Yankee Hood Drying Temperature Versus Impingement Velocity

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Objectives

- Review various factors that affect Tissue paper drying

- Designing new hood and air systems for optimal energy efficiency based on natural gas and electricity costs:
  - → Impact of Yankee hood supply air temperature and impingement velocity on total operational drying costs.
  - → Establish the <u>practical limits</u> of a Yankee Hood Process Air system

- Assumption: Yankee cylinder drying contribution (R_w steam) constant

Brief Review of Drying Principles

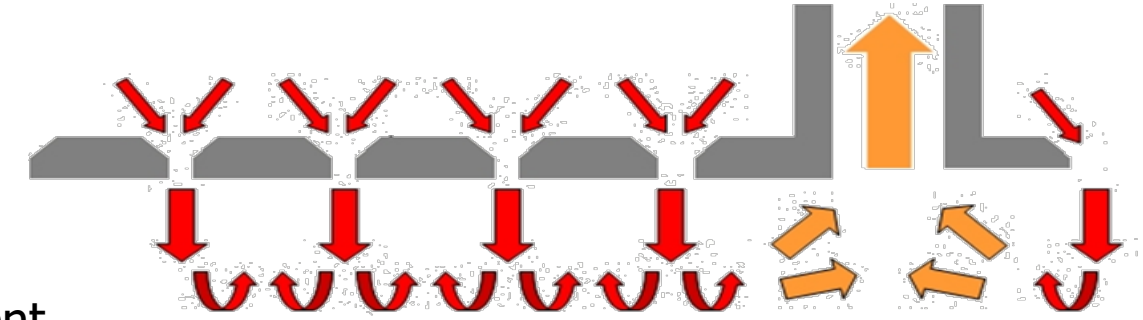
$R_w Hood \infty H \times A (T_{air} - T_{sheet})$

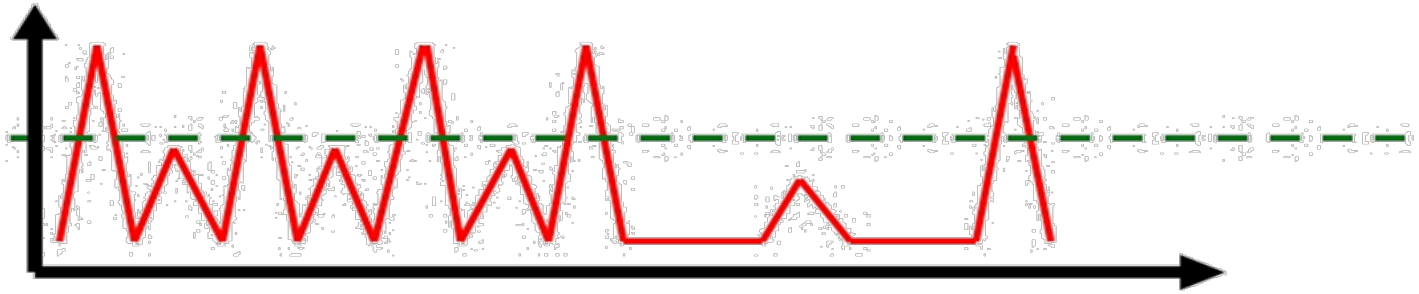
R_wHood: Yankee Hood drying capacity

H: Convection heat transfer coefficient

T_{sheet}: Sheet temperature

T_{air}: Supply air temperature

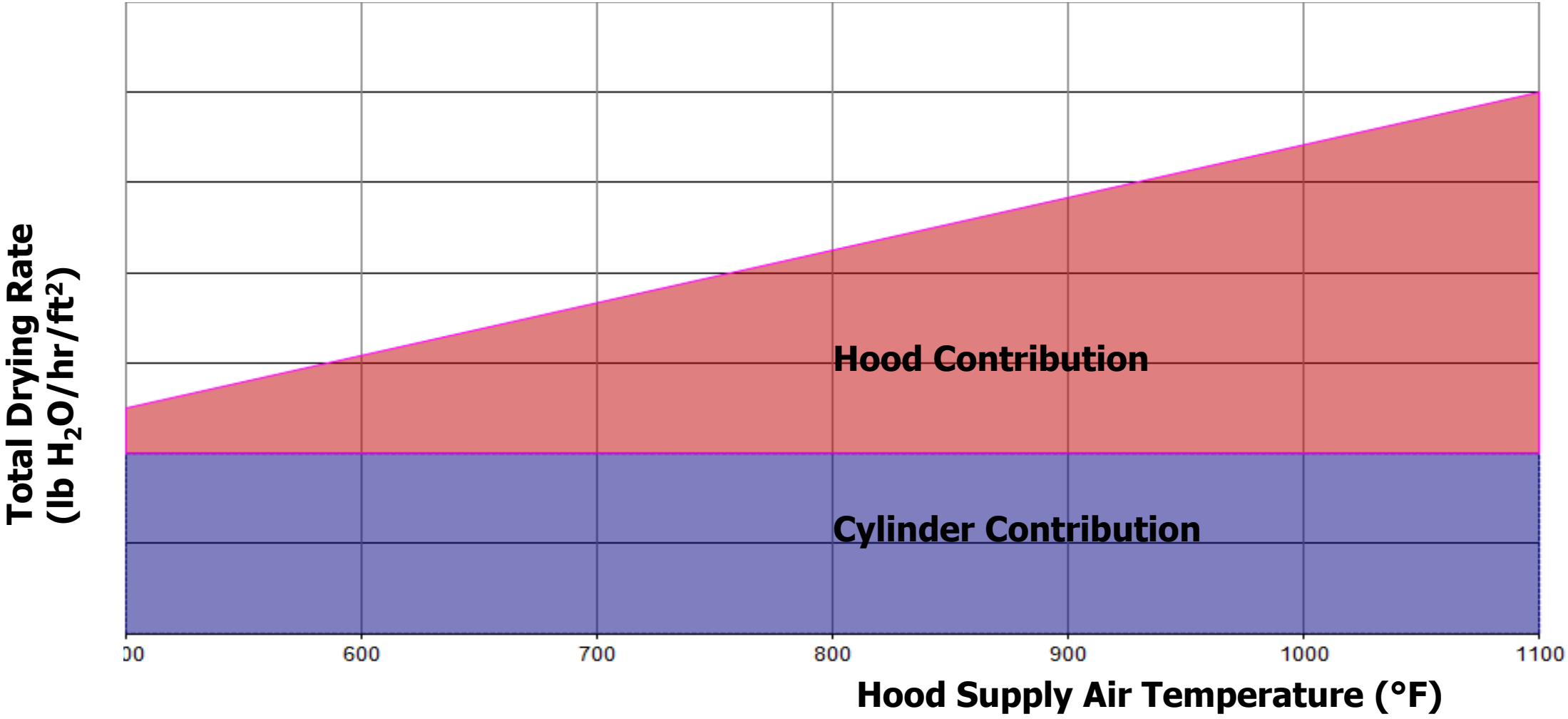




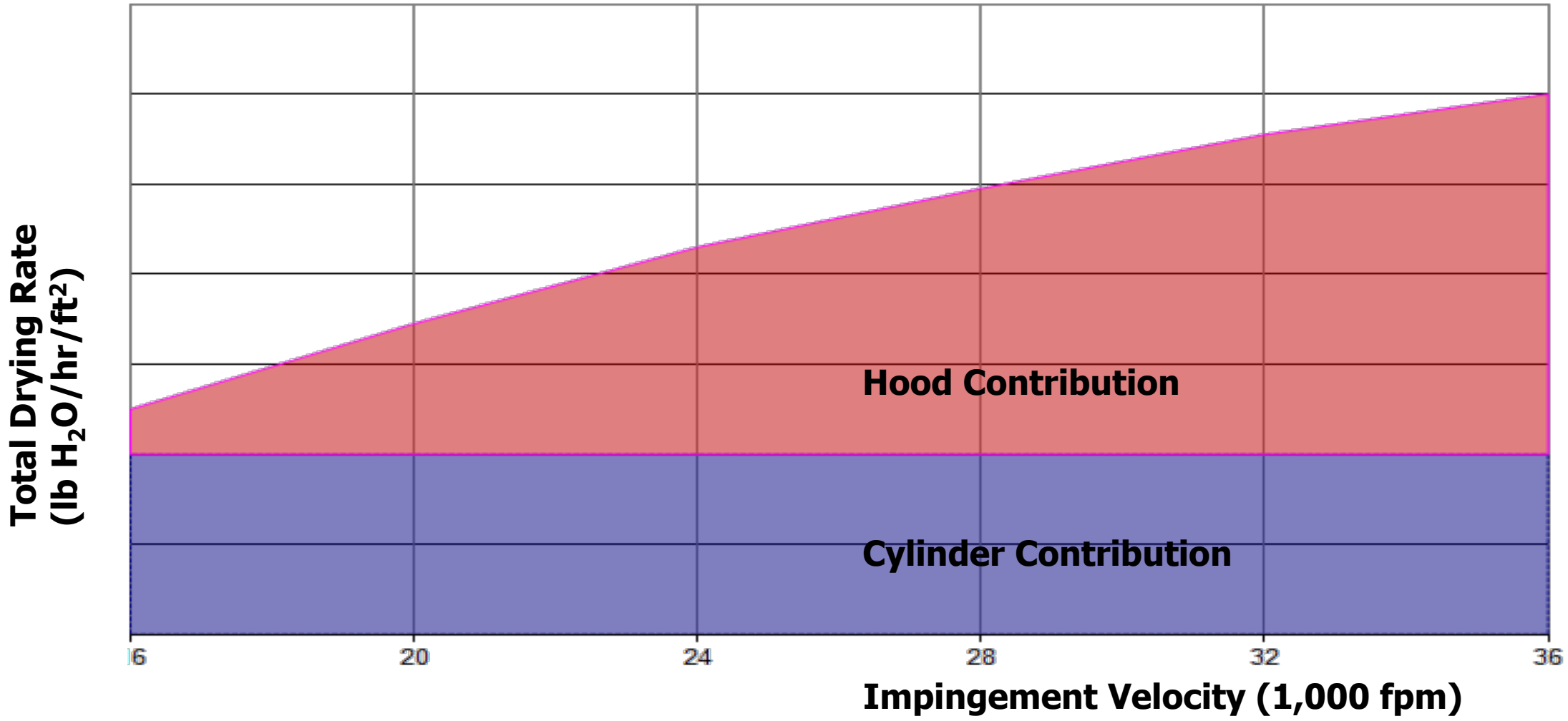
Effect of temperature: temperature differential between air supply temperature (T_{air}) and sheet temperature (T_{sheet}) is one of the main driving forces contributing to drying.

R_w hood is directly proportional to this temperature differential.

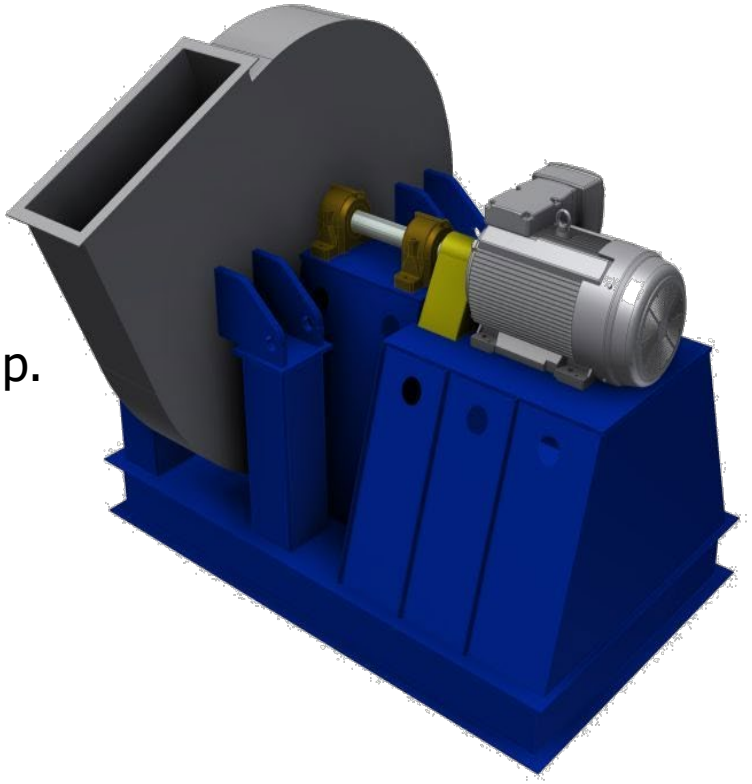
Effect of Supply Temperature on Hood Drying Rate



Effect of Impingement Velocity on Hood Drying Rate



Temperature Limitations



Supply fan metallurgy vs recirculation air temperature:

- Very high operating temperatures require exotic/expensive metallurgy
- Practical design temperature for high temperature fans is:
  - Maximum inlet (discharge) temp. 850F
  - Heat of compression: 50F
  - Hood recirculation temperature typically 75% of hood supply temp.

→ 850F/0.75 = 1,100 F, close to maximum supply temperature while remaining within the comfortable zone.

Minimum temperature to prevent impingement holes plugging problems;
Minimum supply temperature of operation should be approximately 600 to 650F for a recirculation temperature remaining over 450 F (auto-combustion of paper and paper dust).

→ Running for too long below that temperature will cause dust accumulation inside the hood/plugging

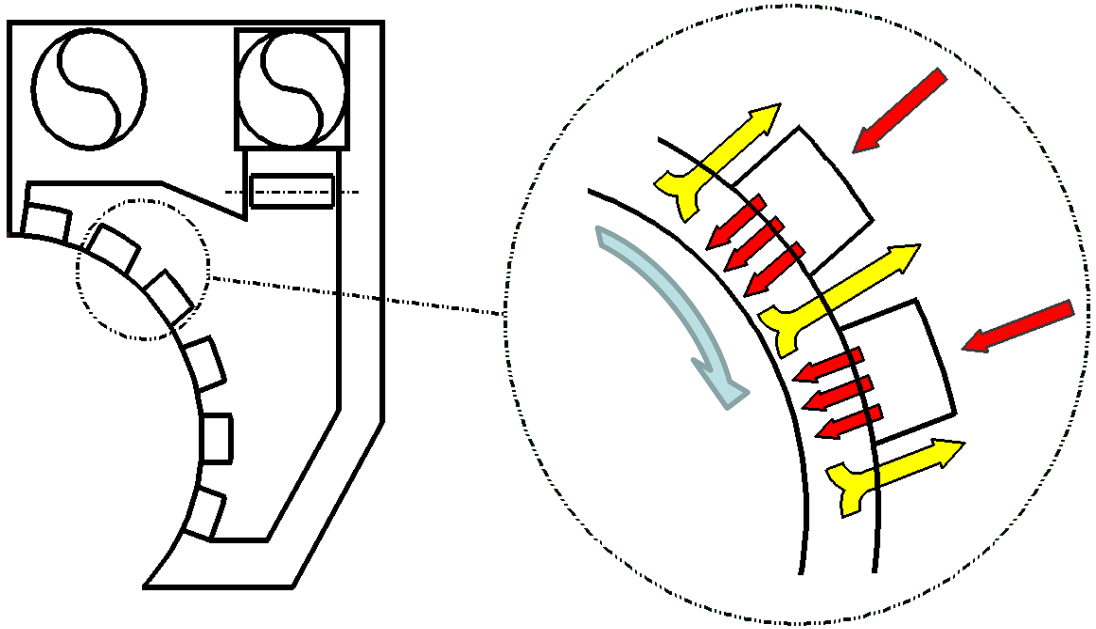
Impingement Velocity Limitations

Supply Fan static pressure limitations vs desired impingement velocity

- Impingement velocity generated by fan static pressure
- **Wheel size** & **RPM** drive **tip speed**. **Tip speed** drives **static pressure**
- Maximum tip speed ~ 40,000 fpm
  - → maximum static pressure = 100 inch w.g. at standard conditions (40 in. at 0.03 lb. Dry Air/ft^3)
  - → 40 inch static pressure corresponds to approximately 36,000 to 40,000 fpm impingement
  - → 40 inch static pressure is considered the economical/efficient fan operational limit.

Minimum impingement velocity vs Yankee dryer speed.

- Impingement velocity should be at least 4 times higher than the Yankee speed.
- When operating below this ratio, the convective heat transfer coefficient is affected negatively.



Drying split: Yankee Cylinder vs Yankee Hood

Typical Energy Split

- 40 to 50% Yankee cylinder
- 50% to 60% Yankee hood

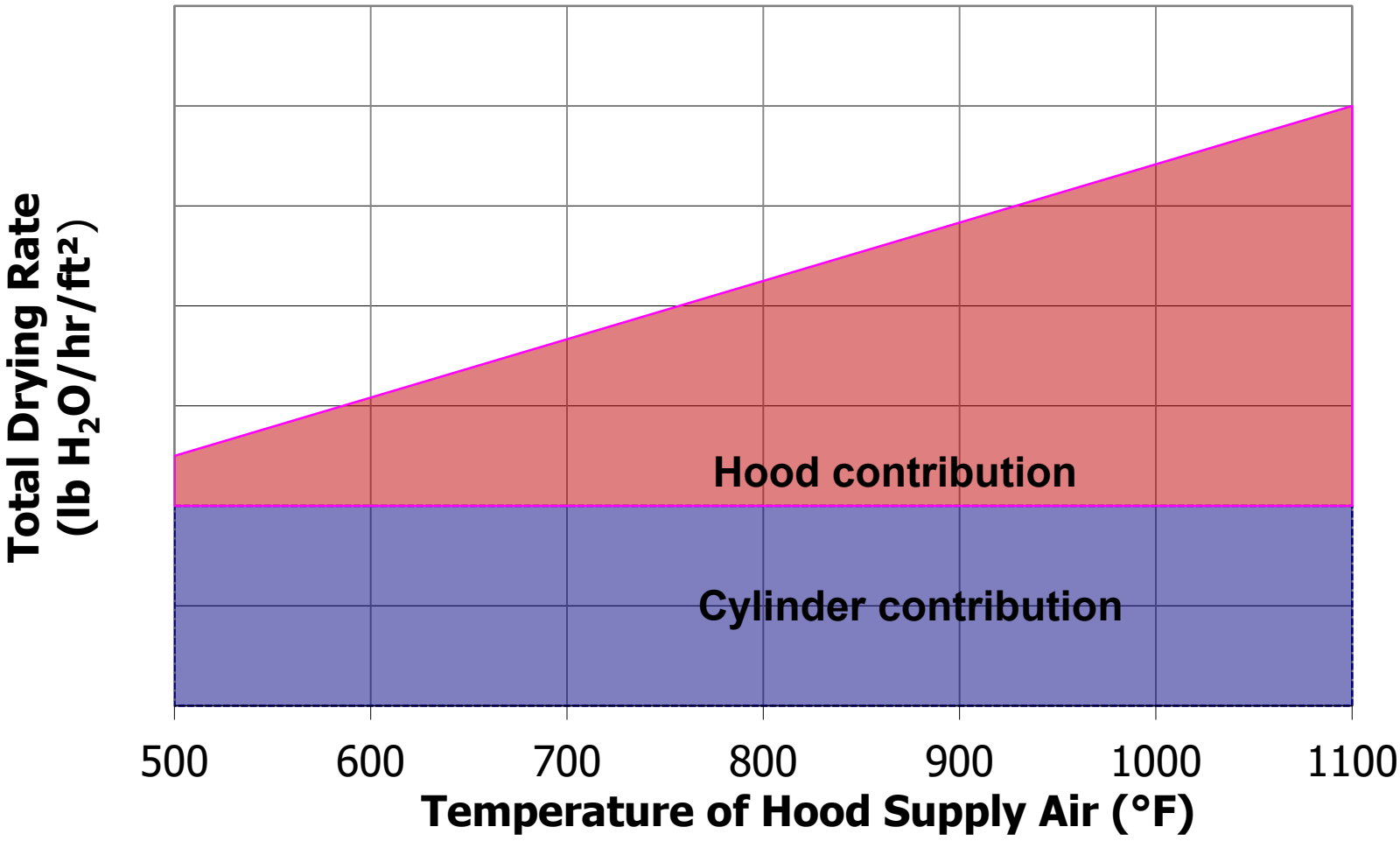
Upper Limits

Steel Yankee cylinders:

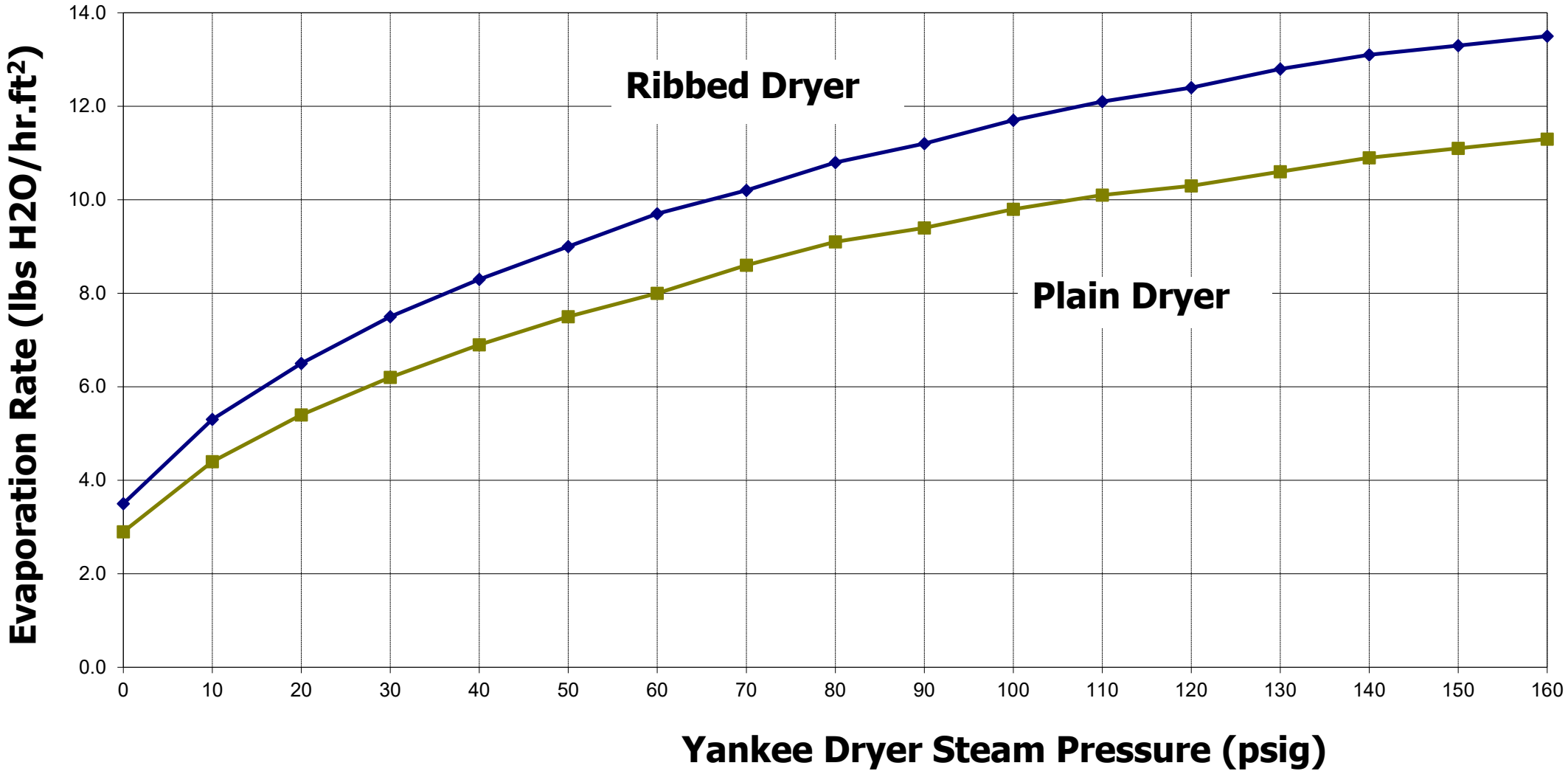
- R_w steam = ± 15 lbs $H_2O/hr/ft^2$

High Temperature Yankee Hoods:

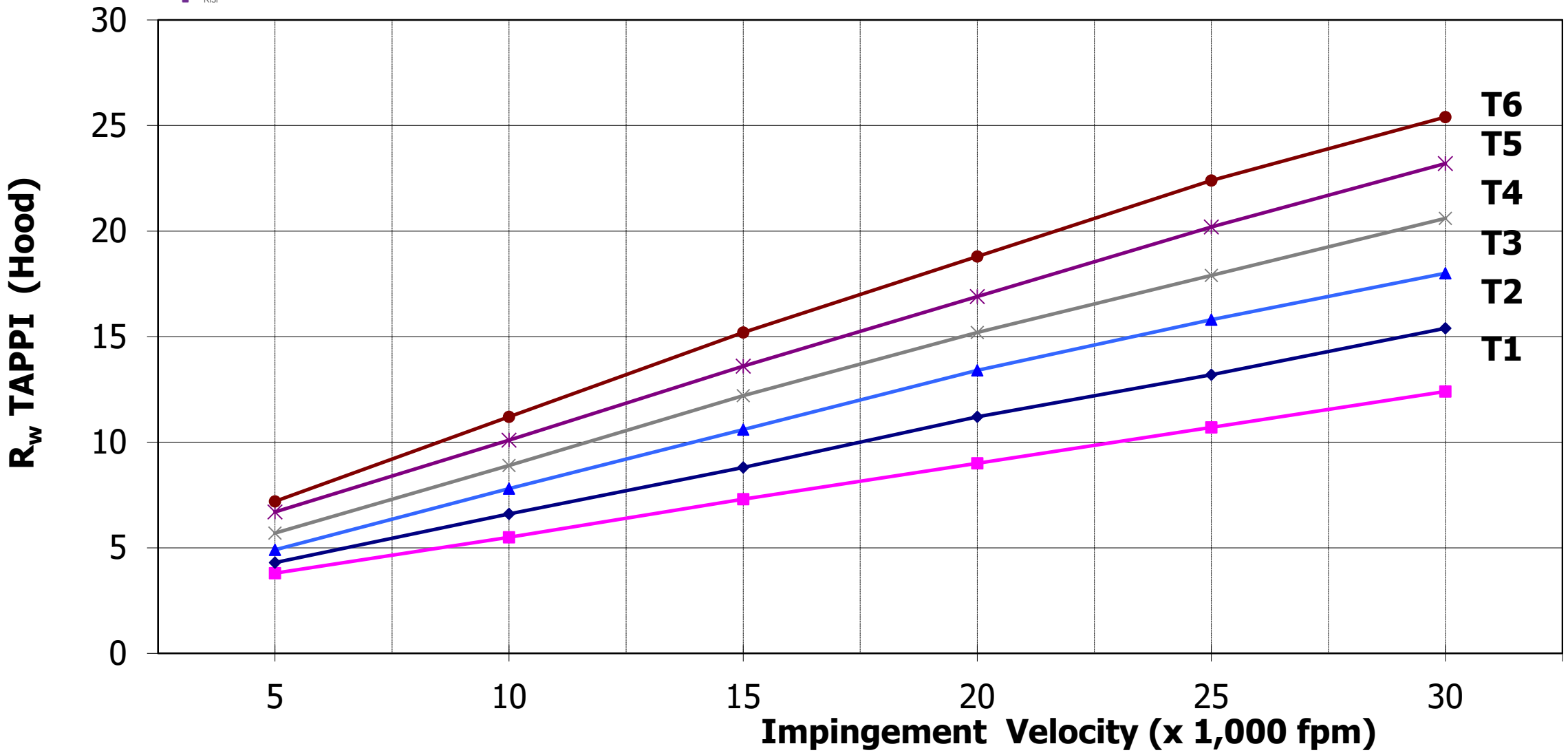
- R_w hood up to 30 lbs $H_2O/hr/ft^2$
- The drying split becomes;
- 66% hood / 33% cylinder



Evaporation Rate vs Yankee Steam Pressure



Typical Yankee Hood Drying Curves



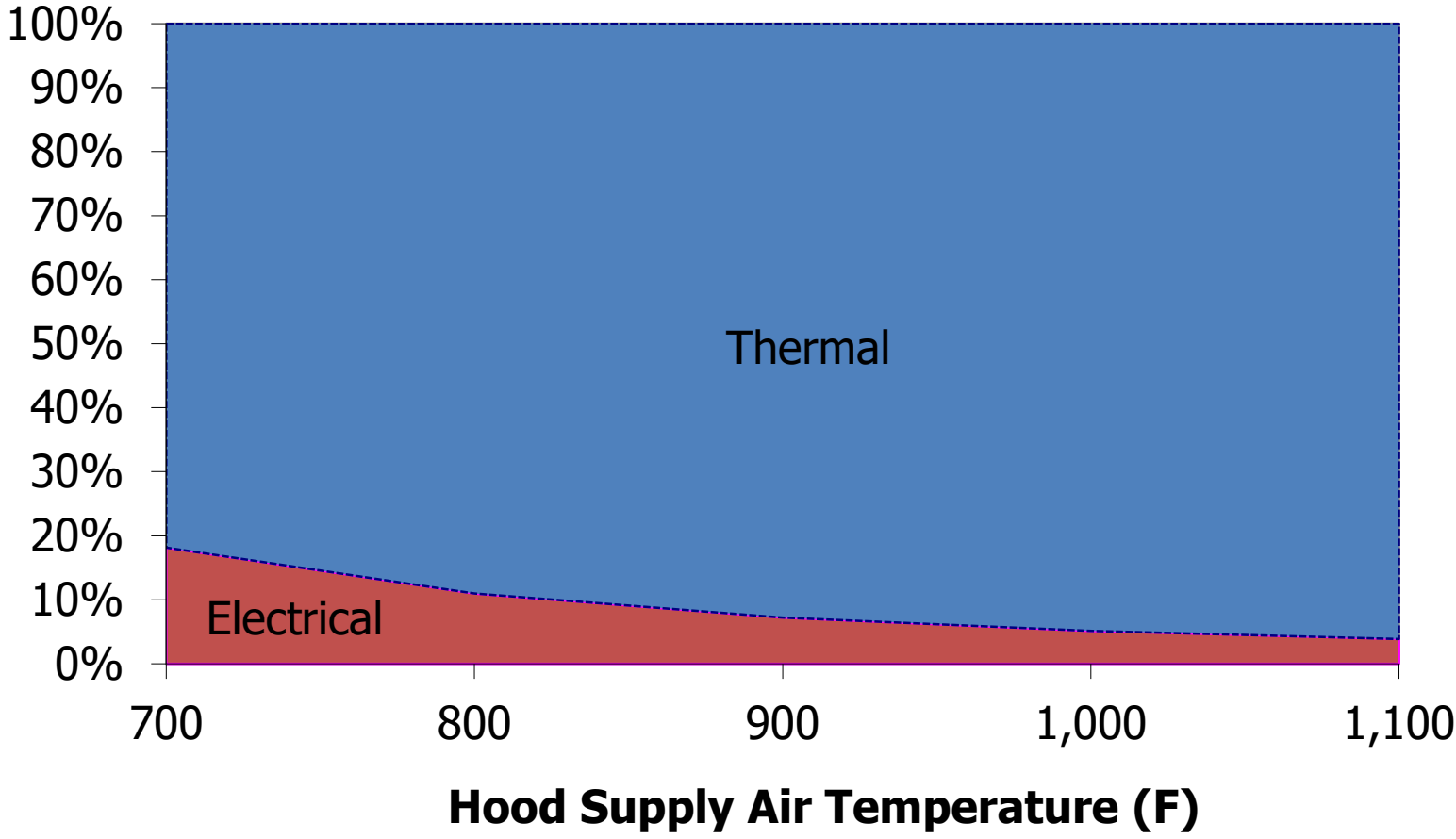
Hood Energy Split: Thermal vs. Electrical

<u>For typical operating temperatures</u>
800°F ≤ T° supply ≤ 1000 °F

- **Thermal Energy = 90% to 95%**
- **Electrical Energy = 5% to 10%**

Electrical energy based on 75% fan static efficiency.

Thermal energy based on 100% hood air balance, 30,000 fpm impingement velocity.



Thermal Efficiency

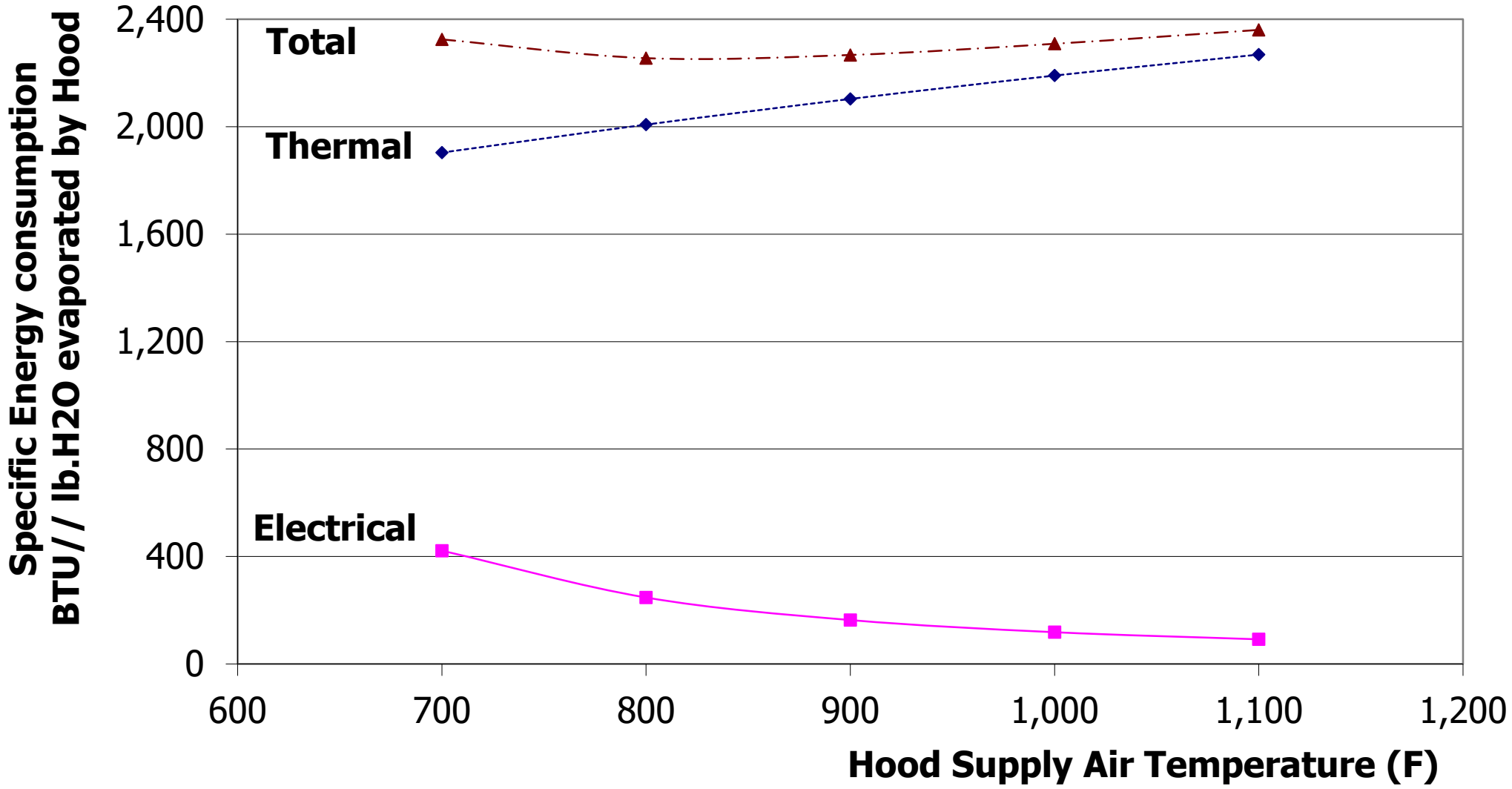
Hood Thermal Efficiency:

Thermal energy required by the hood to evaporate one pound of water (Btu/lb H_2O)

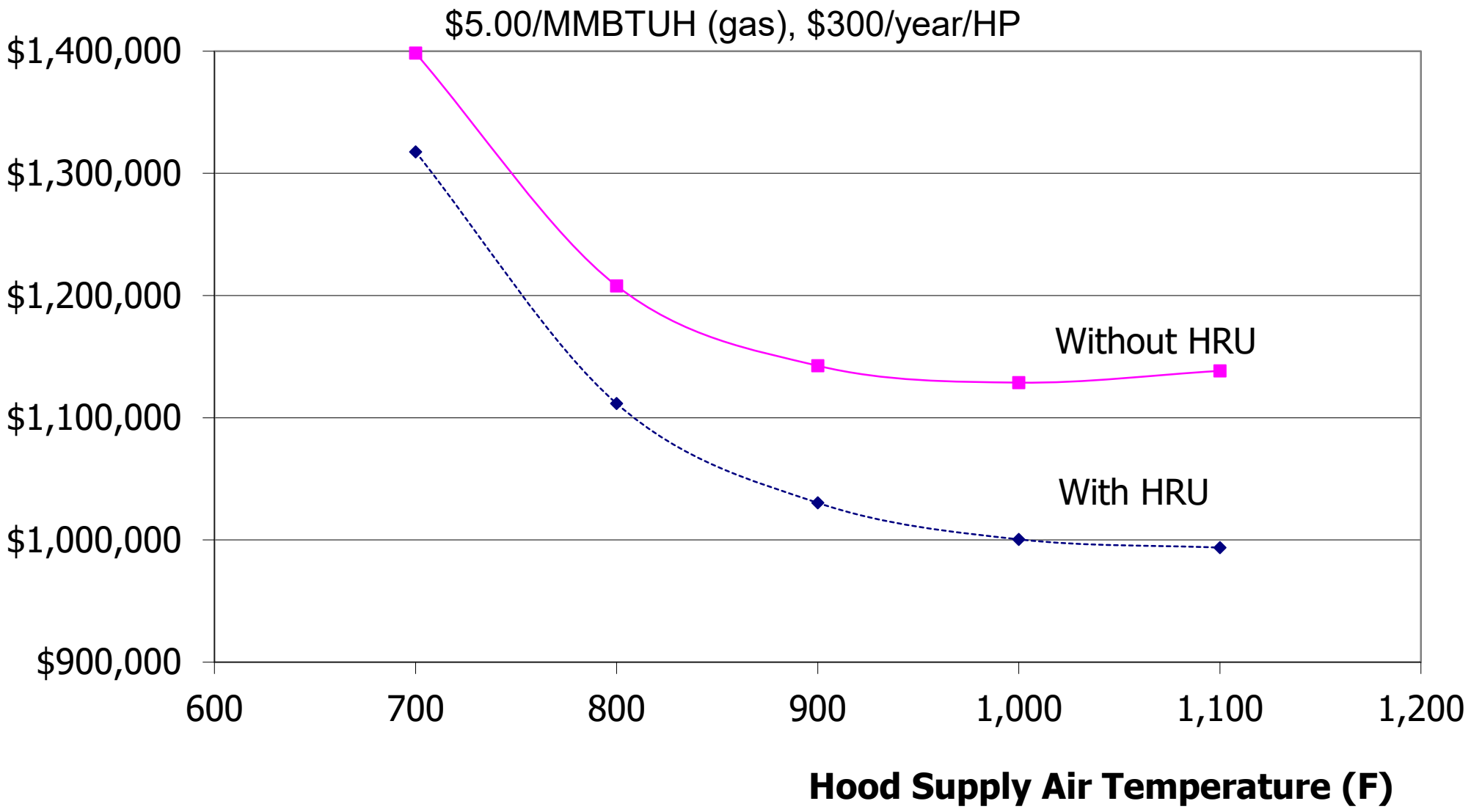
Thermal Efficient for modern hoods → 1,650 to 2,200 Btu/lb H_2O

Cylinder consumes → 1,300 to 1,400 Btu/lb H_2O

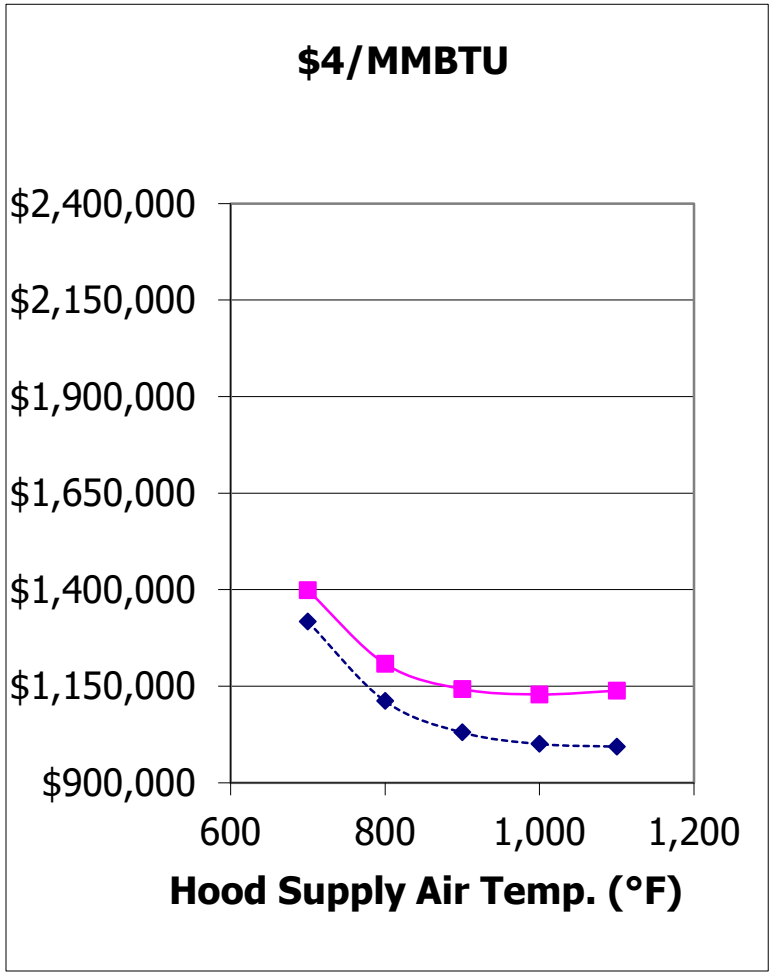
Thermal Efficiency: Air Side Specific Energy Consumption

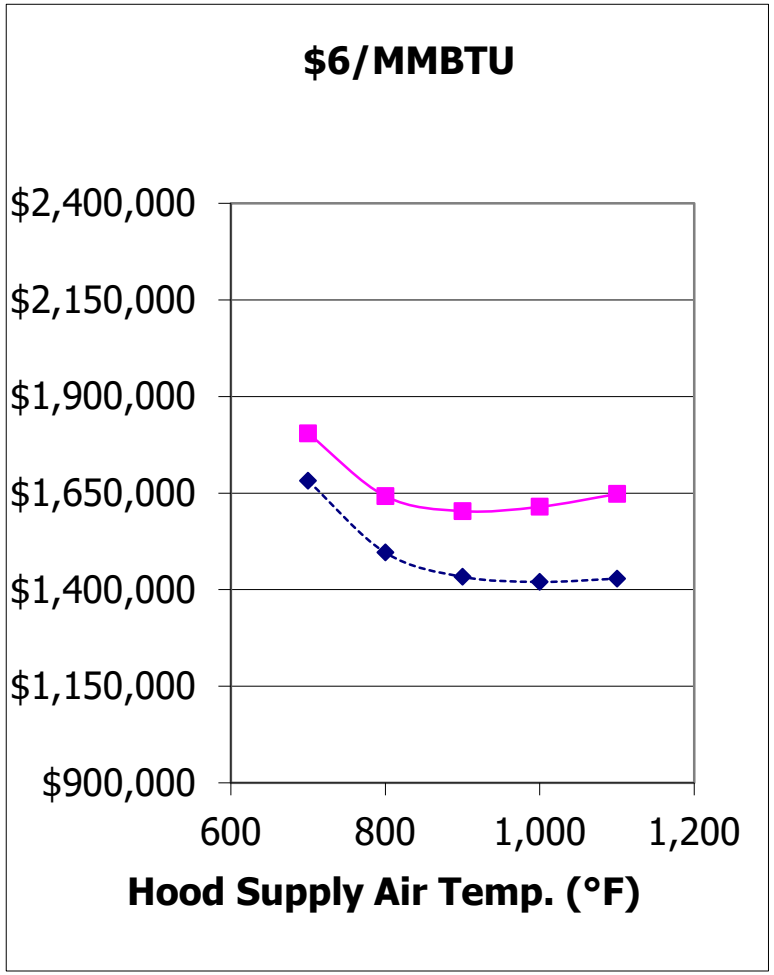


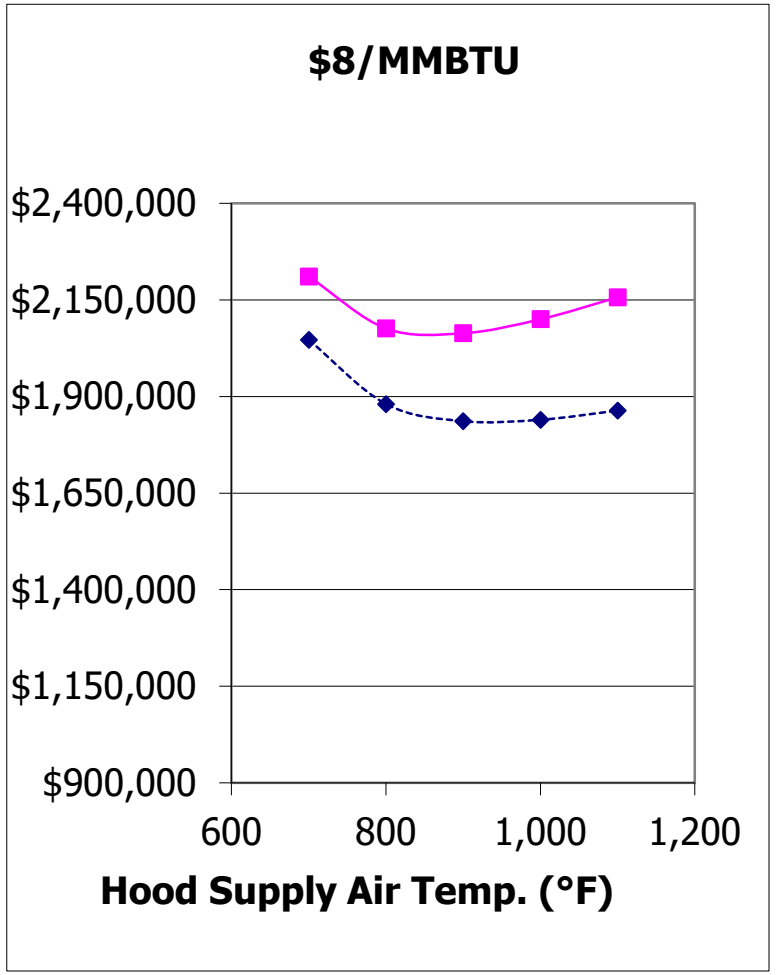
Thermal Efficiency: Annual Oper. Costs (Gas & Electricity)



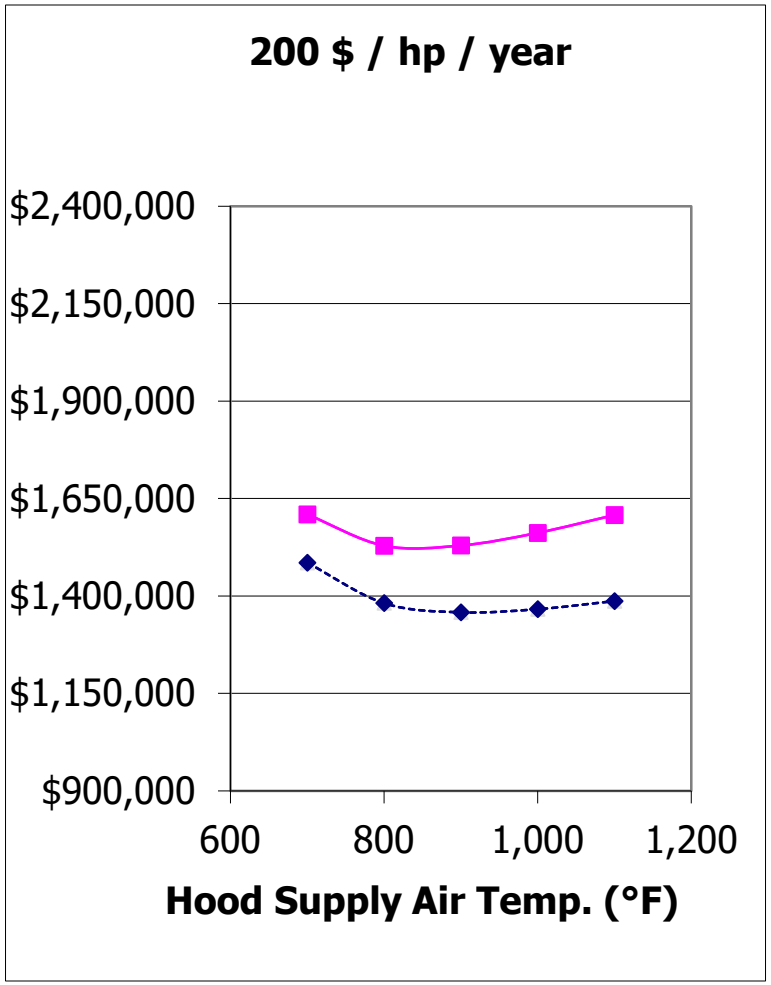
Annual Operating Costs: Varying Cost of Natural Gas

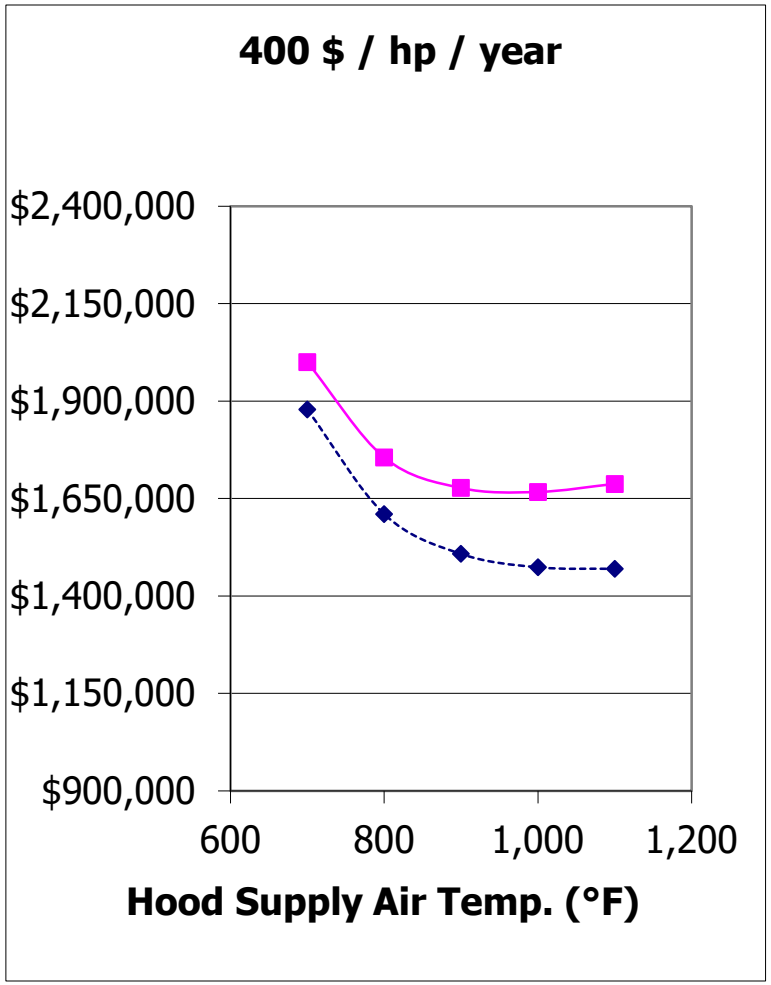


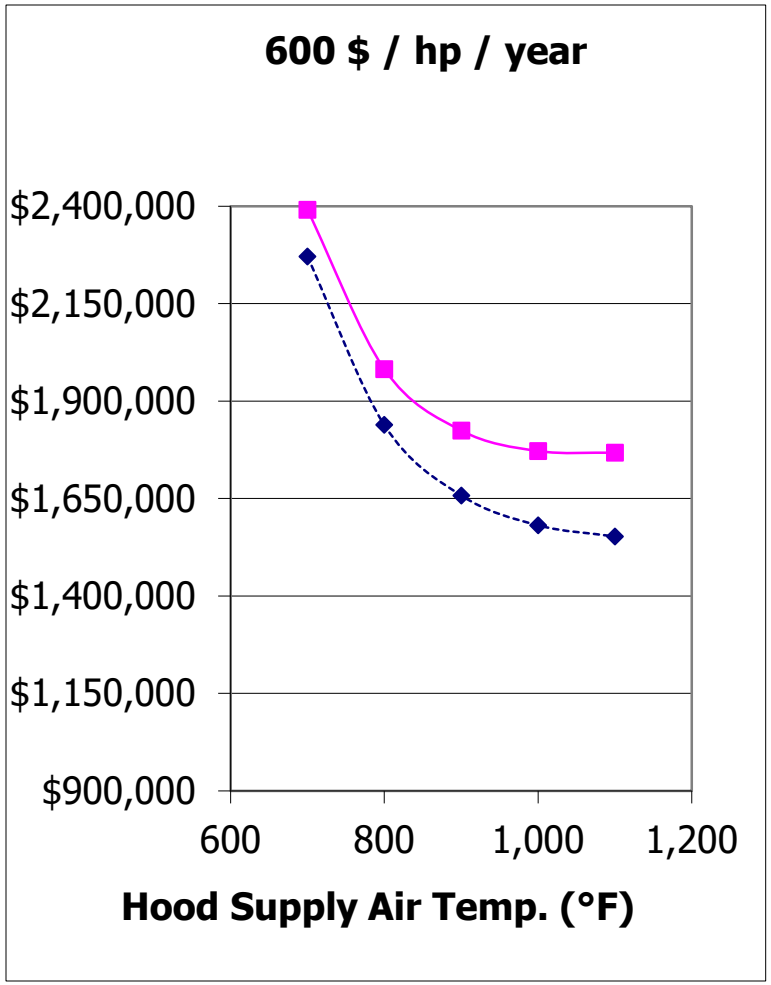




Annual Total Operating Costs: Varying Cost of Electricity





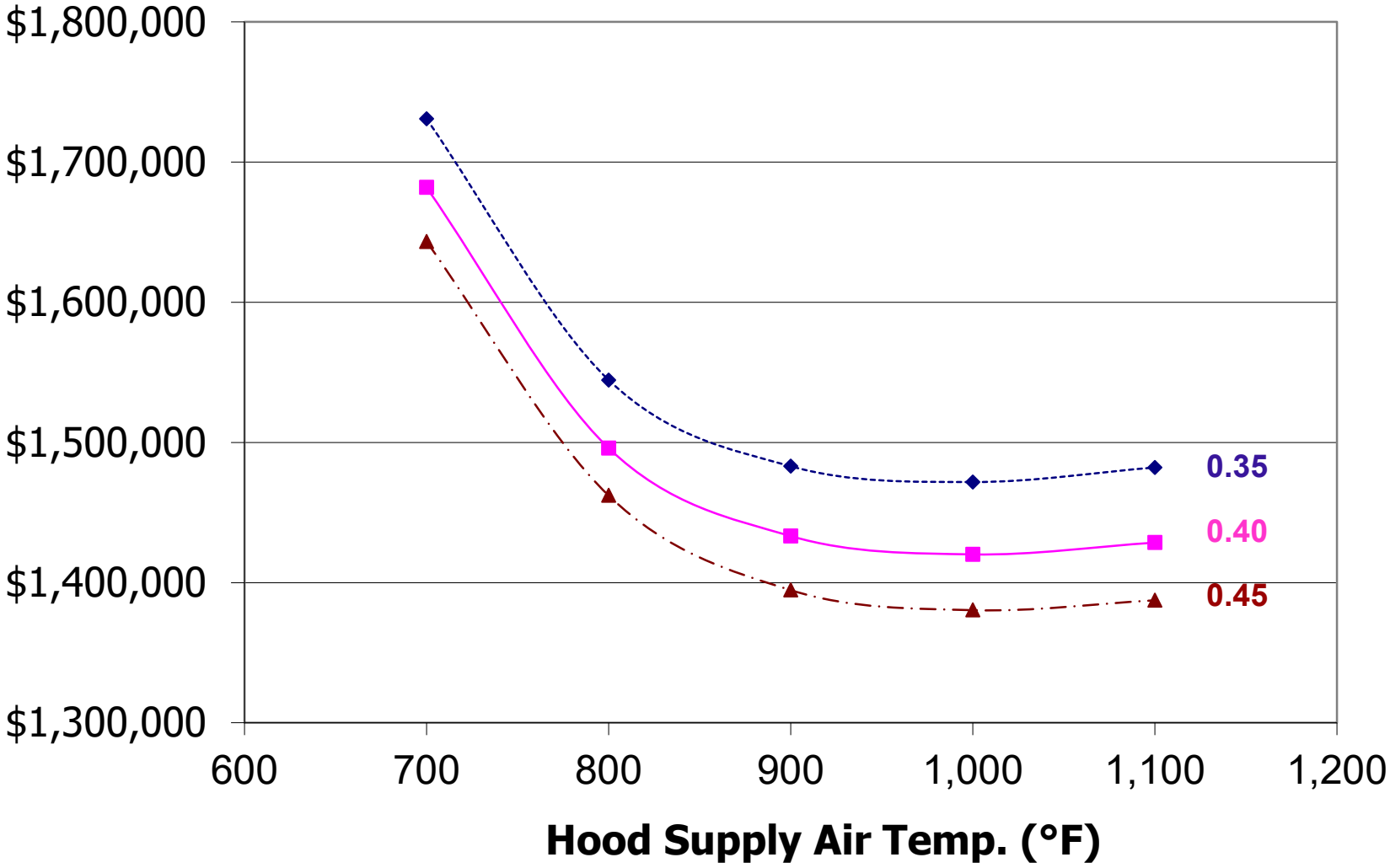


Annual Operating Costs: Varying Exhaust Humidity

Model design parameters:

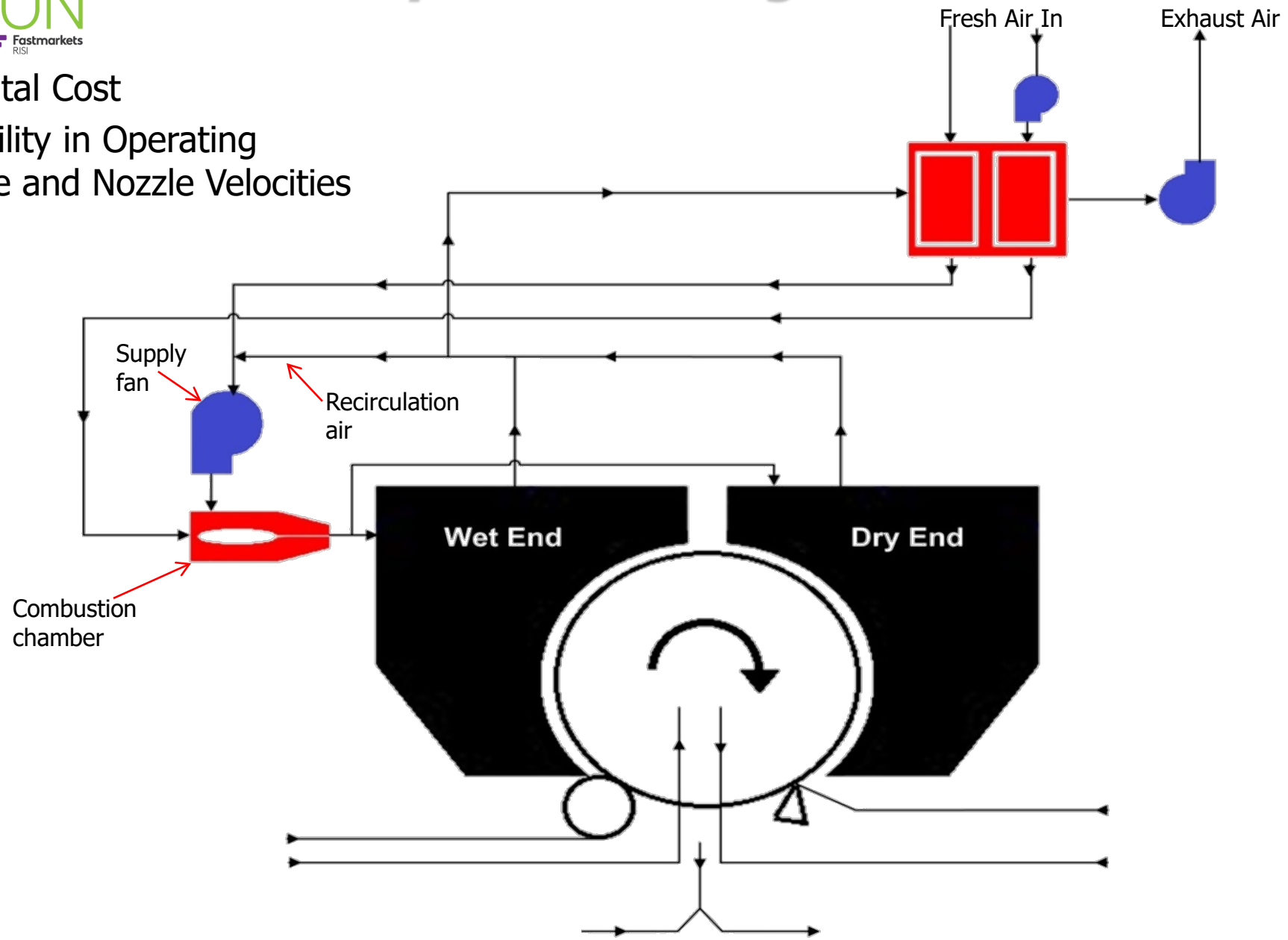
- 150 Ton/day with Heat Recovery
- $6.00/MMBTUH natural gas
- $300 /year/horsepower electrical
- 12 ft. diameter Yankee cylinder

- **Vary Hood Exhaust Humidity**
  - Humidity = 0.35 lb/lb
  - Humidity = 0.40 lb/lb
  - Humidity = 0.45 lb/lb



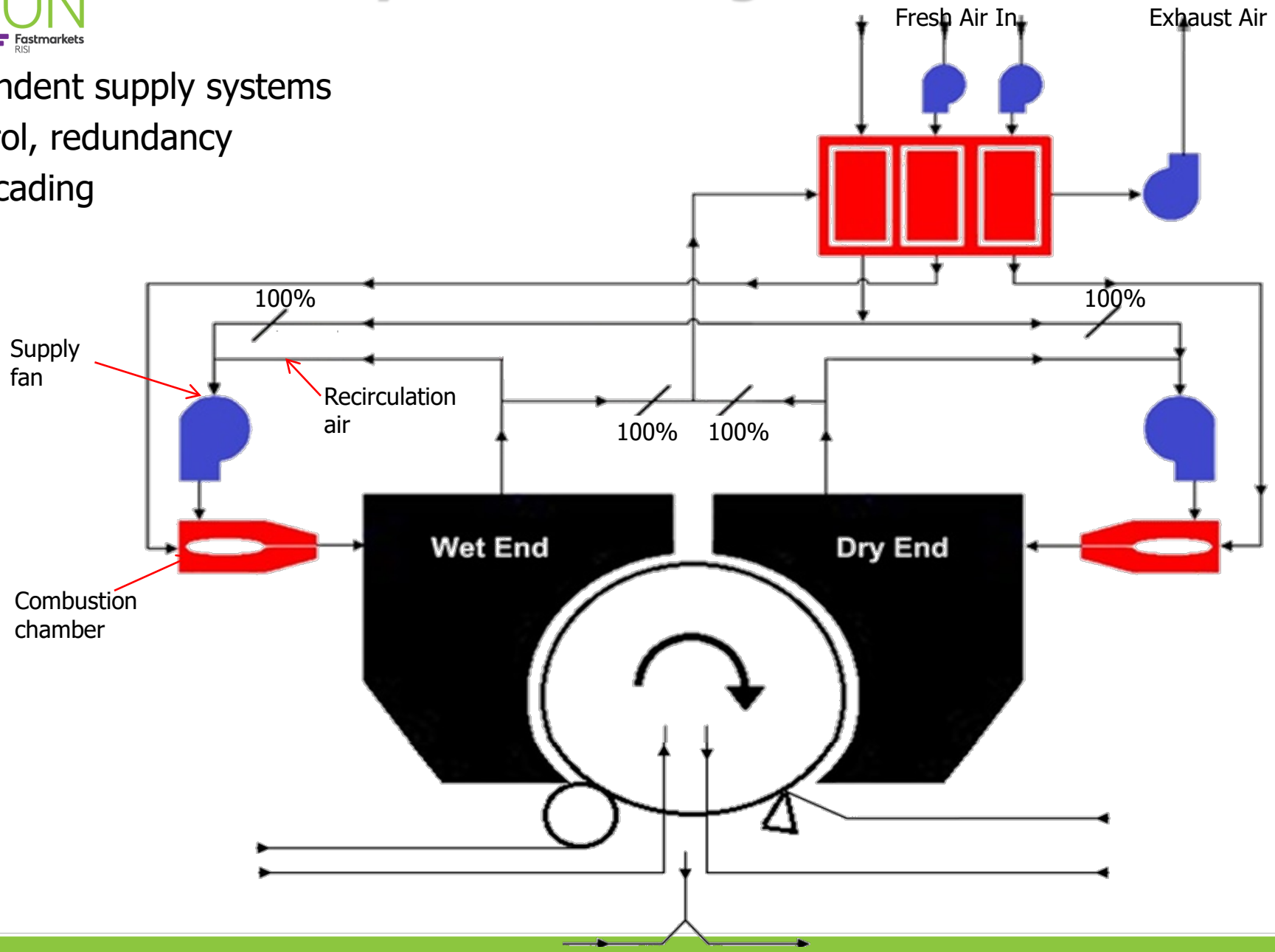
Process Air Systems Configuration: Mono Arrangement

- Lowest Capital Cost
- Least Flexibility in Operating Temperature and Nozzle Velocities



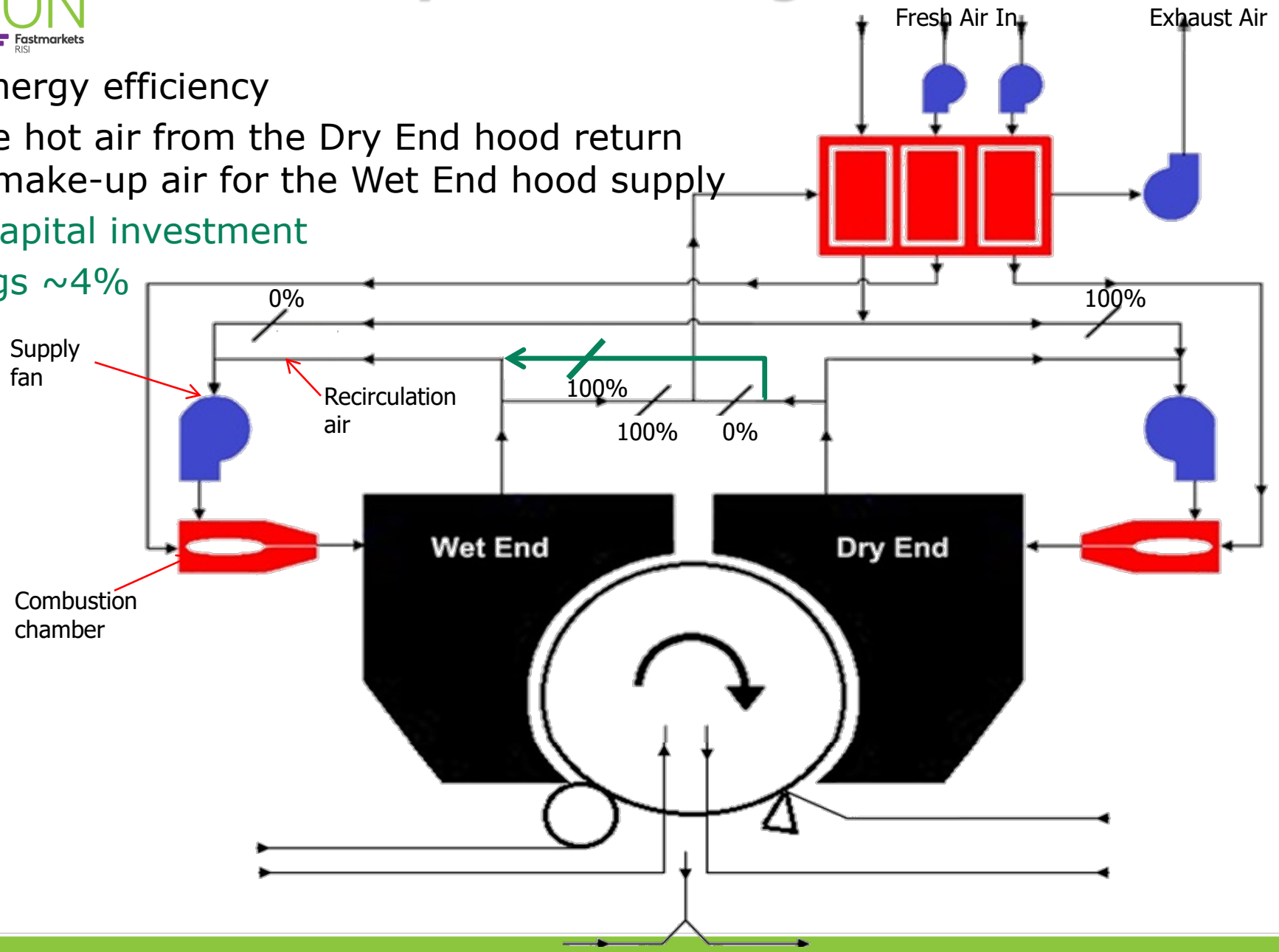
Process Air Systems Configuration: Parallel Arrangement

- Two independent supply systems
- Better control, redundancy
- Permits cascading



Process Air Systems Configuration: Parallel Cascading

- Optimal energy efficiency
- Reuses the hot air from the Dry End hood return to use as make-up air for the Wet End hood supply
- Very low capital investment
- Gas savings ~4%



Process and Combustion Air Heat Recovery Equipment

Recovers additional **sensible heat**

Pre-heating of **combustion air**:

- Always running, very good recovery potential
- Temperature rise limited (Burner components)

Pre-heat combustion air: up to 5% gas savings

Pre-heating of **process make-up air**:

- Not always required (depends on Hood Balance)
- No temperature rise limitations
- Make-up Air is the first cut-back by the operators

Pre-heat make-up air: up to 5% gas savings

Conclusions

When purchasing a new Yankee Hood and Process Air System:

- Maximize the cylinder drying rate first; cylinder thermal efficiency is normally better than hood thermal efficiency
- Optimize impingement velocity vs supply temperature based on current energy costs
- Ideally, choose the parallel system for more flexibility
- For dry crepe operation , going with cascading system is more efficient
- Optimize Combustion and Make-up air preheating
- Operating with "State of the art equipment" will win half the battle on the way to an energy efficient/low cost operation.

Thank you

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