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Nestlé Purina Dryer Efficiency

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Nestlé PURINA

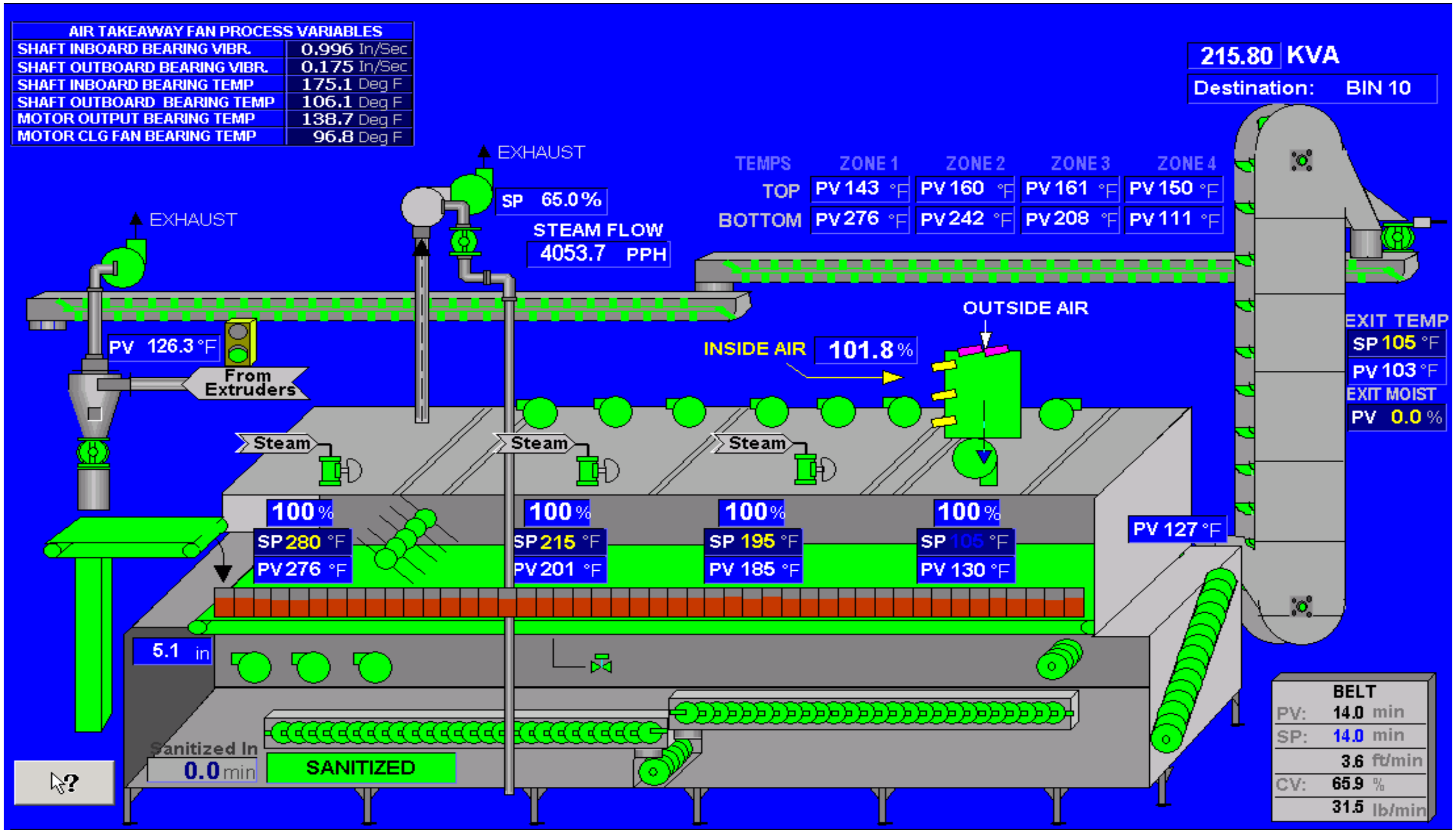
Overview of Presentation

- Company Overview
- Review of Problem Statement
- Introduce Dryer Operation
- Design Requirements
- Overview of Design Solution
- Thermodynamic Model
- Thermodynamic Analysis
- Heat Transfer Model
- Heat Transfer Results
- Cost Analysis
- Conclusion

Introduction

- Nestlé Purina Overview
- Problem
  - Dryer 3 uses significantly more energy than the other four dryers to extract moisture from the product.

Current System



Design Requirements

- Product must be dried to meet 11.5% moisture content
- Outlet air temperature of heat exchanger to be 280°F (410 K)
- Dryer must process 200 tons of food per day
- Less than 3 year payback period

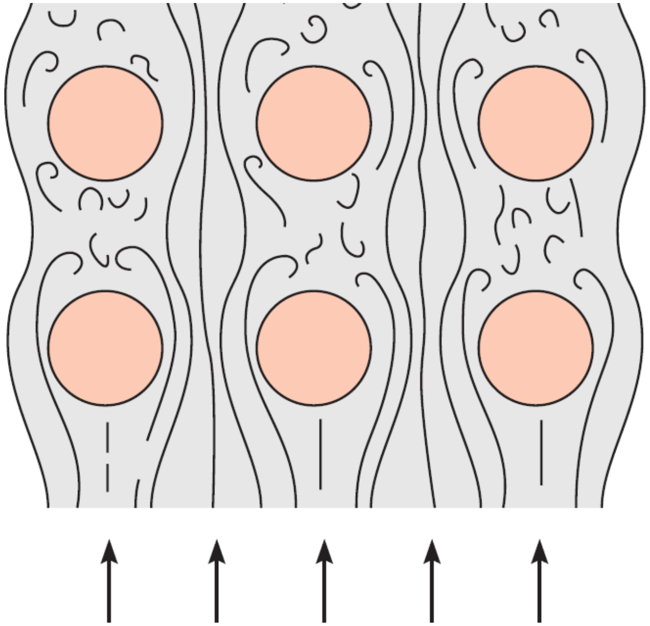
Design Development

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
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

Design Process

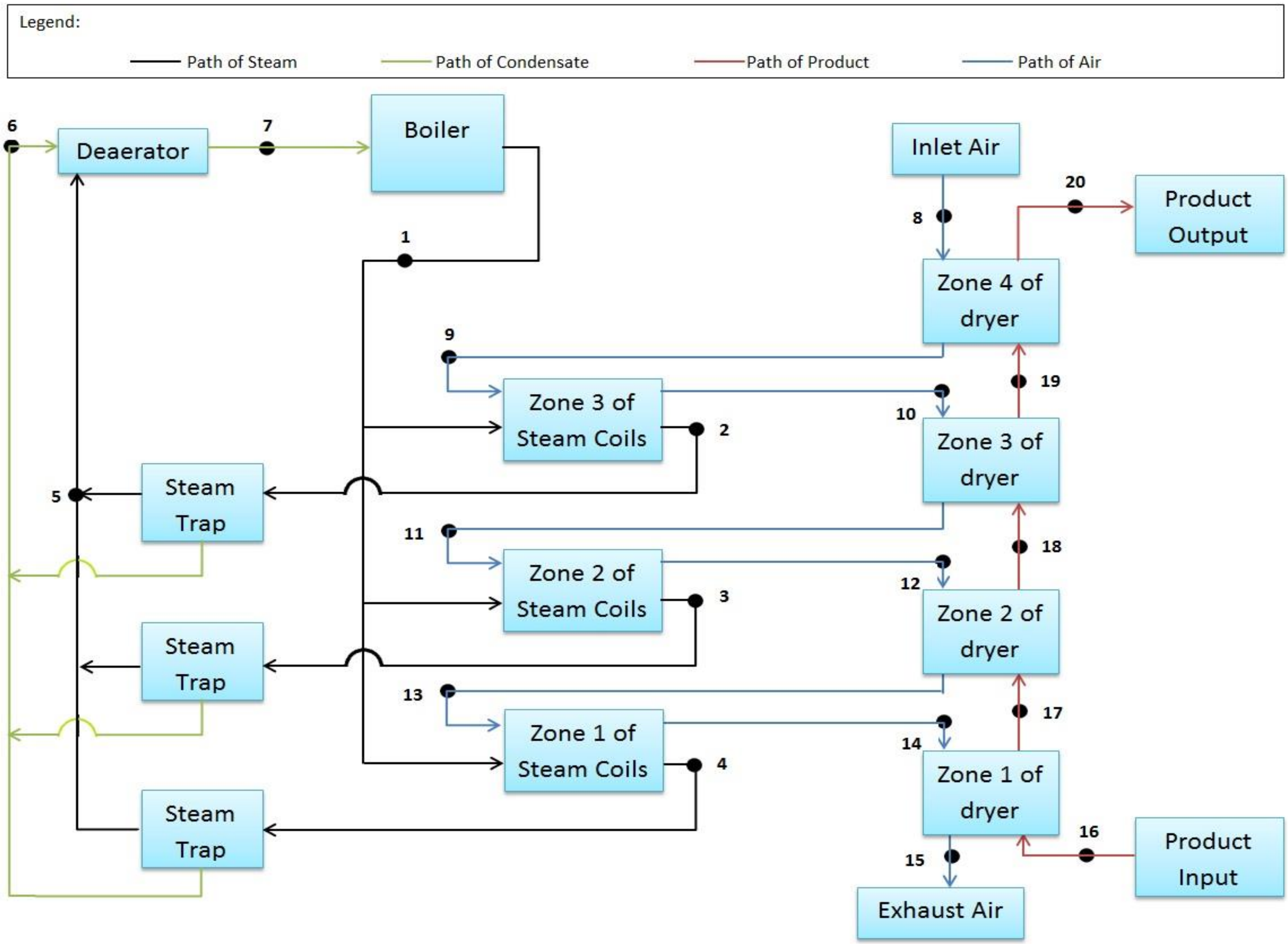
- Using thermodynamics and heat transfer to determine:
  - Efficiency of steam dryer compared to other dryers
    - 34.7 % less inch food per steam flow rate
  - Where largest losses occur
    - Steam traps
    - Steam heat exchanger
  - Cost analysis of natural gas burner versus steam
    - Natural gas burners more efficient
  - Natural gas burner conversion
    - Analysis of one thermodynamic zone

Current Steam Heat Exchanger



Source: Moran, Michael J., and Howard N. Shapiro. *Fundamentals of Engineering Thermodynamics*.

Thermodynamic Model



Thermodynamic Results

- Used Interactive Thermodynamic (IT) software
- Calculated amount of heat transfer needed to occur in order to meet energy transfer requirements
  - Approximately 123,000 BTU per day
- This results in a total cost of $775.20 per day

Materials & Equipment

- Using 304 Stainless Steel pipes with fins
  - Melting temperature of 1673 K
  - Corrosive resistant
  - Easy to clean and maintain
  - Fits in with Nestlé's kitchen concept

- Burner with automated valves
  - Control amount of Natural Gas and air
  - Safety:
    - Prevents back flow
    - High operating temperatures

Combustion Requirements

- Natural gas is 95% Methane (CH_4)
- Using Enthalpy of formation values, we are able to calculate the temperature of the products
- Combustion with Methane and air under theoretical conditions:

$$CH_4 + 2(O_2 + 3.76N_2) = CO_2 + 2H_2O + 7.52N_2$$

- This results in a temperature of the products of 2328 K

Combustion Requirements

- **In order to maintain at least a factor of safety of 2.5 of the melting temperature of stainless steel we used 1200% theoretical air**

$$CH_4 + 12 * 2(O_2 + 3.76N_2) = CO_2 + 2H_2O + 22O_2 + 90.24N_2$$

- **This provides a temperature of the products of 533 K**

Combustion Requirements

- The law of Conservation of Matter states what goes in must come out
  - Mass flow rate of the products must be the same as the reactants

- Used densities of Air and Methane at NTP (1atm and 293K)
  - Calculated the daily input of Methane to be $37.36\ \frac{ft^3}{day}$
  - Which provides $38,111.20\ \frac{BTU}{day}$
  - Total estimated cost is $196.65

Heat Transfer

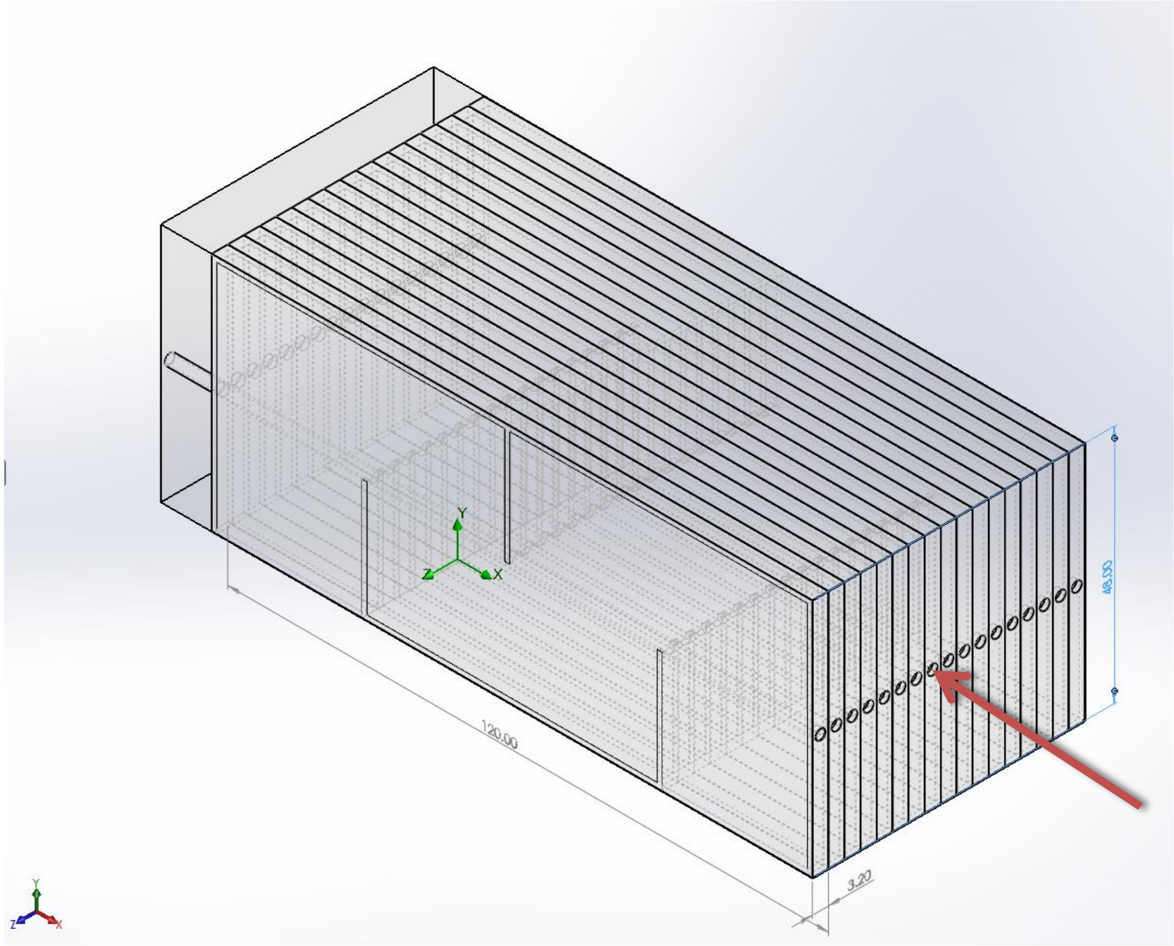
Heat Exchanger Dimensions:

Length: 12ft.

Height: 4ft.

Width: 4ft.

Pipe diameter: 2 inch

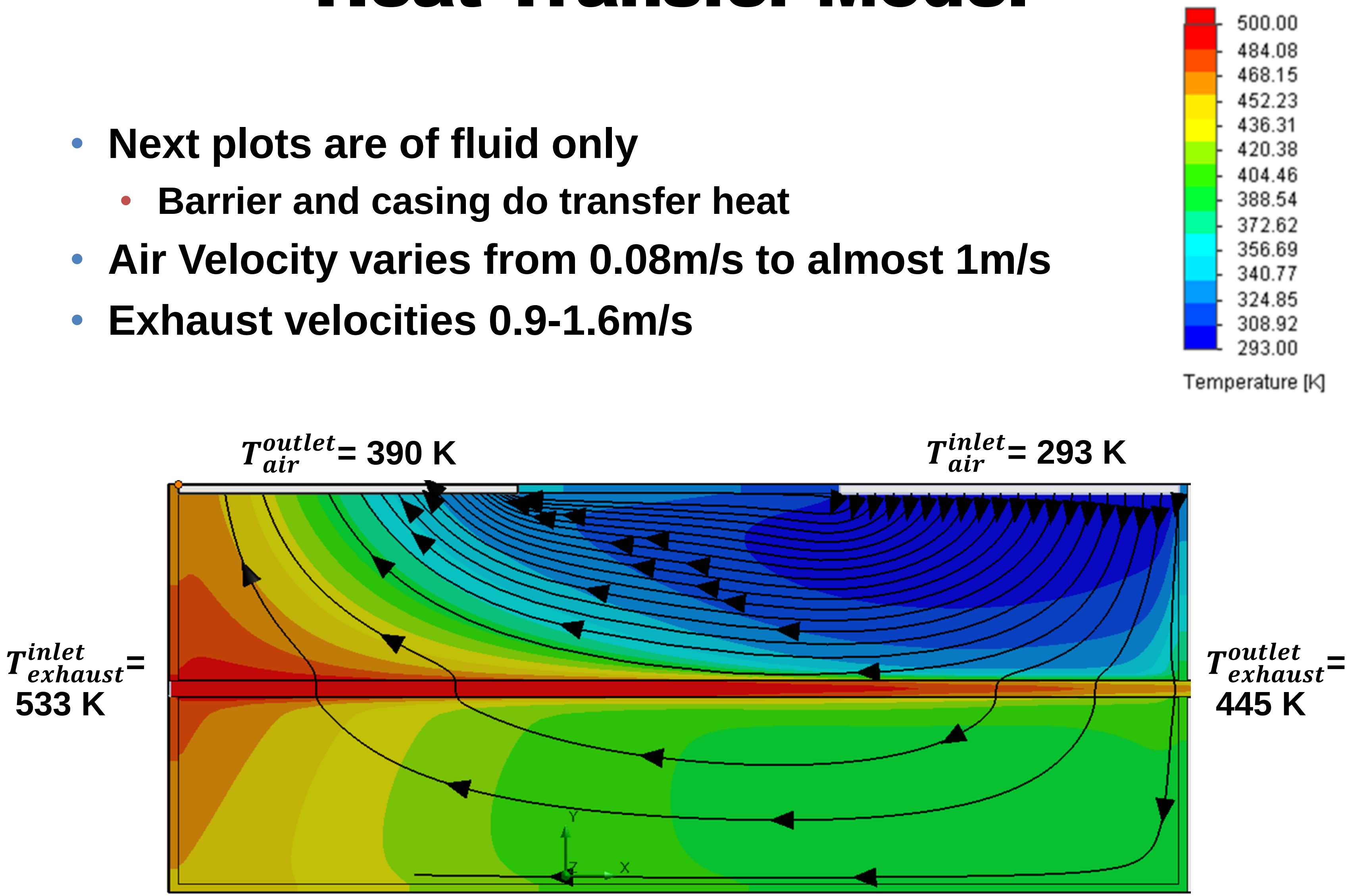


SolidWorks Flow Simulation

- **Computational Fluid Dynamics (CFD)**
  - **Quick, efficient simulation of fluid flow and heat transfer**
- **Heat transfer in solid (Stainless Steel, $k = 16.3\ W/mK$)**
  - **Negligible transfer between pipe and barriers**
- **Adiabatic wall condition for outer walls**
- **Simulation with same input conditions**
  - **Comparison of output temperatures**

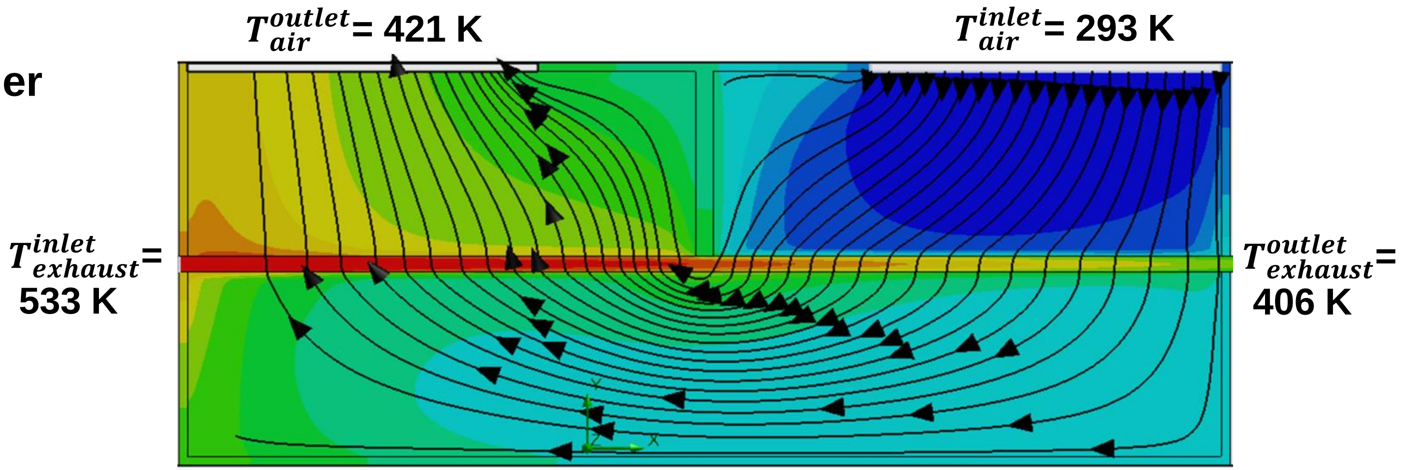
Heat Transfer Model

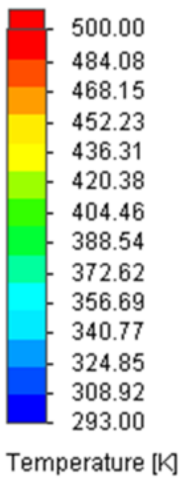
- Next plots are of fluid only
  - Barrier and casing do transfer heat
- Air Velocity varies from 0.08m/s to almost 1m/s
- Exhaust velocities 0.9-1.6m/s

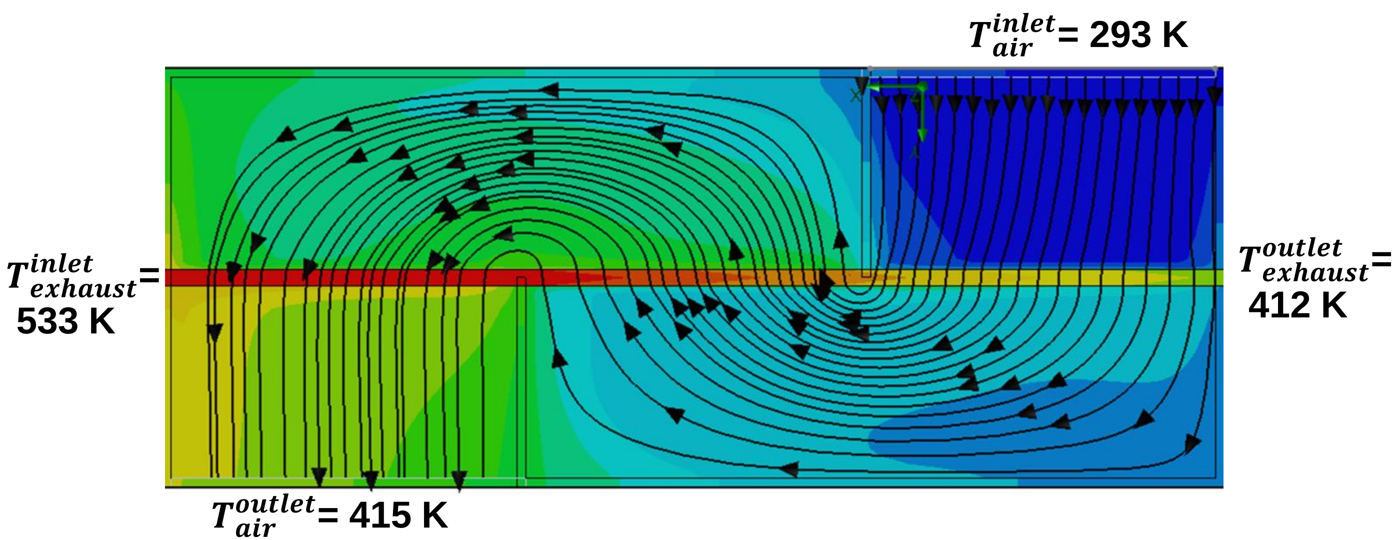


Models Continued

Single Barrier Design





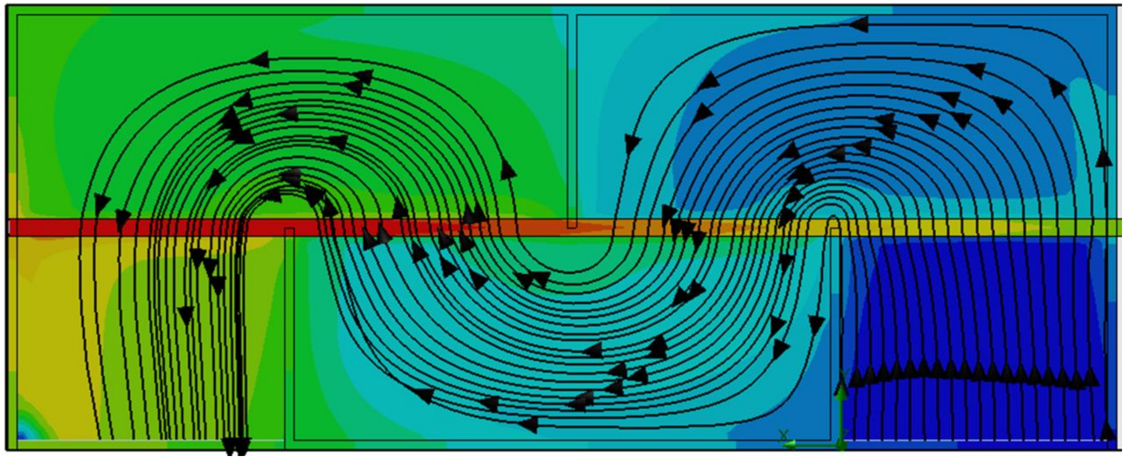


Two Barrier Design

Models Continued

Three Barrier Design

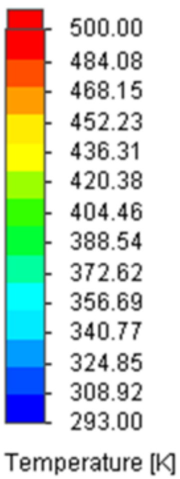
$T^{inlet}_{exhaust}$ = 533 K



$T^{outlet}_{exhaust}$ = 415 K

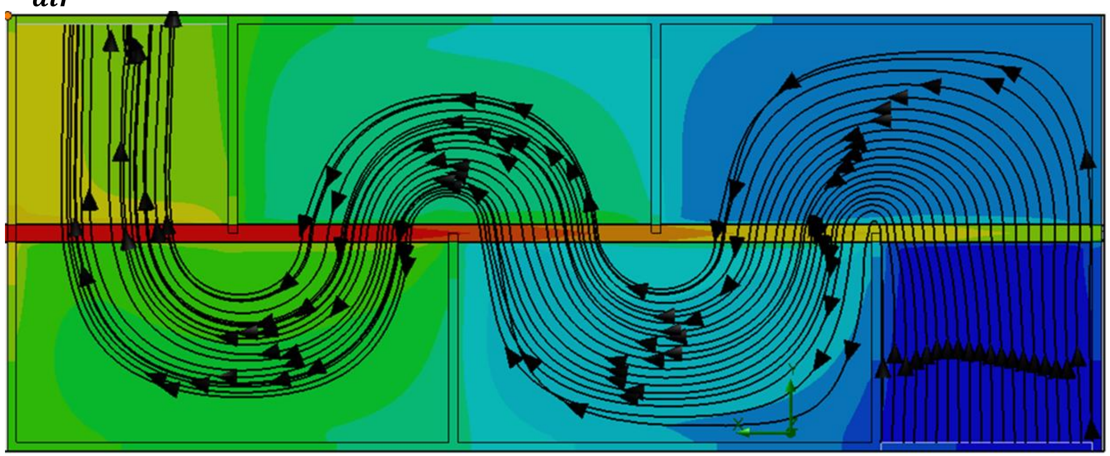
T^{outlet}_{air} = 412 K

T^{inlet}_{air} = 293 K



T^{outlet}_{air} = 405 K

$T^{inlet}_{exhaust}$ = 533 K



$T^{outlet}_{exhaust}$ = 420 K

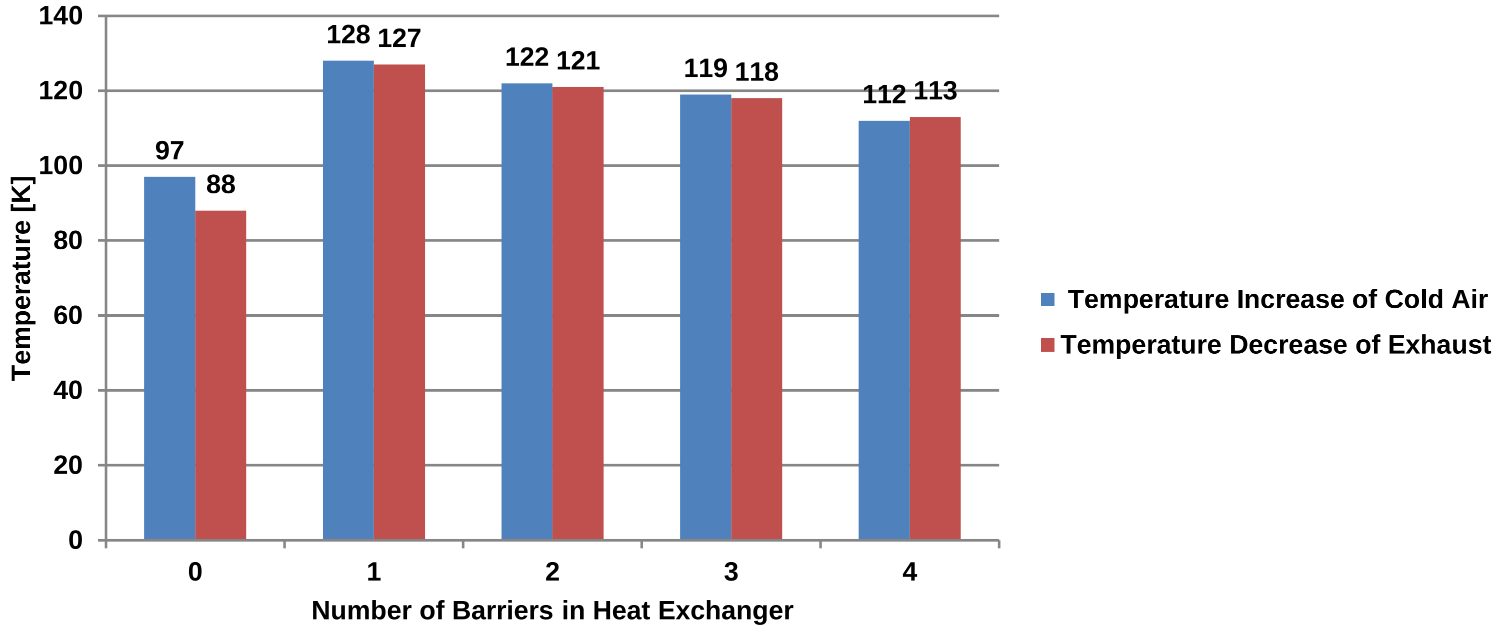
Four Barrier Design

T^{inlet}_{air} = 293 K

Heat Transfer Results

Type	Air Outlet Temperature [K]	Exhaust Outlet Temperature [K]	Efficiency
No barrier	390	445	0.37
1 Barrier	421	406	0.53
2 Barriers	415	412	0.50
3 Barriers	412	415	0.49
4 Barriers	405	420	0.47

$$\varepsilon = \frac{T_{air}^{outlet} - T_{air}^{inlet}}{T_{exhaust}^{inlet} - T_{air}^{inlet}}$$



Cost Analysis

Calculations		
Energy per ft^3 of natural gas	1,028	BTU
Total Energy in a day	1,227,304,528	BTU
Plant Usage January 2013	29,356,000	ft^3
Price / 1,000 BTU	$5.16	
New Heat Exchanger Uses	38,111.20	$\frac{BTU}{day}$
Price / Day	$196.65	
Price / Day of Steam	$775.20	
Savings / Year	$196,707	
Payback Period	$\leq$ 3 years	
Max Allowable Investment	$590,121	

Conclusion

- Natural gas burner design
- Heat exchanger with 1 barrier has best heat transfer
- Use exhaust air to run through heat exchanger
- Proposed design will process over the 200 ton constraint
- Estimated savings of $197,000 per year
- To meet the constraint of a 3 year payback, the max allowable investment is $590,000

References

- **Clint Chadwick**
  - **Environmental Coordinator**
  - **Nestle Purina Pet Care, Flagstaff, AZ**
- **Chad Girvin**
  - **Processing Maintenance Team Leader**
  - **Nestle Purina Pet Care, Flagstaff, AZ**
- **Buhler Aeroglide Natural Gas Dryer**
  - **http://www.aeroglide.com/snack-dryers-roasters-ovens.php**
- **Figliola, R. S., & Donald E. Beasley. 2011, *Theory and Design for Mechanical Measurements* (5th ed.; Hoboken, NJ: Wiley)**
- **Baumeister, Theodore, & Ali M. Sadegh, & Eugene A Avallone. 2007, *Marks' Standard Handbook for Mechanical Engineers* (11th ed.; New York, NY: McGraw-Hill)**
- **White, Frank M. 2011, *Fluid Mechanics* (7th ed.; New York, NY: McGraw Hil)**