IPRO 354 Final Report
Fall 2013

Developing Sustainable Production Support Systems

Quam

Since 1930

Advisor: William Maurer

1. Executive Summary

Quam-Nichols Company, a manufacturer of loudspeaker technologies, sponsored a process improvement project aimed at delivering alternative approaches to managing its customer's quality expectations.

The two areas of focus;

- Black powder coating
- Tile housing unit fabrication

The IPRO team split into two groups in order to face both challenges
Each team became familiar with their respective manufacturing processes through scholarly research, on-site data collection, on-site experimentation, and professional industry networking. The information gathered throughout the IPRO term was used to make final recommendations aimed to improve the tile housing unit manufacturing process and to address inconsistencies with the quality of the black powder coating operation.

2. Purpose and Objectives

The Quam-Nichols Company is a loudspeaker manufacturer that has operated in Chicago since its establishment in 1930. Quam-Nichols takes great pride in having their products manufactured in Chicago by native Chicagoans. The company designs and manufactures a wide range of loudspeaker and installation solutions for the installed sound industry.

One of Quam's installation products is the tile housing unit. The tile housing unit assembly (housing & speaker) can be flush mounted in drop-ceilings (i.e. office buildings, etc.), and is used to deliver quality acoustic sound. The tile housing unit is composed of three separate parts: the main body that houses the speaker, and two identical railings that support the main body. The rails are riveted by hand at an angle to the main body. Once riveted, the assembly is labeled and packaged according to customer specification. This process is a relatively short side task for employees who hold other responsibilities in the plant. Improvements made in this process would mean more time devoted to their main responsibilities. Many of Quam's speaker assemblies go through a powder coating process to add a durable and aesthetically pleasing texture to the finished products. The powder coating at the Quam-Nichols company uses electrostatic spray deposition to apply a fine polymer powder to a metal surface. This electrostatically charged layer is then cured within an oven to form a durable finish. Many Quam-Nichols products of various shapes and sizes are powder coated and any issues with this manufacturing step can drastically hinder their production rates. Successful powder coating is important for both the form and function of the final product. Quam-Nichols turned to the Interprofessional Projects at the Illinois Institute of Technology to request assistance in improving their operations. The ultimate objective of the IPRO team was to provide a series of recommendations to Quam-Nichols that address the presented challenges. These will include plans to automate or optimize the existing housing unit manufacturing operations and to enhance the reliability of the powder coating process.

3. Organization and Approach

In order to meet the team's main objectives, Six Sigma DMAIC methodology was used. In defining the problem the IPRO team formed a meeting with the company manager to discuss the challenges and project scope. Two teams were then formed: Powder Coating Team and Automation Team.

In order to stay abreast of the issues, the teams were required to visit the plant on a weekly basis. The first few visits aimed at observing the powder coating process and part assembly process. After observing the powder coating process, the team began to collect data to identify the different variables affecting the undesirable outcome of undercoating, or light paint. At the same time, the Automation Team was observing the part handling and riveting process for the loudspeaker housing units and collecting data to identify the areas where the process can be done more efficiently.

The two teams conducted root cause analysis in an attempt to better understand the process. Scatter plots were generated (XY), and linear regression was used. The outcome of these findings directed the teams in making their final recommendations.

The ultimate goal for the Powder Coating Team was to understand the cause of undercoating and achieve a more consistent coating coverage. To prioritize the variables involved, numerous experiments were conducted. The Automation Team identified material handling, more specifically the flipping of the housing unit for riveting areas on the railing, as a priority for improvement. Both teams used research and discussions with the company employees and managers throughout the process.

The tasks mentioned above were divided among each member of the two teams. For example, for the Powder Coating Team two members worked on the hanger design experiment while the other three worked on the rest at a given point. Such task as data collection was everybody's responsibility. Similarly, half of the Automation Team devised an automated solution to eliminate the manual handling process while the other half worked on a non-automated solution.

Defining the problem, including observations, required the first 3 weeks (about 2 visits). Two more weeks for identifying variables. The data collection process was ongoing; experimentation took 6 weeks in total. Data analysis and conclusion required 2 weeks in total.

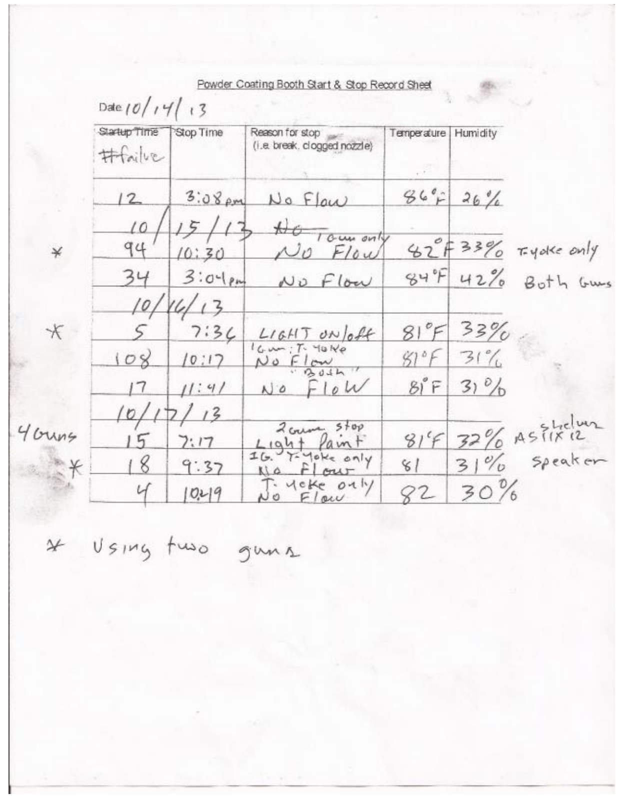
The teams used Gantt Charts and Network Diagrams to assign responsibilities and set start and end dates for each of the tasks. Both teams met with the Quam-Nichols managers frequently for discussions on process improvement for their company, as well as giving updates on the two team's progress.

4. Analysis and Findings

Powder Coating Team

Variables were identified within the powder coating process that were suspect of affecting the product quality. The variables included humidity, temperature, air pressures, output voltage, part orientation, part grounding, and booth maintenance. Each variable was studied through scholarly research, on-site data collection, experimentation, and professional industry networking. These findings were used to identify which variables were critical to the success of the powder coating process and the recommendations for Quam-Nichols were drafted accordingly.

>Data Collection & Quality Control
One of our initial observations was that Quam (specifically Quality Control) had not been recording the number of parts sent back through the booth due to overcoat. While undercoated parts that reached the end of the line were already being measured by Quam (and in part prompted commissioning of this IPRO), production loss due to redundant booth runs (where parts were sent through the booth a second time instead of progressing down the line) had not. To better understand and quantify booth malfunction (specifically undercoat) we created and presented to Quam record sheets for the booth (see right) to self-report.


Powder Coating Booth Start & Stop Record Sheet

Date 10/14/13

	Startup Time #failure	Stop Time	Reason for stop (i.e. break, clogged nozzle)	Temperature	Humidity	
	12	3:08pm	No Flow	86°F	26%	
	10/15/13		~~No~~			
*	94	10:30	1 Gun only No Flow	82°F	33%	T-yoke only
	34	3:04pm	No Flow	84°F	42%	Both Guns
	10/16/13					
*	5	7:36	LIGHT ON/off	81°F	33%	
	108	10:17	1 Gun: T-Yoke No Flow	81°F	31%	
	17	11:41	"Both" No Flow	81°F	31%	
	10/17/13					
4 Guns	15	7:17	2 Guns stop Light Paint	81°F	32%	shelver AS11X12
*	18	9:37	1G. T-Yoke only No Flow	81	31%	speaker
	4	10:19	T-Yoke only No Flow	82	30%	

* Using two guns

Temperature and humidity at time of stoppage were recorded to help us investigate these environmental factors.

Quam's existing Quality Control measure of speakers' powder coats includes a visual end-of-line inspection performed visually on all speakers, and random daily thickness measurements performed with a gauge on 20 parts (10 baskets and 10 t-yokes). The visual end-of-line inspection appeared satisfactory. The random measurements, however, should have prevented cases of systematically overcoated (average > 2 mil) batches observed by the IPRO team. Ideally Quality Control would alert the Line Supervisor of overcoat, who would adjust the booth accordingly. Furthermore booth performance was too erratic for the once-daily QC thickness data to be of use for our booth performance analysis. These observations formed the basis for recommendations to improve the Quality Control process.

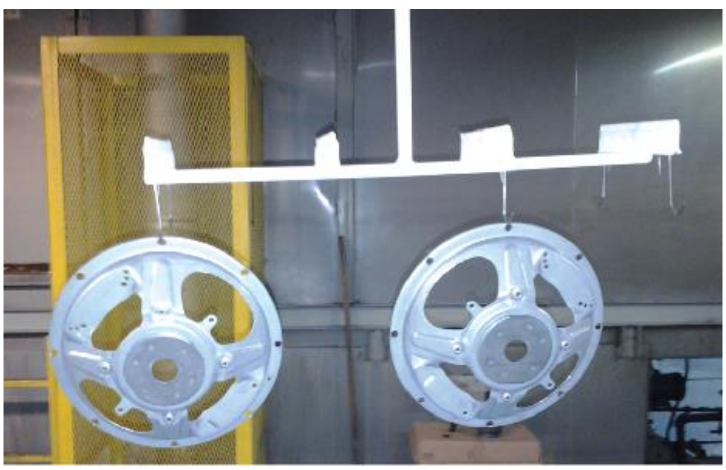
Upon consideration of the variables affecting the process, the powder coating team set about designing experiments to better understand how these factors affected coating thickness. There were two main areas we looked at; the various settings on the powder booth (gun pressure, voltage, etc.) and rack configuration. From our observations we believed the current rack setup was causing interference effects reducing paint coverage; the rack itself absorbed coating and the close proximity of the pieces likely was causing competition between the pieces.

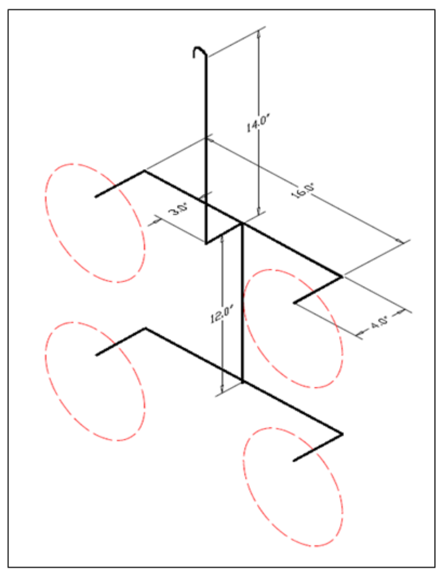
>Rack Design

One of our first experiments tested a simple rack design; we ran pieces on this simple hanger and compared coating thickness with pieces using the standard rack design.

From our data we saw that coating thickness was almost twice what occurred on the pieces hung on the standard rack design. This was pretty good evidence to suggest that alternate rack configurations could significantly affect coating thickness. With this in mind we set about testing an alternate rack the company possessed (in small numbers) which we believed would also have fewer interference effects and thus improve coating consistency.

Using an existing rack called the T-Rack, pictured below, we were able to perform trials with a rack that supports our ideas that hanging parts as far away from the rack would yield better results.



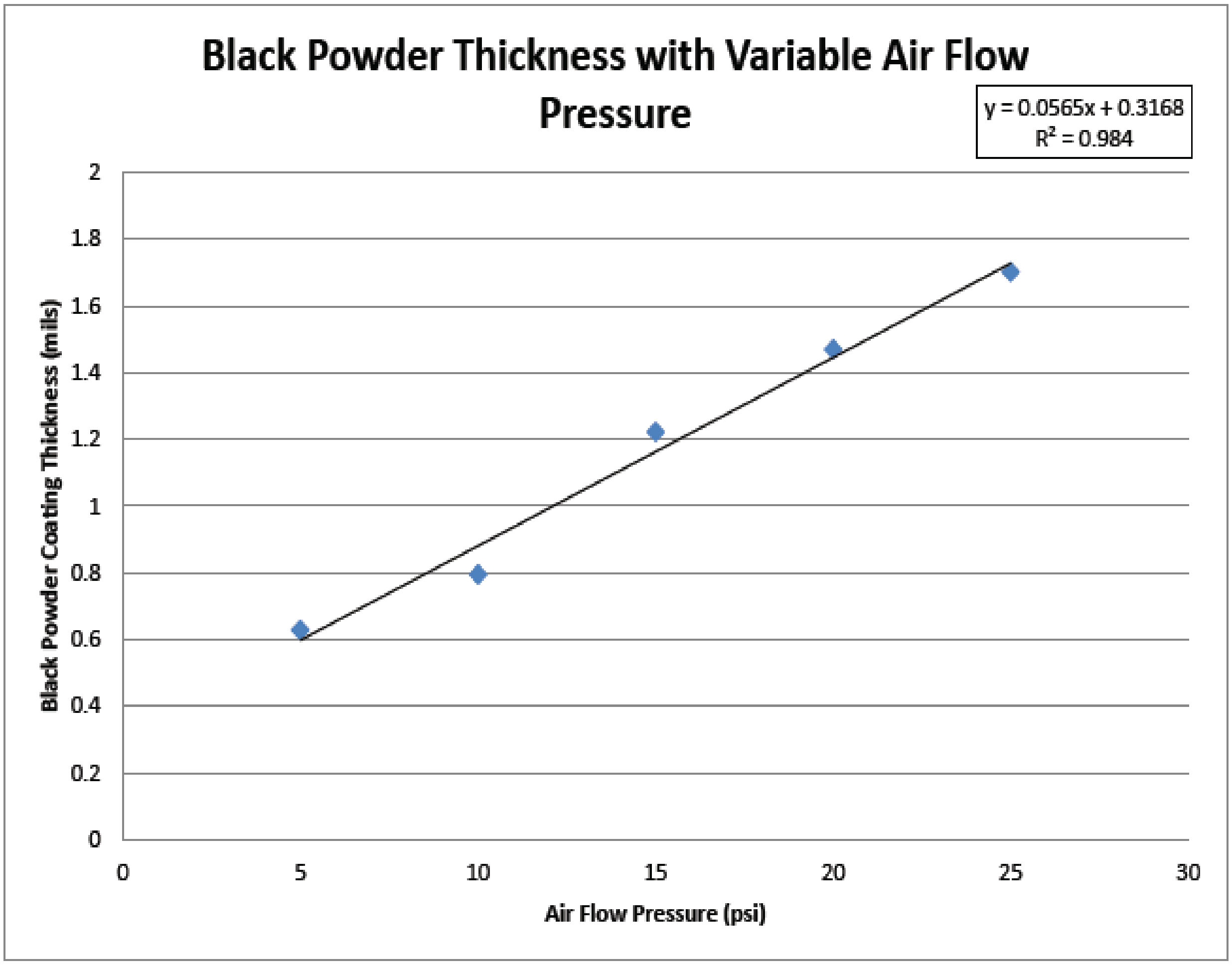


The results of the experiment with the ‘T-rack’ further confirmed our guess that the current rack design had an effect on coating thickness.

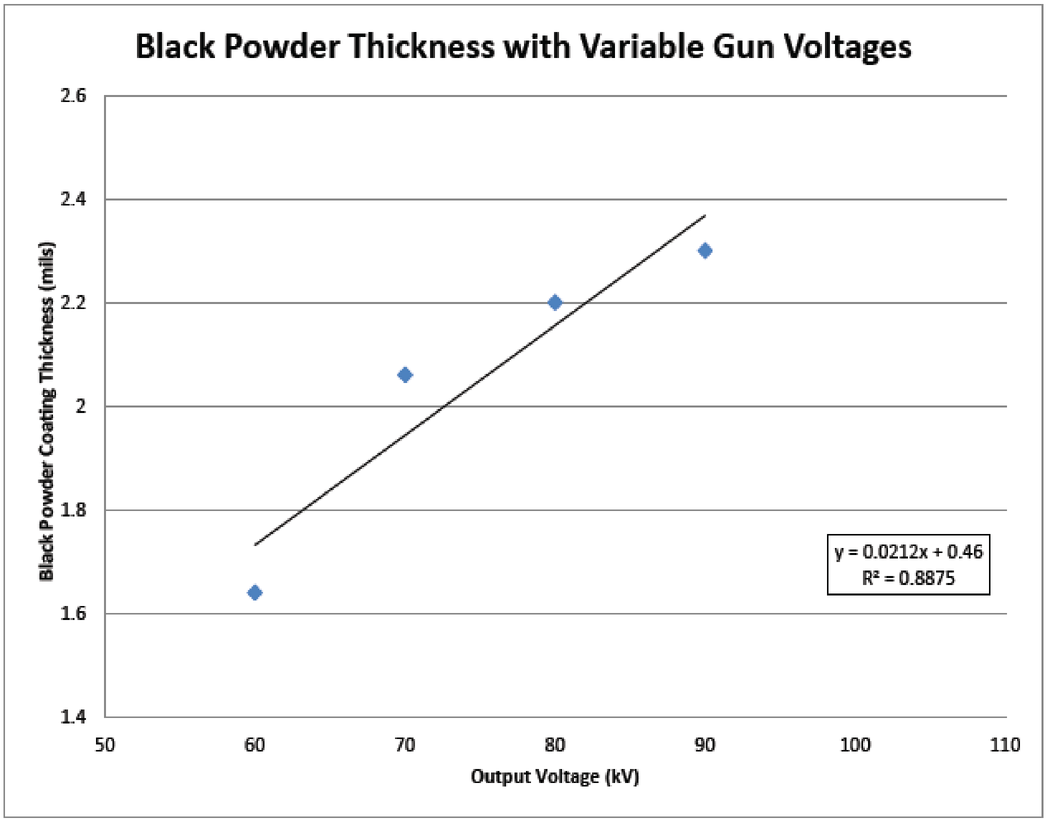
A member of our team also designed a brand new rack design which would hold the needed number of parts as far away from the rack as we could see possible. The sketch is posted above next to the T-Rack.

>Booth Settings

At the same time we performed the rack experiments, we also designed experiments to test the booth settings. We first looked at the air flow pressure and tested 100 parts total, with 20 parts at five different pressure settings. All other settings were kept at standard settings (77kV voltage setting, 22 psi for atomizing air pressure).

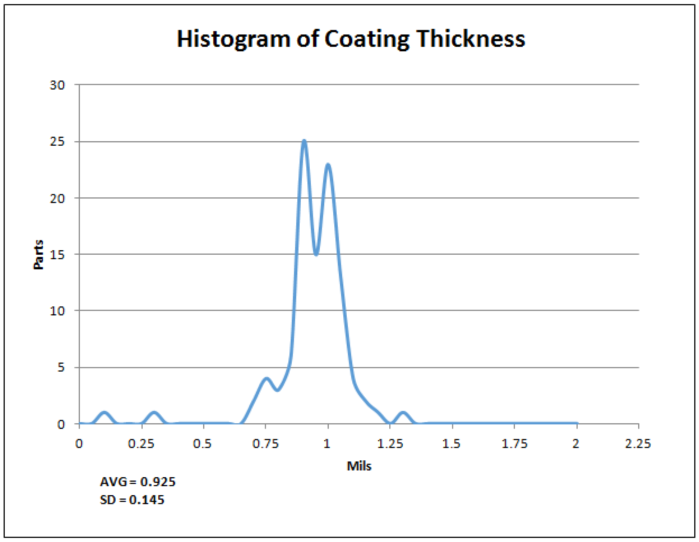


The results show a very strong linear correlation between coating thickness and air flow pressure. We then went on to perform a similar experiment with gun voltage. The same amount of parts were used with 20 parts at five different voltage settings. Gun pressure was kept at the default setting (15 psi) along with atomizing air pressure, but on the day of the experiment two guns were being run.



The additional gun appeared to have greatly increased average thickness as well as the spread. This does reduce the usefulness of the data, but there does still appear to be a strong linear correlation.

In addition, post maintenance, we also took a sample of 100 3-inch baskets (8 inch baskets were not in production that day) to measure the spread of the new process.



Although this isn't necessarily representative of the 8 inch speaker parts, the data appears to show a process that is much more controlled than previously seen.

Automation Team
The automation team made several observations in regards to the current manufacturing process. The two biggest hindrances to the current process are the excessive part handling and the riveting machines jamming and misfiring.

Because the two rails have to be riveted on both sides, a considerable amount of part handling occurs in the individual work stations. The part must be flipped over and realigned to the riveting machine to rivet the other rail. From the timing data and video recordings of the process, currently about one-third of the manufacturing time is spent on part handling, mostly to flip over the product.

In addition, as previously mentioned, the team observed that the line is halted a multitude of the times due to jams or misfires in the machines.

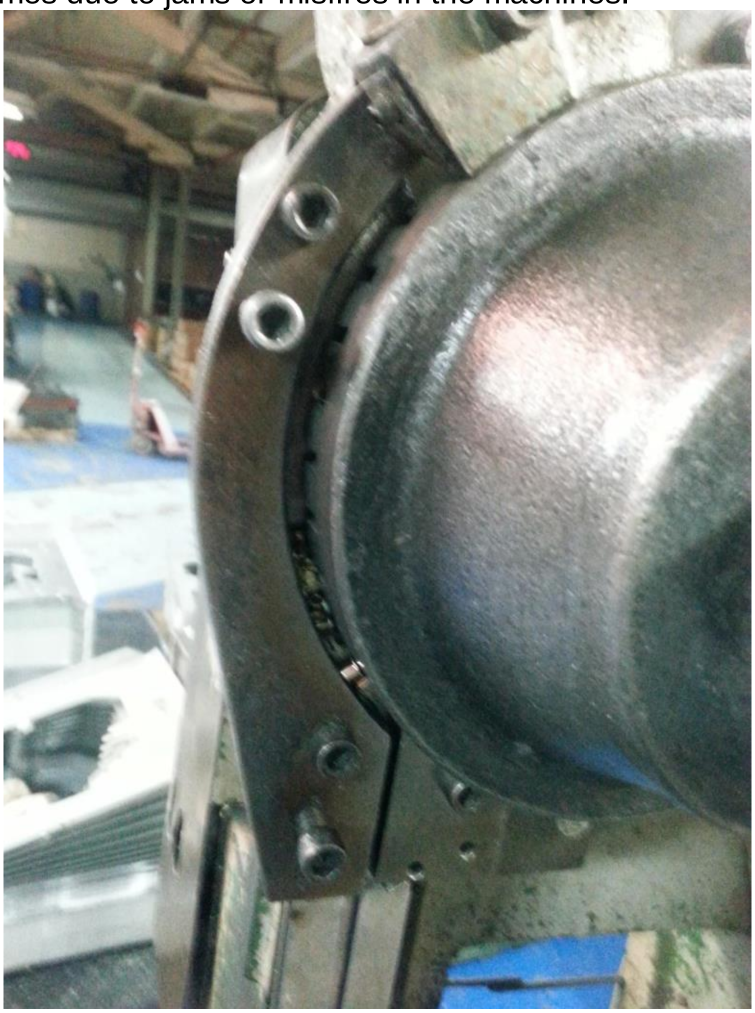


Figure: A rivet jammed in a riveter

During the visits, the team observed on average of 2.5 minutes of downtime per hour of manufacturing due to jamming alone. The team also observed some more serious malfunctions that took more than 10 minutes to fix.

Misfires are also a concern for the manufacturing line; this became more evident during the dialogues with the line workers. Misfires can damage the product, waste manufacturing time, and relies heavily on visual inspection to correct the procedure.

In addition, there are other concerns the team observed, such as the variance in the operating procedure. We observed that different workers had different method in conducting the line, and for example, for a certain product, the standard deviation in the timing was up to a minute.

5. Conclusions and Recommendations

Powder Coat Team

From our data and general observations there are some conclusions we can draw. The current rack configuration appears to be impeding the powder coating based on our experiments. We also found that the booth settings we experimented with show a linear relationship with coating thickness. In addition, we found that there was minimal correlation between temperature and humidity and that that the data we collected appeared to show a reduction in the amount of defects produced post maintenance.
It is recommended that the Quam-Nichols facility continue to use the standard operating procedures set out by the IPRO team. Data collection and analysis should continue to be a priority.
In addition, it is recommended that quality control continue testing at recommended increments established by the IPRO team.
Booth maintenance should be performed regularly, as that alone had a dramatic impact on the amount of defective parts.
The team has also recommended that Quam-Nichols pursue a different rack design; one that interfere less with the pieces being powder coated (i.e. T-rack design).
The IPRO team suggests that Quam-Nichols look into creating specialized booth settings for different parts, as various parts get coated differently with different settings. Some of the experimental data obtained by the team should guide Quam-Nichols in this decision.

Automation Team

After carefully finding alternatives to change the automation process the automation team came up with the following recommendations; An alternative layout plan of the work area was designed that would resemble that of the “make one, move one” process. This new process would allow the workers to eliminate excessive part handling. In the given case that a riveting machine would suddenly have a problem, the automation process would not be disturbed due to the use of the second worker.

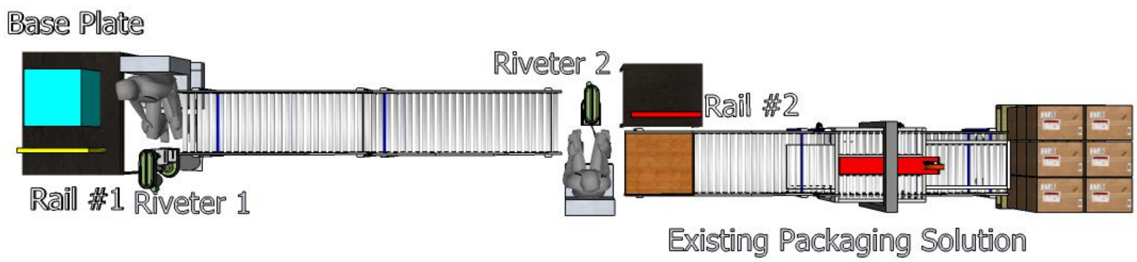
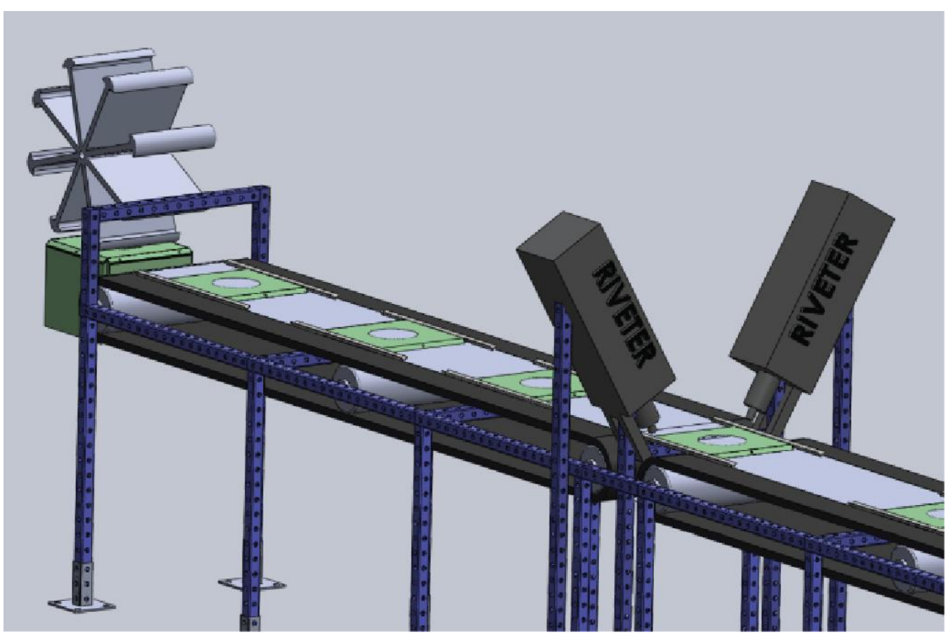


Figure: A model of the proposed new layout

Next the team recommends that if the company would like to seek out a company that could fulfill a complete automation system, Norlok would be able to provide so. A separate concept was developed by the automation team, this concept would then satisfy the required parts per week. The structure and design of this assembly concept can be seen below.



6. Appendices

Appendix A: Team Organization

Automation Team

Robert Farmer - Mechanical Engineering
Chi Moon - Aerospace Engineering
Pablo Portilla - Information Technology

<u>Powder Coating Team</u>
Alan Beyer - Industrial Technology
Anish Ramanathan - Physics
David Stuart - Aerospace Engineering
Nick Taluzek - Aerospace Engineering
Zaien Wasfi - Electrical Engineering

Appendix B: Project Plan

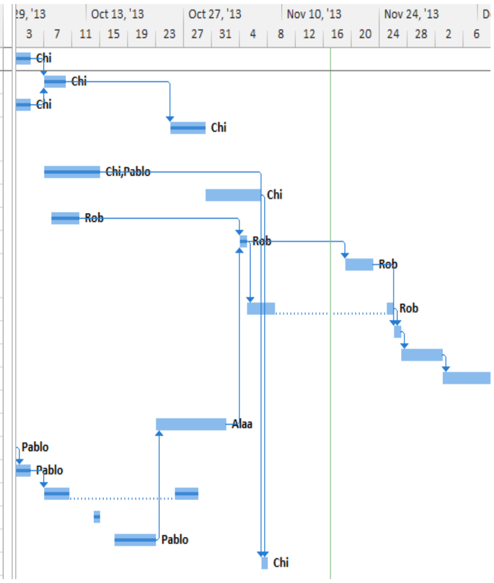
Gantt Chart: Powder Coating Team

ID	Task Name	Duration	Start	Finish	% Complete	Res:
1	**SOP's**	34 days	Mon 9/30/13	Thu 11/14/13	100%	Nick
2	**MAINTENANCE**	**39.1 days?**	**Tue 10/1/13**	**Mon 11/25/13**	**82%**	
3	**Experiment A**	**39.1 days?**	**Tue 10/1/13**	**Mon 11/25/13**	**93%**	
4	Grounding	16 days?	Thu 10/17/13	Thu 11/7/13	100%	Zain and Anish
5	Rack Enhancement	**39.1 days?**	**Tue 10/1/13**	**Mon 11/25/13**	**83%**	
6	Design	7.5 days?	Tue 10/1/13	Fri 11/22/13	75%	Zain ans Alan
7	Test	5 days?	Fri 11/1/13	Mon 11/25/13	96%	Zain and Alan
8	**Experiment B**	**33 days?**	**Mon 10/7/13**	**Wed 11/20/13**	**53%**	
9	Atomizing Air Pressure	5 days?	Thu 11/14/13	Wed 11/20/13	0%	Nick
10	Gun Pressure	3 days?	Mon 10/7/13	Wed 10/9/13	95%	David and Anish
11	Gun Voltage	3 days?	Mon 10/14/13	Wed 10/16/13	100%	David and Anish
12	**DATA COLLECTION**	**54 days?**	**Sun 9/1/13**	**Thu 11/14/13**	**100%**	
13	Collection Tools	54 days?	Sun 9/1/13	Thu 11/14/13	100%	ick, Anish, David
14	Humidity/Temperature	54 days?	Sun 9/1/13	Thu 11/14/13	100%	All
15	Main Line Rejects Data Analysis	22 days?	Thu 10/3/13	Fri 11/1/13	100%	Nick
16	**LATER EXPERIMENTS**	**4 days?**	**Mon 11/18/13**	**Thu 11/21/13**	**0%**	
17	Setting List for Varied Parts	4 days?	Mon 11/18/13	Thu 11/21/13	0%	
18	**IPRO DAY**	1 day?	Fri 11/22/13	Fri 11/22/13	0%	
19	**FINAL PROPOSAL**	1 day?	Mon 11/25/13	Mon 11/25/13	0%	

Gantt Chart: Automation Team

GANTT CHART

ID	Task Name	Duration	Resource Names	Start	Finish	Predecessors
1	Gather timing date into spreadsheet	3 days	Chi	Wed 10/2/13	Fri 10/4/13	
2	Put data into words/report	3 days	Chi	Mon 10/7/13	Wed 10/9/13	1,3
3	Rewrite recommendations	3 days	Chi	Wed 10/2/13	Fri 10/4/13	
4	Create baseline effiency of system for comparison	3 days	Chi	Fri 10/25/13	Tue 10/29/13	2
5	Design new workspace plan	6 days	Chi,Pablo	Mon 10/7/13	Mon 10/14/13	
6	Write new procedures	6 days	Chi	Wed 10/30/13	Wed 11/6/13	
7	Assemble parts in CAD	4 days	Rob	Tue 10/8/13	Fri 10/11/13	
8	Design streamline assembly line	1 day	Rob	Mon 11/4/13	Mon 11/4/13	7,15
9	Determine the amount of work/time required	4 days	Rob	Tue 11/19/13	Fri 11/22/13	8
10	Create bill of materials	5 days	Rob	Tue 11/5/13	Mon 11/25/13	8
11	Prove Plausibility of incorporation	1 day		Tue 11/26/13	Tue 11/26/13	10,9
12	Order Parts	4 days		Wed 11/27/13	Mon 12/2/13	11
13	Assembly	11 days		Tue 12/3/13	Tue 12/17/13	12
14	Run diagnostic tests for efficiency	5 days		Wed 12/18/13	Tue 12/24/13	13
15	Determine belt/drive system	8 days	Alaa	Wed 10/23/13	Fri 11/1/13	20
16	Determine needs	1 day	Pablo	Wed 10/2/13	Wed 10/2/13	
17	Contact Pressotechnik	2 days	Pablo	Thu 10/3/13	Fri 10/4/13	16
18	Meet with Pressotechnik	5 days		Mon 10/7/13	Mon 10/28/13	17
19	Prepare presentation for progress report	1 day		Mon 10/14/13	Mon 10/14/13	
20	Look into premade systems	4 days	Pablo	Thu 10/17/13	Tue 10/22/13	
21	Present practical solutions	1 day	Chi	Thu 11/7/13	Thu 11/7/13	6,5



The Interprofessional Projects (IPRO®) Program at Illinois Institute of Technology

An emphasis on multidisciplinary education and cross-functional teams has become pervasive in education and the workplace. IIT offers an innovative and comprehensive approach to providing students with a real-world project-based experience—the integration of interprofessional perspectives in a student team environment. Developed at IIT in 1995, the IPRO Program consists of student teams from the sophomore through graduate levels, representing the breadth of the university's disciplines and professional programs. Projects crystallize over a one- or multi-semester period through collaborations with sponsoring corporations, nonprofit groups, government agencies, and entrepreneurs. IPRO team projects reflect a panorama of workplace challenges, encompassing research, design and process improvement, service learning, the international realm, and entrepreneurship. (Refer to http://ipro.iit.edu for information.) The Developing Sustainable Production Support System team project represents one of more than 40 IPRO team projects for the
Fall 2013 semester.