Paper Machine Room Ventilation Guidelines

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TIP 0404-50 Paper Machine Room Ventilation Guidelines

• Purpose of 2009 Revision
  – Earlier issues: Numerous methods → wide range of flow rates
  – Establish base ventilation rates tied to machine parameters

• Scope
  – Guidelines for designing systems
    • Design criteria
    • Ventilation principles
    • Sizing or dimensioning exhaust, supply, and misc. systems
    • Overview of heat recovery options
  – Air surveys
  – Performance indicators
Perception

• Statements often made in discussing ventilation:
  – Doesn’t directly make paper
  – Only for personnel comfort
  – Added equipment to operate and maintain
  – Increased energy consumption
  – Increased exhaust didn’t improve conditions
Purpose

1. Replaces air removed as part of process, drying, and vacuum systems

2. Provide a “controlled” environment for papermaking, personnel, and preservation of the building which includes containment and removal of:
   - Water vapor
   - Heat
   - Dust
Consequences – Fog
Consequences – *Fog* – *Stratified flows*
Consequences – Condensation

Deteriorated Girts
Consequences – *Structural Failure*
Consequences – *Structural Failure*
### Basis of Guidelines – *Design Criteria*

- **Temperature**

<table>
<thead>
<tr>
<th>Location</th>
<th>Minimum °F</th>
<th>Maximum above ambient °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground floor</td>
<td>65</td>
<td>≤ 10</td>
</tr>
<tr>
<td>Operating floor – tending side, wet end</td>
<td>75</td>
<td>≤ 5</td>
</tr>
<tr>
<td>Operating floor – tending side, elsewhere</td>
<td>65</td>
<td>≤ 5</td>
</tr>
<tr>
<td>Operating floor – drive side</td>
<td>65</td>
<td>≤ 10</td>
</tr>
<tr>
<td>Mezzanine</td>
<td>-</td>
<td>≤ 20</td>
</tr>
<tr>
<td>Underside Roof</td>
<td>-</td>
<td>≤ 25</td>
</tr>
</tbody>
</table>
Basis of Guidelines – *Design Criteria*

- Water vapor

<table>
<thead>
<tr>
<th>Location</th>
<th>Maximum above ambient Grains/lbDA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground floor</td>
<td>≤ 50</td>
</tr>
<tr>
<td>Operating floor</td>
<td>≤ 50</td>
</tr>
<tr>
<td>Mezzanine</td>
<td>≤ 100</td>
</tr>
<tr>
<td>Underside Roof</td>
<td>≤ 150</td>
</tr>
</tbody>
</table>
Basis of Guidelines – Design Criteria

• Dust
  – OSHA Requirements
    • Total airborne particles: 15 mg/m³
    • Respirable particles, less than 10 µm: 5 mg/m³
Basis of Guidelines – *Displacement Ventilation*

- Air supplied into occupied zone at low velocity
- Bouyant source
- Roof exhaust
- Stratified layer
- Rear curtain
- Mezzanine floor
- Operating floor
- Ground floor

Air supplied into occupied zone at low velocity.
Basis of Guidelines – *Exhaust Systems*

- **Exhaust systems**
  - Process
    - Former
    - Vacuum
    - Dryer section hood
    - Saveall
    - Pulper
  - Building
    - Wet end false ceiling
    - Size press and coater false ceiling
    - Roof
    - Summer
**Exhaust Systems – Former**

- **Purpose:** Capture and contain water vapor carried with the wire and mist from showers

- **Exhaust rate is a function of former type, machine speed, geometry, and stock temperature**

- **Higher exhaust rates**
  - Fourdrinier w/top ply > Gap former > Fourdrinier
  - On machine silo > Off machine silo
  - Increased machine speeds
  - Higher stock temperatures
Exhaust Systems – Former

- Based on flow per trim width and speed with correction for temperature

\[
\dot{V} = \left( \sum_{i} B_i + \nu w \sum_{i} F_i \right) C_t
\]

- Flow Adjustment, \( B \) – added exhaust to ensure in flow
- Flow Factors, \( F \) – total pumped air flow
Exhaust Systems – *Fourdrinier Air Flows*

**Diagram:**
- **Headbox**
- **Breast Roll**
- **Exhaust**
- **Boundary Layer**

**Text:**
- Flow Factor (F) air pumped through and with wire
- Flow Adjustment (B) to maintain an inflow

*PaperCon '09*
## Exhaust Systems – *Fourdrinier*

<table>
<thead>
<tr>
<th>Fourdrinier Pickup Location</th>
<th>Flow Factor, $F$ (ft)</th>
<th>Flow Adjustment, $B$ (ft$^3$/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below Wire – Headbox &amp; Breast Roll</td>
<td>0.13</td>
<td>11,000</td>
</tr>
<tr>
<td>Couch Pit</td>
<td>0.13</td>
<td>0</td>
</tr>
<tr>
<td>On-Machine Silo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Below and inside wire loop – drive side plenum</td>
<td>0.47</td>
<td>0</td>
</tr>
<tr>
<td>Off-Machine Silo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inside wire loop</td>
<td>0.26</td>
<td>0</td>
</tr>
<tr>
<td>Flume and silo</td>
<td>0.10</td>
<td>0</td>
</tr>
</tbody>
</table>
Exhaust Systems – Top Wire

<table>
<thead>
<tr>
<th>Top Wire/Top Ply Pickup Location</th>
<th>Flow Factor, $F$ (ft)</th>
<th>Flow Adjustment, $B$ ($ft^3/min$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beneath top former headbox (Top Ply)</td>
<td>0.13</td>
<td>5,500</td>
</tr>
<tr>
<td>Inside top wire loop</td>
<td>0.21</td>
<td>0</td>
</tr>
<tr>
<td>After high pressure shower</td>
<td>0.16</td>
<td>0</td>
</tr>
</tbody>
</table>
Exhaust Systems – Gap Former

<table>
<thead>
<tr>
<th>Gap Former Pickup Location</th>
<th>Flow Factor, $F$ ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headbox area</td>
<td>0.47</td>
</tr>
<tr>
<td>No. 1 Outer/Backing Wire Loop &amp; Saveall</td>
<td>0.28</td>
</tr>
<tr>
<td>No. 1 Stretch Roll</td>
<td>0.24</td>
</tr>
<tr>
<td>No. 2 Inner/Conveying Wire Loop &amp; Saveall</td>
<td>0.24</td>
</tr>
<tr>
<td>Silo</td>
<td>0.05</td>
</tr>
</tbody>
</table>
Exhaust Systems – *Former*

Exhaust rate versus former type and speed

- **Fourdrinier + Top Ply 140°F**
- **Fourdrinier + Top Wire 120°F**
- **Fourdrinier On Machine Silo 140°F**
- **Fourdrinier Off Machine Silo 120°F**
- **Gap Former 120°F**
Exhaust Systems – *Wet End*

Heat and water vapor transferred to room
Exhaust Systems – *Wet End*

• **Purpose:** Capture and contain water vapor originating from former and press top surfaces

• Exhaust rate is a function of surface area, machine speed, geometry, number of steam boxes, and stock temperature

• Based on flow per surface area with correction for temperature, and geometry
Exhaust Systems – *Wet End*

- **Exhaust Rate**

\[
\dot{V} = \left( 0.0107v + B \right) AC_t C_w + nDw \cdot E
\]

- **Turbulent mass transfer rates across a flat plate**
  - constant air and water temperatures
    - 100 grain/lbDA pickup ratio
Exhaust Systems – *Wet End*

Vaporization rate versus stock temperature and machine speed

<table>
<thead>
<tr>
<th>Stock Temperature, °F</th>
<th>Vaporization Rate, lbH₂O/hr/ft²</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>0.0</td>
</tr>
<tr>
<td>80</td>
<td>0.0</td>
</tr>
<tr>
<td>90</td>
<td>0.0</td>
</tr>
<tr>
<td>100</td>
<td>0.0</td>
</tr>
<tr>
<td>110</td>
<td>0.0</td>
</tr>
<tr>
<td>120</td>
<td>0.0</td>
</tr>
<tr>
<td>130</td>
<td>0.0</td>
</tr>
<tr>
<td>140</td>
<td>0.0</td>
</tr>
<tr>
<td>150</td>
<td>0.0</td>
</tr>
</tbody>
</table>

- **Marshall - 3000 ft/min**
- **4000 ft/min**
- **3000 ft/min**
- **2000 ft/min**
- **1000 ft/min**
Exhaust Systems – Supplemental Roof Exhaust

Purpose: Remove heat and water vapor not contained by other exhaust systems

- Exhaust rate is a function of:
  - Water vapor from open and uncontained sources:
    - False ceiling
    - Dryer section hood – sheet break
    - Open tanks and chests
  - Heat gain from the following sources:
    - Paper product
    - Refiners
    - Pumps and fans
    - Motors
    - Tanks
    - Piping
<table>
<thead>
<tr>
<th>Source</th>
<th>Floor Level</th>
<th>Heat 10^-3 Btu/ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refiners</td>
<td>Operating</td>
<td>58 – 88</td>
</tr>
<tr>
<td>Cleaners</td>
<td>Operating</td>
<td>1,000 Btu/h/ft²</td>
</tr>
<tr>
<td>Stock Prep – Pumps &amp; Piping</td>
<td>Ground</td>
<td>20</td>
</tr>
<tr>
<td>Vacuum System</td>
<td>Operating</td>
<td>37</td>
</tr>
<tr>
<td>Forming &amp; Press – Pumping &amp; Piping</td>
<td>Ground</td>
<td>75</td>
</tr>
<tr>
<td>Forming &amp; Press – PM Drives</td>
<td>Operating</td>
<td>51.6</td>
</tr>
<tr>
<td>Main Dryer – PM Drives</td>
<td>Operating</td>
<td>18.5</td>
</tr>
<tr>
<td>Winder – PM Drives</td>
<td>Operating</td>
<td>44.4</td>
</tr>
</tbody>
</table>
Supplemental Roof Exhaust – *Process Heat Gains*

- **Refiner loads**
  - Based on paper grade
  - 10% of total motor load

- **Pumps and AC motors**
  - 10% of motor nameplate

- **PM drive motors**
  - Calender, coater, reel, and winder – 50% of motor load
  - All others – 15% transferred into room
Exhaust Systems – *Supplemental Roof Exhaust*
Exhaust Systems – *Supplemental Roof Exhaust*

- **Exhaust rate for water vapor sources**
  - Minimum truss area exhaust
    - 25% of wet end false ceiling exhaust rate
    - 10% of dryer section hood exhaust rate

- **Exhaust rate for heat sources**
  - Minimum Winter: 25°F temperature differential
  - Summer: 10°F temperature differential for ground floor heat loads
Supply Systems – Fog

What role do supply systems have in eliminating fog?
Basis of Guidelines – *Supply Systems*

- Exhaust and make-up air systems are required to prevent fog and condensation:
  - Increase humidity load = Condensation
  - Decrease temperature = Condensation

- Key is to prevent uncontrolled air infiltration:
  - Building air balance of 90-to-105% exhaust mass flow rate
  - Proper air distribution

- Supply air to operating areas
  - Displace heat and vapor
Basis of Guidelines – *Miscellaneous Systems*

- **Pocket Ventilation and Hood Make-up**
  - Hood Balance: 60-to-70% of hood exhaust mass flow
  - Source: mezzanine

- **Roof Supply**
  - Required flow rate:
    - Roof heat loss (R-value)
    - Humidity load
  - Minimum of R18 (ft\(^2\)-°F-hr/Btu) recommended
  - Wet end: 1.5 cfm/ft\(^2\)

- **Trim Systems**
  - 70-to-80% of air should be extracted before entering pulper
System Performance

1. Condensation or Corrosion?
2. Water vapor containment?
3. Cold weather operation?
4. Dryer hoods spillage?
5. Building air pressure?
6. Cold spots or hot spots?
7. Temperature and humidity levels?
8. Energy consumption?
Air System Surveys

• Purpose
  – Identify root causes
  – Establish a benchmark for future improvement

• Scope
  – Condition of equipment
  – Exhaust and supply airflows
    • Compare to rated performance
    • Building air balance
  – Exhaust system effectiveness
  – Dryer section hood
  – Airflow paths
  – Temperature and humidity distribution
  – Control strategy
  – Performance indices
Performance Indices – *Overall Exhaust Rate*

Exhaust air compared to production rate

*Total Winter Exhaust* *(ft^3 or m^3 / min)*

*Production Rate* *(lb or kg/ min)*

<table>
<thead>
<tr>
<th>Paper Grade</th>
<th>ft^3/lb paper</th>
<th>m^3/kg paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bleached Board</td>
<td>545 – 645</td>
<td>36.4 – 43.1</td>
</tr>
<tr>
<td>Corrugating Medium</td>
<td>375 – 545</td>
<td>25.0 – 36.4</td>
</tr>
<tr>
<td>Fine</td>
<td>530 – 630</td>
<td>35.4 – 42.1</td>
</tr>
<tr>
<td>Linerboard</td>
<td>375 – 575</td>
<td>25.0 – 39.4</td>
</tr>
</tbody>
</table>
Performance Indices – *Wet End Exhaust*

- **Flow rate**
  
  $$\text{Wet End Exhaust} \left( \text{scfm or m}^3/\text{min} \right)$$
  
  $$\text{Former + Press Area} \left( \text{ft}^2 \text{ or m}^2 \right)$$

- **Temperature and Humidity**

  *Roof Exhaust DB – Operating Floor DB* < 25°F

  *Dry Bulb – Dew Point* > 5°F

  *Humidity Ratio Pick up* < 150 grains H₂O/lbDA
Performance Indices – Building Make-up

• Air Balance
  – 90-to-105% of Exhaust
  – 50% of wet end

• Air Distribution (%)

<table>
<thead>
<tr>
<th>Floor Level</th>
<th>Total</th>
<th>Tending Side</th>
<th>Drive Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mezzanine</td>
<td>0 – 5</td>
<td>-</td>
<td>0 – 5</td>
</tr>
<tr>
<td>Operating</td>
<td>70 – 80</td>
<td>50 – 60</td>
<td>10 – 20</td>
</tr>
<tr>
<td>Ground</td>
<td>20 – 30</td>
<td>10 – 20</td>
<td>5 – 10</td>
</tr>
</tbody>
</table>
Performance Indices – Maintenance

• Equipment Performance

\[
\frac{\text{Measured Exhaust} + \text{Supply Flows}}{\text{Rated Exhaust} + \text{Supply Flows}} \left( \text{cfm or } m^3/\text{min} \right)
\]

- Excellent ≥ 90%
- Good ≥ 75%
- Poor < 75%
Summary

- Room ventilation is a necessary component of papermaking with serious consequences when ignored.

- TIP 0404-50 provides a starting point for ventilation design based on heat and water vapor loads.

- Performance indices should be tied to machine parameters.