Hybrid Tunnel Ventilation
Combination of Exhaust Fans with Directional ECV Fans
Adult Facility Ventilation

• Freestall (lactating, dry cows & prefresh heifers)
• Parlor
• Holding & Connecting Links
• Active Ventilation is NOT a Seasonal Luxury

Goals of Hybrid Ventilation
Three Legged Stool

• Fresh Air (dynamically balanced inlet & exhaust)
• ECV (Effective Cow-Cooling Velocity)
• Ambient Temperature Drop by High Pressure Fog (supplement as needed with soakers)
Hybrid Tunnel Ventilation Components

- Roof Insulation
- Dynamic Inlet
- Recirculating Fans w/wo Baffles
- Shutter Tie Bar Stabilization
- Exhaust Fans
- Control System (component staging & enviro management)

Other Considerations

- Barn Location & Orientation
- Prevailing Winds
- Lagoon Location
- Flume Vents
- Connecting Links
- Curtain or Polycarb Side Walls
Other Advantages

- **Bird Control** $170/100 Hd Cost (feed, milk loss not including disease potential)
- **Fly Control** (reduced costs, environmental safety)
- **Keep Cows in TNZ** (20-65°F reduced maintenance cost)
- **Seasonal Manure Handling Challenges**

Under Roof Insulation

- **Reduces Heating of Barn Air by Convection**
- **Reduces Thermal Loading from Infrared Radiation**
- **Reduced IR to Cows**
- **Reduced IR to Building Components Concrete, Steel**
Does Insulation Matter?

• Metal roof with no insulation adds 5.5 F by convection to a building environment


Inlets

• Must be Balanced with Fan CFM Capacity
• 1.5 sq ft Opening per 1000 CFM Exhaust Fan Capacity
• Unbalanced Inlet will Increase Facility SP (Static Pressure)
• As SP Increases Fan Performance Decreases
• Air Flow Ratio of Fans
Baffles

- Increase Air Velocity by Reducing Cross Sectional Area
- Velocity = Total Fan CFM ÷ Cross Sectional Area
- Must be Designed to **NOT** Increase SP
- Should Be Located Less than 50 Ft Apart
- Air Follows Path of Least Resistance
- Feeder Lanes & Scrape Alleys Highest Velocities
- Block LDPP Lighting Patterns if Not Translucent

Exhaust Fans

- Determine the Desired Air Exchange Rate of Barn
- Total CFM = Cross Sectional Area X Target FPM
- Role of Exhaust Fan Cones
- Air Flow Ratio > 0.80 = (cfm @ 0.20 SP ÷ cfm @ 0.05 SP)
- CFM/Watt > 19
Energy Efficiency

- CFM/Watt
- AFR (air flow ratio)
- Conflict Between These Two Factors

Air Flow Ratios

Figure 1. Air flow Vs. Static Pressure
Why Are These Shutters Fluttering?

• Fan Belts are Not Tight
• Dirty Fan Blades and Shutters
• Shutters not Tie Barred
• Wind Direction (puts static pressure back against the fans & also impacts inlet)
• Long Cones or Restrictive Exhaust Hood
• Inlet Not Adequately Sized for the Fan Capacity Running (high static pressure)
• Exhaust Obstruction
Cones & Zone of Influence

- Long Exhaust Cones

- Intake Influence Zone is 1.5X the Fans Diameter

- Restricted Intake Zone of Influence adds Static Pressure
Details Matter

40% Reduction in Potential CFM Capacity
**Air Exchange Strategy**

Dilution is the Solution to Pollution

- **Summer Rate:**
  1 Complete Air Exchange/Min
- **Winter Rate:**
  1 Complete Air Exchange/15 Min (may change based on animal size, density & barn length)
- **Winter-Summer Transition Ventilation:** Staging should be no more than 2X the previous setting for CFM output

**THI & ECV**

- **THI Considerations** (Temp/Humidity/ECV)
- **Current Accepted Dairy THI** does not Consider ECV
- **Feed lots** consider Temp, %RH, Solar Gain & Wind Speed
- **Feed Lots Credit for 1.1 ↓ THI per 1 mph Wind Speed**
- **ECVs of 5-7 mph** Reduces THI by 5.5-7.7 Points
Stress Threshold: Respiration rate exceeds 60 BPM. Milk yield losses begin. Repro losses detectable. Rectal Temperature exceeds 38.5°C (101.3°F)

- Milk-Moderate Stress: Respiration Rate Exceeds 75 BPM. Rectal Temperature exceeds 39°C (102.2°F)
- Moderate-Severe Stress: Respiration Rate Exceeds 85 BPM. Rectal Temperature exceeds 40°C (104°F). Death Rates Rise
- Severe Stress: Respiration Rate 120-140 BPM. Rectal Temperature exceeds 41°C (106°F)

- Stress Monitoring System:
  - Logger & cow guard
  - Data acquisition and monitoring
  - Heat stress graph

- THL (Heat Load) in Days:

<table>
<thead>
<tr>
<th>THL Level</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
<th>Day 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Interm.</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>3.5</td>
<td>0.0</td>
</tr>
<tr>
<td>Mild</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>24.6</td>
<td>19.5</td>
<td>0.5</td>
</tr>
<tr>
<td>None</td>
<td>24.0</td>
<td>24.0</td>
<td>24.0</td>
<td>0.0</td>
<td>1.0</td>
<td>23.6</td>
</tr>
</tbody>
</table>
Integrated Dynamic Controls

RH & HPF or Pad System

Cooling Potential

![Graph showing cooling potential vs. relative humidity for different temperature conditions: 90°F/32.2°C, 80°F/26.7°C, 100°F/37.8°C. The graph highlights a 10 Degree Cooling Potential at specific humidity levels.]

Smith et al: (2008)
Control = no cooling system, FRT-500 = head to tail airflow at 500 CFM, FRT-750 = head to tail airflow at 750 CFM, FRT-900 = head to tail airflow at 900 CFM, SIDE-500 = right side airflow at 500 CFM, SIDE-750 = right side airflow at 750 CFM, and SIDE-900 = right side airflow at 900 CFM.

Figure 3. Average Vaginal Temperature of Cows Treated with Different Cooling Systems.
Cyclone Fan

- Designed Specifically to Create Max ECV to Cool Cows
- Creates Laminar Air Flow
- Can be Paired with HPF
- High CFM/Watt (including entrained air)
- Can be VFD Controlled
- Reduce SP Experienced by Exhaust Fans
- De-Stratify Air in Barn
Simulated Cyclone ECV Pattern

ECV Coverage Comparisons

<table>
<thead>
<tr>
<th>Fan</th>
<th>Width</th>
<th>Length</th>
<th>Sq Ft</th>
<th>Fans/Cyclone Equivalent</th>
<th>Watts/Fan</th>
<th>Total Watts</th>
<th>Cost/Hr</th>
<th>Cost/Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>36&quot; Basket</td>
<td>8</td>
<td>24</td>
<td>192</td>
<td>9</td>
<td>550</td>
<td>4950</td>
<td>0.50</td>
<td>$11.88</td>
</tr>
<tr>
<td>50&quot; Panel</td>
<td>12</td>
<td>36</td>
<td>432</td>
<td>4</td>
<td>1100</td>
<td>4400</td>
<td>0.44</td>
<td>$10.56</td>
</tr>
<tr>
<td>72&quot; Cyclone</td>
<td>24</td>
<td>72</td>
<td>1728</td>
<td>1</td>
<td>2200</td>
<td>2200</td>
<td>0.22</td>
<td>$5.28</td>
</tr>
</tbody>
</table>
4 Row Tail-Tail
### Combined Average 2, 4 & 6 Ft Level

<table>
<thead>
<tr>
<th></th>
<th>FL</th>
<th>FA</th>
<th>I-TT</th>
<th>SA</th>
<th>O-TT</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ave</td>
<td>305</td>
<td>425</td>
<td>526</td>
<td>478</td>
<td>370</td>
<td>450</td>
</tr>
<tr>
<td>Max</td>
<td>785</td>
<td>819</td>
<td>1416</td>
<td>840</td>
<td>855</td>
<td></td>
</tr>
<tr>
<td>Min</td>
<td>0</td>
<td>108</td>
<td>0</td>
<td>203</td>
<td>46</td>
<td></td>
</tr>
</tbody>
</table>
4 Row H-H Freestall
120 ft Section 4 Row H-H Hybrid Tunnel
Entrained Air

Tunnel with 12 Ft Baffle
Cyclone Mis-Installation

Air Flow Counter Current
Performance Tools & Standards

- What are Your Ventilation Performance Goals?
- Velocity Meter
- Temp & Humidity Meter
- Light Meter
- Manometer for SP measurement
- CFM/Watt Exhaust Fans
- CFM of a Fan & ECV Created
- Air Flow Ratios
## Ventilation Economics

### 10 Year Annualized Comparison

#### Comparison of Current State High Loss-Low Ownership Cost vs. Low Loss High Ownership Cost

<table>
<thead>
<tr>
<th>Current State Summer Only System vs. Year Around Ventilation System</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High Loss-Low Input</strong></td>
<td><strong>Low Loss-High Input</strong></td>
<td><strong>Net Ownership Advantage</strong></td>
</tr>
<tr>
<td><strong>($134,879)</strong></td>
<td><strong>($54,529)</strong></td>
<td><strong>$80,349</strong></td>
</tr>
</tbody>
</table>

#### HL-LI Scenario

<table>
<thead>
<tr>
<th></th>
<th>Opportunity Cost</th>
<th>Investment &amp; Operational Costs</th>
<th>Total Opportunity, Operation &amp; Ownership Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost/CFW</strong></td>
<td>$100</td>
<td>$175</td>
<td>$275</td>
</tr>
<tr>
<td><strong>Net CFW</strong></td>
<td>$100</td>
<td>$175</td>
<td>$275</td>
</tr>
<tr>
<td><strong>Replacement Heater Value</strong></td>
<td>$1,000</td>
<td>$1,400</td>
<td>$2,400</td>
</tr>
<tr>
<td><strong>Am Ckt Value (including boiler)</strong></td>
<td>$1,000</td>
<td>$1,400</td>
<td>$2,400</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$1,100</strong></td>
<td><strong>$2,800</strong></td>
<td><strong>$3,900</strong></td>
</tr>
</tbody>
</table>

#### LL-HI Scenario

<table>
<thead>
<tr>
<th></th>
<th>Opportunity Cost</th>
<th>Investment &amp; Operational Costs</th>
<th>Total Opportunity, Operation &amp; Ownership Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost/CFW</strong></td>
<td>$100</td>
<td>$175</td>
<td>$275</td>
</tr>
<tr>
<td><strong>Net CFW</strong></td>
<td>$100</td>
<td>$175</td>
<td>$275</td>
</tr>
<tr>
<td><strong>Replacement Heater Value</strong></td>
<td>$1,000</td>
<td>$1,400</td>
<td>$2,400</td>
</tr>
<tr>
<td><strong>Am Ckt Value (including boiler)</strong></td>
<td>$1,000</td>
<td>$1,400</td>
<td>$2,400</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$1,100</strong></td>
<td><strong>$2,800</strong></td>
<td><strong>$3,900</strong></td>
</tr>
</tbody>
</table>

#### Difference

<table>
<thead>
<tr>
<th></th>
<th>Current State</th>
<th>Year Around System</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Net Opportunity Cost/CFW</strong></td>
<td>$179</td>
<td>$179</td>
</tr>
<tr>
<td><strong>Net Operational Cost/CFW</strong></td>
<td>$154</td>
<td>$154</td>
</tr>
<tr>
<td><strong>Net Cost Differential</strong></td>
<td>$25</td>
<td>$25</td>
</tr>
</tbody>
</table>
### High Loss/Low Investment

<table>
<thead>
<tr>
<th>Farm Style</th>
<th>Dairy Required</th>
<th>Total Power Requirement</th>
<th>Total Power Usage in kW</th>
<th>Cost to Operate per Hour on High based on Cell 88/Cell 89</th>
<th>Annualized Cost of Ownership</th>
<th>Yearly Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Opportunity Costs of Current Performance

**Milk:**
- **B of Cows:** $100
- **Percent of Heat at F 3:** 25%
- **Cost per Case:** $5.00
- **Marginal DM % of Marginal Milk:** 0.16
- **Increased DCPN:** 0.20
- **Heat Related Costs:** $150
- **Marginal Value DM (1/10):** $0.16
- **Milk Price Loss per DM Cost:** $0.17
- **B Cows:** $12.00
- **Total Milk $1 Season:** $61,280
- **Peak Milk Loss:** $6
- **Peak Milk Loss on Lactation:** $181,150
- **Annual Milk Loss Value:** $79,530

### 10 Year Low Loss/High Investment

<table>
<thead>
<tr>
<th>Farm Style</th>
<th>Dairy Required</th>
<th>Total Power Requirement</th>
<th>Total Power Usage in kW</th>
<th>Cost to Operate per Hour on High based on Cell 88/Cell 89</th>
<th>Annualized Cost of Ownership</th>
<th>Yearly Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Opportunity Costs of Current Performance

**Milk:**
- **B of Cows:** $100
- **Percent of Heat at F 3:** 25%
- **Cost per Case:** $5.00
- **Marginal DM % of Marginal Milk:** 0.16
- **Increased DCPN:** 0.20
- **Heat Related Costs:** $150
- **Marginal Value DM (1/10):** $0.16
- **Net Milk Loss:** $0.17
- **B Cows:** $12.00
- **Total Milk $1 Season:** $15,345
- **Peak Milk Loss:** $12,788
- **Peak Milk Loss on Lactation:** $28,133

#### Reproduction & Culling

<table>
<thead>
<tr>
<th>Reproduction &amp; Culling</th>
<th>Lameness</th>
<th>Annualized Cost of Ownership</th>
<th>Yearly Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Reproduction

<table>
<thead>
<tr>
<th>Reproduction per Case</th>
<th>Cost per Cows</th>
<th>Lameness</th>
<th>Annualized Cost of Ownership</th>
<th>Yearly Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Lameness

<table>
<thead>
<tr>
<th>Lameness</th>
<th>Annualized Cost of Ownership</th>
<th>Yearly Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Annualized Cost of Ownership

<table>
<thead>
<tr>
<th>Yearly Maintenance</th>
<th>Annualized Cost of Ownership</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Annualized Cost of Ownership

- **5.0% interest**: $3,000
- **10.0 years**: $3,000
- **$151,000 Purchase & Installation**: $151,000
- **$19,555 Annual Payment**: $19,555
- **$17,191 Annual Electrical Costs**: $17,191
- **$1,160 Annual Maintenance**: $1,160
- **($37,089) Annual Cost of Heat Abatement**: ($37,089)
- **($38,010) Cumulative Productivity Cost**: ($38,010)
- **$76,531 Annual Total Costs**: $76,531
2.1 Years to Pay Back Investment

### Comparison of Current State High Loss-Low Ownership Cost vs. Low Loss High Ownership Cost

<table>
<thead>
<tr>
<th></th>
<th>HL-LI Scenario</th>
<th>LL-HI Scenario</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost F/KW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Replacement Inside Value</td>
<td>($1,000)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Opportunity Costs</td>
<td>($3,013)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investment &amp; Operational Costs</td>
<td>($4,068)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operational Costs F/KW</td>
<td>($27)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access Value (including Debt)</td>
<td>($226)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net Operating Advantage</td>
<td>$371</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Ventilation Systems Should Uniformly Deliver

- **Air Exchange CFM**
- **Effective Cow Side Velocity or ECV** (Air Velocity FPM between 2-6’ of Ht)
- **Direct Cow Cooling by Soaking** (holding areas, return & feed lanes)
- **Ambient Temperature Drop with HPF** (when Ambient RH% Conditions Present Opportunity)
- **Maximize the Opportunity for Dairy Cattle to be in Their TNZ (20°- 65°F) 24/7/365.**
Questions?

Thank You!

That's alota of Bull!