Purina Dryer Efficiency

By
Daniel Andenmatten, Brandon Hoffman, Nathan Kish, Chris Simpson, Pengfei Wu
Team 2

Concept Generation and Selection

Submitted towards partial fulfillment of the requirements for
Mechanical Engineering Design – Fall 2012

Department of Mechanical Engineering
Northern Arizona University
Flagstaff, AZ 86011
ME 476C: Senior Design

Northern Arizona University

Srinivas Kosaraju

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 1 and 2. Figure 1 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 2.

The percentages displayed along the dryer bed represent the percentage of dryer steam usage as a comparison to the dryer capacity. Figures 1 and 2 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.

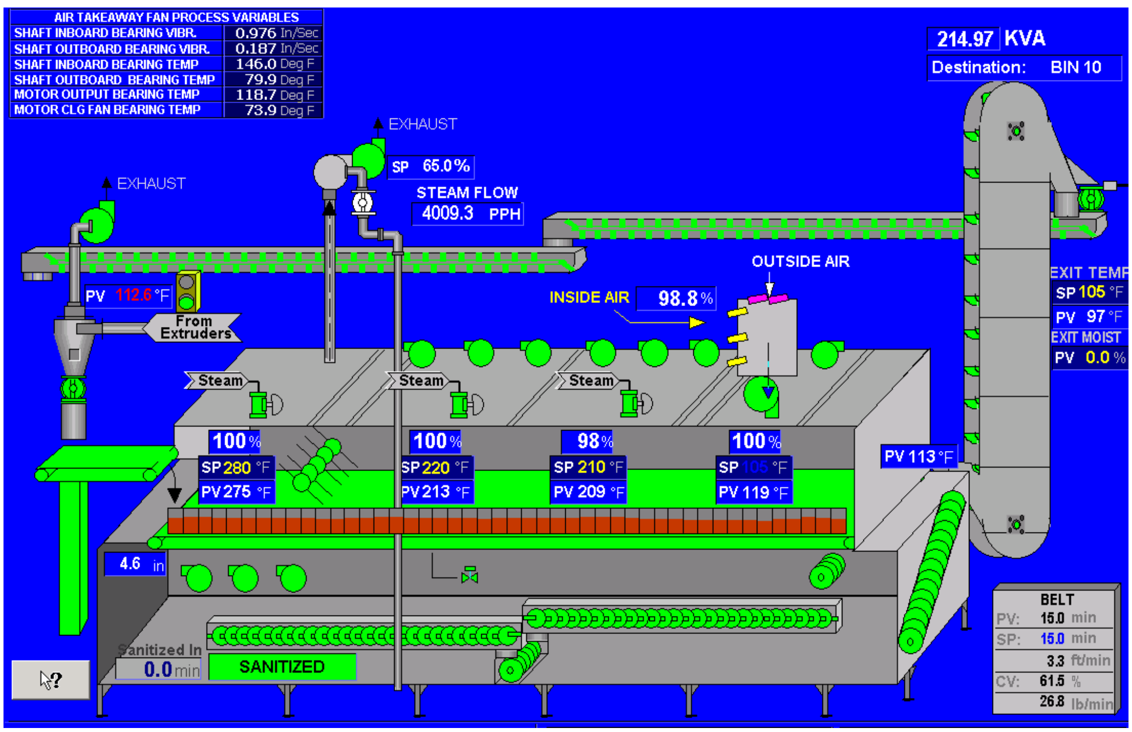

Figure 1, Dryer 3 Source: Nestle Purina Process Monitoring System

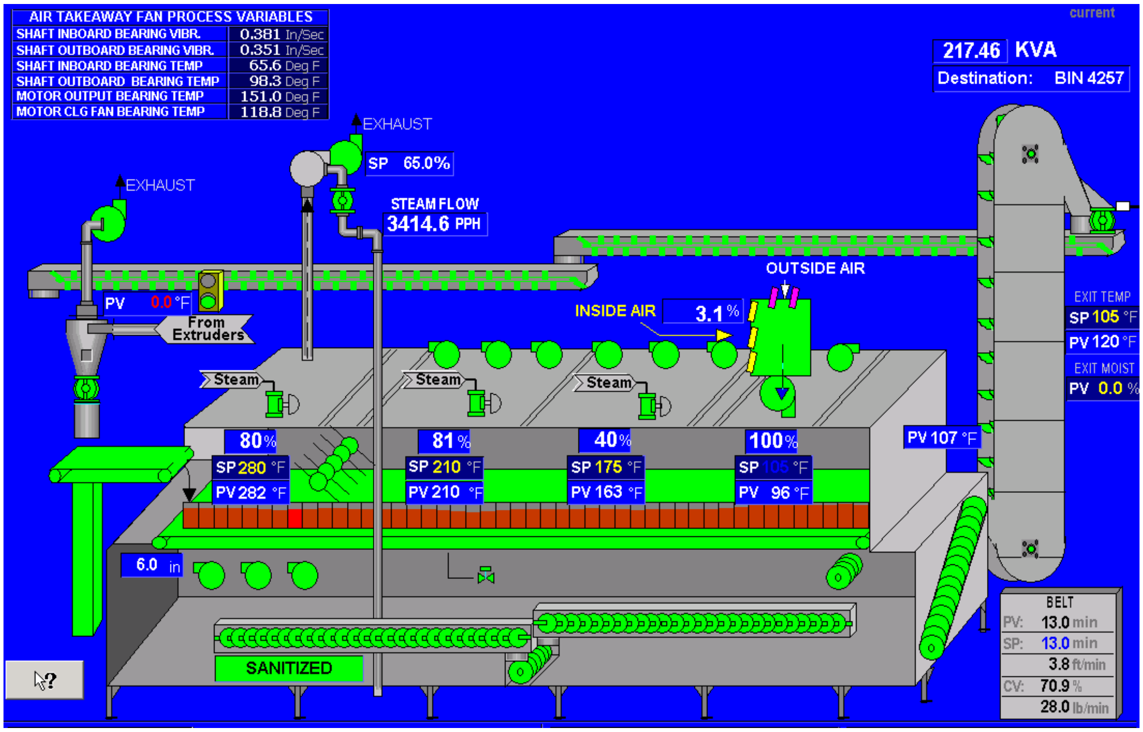

Figure 2, Dryer 1 Source: Nestle Purina Process Monitoring System

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 and the efficiency index of dryer 1 was determined to be 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. 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.

Table 1, Osborn's Checklist

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		

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.

The scale is from 1 to 9. Number "1" represents two criteria are equally important. Number "5" represents one criterion is strongly more important than the other criterion. Number "9" represents one criterion is extremely more important than the other criterion.

In the Pairwise Comparison Matrix, 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 putted 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 the Normalized Importance and Overall Importance table. 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 is 0.211. The overall importance of moisture control is 0.102. The overall importance of production is 0.686.

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

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

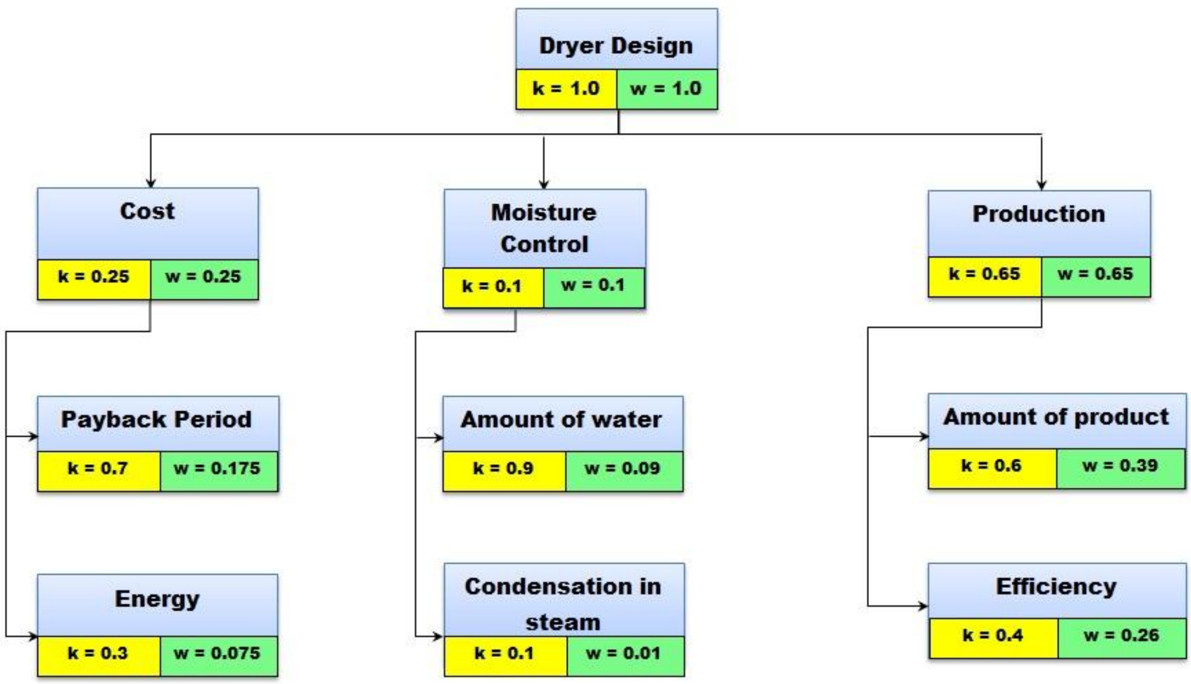

Figure 3, Weighted Criteria Tree

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 were to the overall design.

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 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.

Appendix

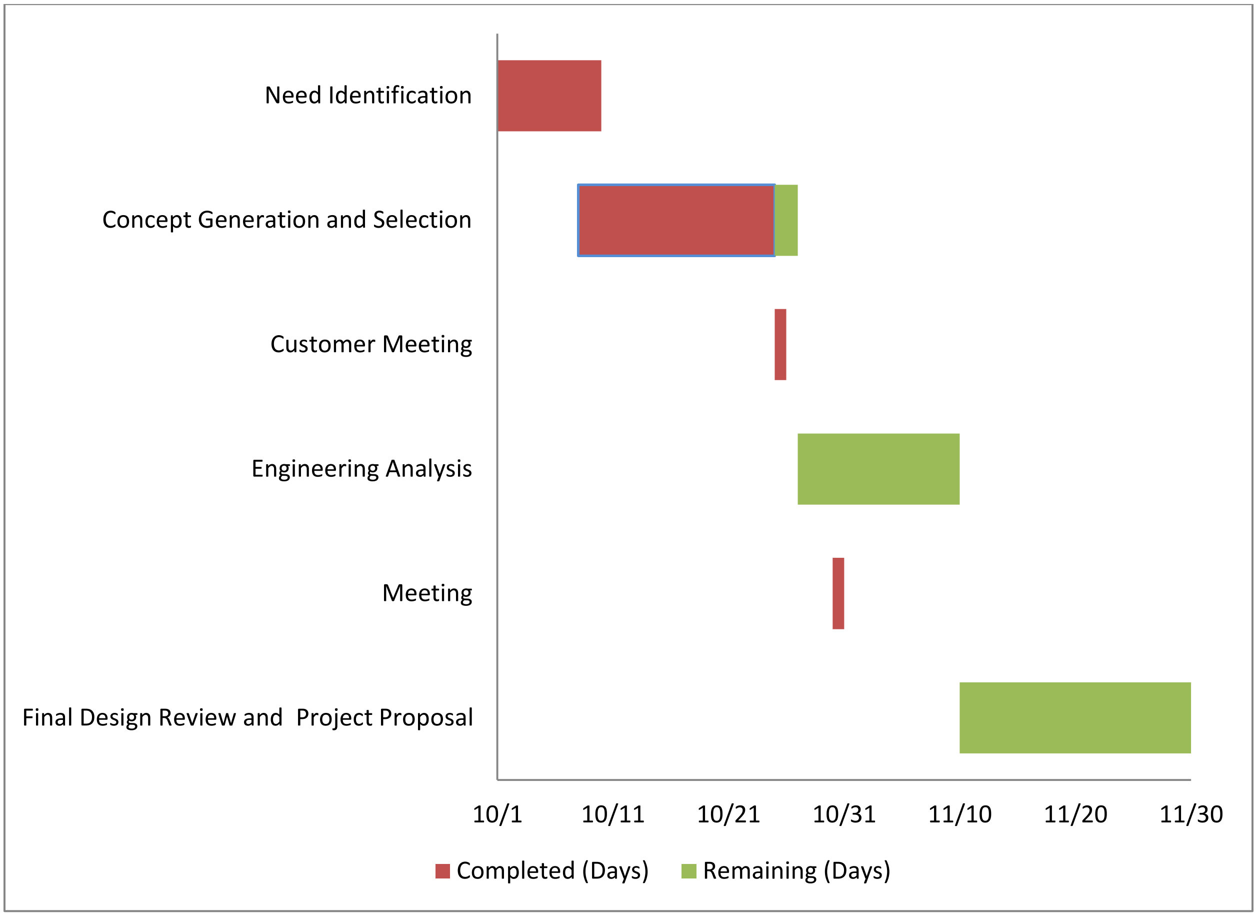

Figure 4, The proposed schedule for each of the 4 sections.

Table 5, Decision Matrix

Design Type	Cost		Moisture Control		Production		Total
	Value	Normalized Value	Value	Normalized Value	Value	Normalized Value	
Change steam properties. Latent heat, pressure, density, etc.	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
Look at other plants operating conditions	10	2.11	4	0.408	3	2.058	4.576
Increase bed surface area so depth will decrease	3	0.633	4	0.408	5	3.43	4.471
Performance contracting insulators, 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	

<u>References</u>

Clint Chadwick
Environmental Coordinator
Nestle Purina Pet Care, Flagstaff, AZ

Chad Girvin
Processing Maintenance Team Leader
Nestle Purina Pet Care, Flagstaff, AZ