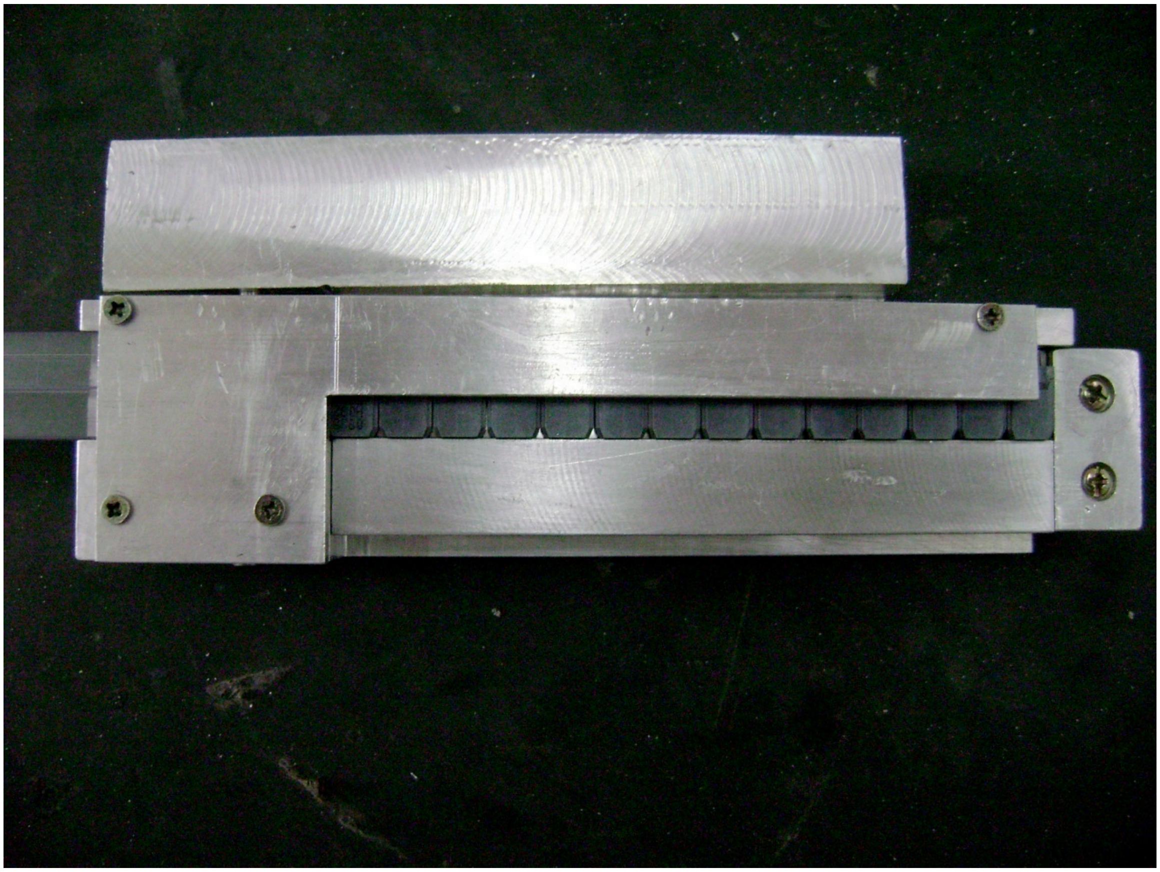
Cover of Tool



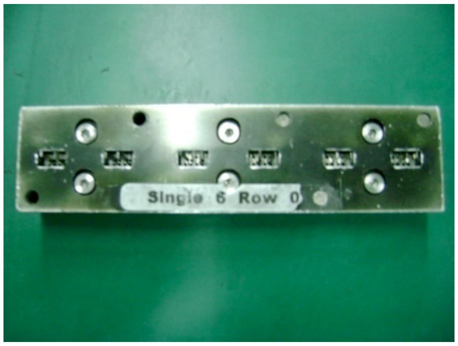
Shaft of Tool



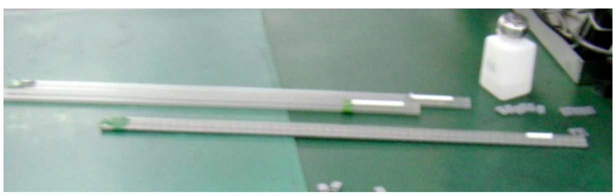
Picture of Printing Tool



Appendix C: Items Used on the VHDM Connector Line



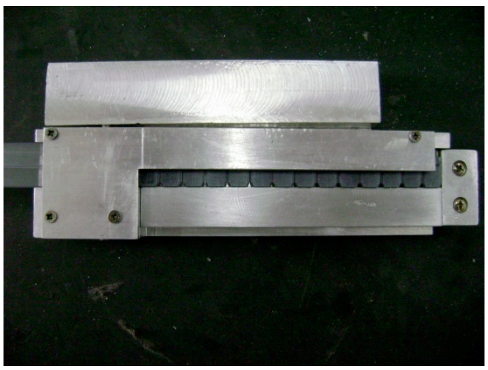
Fixture



Tooling tube

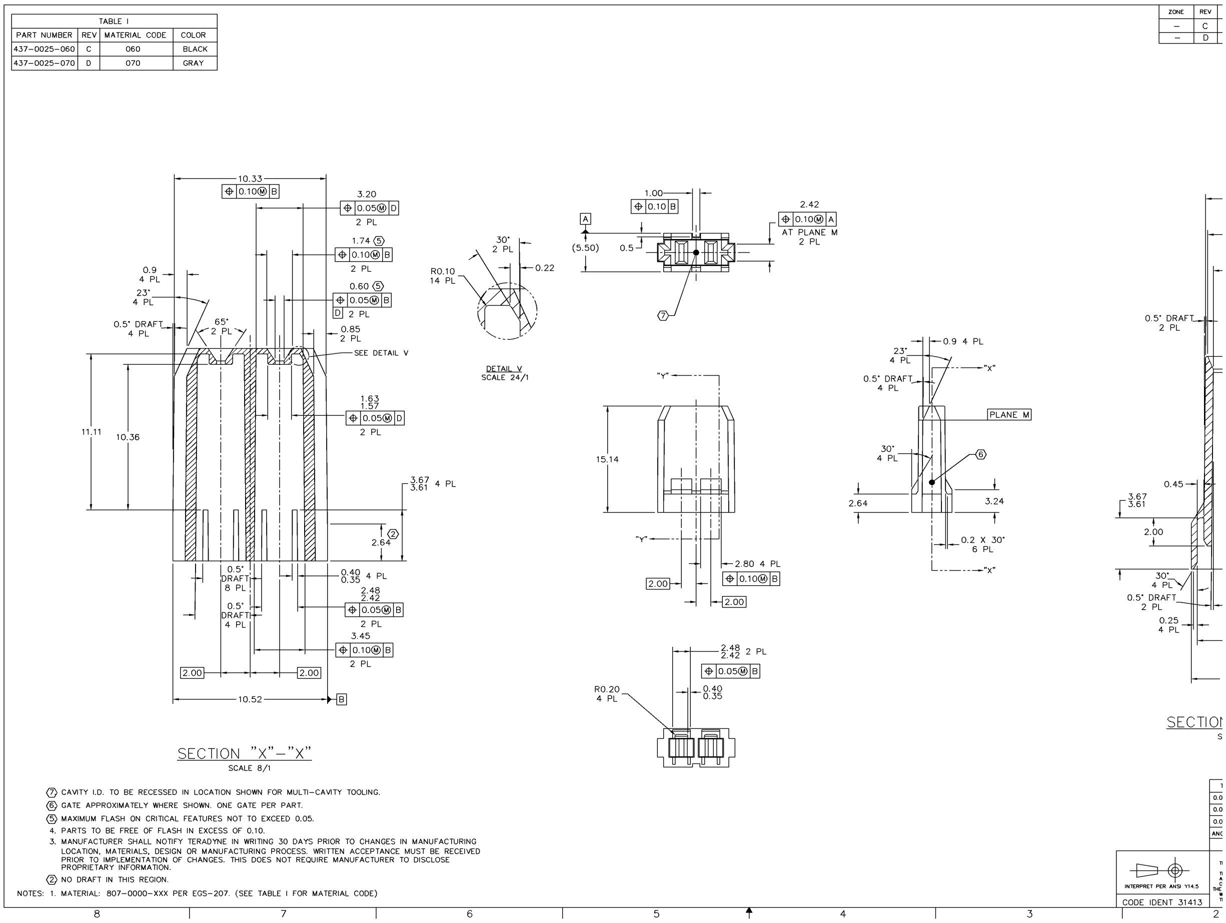
Final tube

Printing mould



Printing tool

Appendix D: VHDM Power Module



Technical Drawing of VHDM Power Module Courtesy of Amphenol TCS

VHDM Power Module