Spring Progress Report

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Team 2

Purina Dryer Efficiency

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Contents

Problem Statement ... 3

Introduction ... 3

Objectives ... 4

Constraints ... 4

Criteria Tree ... 4

Functional Diagram ... 5

Quality Function Deployment ... 6

Concept Generation ... 7

Concept Selection ... 10

Engineering Analysis ... 13

Current System ... 13

Analysis of Steam ... 14

Natural Gas Conversion ... 16

Mid-Year Progress ... 18

Future Tasks (Progress Report) ... 19

Project Plan ... 21

Conclusion ... 21

References ... 23

Appendix: ... 24

Osborn's Checklist ... 24

Decision Matrix ... 25

Problem Statement

Introduction

Nestlé Purina is one of the top manufactures of pet food in the United States. The Flagstaff, AZ plant produces about 1,000 tons of pet food each day. When the food is done cooking it contains 35% moisture content. Therefore, all of the food produced needs to be properly dried to meet the 11.5% moisture content requirement. This requirement was set forth to reduce the risk of mold growth due to the build-up of condensation in the bags while cooling. To dry the food, the Flagstaff plant has five steam powered dryers, each responsible for about 20%. However, dryer three is not running as efficient as the other dryers. Dryer 3, shown in Figure 1, should be capable of producing 200 tons per day, but has recently been producing only 150 tons per day, while still using the same amount of energy as the other four dryers.

Figure 1 – Dryer 3

After the product enters the dryer, it is passed through four sections. The first three sections are responsible for removing moisture from the product, and the fourth section is responsible for cooling the product. Each section has its own dedicated air flow, temperature control, and steam coils. The steam coils are used to heat up the air that moves through each section, as hot air can contain much more moisture than cool air. The lack of productivity is largely due to the condensation in the steam used for drying the pet food. Because of the large scale of production, this degree of inefficiency costs our client a large amount of money in terms of unmade product. Our goal is to increase the efficiency and throughput of dryer 3 for Nestlé Purina.

Objectives

Table 1 is a list of the objectives and measurement basis we have come up with for the implementation of this project to increase the efficiency of dryer 3. This table also includes all of the units for each of the individual objectives.

Table 1 – Objectives broken into how they are measured.

Objectives	Basis for Measurement	Units
Inexpensive	Implementation costs	$
Production output	Weight of product	Tons
Moisture content	Amount of water	%
Efficiency	Energy used	BTU/ ton
Condensation	Weight of water in the steam	Kg water/ kg steam

Constraints

Overall, we were given three constraints to meet during the project. The first constraint is that the moisture content must be less than 11.5% to avoid the growth of mold in the product. The second constraint is that the payback period should be less than eight years to justify the cost of the project. The last constraint is there must be no condensation in the steam coils so heat transfer can occur optimally.

Criteria Tree

In order to show how each of the criterion related to each other, a criteria tree was developed (As seen in Figure 2). The criterion was split into three different categories: costs, moisture control, and production. The most important criteria to consider with the designs of the dryer are the amount of money that will be spent. The total cost includes the payback period which is the amount of time that it takes for the money spent to pay for itself. The next category is moisture control. This category was then split into the amount of water that is still in the product, and the amount of condensation that is in the steam. The final category is the total production of the dryer. This includes the total amount of product that can be pushed through the dryer in a span of an hour and how much power we need to push that much product through. We also need to compare the new efficiency of the dryer to the efficiency of the old dryers.

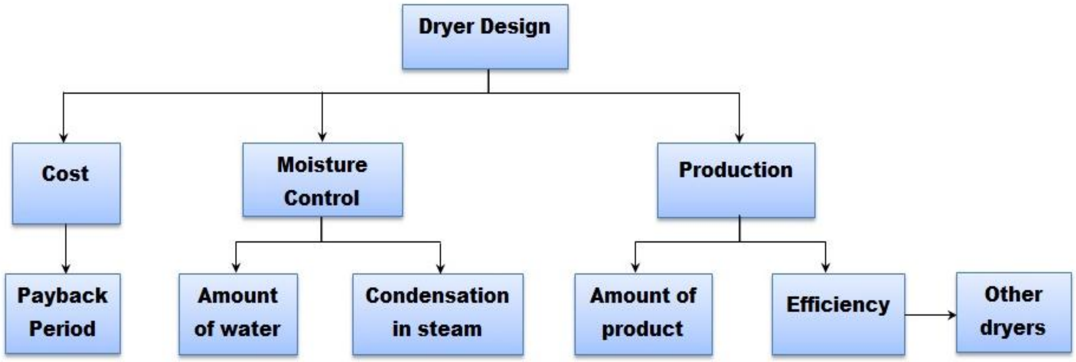


Figure 2 – Criteria Tree

Functional Diagram

To better understand the process of the dryer and where to perform our engineering analysis, a functional diagram of dryer 3 was made. This is shown in Figure 3 below. The dryer runs on steam in conjunction with an air circulation system. The plant produces its own steam in a natural gas boiler. This steam is then pumped at approximately 100 psi to the dryer unit. In the dryer, steam is continually pumped through steam coils. The air circulation system blows air over the steam coils to heat the air to around 280 degrees Fahrenheit. Hot air has a larger capacity to remove moisture than air at a lower temperature. This air passes through the moist product and removes moisture from it. After this, the air is re-heated and passed through the product twice more. The product enters the fourth and final section of the dryer where it is cooled to about 100 degrees Fahrenheit before it is sent to further processing.

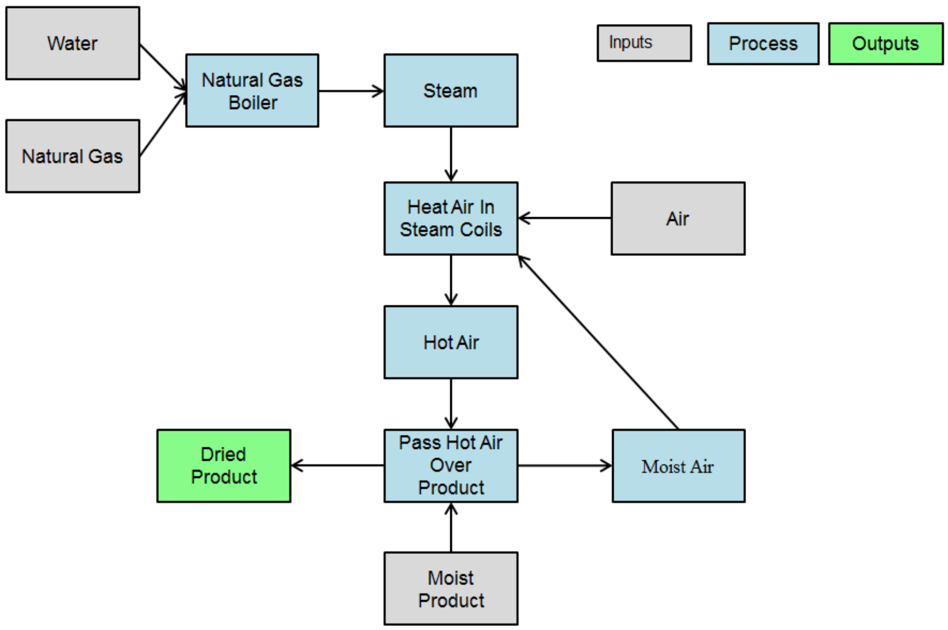
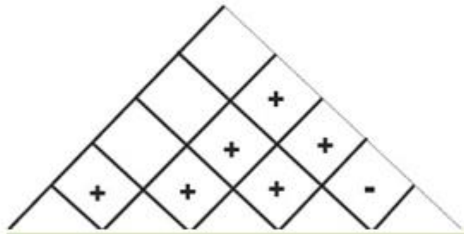


Figure 3 – Function Diagram

Quality Function Deployment

A quality function deployment table, Figure 4, compares customer needs to engineering needs. It relates overall design to reasonable engineering specifications. From the figure, cost relates to all of the customer requirements. To make the dryer more efficient for allowing more product throughput, the cost will increase. To be more durable, there will be more materials used or longer lasting parts which will be more expensive. This also affects the overall weight of the dryer and energy reduction. Ideally, the output should be 10% more efficient than the dryers already in use which gives us the engineering targets. The house of quality refers to how the engineering requirements relate to each other. There is a positive correlation (+) between cost and energy reduction. This means that by increasing the cost, the energy reduction should be larger. By increasing the energy reduction, the output tonnage decreases. This is a negative correlation (-).



Engineering Requirements		Weight	Cost	Payback Period	Energy reduction	Tonnage
Customer Requirements	Inexpensive	x	x	x	x	
	Allow for more product throughput		x	x	x	x
	Durable	x	x	x		
	Units	ton	$	yrs	%	ton
Engineering Targets		100	250k	8	10	20/day

Figure 4 – Quality Function with House of Quality

Concept Generation

Before we were able to select a design to move forward with, we first had to generate a multitude of concepts to choose from. We accomplished this by breaking the concept generation section into multiple stages. These stages are: defining the problem, defining the system, brainstorming, using Osborn's Checklist to expand these ideas, and then refining the ideas to prepare for concept selection. Through our previous work, we were able to interpret our client's need and generate a concrete problem statement. We determined that the problem was: Dryer 3 at Nestle Purina uses significantly more energy than the other four dryers to extract moisture from the product.

The next step in our concept generation and selection process was to define the system and understand it as completely as possible. We were able to meet with Chad Girvin, the processing maintenance team leader at the Nestle Purina plant in Flagstaff. Chad was able to provide us detail about the system that one would only learn by spending years with a specific system.

We realize now that the drying process at Nestle Purina is very complicated, but we were able to take note of the most critical pieces of the system and its operation. The first step of the drying process is bringing the product to the front of the dryer from the exit of the extruder, or product cooker. This is done with a vacuum conveyance system. Each dryer has a dedicated blower that creates a vacuum to pull the product to the dryer. The vacuum conveyance system is a very important part of the drying process as it provides about ¼ of the moisture removal as a fraction of the entire drying process.

Once the product is pulled through the vacuum conveyance system, it is deposited onto the dryer bed by an oscillating belt. This belt speed can be controlled, and helps to control the product depth and uniformity. The belt speed also affects the time the product spends in the dryer. After the product enters the dryer, it is passed through 4 sections of the dryer. The first 3 sections are responsible for removing moisture from the product, and the fourth section is responsible for cooling the product. Each section has its own dedicated air flow, temperature control, and steam coils. The steam coils are used to heat up the air that moves through each section, as hot air can contain much more moisture than cool air.

In addition to using Chad Girvin as a resource for information, we were also able to use Nestle Purina's process monitoring system called iFix to gather information on the system. The computer interface with this system is shown in Figures 5 and 6. Figure 5 depicts all of the relevant information for dryer 3, which is the focus of our project. iFix provides a large amount of data, and we focused on a few key details to determine the relative efficiency of dryer 3. We used dryer 1 as a reference; data for dryer 1 can be found in Figure 6.

The percentages displayed along the dryer bed represent the percentage of dryer steam usage as a comparison to the dryer capacity. Figures 5 and 6 show that dryer 3 is running at near capacity, while dryer 1 is running at approximately 70% capacity. To quantify the dryer steam usage, we were able to access the steam flow rate for each dryer, in terms of pounds of steam per hour, or pph. The steam flow rate for dryer 3 was 4009.3 pph at the time of measurement and the steam flow rate for dryer 1 was 3414.6 pph.

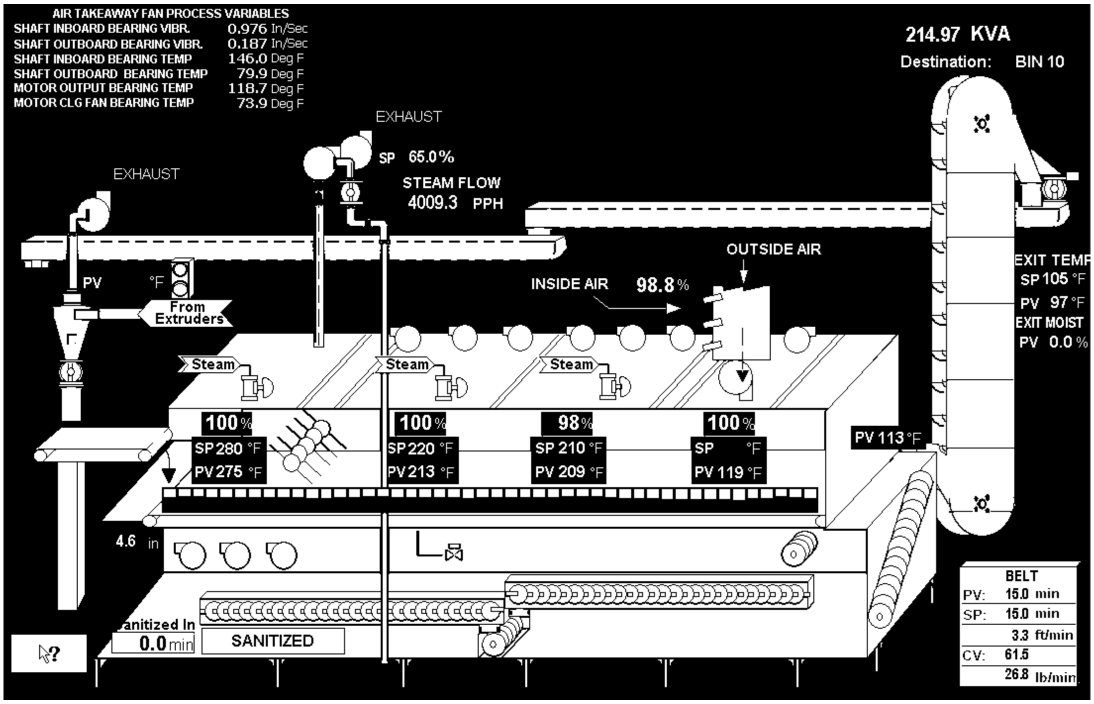


Figure 5 - Dryer 3 Source: Nestle Purina Process Monitoring System

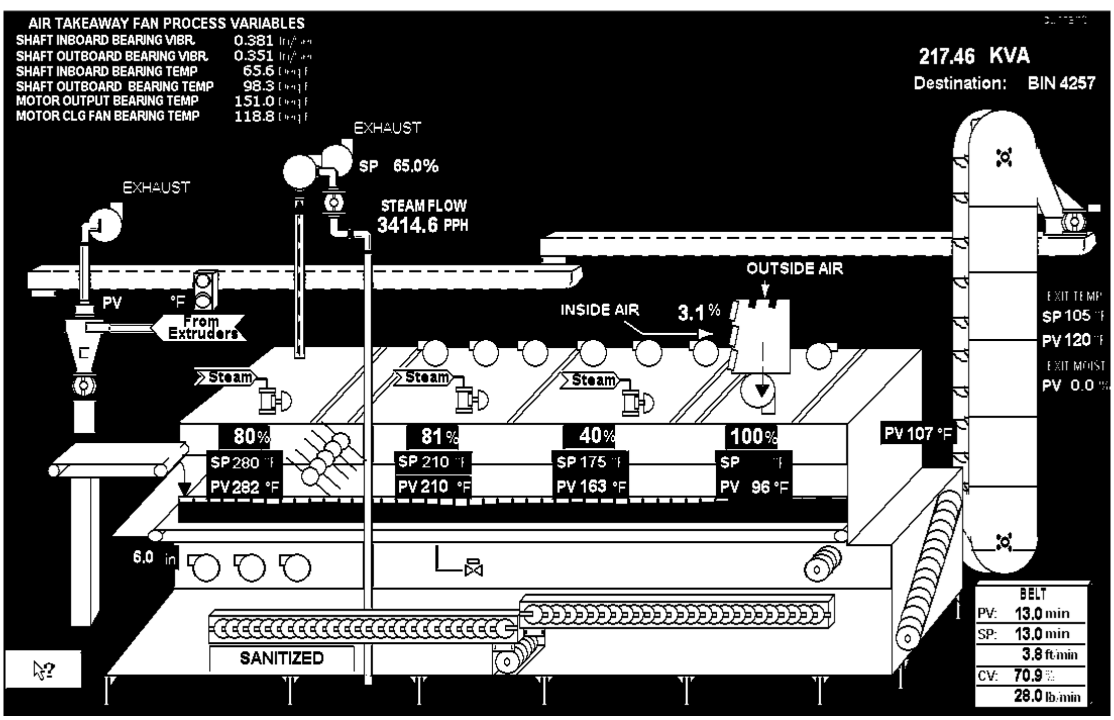


Figure 6 - Dryer 1 Source: Nestle Purina Process Monitoring System

We also needed a way to quantify the product throughput through the dryer. iFix provides the product bed depth, and the dryer bed operates at a constant speed, so we decided to define a dryer efficiency index as inches of product depth per steam flow rate in pounds per hour. The indexes were small, so we made them easier to read by multiplying by 1000. The efficiency index of dryer 3 was determined to be 1.147 while the efficiency index of dryer 1 was 1.7516. The percent difference between the efficiency index of dryer 3 and 1 was 34.7%, with dryer 1 displaying a significantly higher efficiency rating. We used all of this information to aide our brainstorming, concept generation, and concept selection.

In the brainstorming stage, we came up with any and all solution ideas to achieve better efficiency in dryer 3 compared to the other 4 dryers. There were no bad ideas or negative feedback in this stage, as one idea can lead to another. Some ideas range from outright buying a new boiler from off the shelf to redesigning the existing boiler to changing the insulation and fuel for the boiler itself. Initial research and price quotes for these solutions range upward of half a million dollars so a careful inspection of these ideas are necessary.

To further generate concepts from the brainstorming stage, we used Osborn's Checklist shown in Table 1 in the Appendix. This method allows one to expand the list of ideas by asking how to adapt, modify, magnify, minify, substitute, rearrange, and combine. By following this procedure, we obtain many more concepts; some good and some unreasonable. For example, by taking the original concept of insulation, we can increase the amount of insulation around main pipes, decrease insulation around other pipes, use different insulation material, or a combination of these designs. Then, to refine the list for top, viable concepts, we used a weighted criteria tree with a decision matrix.

Concept Selection

Since there are three criteria, the team needs to determine the overall importance for the criteria. So the team can make a decision matrix for the concepts. Therefore the Analytical Hierarchy Process is applied to determine the overall importance. Table 2 describes the overall scale to judge the overall importance of each category.

Table 2 - Scale of the Judgment of Importance

Judgment of Important	Equally important		Moderately more important		Strongly more important		Very strongly more important		Extremely more important
Numerical Rating	1	2	3	4	5	6	7	8	9

In the Pairwise Comparison Matrix (Table 3), the team determines that the moisture control is moderately more important that the cost. The production is strongly more important than the cost and moisture control. So the values are put in the matrix. The total value is the sum of the values in each column. The value of each criterion in the matrix is divided by the total value in that column. The normalized values are shown in Table 4. By taking the average of the normalized value in the row, the team gets the overall importance for the criteria. The overall importance of the cost, moisture control, and production is 0.211, 0.102, and 0.686 respectively.

Table 3 - Pairwise Comparison Matrix

	Cost	Moisture Control	Production
Cost	1	3	1/5
Moisture Control	1/3	1	1/5
Production	5	5	1
Total	19/3	9	7/5

Table 4 - Normalized Importance and Overall Importance

	Cost	Moisture	Production	Overall Importance
Cost	0.158	0.333	0.143	0.211
Moisture Control	0.053	0.111	0.143	0.102
Production	0.789	0.556	0.714	0.686

Each criterion was given a relative weight of how important they are to each other for each category. Cost was determined by our client to be of twenty-five percent importance, while moisture control was ten percent importance and production was sixty-five percent. In each of the three categories; cost, moisture control, and production were broken down into their sub criteria and ranked on importance of each other. Under cost, the payback period was rated as an overall seventy percent while the energy to run the dryer was ranked as thirty percent important. The same technique was applied to the other categories. After each of the criteria received their specific weight, they were then multiplied by the overall weight for that category. This allowed for an overall ranking of how important each of the criteria was to the overall design (shown in Figure 7).

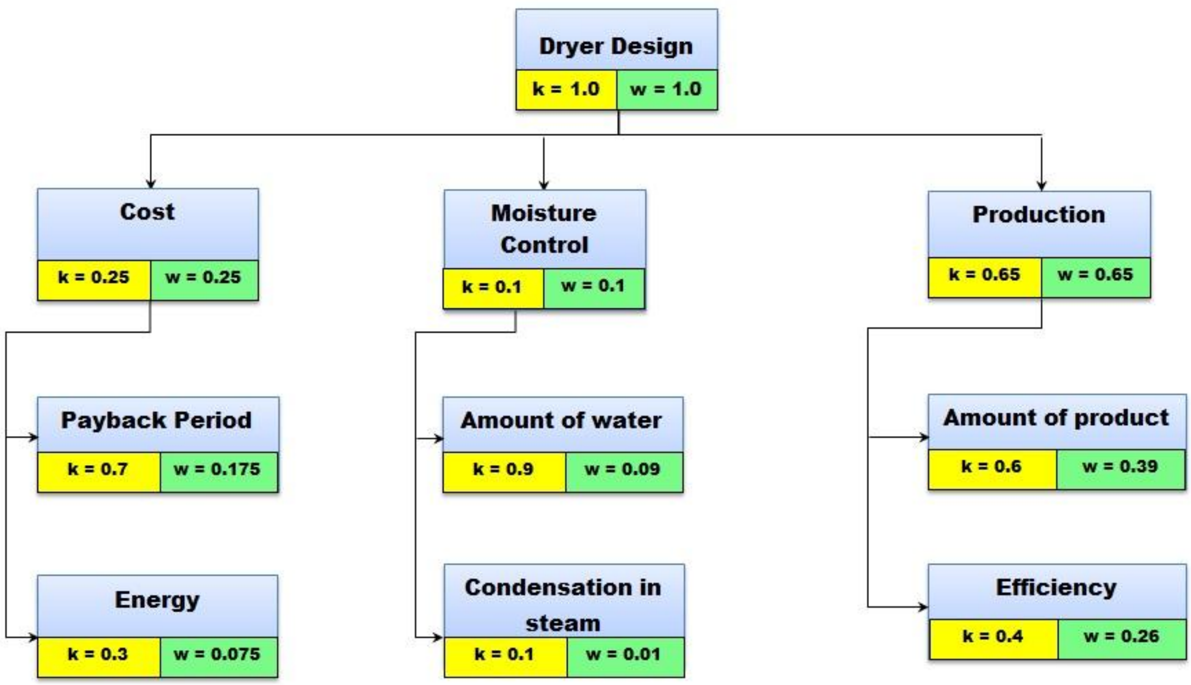


Figure 7 - Weighted Criteria Tree

We used a clearly defined strategy to generate concepts to solve this problem, and also to select which concepts we would be pursuing in our engineering analysis. This strategy was to clearly define our problem, clearly define our system, brainstorm ideas, and then use Osborn's checklist (seen in Table 1 in the Appendix) to expand and refine these raw ideas. Then, we used a weighted criteria tree as well as an analytic hierarchy process to determine our best solution options from our refined idea list. As a result, we were able to conclude that our best three solution options are: Analyzing the steam characteristics, analyzing the air flow inside the dryers, and re-designing the dryer air flow. These three ideas will be our basis when we begin to look into the engineering analysis section of our design process.

Engineering Analysis

Current System

After the product enters the dryer, it is passed through 4 sections of the dryer. Figure 8 shows a schematic of how the dryer operates. The first 3 sections are responsible for removing moisture from the product, and the fourth section is responsible for cooling the product. Each section has its own dedicated air flow, temperature control, and steam coils. The steam coils are used to heat up the air that moves through each section, as hot air can contain much more moisture than cool air.

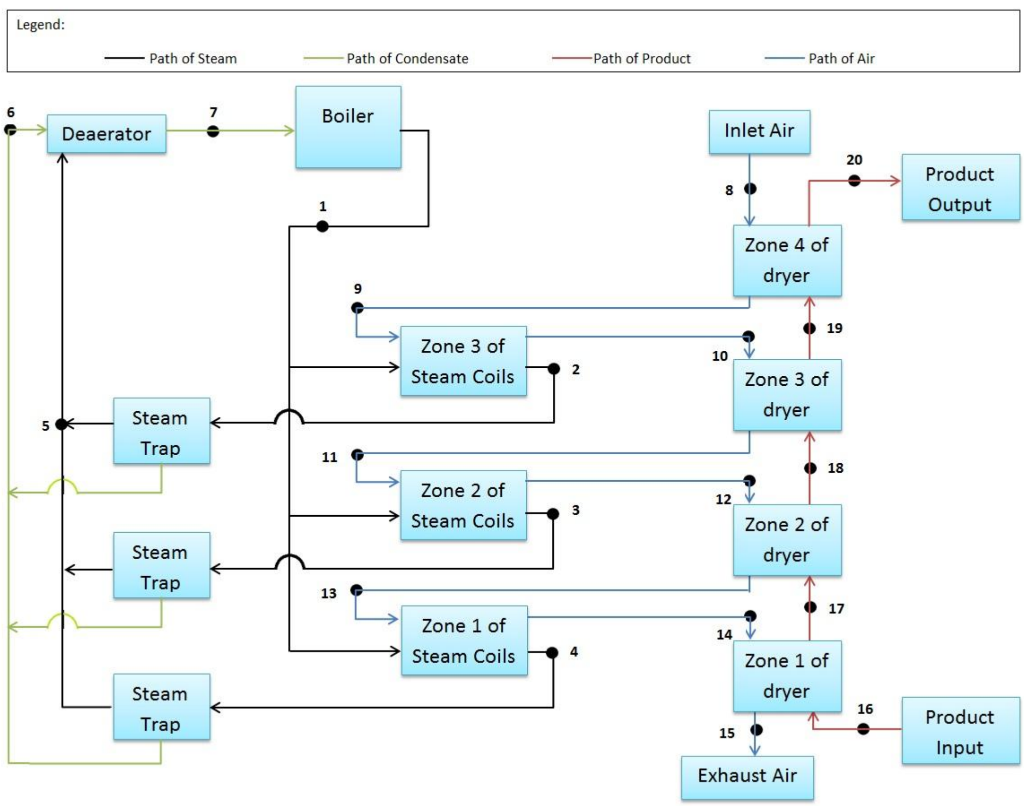


Figure 8 – Overall schematic of how the dryer works with points of interests for thermodynamic analysis.

Analysis of Steam

In order to ensure the system is operating correctly, the operation of the subcomponents must be analyzed. The analysis conducted below is for an individual steam coil. Each steam coil acts as a heat exchanger where an input of steam heats up air in a cross flow pattern. The energy balance for the control volume is as follows:

$$\frac{dE}{dt} = Q_{in} - W_{out} + \sum \dot{m}\imath \left[h_i + \frac{V^2{}_i}{2} + gz_i\right] - \sum \dot{m}\imath \left[h_e + \frac{V^2{}_e}{2} + gz_e\right] \tag{1}$$

Where:	h	Enthalpy
	Q_{in}	Heat in
	W_{out}	Work done
	$\dot{m}$	Mass flow rate
	V	Velocity of fluid
	g	Gravitational constant
	z	Elevation

The above equation is simplified with the assumptions that kinetic and potential energy can be neglected. Furthermore no work is done by the system; however loss of energy must be accounted for. Thus equation 1 can be rewritten as:

$$E_{Loss} = \dot{m}_{steam}(h_1 - h_2) + \dot{m}_{air}(h_3 - h_4) + \dot{m}_{vapor}(h_3 - h_4) \tag{2}$$

In order to solve the above equation, the properties of the steam and drying air at every node must be known. All of the properties for the steam are known, however the mass flow rate for the air is not determined by the facilities software. Therefore the mass flow rate of air is estimated by using the known power of the motors that move the air. The following equation relates power to mass flowrate:

$$P = \frac{\frac{\dot{m}gh}{33000}}{\eta\eta_e} \tag{3}$$

Where:	$\dot{m}$	Mass flow rate
`	g	Gravitational constant

h Total head

η Efficiency of the motor

η_e Mechanical energy (converting electricity)

Since the values for the amount of power for the motor is known (10 horsepower), we can determine the overall expected mass flow rate once we get the data about the overall efficiency of the motor, the mechanical energy, and the total head caused by the velocity and pipe frictions. Once we have calculated the mass flow rate, we need to determine how much of the mass is made up of water vapor and how much is made up of air. By using the equation for moisture content it allows us to determine the ratio of vapor to air:

$$\omega = \frac{m_{vapor}}{m_{air}} \tag{4}$$

Equation 2 will be utilized to determine the operational condition of each independent heat exchanger of the dryer. Those values will be compared to each of the heat exchangers in another dryer found in the plant. This will allow us to determine how differently dryer three is operating from dryer one.

The only data that we have collected so far is listed in Table 6, where each point was defined earlier in Figure 8. This data in combination with the data from the other dryers will allow us to determine if there is a discrepancy with the heat exchangers.

Table 6 – Collected thermodynamic properties for each point defined in Figure 8.

Point	**Description**	**Property**	**Others**
1	Stream inlet	T = 273F P = 50psi	should be saturated steam
2	zone 3 steam outlet	T = 230F	
3	zone 2 steam outlet	No Data Collected	
4	zone1 steam outlet	No Data Collected	
5	steam trap outlet	T = 100F	
6	condensate return	T = 180F	
7	Boiler inlet	P = 148psi	efficiency: 84.09%

8	Air inlet	P = atmospheric T = 139F	
9	zone 4 air outlet	T = 63F	
10	zone 3 air inlet	T = 187F	
11	zone 3 air outlet	T = 184F	
12	zone 2 air inlet	T = 226F	
13	zone 2 air outlet	T = 178F	
14	zone 1 air inlet	T = 216F	
15	exhaust	P = atmospheric	standard pressure
16	product inlet (cyclone exit)	T = 150F	22% moisture content
17	zone 1 (inlet)	T = 215F	22% moisture content
18	zone 2 (inlet)	T = 200F	15.5% moisture content
19	zone 3(inlet)	T = 180F	11.5% moisture content
20	zone 4 (inlet)/ dryer outlet	T = 100F	9% moisture content

After our analysis, we are going to determine the best way to fix whatever is causing the problem. To determine the best way of fixing the problem, we are going to perform a cost analysis. This will allow us to determine exactly how much the increase in cost will be, and how long it will take for the increase in productivity to pay for the increase in costs.

Natural Gas Conversion

Another idea that we are looking into is converting the steam dryer over to a dryer that runs on natural gas. This would replace the use of steam to this dryer therefore eliminating the issue of the problematic drying. Instead of using the three different steam coils and steam traps, all of that would be replaced by a natural gas burner which heats the air directly drying the product as a result. Figure 9 shows a schematic of how the natural gas dryer operates.

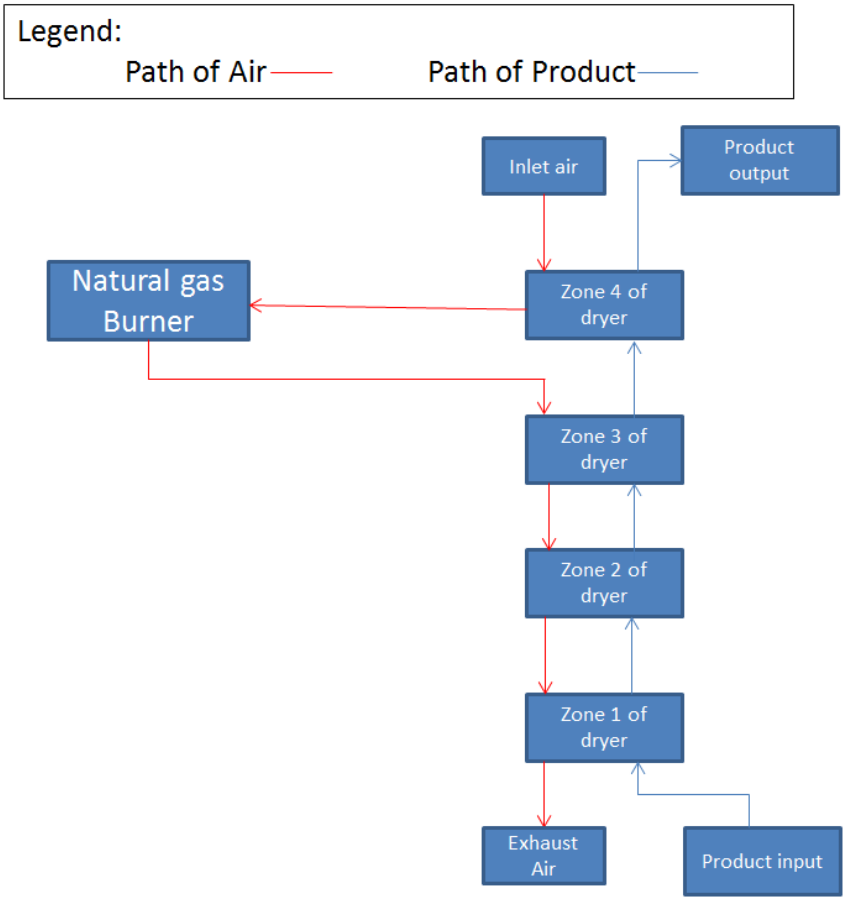


Figure 9 - Schematic of the natural gas dryer.

After the product enters the dryer, it is passed through 4 sections of the dryer. Air enters the fourth zone to cool the product down. Then the air will be heated up by the natural gas burner. After air being heated up, it enters the other 3 sections of the dryer which will remove the moisture from the product.

$$Q_{Combustion} = \dot{m}_{air} * (h_1 - h_2) + \dot{m}_{vapor}(h_1 - h_2) + E_{Loss} \quad (5)$$

$$Q_{Combustion} = \dot{m}_{gas} * \Delta H_{comb} * \eta \quad (6)$$

Where:

	h	Enthalpy
	Q_{Comb}	Heat
	W	Work done
	$\dot{m}$	Mass flow rate

ΔH_{comb} Heat of combustion

η Burner Efficiency

The energy released by the burning of natural gas is given in equation 6, which is used in equation 5 to find the energy lost to entropy generation. The mass flow rates are determined either using the flow to power relationship given in equation 3 or are measured.

These dryers have a much higher efficiency than the steam dryers, reducing the overall amount of cost for fuel while greatly increasing the amount of product that can go through the dryer at any given time. However, this conversion is a very significant cost so it ultimately would depend on whether our client would want to go that route. If they do decide to go that route, the payback period is only a couple of years due to the increase in efficiency and throughput.

In order to do analysis on this, we would have to consult with a sister Purina plant in Clinton, IA. They are currently implementing a similar conversion in their plant and should be up and running in the near future. We would be able to see the direct effect of the increase in productivity for this type of dryer and present this to our client for his considerations.

Mid-Year Progress

We presented the final plan from the Fall semester to Nestle Purina, and decided to change the direction of our project between the end of the Fall semester and the beginning of the Spring semester. The final goal at the end of the Fall semester was to design, build, and test a prototype to prove that a natural gas system will show increased efficiency when compared to a steam coil driven dryer. After discussing at length with our client, we have decided that to accurately compare the two systems, we would have to create a prototype for a steam powered dryer as well as a natural gas fire dryer. There were also issues with scaling these projects, as the natural gas system would perform better at small scale than it would in a large scale setting when compared to the steam prototype. This is mainly due to the efficiency benefits the full size steam dryer sees when steam traps, heat transfer fins, and the steam recycling system are installed. The prototype for the steam dryer would be difficult to make because we would have to make steam and then somehow pump the steam across the prototype. Also dealing with steam running in an open prototype can be very dangerous if something was to go wrong. Overall, the whole idea of making a prototype was scrapped because of the difficulty of making the prototypes and the lack of quality information we would have received from preforming these experiments.

Future Tasks (Progress Report)

Because our prototype plan is flawed, we decided to model a simplified full scale dryer (seen in Figure 10) using numerical modeling software. To accomplish our goal of showing the benefit of switching to a natural gas system, we will fully define the steam and natural gas dryers at the Nestle Purina plant using our software. This will serve as a bench test for our numerical modeling program, and we will be able to utilize real time data to verify our model. Once we have tested and verified our numerical model, we will use the design process to design a conversion plan for dryer 3 at the Nestle Purina plant.

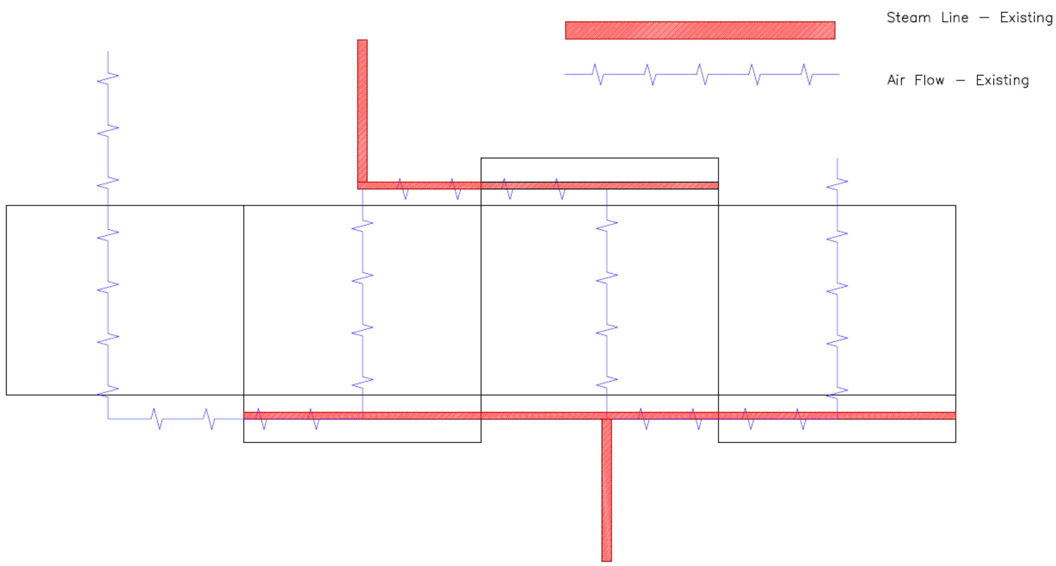


Figure 10 - Steam Dryer Model

Figure 10 shows a simplified steam dryer model. This model shows the existing steam lines, as well as the air flow through the dryer. The air inlet is on the far right side, and travels in a serpentine pattern through the dryer until it is exhausted on the left. The product will travel in the opposite direction of the airflow, from left to right. There are currently three steam coils in the steam dryers at the plant, each shown above as a box above or below the main dryer volume. These steam coils act as a closed heat exchanger, with no mixing of the two fluids involved, steam and air. Our current design goal involves replacing these heat exchangers with furnaces powered by natural gas. We plan to keep the product and air flow through the system the same, and make changes to only one component.

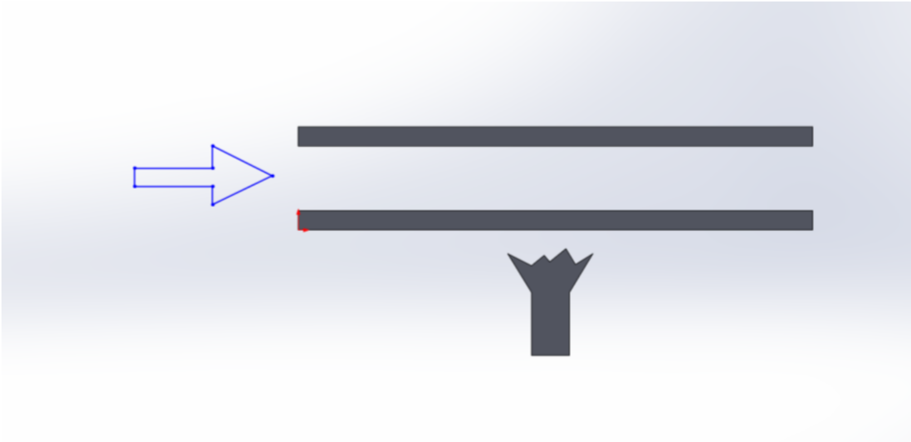


Figure 21 – Natural Gas Model

Figure 11 shows a model for the natural gas fire dryer. The fire underneath the bottom plate will heat the plate. Air flow is represented by the blue arrow, and will flow over the plate, and then flow over the product. The natural gas fire in conjunction with the air flow will replace the steam coils in the current design. The efficiency increase that we expect from this design comes from two sources. The first is the raw efficiency of heat transfer that we will experience using a different heat source. We will measure this by comparing the inlet and exit temperatures of the air. Then we will take into account the cost of the fuel required to heat the air by this amount. The second source of efficiency upgrade will be from the transmission costs of steam. In the plant, steam is currently produced in the boiler, and then travels approximately 300 feet to reach the dryer. By piping the natural gas directly to the dryer, we are able to cut down on the approximate 15% loss that is a direct result of transporting the steam to the dryer.

In our future design, we will take into consideration the loss represented by this transport of steam, as well as the temperature difference compared to fuel costs. This is the strategy we will employ when attempting to prove to our client that a natural gas fire system will increase efficiency. In addition, we will complete the cost analysis based on our found efficiency upgrade, and will present to our client the expected payback period when implementing our system.

Project Plan

Figure 12 shows an updated Gantt chart for the Spring semester. The green bars refer to how many remaining days we plan on spending for each task, while the red bars refer to completed days and milestones.

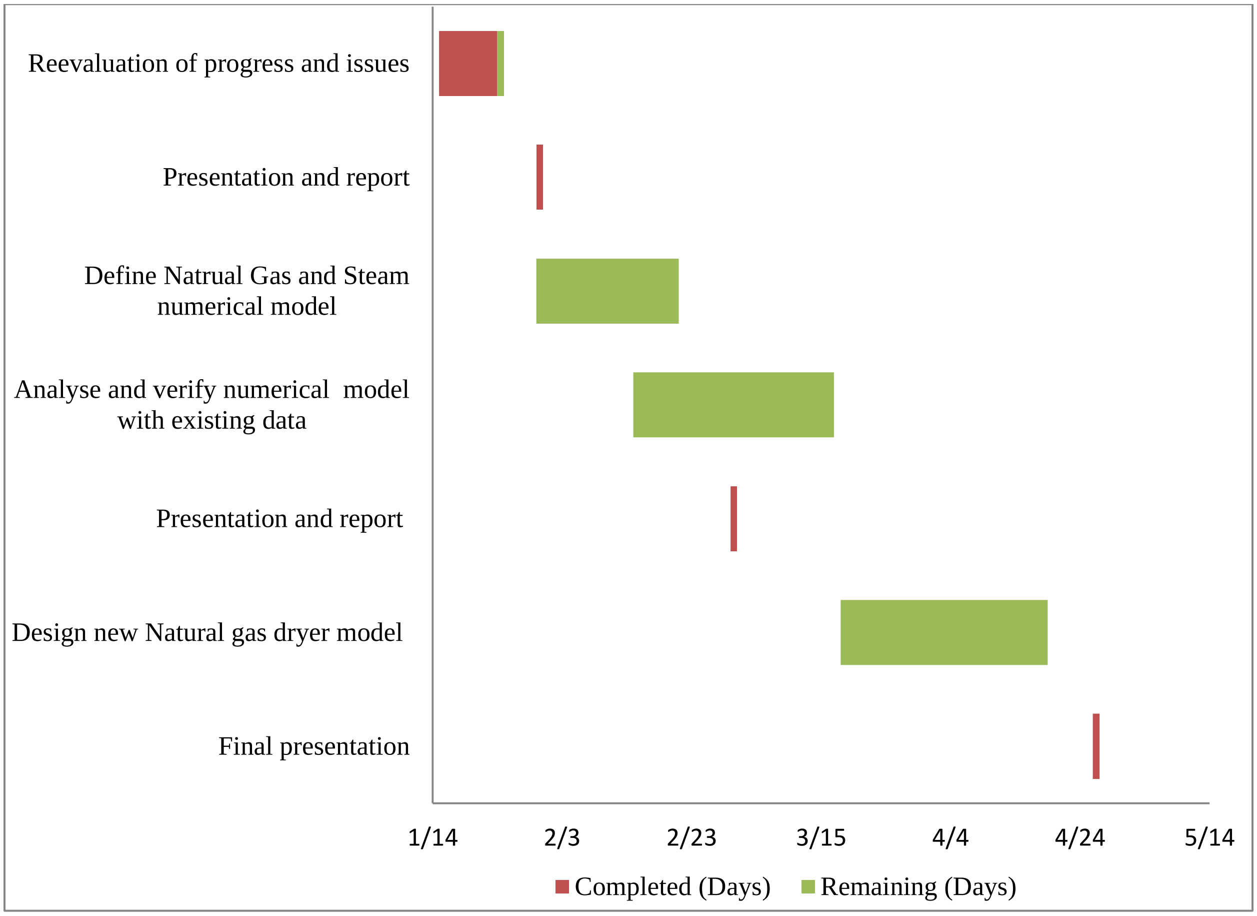


Figure 12 – Gantt chart for the Spring semester.

Conclusion

Dryer 3 having efficiency problems, we decided to fix this with two design solutions. The first is to fix the steam coils, and the second is to convert the system to natural gas. After performing thermodynamic analysis on the steam coils and comparing this to natural gas conversion, we decided to implement a natural gas conversion system for dryer 3. This is a more expensive solution, but in the long term, it will produce more revenue for our client than the steam coil solution. We are going to make a numerical model for the existing steam model. This model will be verified by using data that is collected from the plant. After verification that our model is correct, we will also make a numerical model for the natural gas dryer. This will allow us to make certain our modeling for the natural gas dryer is correct, so we can accurately show the natural gas conversion is the best solution for our client. We will provide the client with a proposal and will await approval for the design as this is a high cost solution. To implement and design an actual natural gas system for a multi-million dollar system is beyond the scope of this class. Therefore, the final product of this class will be to prove the efficiency of a natural gas fire system through the implementation of the prototypes mentioned previously.

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Environmental Coordinator

Nestle Purina Pet Care, Flagstaff, AZ

Chad Girvin

Processing Maintenance Team Leader

Nestle Purina Pet Care, Flagstaff, AZ

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Appendix:

Osborn's Checklist

Table 1 - Osborn's Checklist

Ideas	Adapt	Modify	Magnify	Minify	Substitute	Rearrange	Combine
Rebuild Steam Traps	Buy new steam traps (Industrial Automation Services)	Eliminate need for steam traps	More Steam Traps	Less, more effective steam traps	New steam trap design	Rework how dryer uses steam	
Insulate	Performance contracting insulators, new insulation for steam travel	Insulate entire steam travel distance	More insulation	Different insulation			
Boiler	Look at efficiency of a new boiler	Modify boiler piping	More boiler production	Less boiler use	Look into boiler shut down and start up data	Put small boiler in for dryers	<- less distance steam has to travel
Fuel(Boiler)	Natural gas, coal, No. 6 Fuel	Different boiler fuel source	Run at full capacity for maximum efficiency	Reduce to one boiler from two	Different fuel		Steam system changes
Steam properties	Look at other plants operating conditions	Change steam properties (Latent heat, pressure, density)	Ramp up steam energy	Minimize steam energy	Change steam for natural gas	Max combination of properties to maximize efficiency	
Dryer Fuel	Natural gas conversion	Look into alternative fuels	Max out steam energy transfer	Maximize efficiency to minimize fuel	New steam coil design	Rearrange heat transfer system	
Steam system	Minimize transportation of steam	Eliminate steam	Increase steam capacity to maximize efficiency	Minimize steam use in plant	Substitute out new fuel for dryers	Move boilers	
Product	Look at other plants operational conditions	Only run certain product through dryer 3	Maximize bed depth	Less output from dryer	Run product multiple times through dryer	Change bed arrangement	
Dryer Air Flow	Analyze air flow	Maximize heat transfer	Minimize fan speed	Increase air flow for dryer air	Pull in fresh air in between sections	Dry air between sections	
Dryer size	Buy new dryer	Maximize product bed depth	Increase bed surface to decrease depth	Decrease bed surface area to maximize air flow	New machine to dry product		

Decision Matrix

Table 2 – Decision Matrix

Design Type	Cost		Moisture Control		Production		Total
	Valu e	Normalized Value	Value	Normalized Value	Value	Normalized Value	
Change steam properties.	9	1.899	7	0.714	8	5.488	8.101
Analyze air flow	10	2.11	5	0.51	7	4.802	7.422
Pull in fresh air between section	7	1.477	5	0.51	7	4.802	6.789
Natural Gas Conversion	1	0.211	10	1.02	8	5.488	6.719
New steam coil design	7	1.477	8	0.816	6	4.116	6.409
Dry air between sections	5	1.055	5	0.51	7	4.802	6.367
New steam trap design	7	1.477	5	0.51	6	4.116	6.103
Buy new steam traps	3	0.633	6	0.612	6	4.116	5.361
Other plants operating conditions	10	2.11	4	0.408	3	2.058	4.576
Increase bed surface area	3	0.633	4	0.408	5	3.43	4.471
New insulation for steam travel	5	1.055	5	0.51	4	2.744	4.309
Minimize transportation of steam	4	0.844	6	0.612	4	2.744	4.2
Run product multiple times through dryer	1	0.211	5	0.51	3	2.058	2.779
Scale 1-10		0.25		0.3		0.45	
Overall Importance		0.211		0.102		0.686	