Alabama Industrial Assessment Center

Industrial Dryer Spreadsheet Model

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Outline

- Large energy user report format
- Summary of dryer system
- Current operation of the dryers
- Energy savings recommendation
- Understanding the current system operation
- System Models
  - PHAST
  - Combustion/Heat loss spreadsheet model
  - Minute by minute analysis
- Energy savings projects
- Results

Large Energy User Report Format

- Have the opportunity to work with large energy users from additional funding received from different sources
- LEUs consume over $2.5 million in energy a year
- Choose 2 energy consuming processes
- Perform a detailed analysis of the system
  - Prefer to use DOE Best Practices Software when possible
- Based on detailed analysis come up with energy savings recommendations

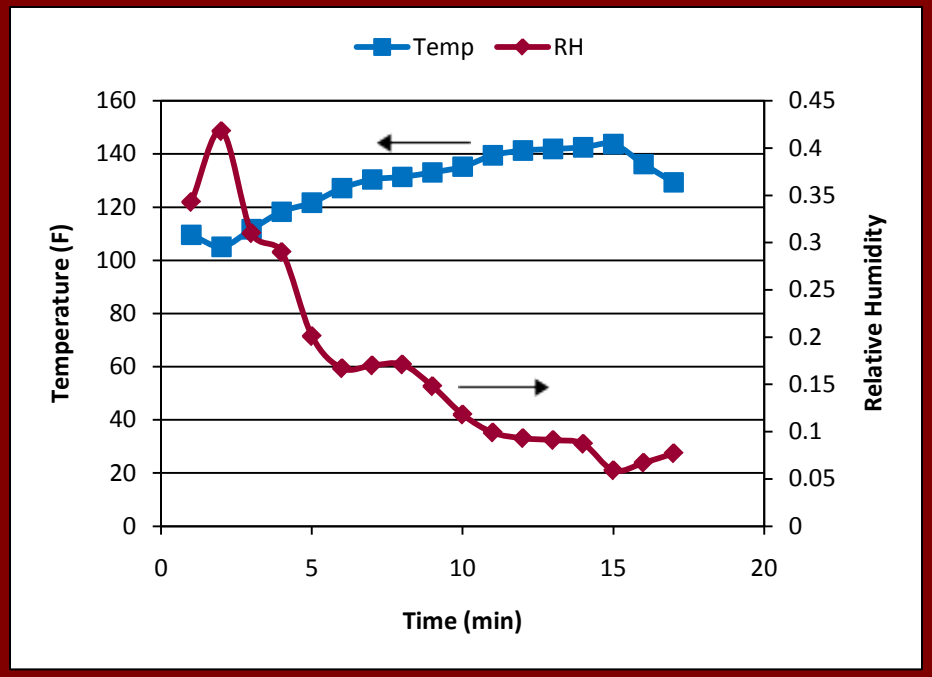
Dryer System

- 17 large industrial dryers
  - Natural gas fired
  - 2.7 MMBtu/hr capacity
- Used to dry about 500 pounds of bathroom style rugs at once after a dying process
- Typical run times of 25 minutes per cycle
- The system consumes about 40,650 MMBtu/yr

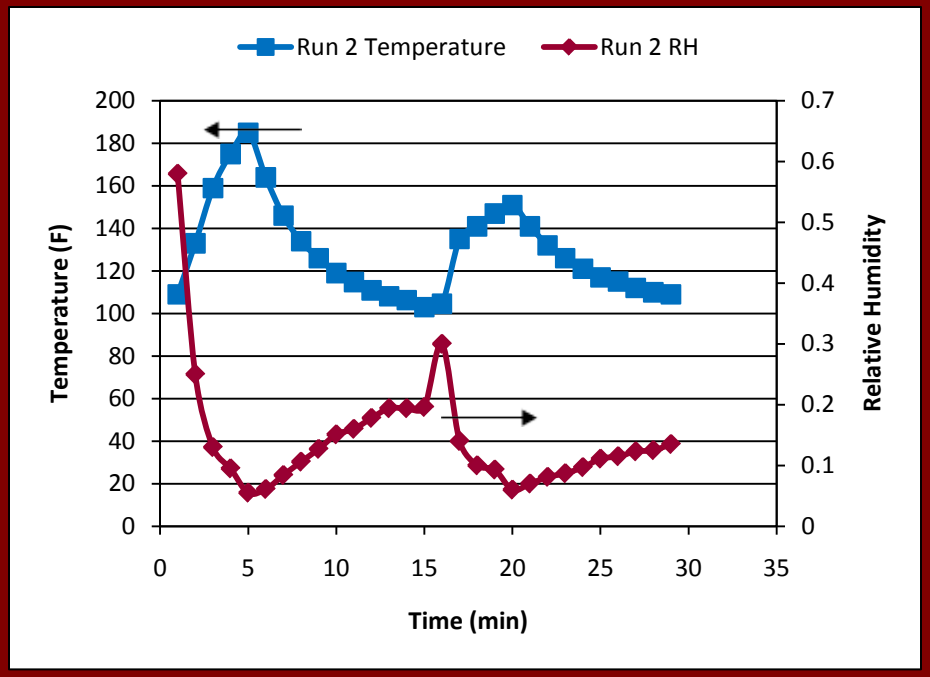
Dryer System Controls

- Each dryer is equipped with a temperature and relative humidity sensor
- The burners are controlled to supply air at prescribed temperature based on product
- Cycle runs either on timer or until the relative humidity of the exhaust stream falls to 10%

Cycle Data



Dryer Data Run 1



Dryer Data Run 2

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Understanding the Current System

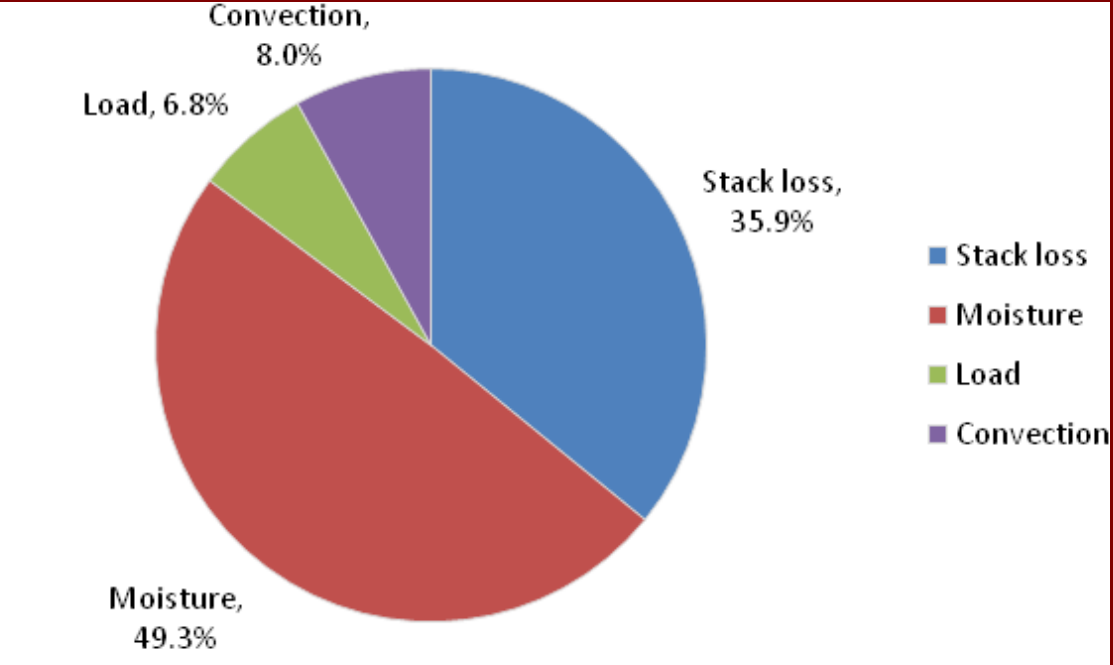
- The DOE software tool PHAST was used to simulate the dryer system
  - Greatly underestimated energy consumption
  - Not designed for such low temperature, dynamic systems

Understanding the Current System

- Because DOE Best Practice Tools were not applicable, spreadsheet models were constructed
- A combustion/heat loss analysis was done to determine an estimate of energy consumption required
  - Exhaust air temperature, O_2 content, wall temperatures and rug initial temperatures and water content are known

Understanding the Current System

- Determined energy consumption to be 0.6 MMBtu/hr for each dryer
  - Energy use is broken down as follows



Understanding the Current System

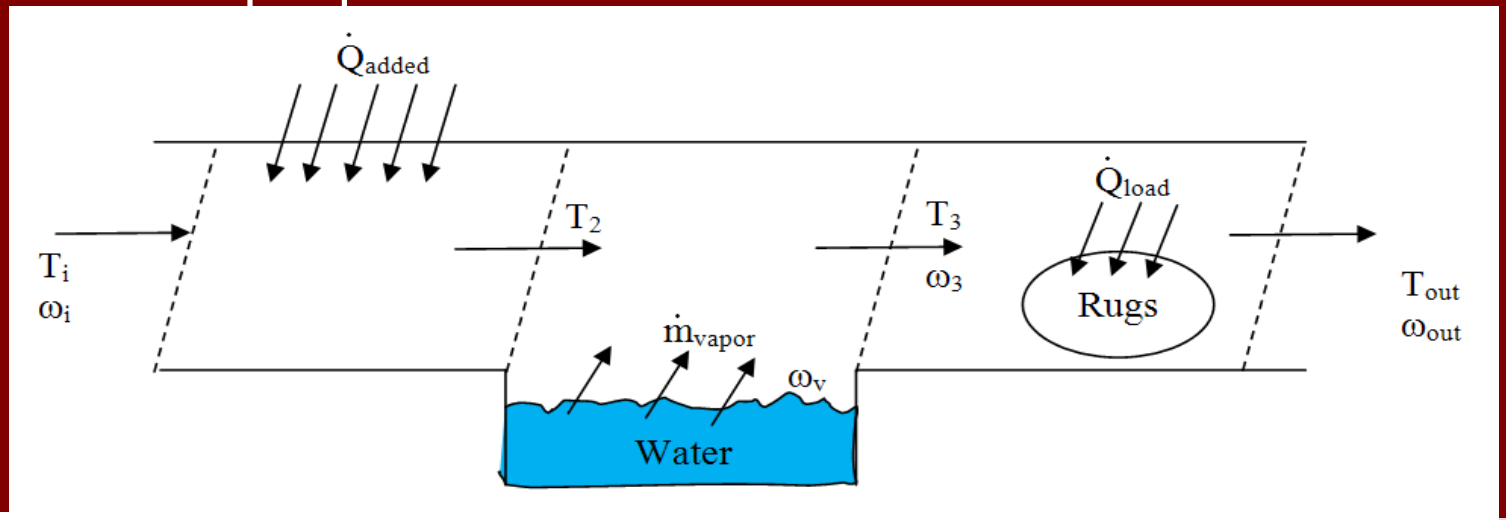
- A third model was created in a spreadsheet to verify the combustion analysis
  - Calculated the energy required on a minute by minute basis based on observed operating conditions
  - The results of this analysis was found to be 0.66 MMBtu/hr, matching closely with the previous analysis

Current Operation

- The hot air forced into the dryer is exhausted to the atmosphere after one pass
- Recommended implementing a system that would allow this hot air to be re-circulated to decrease natural gas consumption

Air Recirculation Model

- Once the baseline operation was established a recirculation spreadsheet model was created
  - This model of the drying process was broken down into 3 simple processes as shown



Air Recirculation Model

- The first section involves heating the air from inlet conditions to the appropriate temperature
- The second section involves the heated air removing moisture from the rugs
- The third section involves adding sensible heat to the rugs to increase their temperature

First Section

- Heat is added to the air which simulates the energy input by the NG burners
- Humidity Ratio (ω_i) is constant while heat is added
- Two mechanisms were included to remove moisture from the rugs
  - Drying by temperature difference
  - Diffusion which is driven by humidity ratio differences

First Section (cont.)

- These two mechanisms are represented by the following equation

$$\dot{m}_v = hA_T \times (T_2 - T_{load}) + hA_{\omega} \times (\omega_v - \omega_i)$$

  - where hA_T and hA_{ω} represent an unknown "mass transfer coefficient times surface area"
  - These two parameters were found by matching the model data to the observed data
- The temperature difference drying mechanism was found to dominate the equation

Second Section

- The incoming conditions to this section are known from the previous analysis
- The air in this section is absorbing moisture from the rugs

$$\omega_3 = \omega_i + \int_t^{t+dt} \dot{m}_v dt$$

- As a result of the moisture absorption, the exiting temperature will be lowered and can be found using an energy balance from state 2 to state 3

$$h_{a,2} + \omega_i h_{v.2} = h_{a,3} + \omega_3 h_{v.3}$$

Third Section

- The third section assumes that the temperature of the rugs will be raised to the incoming air temperature by convection
- This rise in temperature of the rugs is an unavoidable byproduct of removing the moisture from the rugs but is ultimately wasted energy

Dynamic Model

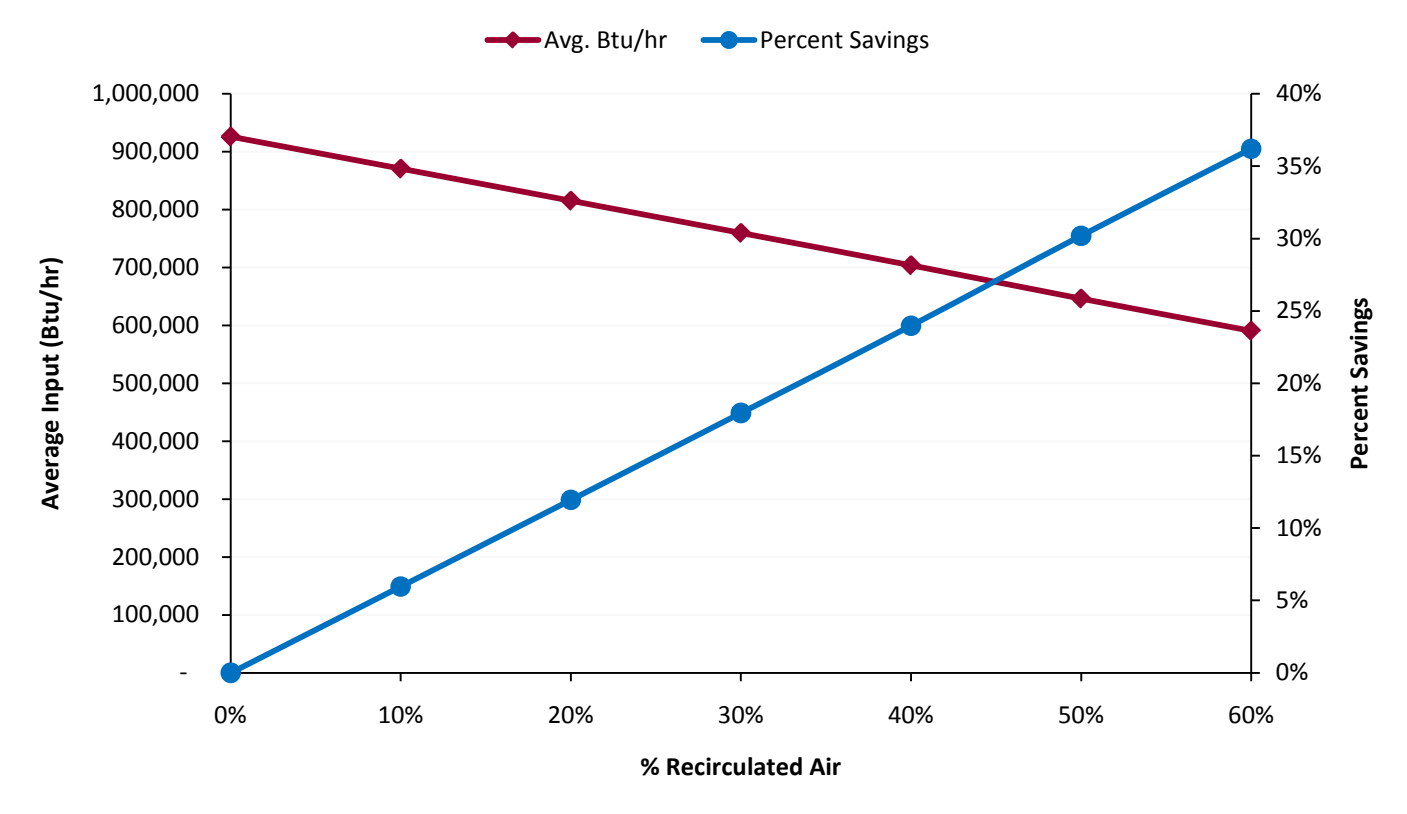
- The three sections were simultaneously calculated in a spreadsheet
- Repeated in 0.1 minute increments until the exhausted air moisture content was negligible
- To consider air recirculation, the inlet temperature and humidity ratio were modified at each time step by mass averaging the assumed amount of recirculated air

Solving the Model

- Because the exhaust temperature profile was known from the observed data, it was used to find a reasonable solution
- The sum of the exhaust temperature products were subtracted from the same from the observed data
- This cell was then set to 0 by utilizing the Solver function in EXCEL and varying the natural gas burner fraction rates

Results

- The previous solution method was repeated for different recirculation percentages and the results are as shown



Recommendation Results

- $91,320/year in energy cost savings based on a 50% recirculation percentage
- $84,320 initial implementation costs including estimated labor costs
- Less than 1 year simple payback
- Reduction of almost 1/3 of the total energy consumed by the system

Questions?

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