Purina Dryer Efficiency

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Engineering Analysis
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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. This dryer 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 4 dryers.

After the product enters the dryer, it is passed through 4 sections of the dryer. Figure 1 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.

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 and our system, brainstorm ideas, and then use Osborn's checklist to expand and refine these raw ideas. By using an analytic hierarchy process we were able to create a weighted criteria tree which allowed to relate criteria to each other, and determine how much more important one criterion was to another. Each of the weighted criteria were applied to each of the brainstorming ideas to get an overall value. This allowed us to refine our large list of ideas into a few of the best ideas. As a result, we were able to conclude that our best two options are: analyzing the steam characteristics and preforming a natural gas conversion. These two ideas will be our basis for engineering analysis.

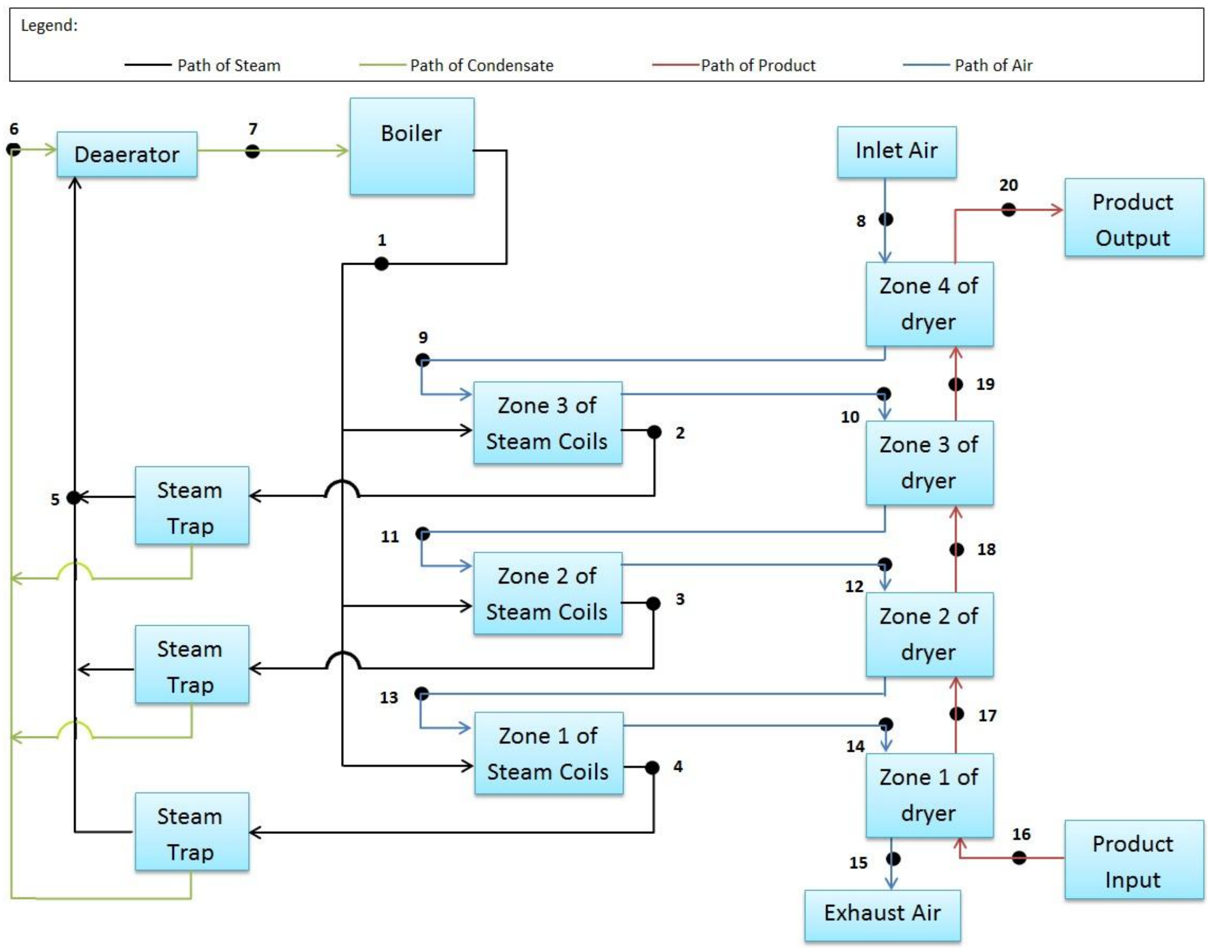

Figure 1 – Overall schematic of how the dryer works with points of interests for thermodynamic analysis.

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:

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

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:

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

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:

$$P = \frac{\frac{\dot{m}gh}{33000}}{\eta\eta_e} \quad (3)$$

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 1, where each point was defined earlier in Figure 1. 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 1 – Collected thermodynamic properties for each point defined in Figure 1.

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 into a dryer that runs on natural gas. This would eliminate the use of steam to this dryer meanwhile 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 fire below the product with natural gas as a fuel. 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.

Conclusion

The Nestlé Purina plant in Flagstaff, AZ is experiencing an issue with one of their dryers. This dryer 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 4 dryers. After gathering data from points of interests (as defined in a thermodynamic model), engineering analysis will be performed. The analysis data will be compared to the data collected from another dryer that is working properly, to determine if there are any issues with the heat exchangers in the problematic dryer. If we cannot determine there is a discrepancy in values when compared to another dryer, converting the steam dryer to a natural gas dryer is an option. Once we have some solutions, we will then perform a cost analysis to determine the best solution for correcting the problem and present this data to our client for his approval.

References

[1] Moran, Michael J., and Howard N. Shapiro. *Fundamentals of Engineering Thermodynamics*. Hoboken, NJ: Wiley, 2008. Print.