Multi-Disciplinary Senior Design Conference
Kate Gleason College of Engineering
Rochester Institute of Technology
Rochester, New York 14623

Project Number: 11458

DRESSER-RAND PORTABLE VENTILATOR CELL ANALYSIS

Abe Ruper- ME
Dan Gruber – ME
Eric Schroder - ME

Abbey Donner – ISE
Patrick Grogan - ISE

ABSTRACT

The primary goal of the Portable Ventilator Cell project was to improve the flow and inventory management processes of this product cell at Dresser-Rand as well as to create a relocation plan to free up the cell's current floor space for other business units. Professor John Kaemmerlen of the Industrial and Systems Engineering Department at Rochester Institute of Technology guided the student team working on this project and provided his professional insight. In order to achieve the goals of this project, work was divided into process improvement planning and implementation and relocation planning. Kaizen events were carried out to implement the designed process improvements, and a new layout, budget proposal, and cutover plan were generated for relocation. Information analysis, design, change proposals, and implementation steps will all be described in this paper.

NOMENCLATURE

CSS- Customer Service and Ordering System
EES- Dresser-Rand's Material Requirements Planning System (MRP)
HVAC - Heating, Ventilation, and Cooling
Kaizen- Japanese term for the Continuous Improvement process
LEAN- A process to create more value for customers with fewer resources
PV - *Portable Ventilator*, essentially the fans that the Dresser-Rand work cell produces
Value Stream Map- A diagram that shows the flow of people, materials, and information through a process
WIP- Work in Process
S&OP- Sales and Operations Planning

INTRODUCTION

The Portable Ventilator (PV) cell at Dresser-Rand Wellsville is a small cell located toward the back of the facility, comprised of approximately 14000 square feet of inventory and five operators, each working in their own work area. There are approximately ten different types of ventilators produced, and most of these customizable. Fans are generally built-to-order, so production is based on forecasting and customer orders. For the purposes of this project, most data and conclusions are based on the top five ventilators by sales volume: Heatkillers, Jectairs, Vanos, Cadets, and Reaction Fans.

This product line was purchased by Dresser-Rand in 2006 from a company in Massachusetts. At the time of purchase, the Portable Ventilator cell was picked up and moved to Wellsville, NY without any change to the physical or information process flows to make the cell fit into the Dresser-Rand facility or culture. Several members of the support staff are still located in Massachusetts, and Dresser-Rand has been working to manage and improve communication.

In its current state, the Dresser-Rand portable ventilator cell is suffering from many problems, many of which involve inventory issues. The cell has an excess of most inventory items, while also having a lack of certain items necessary for production. The cell is also suffering from an excess of work-in-progress and finished goods. On the production end, the PV cell is plagued by backlogged orders and a lack of work leveling. In order to improve the cell's performance, a process of inventory reduction, documentation of the forecasting and ordering process, and cycle time reduction initiatives have been established. Another initiative of this project is the relocation of the PV cell. The cell is a stand-alone business, needing little support from the rest of the plant. Dresser-Rand is interested in relocating the cell to an outbuilding so that the cell's current location may be used for other purposes.

CURRENT STATE ANALYSIS

This project carried three main objectives: to reduce physical inventory in the cell, to improve flow within the portable ventilator manufacturing process, and to complete a feasibility assessment for the relocation of the PV cell to an out building on site. This feasibility assessment also required the optimal cell layout for the proposed building. These were three highly related and dependent objectives as part of the new building proposal relies on a reduced inventory level and proper people, material, and information flow.

Inventory Analysis

The cell currently contains around 14,000 square feet of space, and inventory takes up most of that. Inventory is beginning to take up space on the floor all over the cell. A thorough assessment of the amount of inventory on hand for each product family was performed. Inventory was measured by the amount of weeks on hand for average demand. Many ventilator components are currently stocked at levels reaching 30 or 40 weeks of inventory; some parts are even stocked with up to one year of availability. A further problem is that for parts that have 40 weeks of stocked inventory, some purchase orders are still being made for these parts. The supply chain for the PV cell is currently not operating as it should be. Substantial changes will need to be made within the supply chain in order to reduce this inventory. In order to relocate the PV cell to the outbuilding, the inventory must be reduced by approximately fifty percent.

Flow Analysis

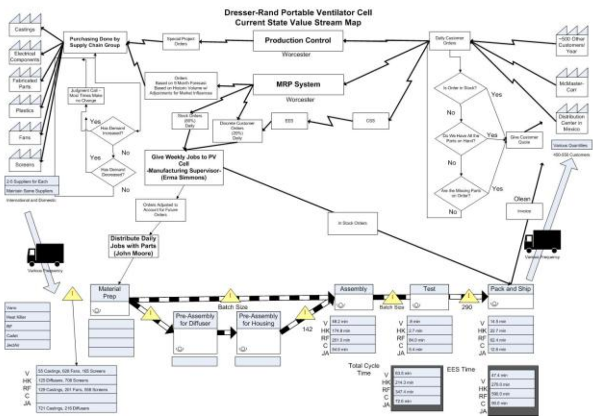
The team wanted to observe how operators maneuvered through the inventory and work stations as well as how signals of what and when to produce were sent. The plan was to then use a number of Lean tools such as value stream mapping, time study, operator balance charting, 5S, Kanban, one piece flow, and producing to takt to improve flow in the cell.

Value Stream Mapping and Analysis

The team worked to produce a Current State Value Stream Map to document current flow in the cell in order to determine the optimal future flow. This was achieved by walking the flow on the floor, speaking with operators, and having several meetings with the cell Supervisor and Sales and Planning associates.

As was stated previously, very little has been changed over the years in the way that parts are purchased, the way planning is done for the operation, or the way that ventilators are assembled. The Portable Ventilator cell is also somewhat of a deviation from Dresser-Rand's core business at the Wellsville site so it gets little attention. These two conditions account for much of the disorganization in the Current State Value Stream Map.

Figure 1- Current State Value Stream Map



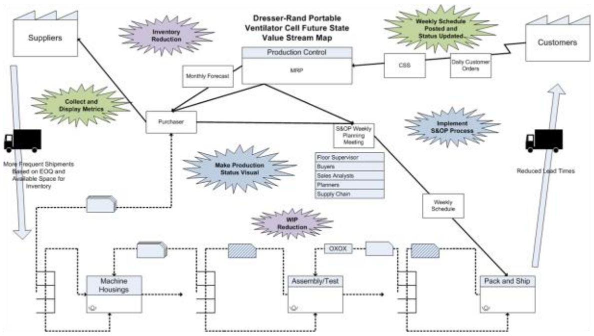
Several areas stood out on the Current State Map as needing immediate improvement. This map is shown above in figure 1. One of these areas was the purchasing of materials for the portable ventilator cell. Safety stock and reorder points are not set up correctly for this cell, so there is a great deal of guessing going on in purchasing decisions.

The way that a cell operator determines what to build next and how that matches portable ventilator demand is something else that does not line up in the value stream map. Customer orders are filtered through several people in the process before making their way to operators in the cell. This leads to an inconsistent amount of work for operators and an inability to meet customer orders on time.

Aside from these information flow issues, the team also observed some material flow issues within the cell. The production system is a broken process. One worker selects which orders he thinks should be built next, pulls the parts for that order, and gives the operators the job with the necessary materials. The problem here is that due to such uncontrolled inventory, many times all of the required parts are not in stock and partially built ventilators are laying around the work floor in various levels of completion.

Preliminary and intermediate manufacturing steps are completed in random, constantly changing batch sizes. There has been no analysis of process and setup times to determine how many pre-assembly tasks should be completed on a given day and in what batch sizes. This further increases the amount of WIP in the system, inflating the footprint of the cell. If improvements were made to work towards one piece flow, eliminating some of the errors in the process, and inventory reduction, the footprint could be reduced.

Figure 2-Future State Value Stream Map



This map along with a Future State Map to improve upon some of the trouble areas found in the current state analysis were presented and checked over at a two separate design reviews with key project members from Dresser-Rand. This future state map is shown above in figure 2. The problems that the team uncovered in this initial analysis and the improvement ideas that were chosen matched up with the desired improvements that Dresser-Rand initially requested: flow and inventory reduction. This lead the team to assume that Dresser-Rand would be on board for the improvements that were necessary to meet these agreed upon goals.

The Future State Map includes a true pull system, the elimination of people manually filtering orders to the manufacturing floor, supplier shipments based on need and not outdated system information, and an improved communication process for planners, sales analysts, supervisors, and buyers for the cell. The team then created a plan to implement several changes to start moving the PV cell towards the Future State Map goals.

DESIGN

There were two main design goals for this project. The first design was generated by the Future State Value Stream map and was a design of better information flow for the entire PV process. The second was a physical cell design for moving the Portable Ventilator into the new building at Dresser-Rand's Wellsville site.

Inventory/ Flow Strategy

Improving information flow became the greatest concern to the team, as this is a part of the system that all other parts depend on. Most specifically, accurate information on demand, lead times, and economic order quantities was thought to be the key to having the right inventory in the right place at the right time and in the right quantity, a goal of any manufacturing facility.

In order to bring these issues to the surface and to facilitate quick change within the time frame of this project, the team decided to structure implementation into three distinct Kaizen events. A Kaizen approach was thought to be a good strategy, because it would get the right people together at the same time to make decisions and make change happen in a short amount of time.

The three Kaizen activities that were planned for the Portable Ventilator Cell involved setting up weekly analysis of three key metrics, implementing a Sales and Operations Planning process, and carrying out a short term Inventory Reduction process. Initially a Kaizen activity to implement a sample Kanban system was planned, but the team quickly realized that the PV cell was not ready for this tool since inventory data was not well enough understood by Dresser-Rand yet.

Metrics

A Kaizen event to facilitate the collection of three important metrics was scheduled first in order to collect and provide the necessary data to make problem areas clear to Dresser-Rand and to encourage participation in the project. The three metrics that the team felt were vital to the cell and that would address the biggest issues were inventory accuracy, on-time orders, and cell efficiency.

Inventory accuracy had never been captured before other than a full inventory audit once a year. The team wanted to introduce weekly cycle counting to find problem areas to start fixing issues of inaccurate inventory data in EES. The percentage of on time orders was another metric the team wanted to collect to measure performance as the customer would see it, because focus should always be on the customer. Cell efficiency, the third metric was being inaccurately calculated and was to be tracked by the supervisor each week by a simple calculation between planned production and actual production. Kaizen event plans were designed for each event, dates were chosen, and the appropriate people were asked to participate in each event. Ample time was given in between events for the team to plan last minute details and to review the results and provide implementation assistance to Dresser-Rand.

Sales and Operations Planning

The team felt that implementing a sales and operations planning process for the PV cell could improve communication and information flow throughout the system. Sales and operations planning or S&OP is a process that integrates the sales, operations (production) and planning (forecasting, purchasing, inventory control) functions of a business to communicate future sales and production goals in order to line up the proper resources (people, materials, time) to meet those goals. The process is carried out through individual preparation throughout each month and monthly meetings to match the sales goals with production. The output of these meetings should be a master schedule for several months out.

This is something that has never been done before in the portable ventilator cell. Dresser-Rand was in the process of trying to implement S&OP throughout the Wellsville facility though, so the team felt that this would be a good opportunity to get a functioning process developed to serve as an example for the rest of the plant.

Since this is relatively new to Dresser-Rand, a concise PowerPoint presentation was created which explains what S&OP is and what needs to be included in a meeting agenda. It also describes how the monthly meetings should be run and which people from Dresser-Rand need to be involved in this process and in attendance at the meetings. Furthermore, the presentation defines what preparation steps need to be taken during the week preceding the monthly meeting and who needs to be responsible for certain action items. Finally, the presentation defines the metrics that should be tracked all year long to measure whether or not the S&OP process is working or needs changing.

Figure 3- S&OP Process Flow

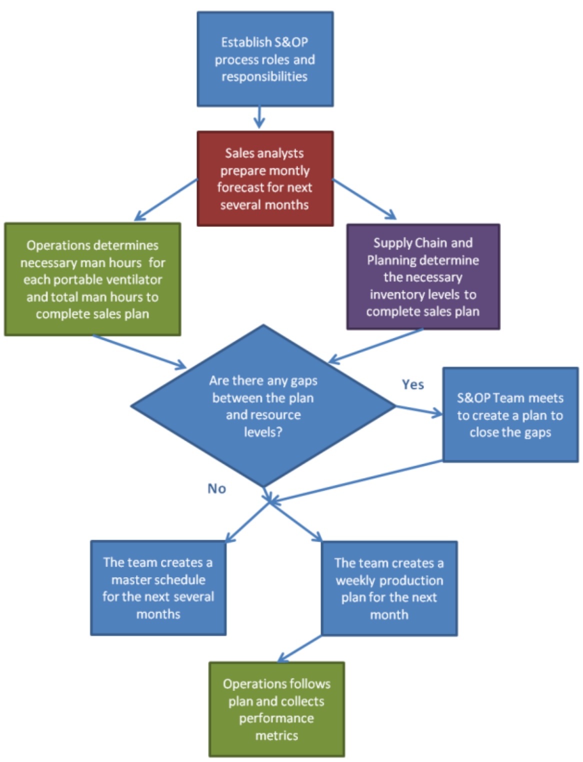


Figure 3 above shows the general flow for the proposed S&OP process. It also shows which departments at Dresser-Rand are responsible for each of the tasks.

Inventory Reduction Process

After the initial inventory analysis, a major goal of this project became reducing the amount of inventory being held by the Portable Ventilator cell to decrease the footprint of the cell and bring the process into control. Inventory reduction is not an easy task that can occur overnight. To cut the inventory in half, the cell has to order less material and order the inventory later, with respect to its need for production. The team created an inventory reduction plan and presented this to the Dresser-Rand team to walk them through the process.

The plan to reduce inventory is to systematically examine each purchase order. The proposed method to do this is to create a weekly meeting involving planners, buyers, and supply chain personnel. At each meeting someone would be responsible for the inventory level of a particular item, and someone would be responsible for an MRP report. This weekly meeting would look at each upcoming purchase order, one at a time, through a Pareto analysis starting with the highest dollar value order. The meeting would cycle through several very important questions for each order:

- What is the current on hand amount of this material?
- How many weeks of inventory are there for this item?
- What is the lead time of this item?
- Are there any special circumstances leading to this order?
- What is triggering the need for this order?
- Can we reduce the quantity of this order? [BUY LESS]
- Can this order be placed later? [BUY LATER]
- Are we sure of the data for this item? (Cycle counts, etc)

Based on the answers to these questions, the goal is to reduce the amount of over-purchasing of particular items. For example, if we have enough inventory of a certain casing to fuel production for 35 weeks, and there is a purchase order up to buy 100 more casings, Dresser-Rand should be able to postpone that purchase as long as there are no large orders on the horizon. Curbing the buying for the PV cell is the only way to reduce the inventory of the PV cell, and these weekly meetings are the most effective way to achieve this goal.

Relocation Feasibility

The team was faced with the design challenge of shrinking the footprint of the current portable ventilator cell in half and moving it to a building without insulation or utilities. The Pattern Storage building where the cell will be moving is 159 feet long by 39 feet wide, providing 6,200 square feet for the PV cell. From an aerial view of the plant from behind the main facility, there is one main industrial door at the left end of the building and a personnel door in the bottom left corner. When considering the new cell layout, three primary factors were considered: racking space, assembly space, and material flow. The team thoroughly analyzed the existing layout and took note of what machines, work benches, and equipment needed to be incorporated into the new design. The team also kept in mind forklift, people, and material flow when coming up with design ideas. Three concepts were developed to try to best use the available space.

Figure 4- Layout 1

The first concept, pictured in figure 4 above, utilizes two narrow rows of shelving along the length of the building. The office space, assembly areas, and the shipping area are located along the opposite wall. While this provides the most racking and inventory space, the assembly area would be quite narrow and limited by the need to maintain an aisle for forklifts.

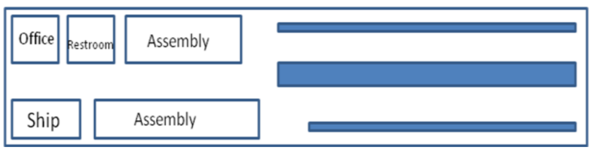


Figure 5- Layout 2

The second concept, shown above in figure 5, places all the racking and inventory at the far end of the building, with four rows of racks and two aisles for forklifts. Four assembly cells are located just left of the racking, with two cells on the top and two cells on the bottom. The office space and restrooms are located in the top left corner, with the shipping and receiving area in the bottom left.

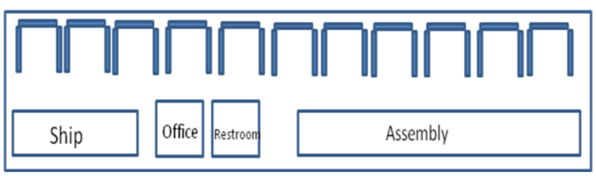


Figure 6 –Layout 3

The third concept, seen in figure 6, is similar to the first concept. The racking is exclusively along the one side, and the shipping, assembly, and office spaces are all along the other length of the building. This concept uses U-shaped shelving patterns. The design was explored to see if it could accommodate more inventory locations, but it turns out that it does not. This provides similar inventory capacity as the first concept with the benefit of all inventory being more easily accessed.

A Pugh matrix was used to select the best design concept. This is a useful tool for evaluating different design options against a baseline. Layout 1 was selected as the baseline, and the Pugh matrix was evaluated to determine whether layouts 2 or 3 were better than layout 1. The criteria that was used to compare layouts was the number of racks or inventory, the amount of available assembly space, the proximity of assembly space to the shipping area, the aisle width that the layout can accommodate, and how well the layout facilitates flow. Each of these areas was easily calculated except for the flow element. This was determined with the use of the team's knowledge of lean principles and how to achieve flow.

Table 1- Pugh Matrix for Layout Selection

Concept	Racks	Space	Distance to Shipping	Aisles	Flow	Total
1	0	0	0	0	0	0
2	-	+	+	0	+	+2
3	-	0	0	-	-	-3

When comparing the three concepts, the first had the most racking capacity, yet less assembly space. Concept 2 has the most assembly space, with slightly less racking capacity. Considering material flow, concepts 1 and 3 were farther away from shipping and possess a "bottle-neck" between the office and racking. The Pugh matrix and its results are shown above in table 1. Ultimately, despite having less racking, concept 2 surpasses the other two layouts.

Construction Analysis

The building which had been proposed to move the PV Cell to is currently being used for storage and is not equipped to be a proper work space. The HVAC, water, and electrical systems in the building all need to be upgraded along with modifications to bring the building up to code for working areas.

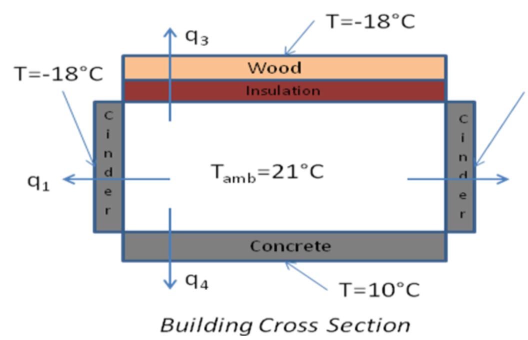
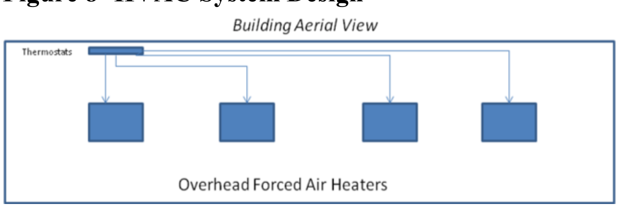


Figure 7- HVAC Analysis

The analysis of the HVAC system began with collecting data on the building's volumetric dimensions and assuming the bulk temperature inside the building should have the ability to maintain 70°F in winter conditions of 0°F. It was also assumed that simple ventilation methods would be able to cool the building to proper levels during the higher heat summertime. The calculation was simplified to a basic conduction problem of internal and external surface temperatures of the walls, floor and ceiling. The analysis is shown in figure 8. This simplification make the analysis conservative as it says the convection heat transfer from the bulk interior and exterior temperatures is great enough to bring the surfaces to equal the bulk temperatures. For these surface temperatures to actually occur the internal temperature would have to higher than the design point and the exterior bulk temperature would have to be lower than the minimum outer design temperature.

The analysis also assumed that a drop ceiling would be installed with insulation in the ceiling while the walls and floor would not be insulated. It was found that a maximum of 100 KW is lost from the building in this configuration. A preliminary system of four 25 KW heaters was selected to split the heating load of the building. The spacing of these heaters also allowed for the building to heat more efficiently as individual zones could be turned on instead of the running the entire system at once. The design of the heating system can be seen in figure 8.

Figure 8- HVAC System Design



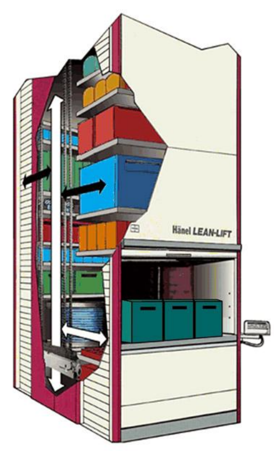
The building needs a complete hydraulic system installed capable of supporting 2 restrooms, a drinking fountain, and a sink in one of the workstations. After compiling the component needs of the system, it was estimated that a pump for the system would need to provide a minimum flow of 28 gpm. The water supply location is not close to the new building so piping estimates for both the grounds and building were needed to estimate the system friction curve. Optimum pipe diameters for both sets of piping were selected to minimize total cost of a pump and piping. It was found that the pump would need to produce 237 feet of total dynamic head to drive the fluid from the water supply building to the new PV building. This analysis is seen in table 2.

Table 2- Hydraulic Analysis

Loss	Value	Unit
$g * z_2$	1610.0	ft²/s²
h_L	4865.2	ft²/s²
h_{Lm}	344.3	ft²/s²
Δp	102.6	Psig
head	236.3	ft

The electrical needs of the building were driven by the various ventilator test tables in the cell, large equipment, and lighting needs. Most notably the option of using electrical heaters would affect the overall power consumption of the building. It was found the electrical needs would total to single and three phase power, voltage levels of 120, 240, 480 and 575 volts, amperage levels of 345 amps and total power consumption of 122 kW (assuming use of 100 kW electric heaters).

As inventory space is limited in the new building, the available inventory space needs to be used as efficiently as possible. In order to do this a combination of well spaced racking heights and new equipment has been recommended. The expanded use of space saving bins would be supplemented with newly fabricated fixtures for stock items which can be consolidated. The PV cell's current small parts room and other small inventory on racks would be replaced with a vertical Lean Lift machine which consolidates the inventory into a single 4' x 8' square floor space unit and operates like a carousel. This Lean Lift machine is seen in figure 9.



(Source:http://www.thefileguy.com/carousels/literature/Lean_Lift.pdf)

Figure 9- Hanel Lean Lift

RESULTS

Implementation of the design ideas for the Portable Ventilator Cell consisted of kaizen events for the process improvement initiatives and getting a contractor's construction estimate and completing a cutover plan for Dresser-Rand to move the PV Cell. Participation in the Kaizen events was difficult for the team to get from Dresser-Rand, so as much as possible was implemented and Dresser-Rand was provided with recommendations to further the work.

Metrics

The three chosen metrics of inventory accuracy, on-time orders, and cell efficiency were to be implemented and started in the first Kaizen event. The cell supervisor and a coordinator for the cell were present with the team to work on the best method to collect this data and how to best use the information once collected.

Cell efficiency was looked at first and was to be collected with a very simple calculation each week. The team asked that the supervisor keep track each week of how many completed ventilators were produced in the cell and divide that by the planned number of ventilators that were to be produced that week. The planned number would change each week due to the product mix planned for the week, but the aim should be to keep that as level as possible.

After discussing this idea with the Dresser-Rand Kaizen team members, we found out that tracking this metric would not be possible until other parts of the project were implemented. The problem here is that there is no weekly or monthly plan for what should be produced in the PV cell, so progress towards a plan cannot be measured. This was surprising to discover and led the team to realize how urgent implementing a sales and operations planning process was.

Next in the kaizen, the team looked at inventory accuracy. Weekly cycle counting was chosen as the initial way to introduce this metric. The supervisor helped identify the appropriate PV operator to perform the cycle count each week, and the cell coordinator helped the team work with this operator to execute the counting. For the first two weeks, the part numbers were kept the same in order to help the operator get used to this new process, but then the part numbers were changed to get a bigger picture of the inventory.

The team then developed a plan for Dresser-Rand to make this process more robust in the future involving A, B, and C inventory classifications and provided them with a spreadsheet to help investigate any issues that arise from this cycle counting. The cycle counting results while the team was working at Dresser-Rand showed a great deal of room for improvement. Errors that were seen involved an incorrect number of parts on hand, a stock-out, or inventory not being in the correct location. The level of issues the team discovered was extremely high and should be a major area of focus for the Dresser-Rand team members.

At the end of this project, tracking on time orders was still a work in progress. The time when completed orders get out the door and to the customer had not been tracked before in the PV cell, and Dresser-Rand could not provide the support to work on this until the end of the project. Towards the end, however, a Dresser-Rand engineer who joined the Kaizen activities began working with the team on this.

Sales and Operations Planning Process

The roadblocks that the team had run into earlier helped to show the importance of getting this S&OP process up and running. It really became the first important step towards a lot of positive change for the cell. The team held an initial Kaizen event to introduce the S&OP presentation to all of the key people involved with the PV cell. During this time, people were able to ask the team questions, and a specific list of who would perform each roll in the process was generated. The team worked with one of the engineers for the PV cell to determine some safety stock numbers and reorder points for inventory while the PV cell sales analysts came to a consensus on a forecast for 2011.

An initial S&OP meeting was held with the team present to make sure everyone was on the same page and that they all knew what to expect in the meetings going forward. Dresser-Rand is equipped with all of the tasks and tools that they need to carry this process into the future, and further implementation would be an immediate help to many of their inventory and flow problems.

Inventory Reduction Process

The Inventory Reduction project was initially met with enthusiasm from the team at Dresser-Rand. The management at Dresser-Rand realized that the major problem with inventory resulted from the over-ordering of components occurring within the cell. The PV cell was not following the rules set by the MRP system and purchase orders seemed erratic and without explanation. The proposed “Buy Less, Buy Later” plan to reduce the inventory is exactly what the plant product manager, Dan Wallace, was interested in.

However, the project had some difficulty getting started. The project became the domain of the Demand manager, who wished to go a different route with the inventory reduction. The new goal to reduce inventory became to perform an overhaul on the rules and values listed within the inventory computer software, EES. The Demand department wished to evaluate each component piece and develop the following values specific to each piece: Safety Stock, Reorder Point, reorder quantity, Stock type (A- stock item, B-order item).

To meet the new needs presented by Dresser-Rand, a short inventory proposal was made. To develop a set of rules for the inventory components, they were broken down into four categories depending on the usage of each piece. The categories are 0-25%

usage, 25-50%, 50-75%, and 75-100% usage. A set of rules for each category was developed and presented to Dresser-Rand. These new rules are currently in review by Dresser-Rand. The next step for this process will be for Dresser-Rand to review the current inventory model and determine if changes need to be made. At the end of this project, though, no steps had been made by Dresser-Rand to curb purchasing.

Layout Design Validation

The proposed layout was validated through meetings with several important people at Dresser-Rand. It was reviewed by the Facilities Manager Ron Coleman, Plant Manager and project sponsor Dan Wallace, PV Cell Supervisor Erma Simmons, and all operators of the PV Cell. Along with this a rough paper simulation was carried out with the operators, where they walked through what they do in the cell each day to make sure that there were no conflicting features of the layout and that everything they need is incorporated. Several small issues came out of this discussion, such as a charging station for the fork truck which had been overlooked, but no major concerns were raised. All of the necessary changes were made to the final layout.

Relocation Estimate

The final relocation estimate was a sum of the building renovation contractor quote, Dresser Rand's purchase of new equipment, and Dresser Rand's cost of electrician burden to install the new electrical system. The quote from the contractor Duggan & Duggan was set to match the needs laid out in the preliminary design with some changes which were discussed, such as the use of gas heaters, the installation of finished and insulated interior walls, two jib cranes for use in the cell and replacing the dry fire sprinkler system with a wet sprinkler system. The team provided the remaining cost to purchase the new fixtures, the electrical equipment needed for the process, and to cover the cost of Dresser-Rand electricians installing the new electrical system.

Relocation Planning and Logistics

If Dresser-Rand approves the plan and wants to proceed with relocating the PV cell, there are certain logistics problems to overcome. The first is clearing the cold pattern storage building and renovating it. Dresser-Rand has taken responsibility for clearing the current contents of the building and letting the contractors perform the renovation without unnecessary restrictions. One of the other issues holding up this project is the severe reduction of inventory. The team has set up a process for Dresser-Rand to follow, but inventory will not be reduced until they decide to take action. It was determined by the team that once the plan is started, it will take approximately 6-8 months to get inventory down to a workable number. After the building is renovated, the focus shifts to getting the racking, fixtures, equipment, and inventory moved into the building. Any new equipment can be moved in again without limitations, but downtime becomes an issue for anything being reused. Equipment relocation will take place with the use of temporary workers or Dresser-Rand employees from outside of the cell. It should be able to occur within a week or two with minimal disruption to production.

CONCLUSIONS AND RECOMMENDATIONS

While the project has not reached its full potential in reducing lead time and inventory during this time period, recommendations and information have been provided in order to allow continuous improvement going forward. Sufficient information has also been provided in order to account for and set up the relocation of the PV Cell from its current location to the out building specified. The culture at Dresser-Rand is this project's biggest obstacle going forward. Work needs to be done to change from a purely reactive culture to one that gets to the root cause of problems and focuses on continuous improvement. There is an abundance of opportunities to improve this product line at Dresser-Rand, and this team has brought these issues to light and gotten them starting on correcting many of them. Through this partnership Rochester Institute of Technology and Dresser-Rand will continue to work together to continually improve operations at Dresser-Rand.

ACKNOWLEDGMENTS

The team would like to express gratitude to those who have invested valuable time and effort in this project. A special thank you goes to Professor John Kaemmerlen for providing constant support and helpful resources throughout the project. Additionally, the team would like to thank the Dresser-Rand sponsors and staff: Dan Wallace, Tanya Black, Erma Simmons, Balbino Arevalo, Lucian Greco, Mike Dollinger, Vince Rybicki, Ron Coleman, and all the operators who work in the Portable Ventilator cell.