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

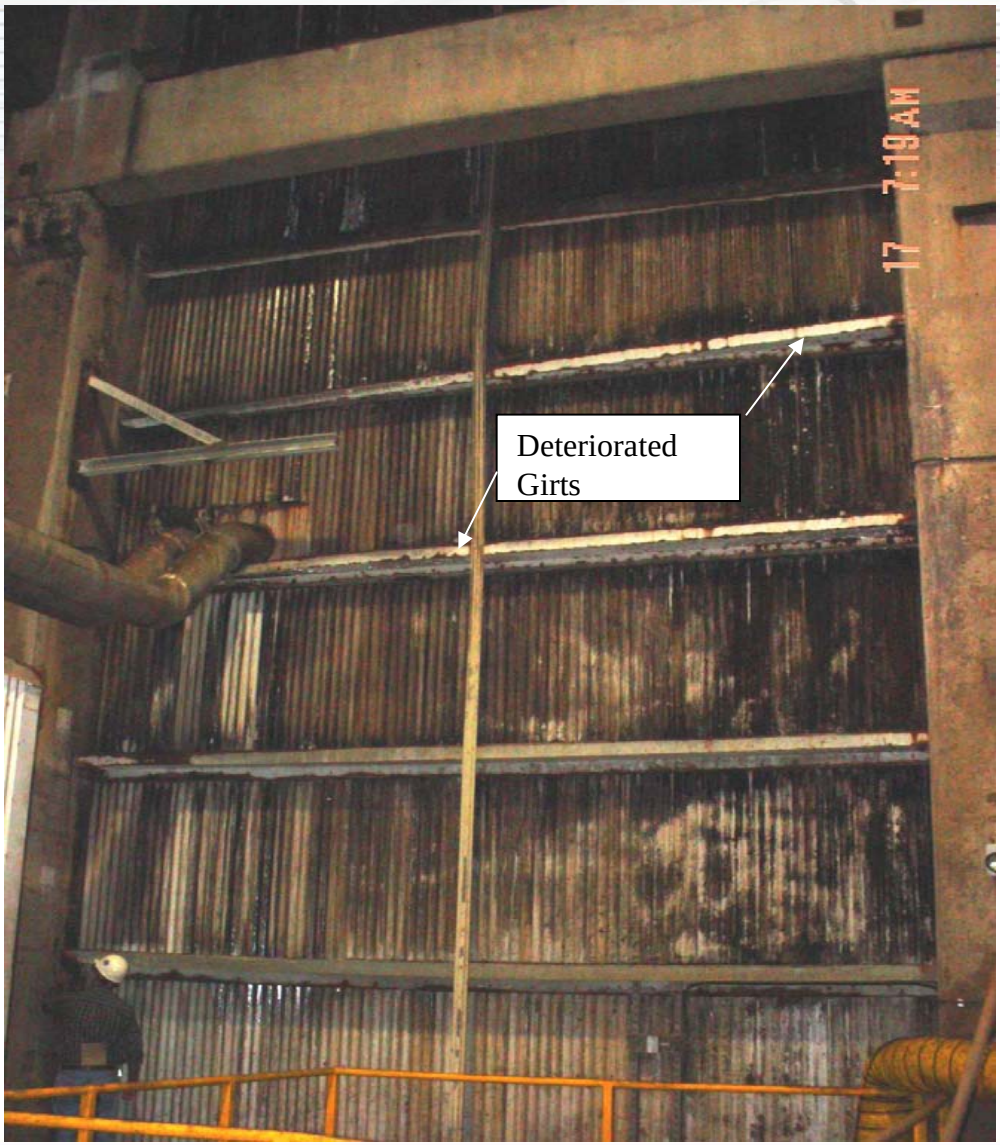
Purpose

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*



Consequences – *Structural Failure*

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Basis of Guidelines – *Design Criteria*

- Temperature

Location	Minimum °F	Maximum above ambient °F
Ground floor	65	≤ 10
Operating floor – tending side, wet end	75	≤ 5
Operating floor – tending side, elsewhere	65	≤ 5
Operating floor – drive side	65	≤ 10
Mezzanine	-	≤ 20
Underside Roof	-	≤ 25

Basis of Guidelines – *Design Criteria*

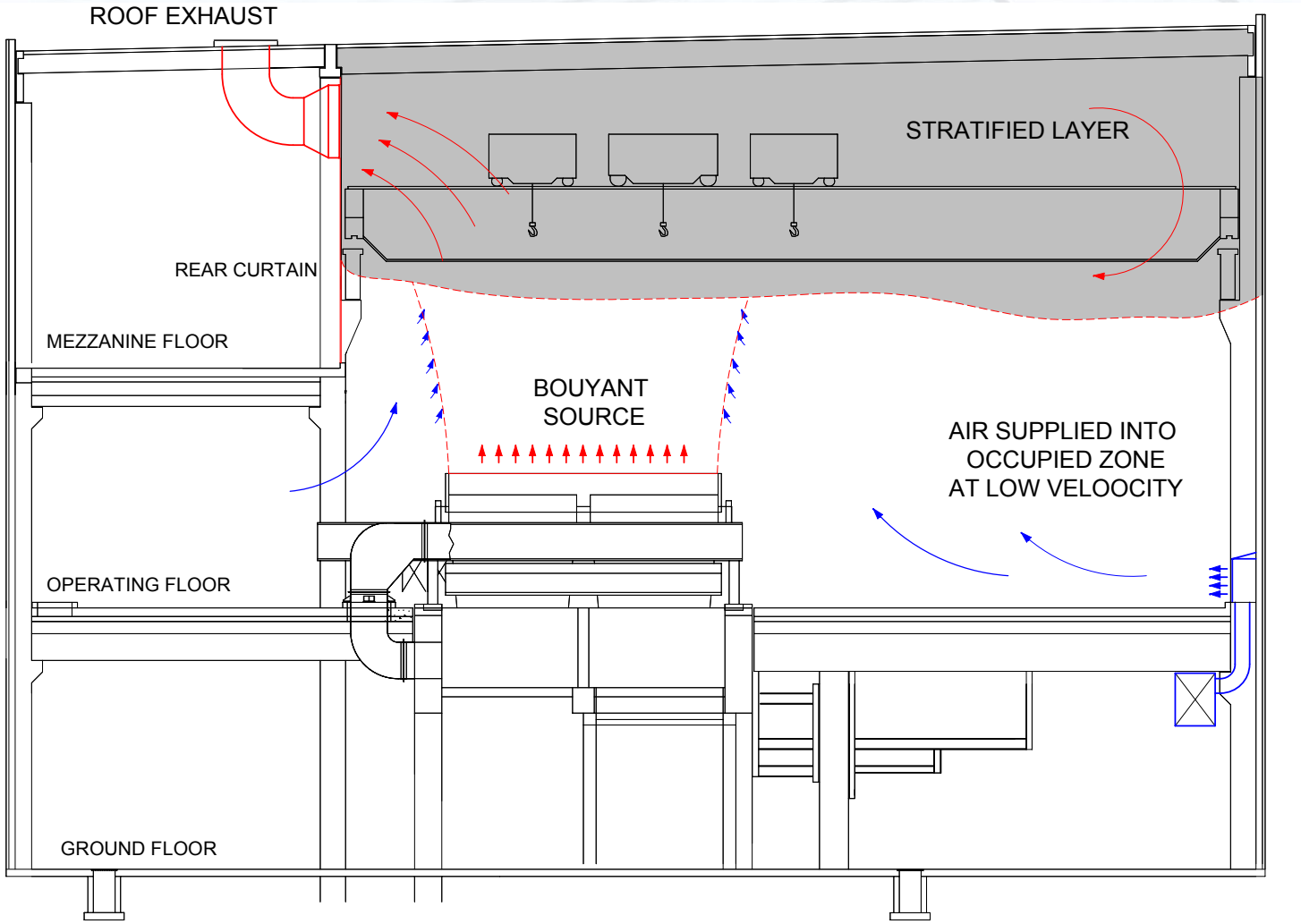
- Water vapor

Location	Maximum above ambient Grains/lbDA
Ground floor	≤ 50
Operating floor	≤ 50
Mezzanine	≤ 100
Underside Roof	≤ 150

Basis of Guidelines – *Design Criteria*

- Dust
  - OSHA Requirements
    - Total airborne particles: 15 mg/m^3
    - Respirable particles, less than 10 µm: 5 mg/m^3

Basis of Guidelines – *Displacement Ventilation*



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

$$\dot{V} = \left(\sum_{i}^{n} B_i + vw \sum_{i}^{n} F_i \right) C_t$$

Volumetric Flow

Flow Adjustment

Trim Width

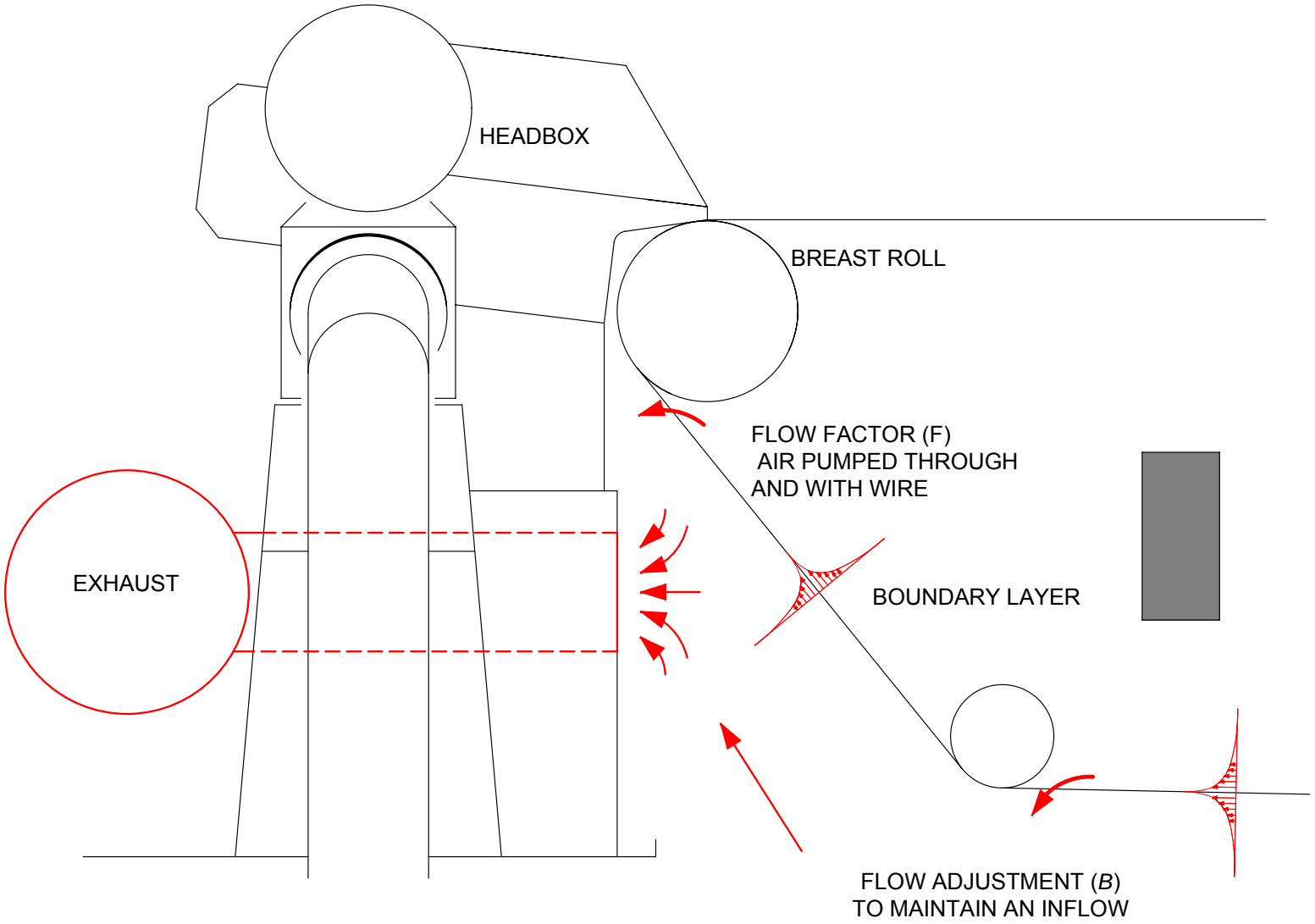
Machine Speed

Flow factor based on former and pickup location

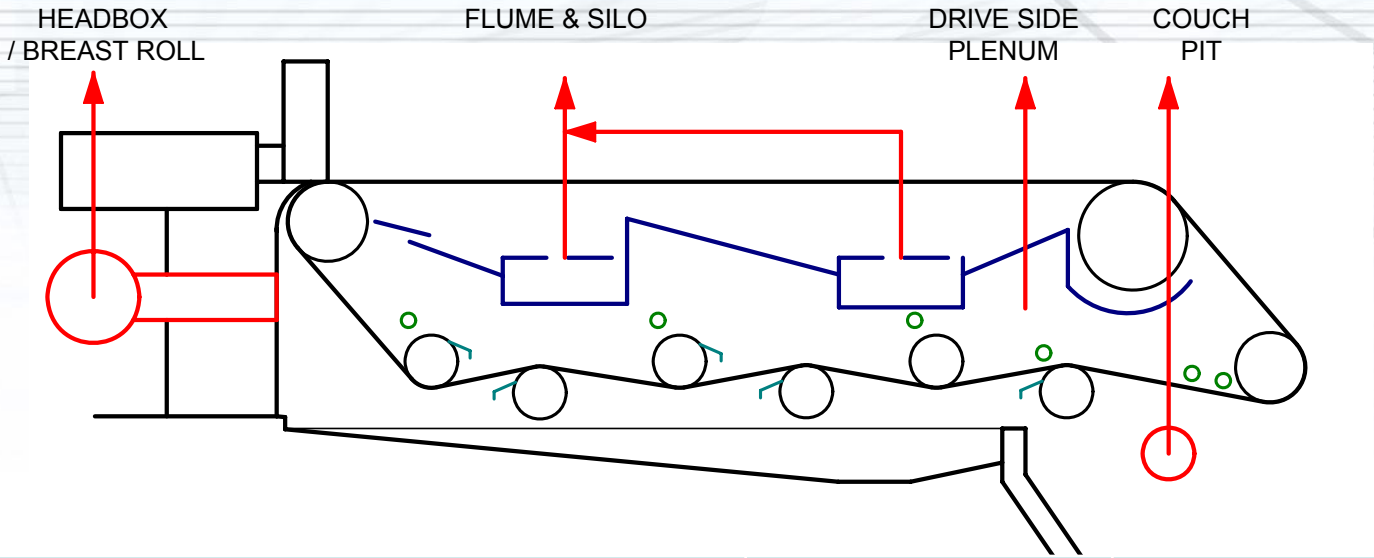
Temperature Correction

- Flow Adjustment, *B* – added exhaust to ensure in flow
- Flow Factors, *F* – total pumped air flow

Exhaust Systems – *Fourdrinier Air Flows*

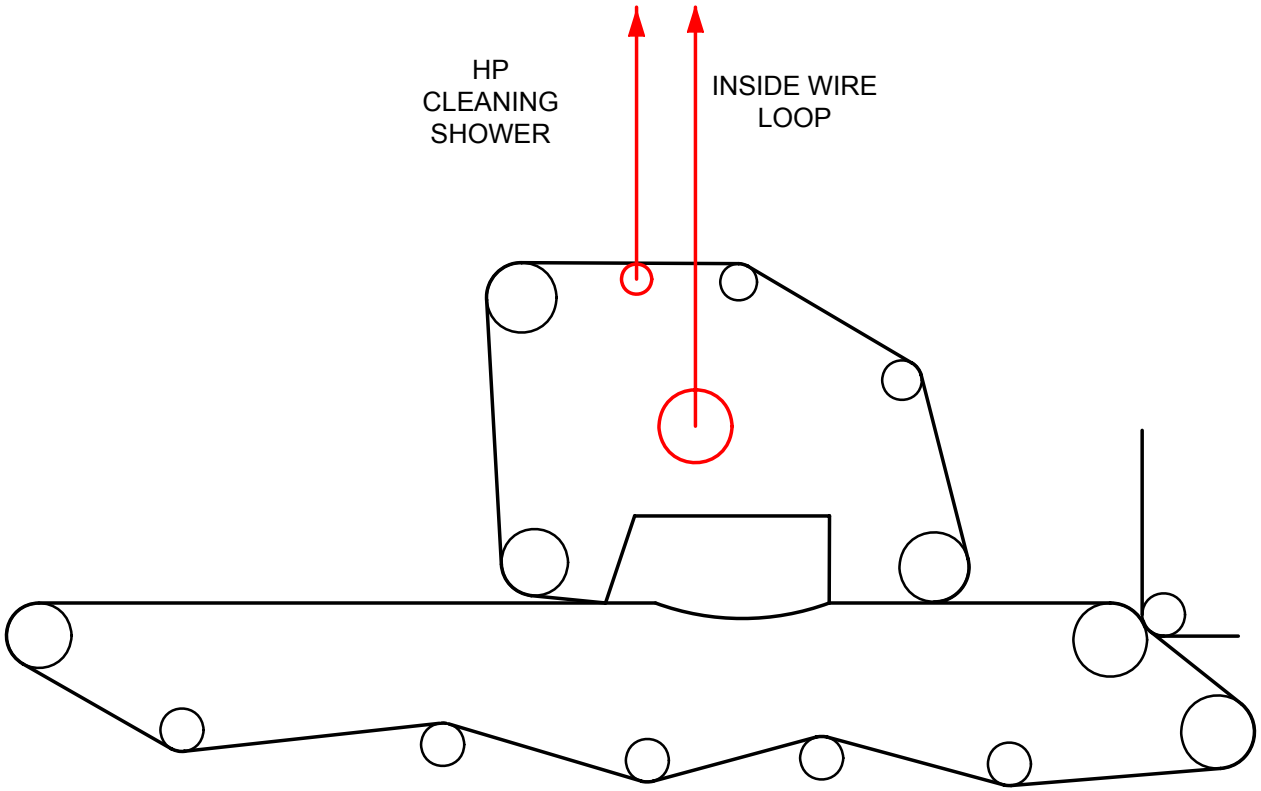


Exhaust Systems – *Fourdrinier*



Fourdrinier Pickup Location	Flow Factor, *F* ft	Flow Adjustment, *B* ft^3/min
Below Wire – Headbox & Breast Roll	0.13	11,000
Couch Pit	0.13	0
On-Machine Silo		
Below and inside wire loop – drive side plenum	0.47	0
Off-Machine Silo		
Inside wire loop	0.26	0
Flume and silo	0.10	0

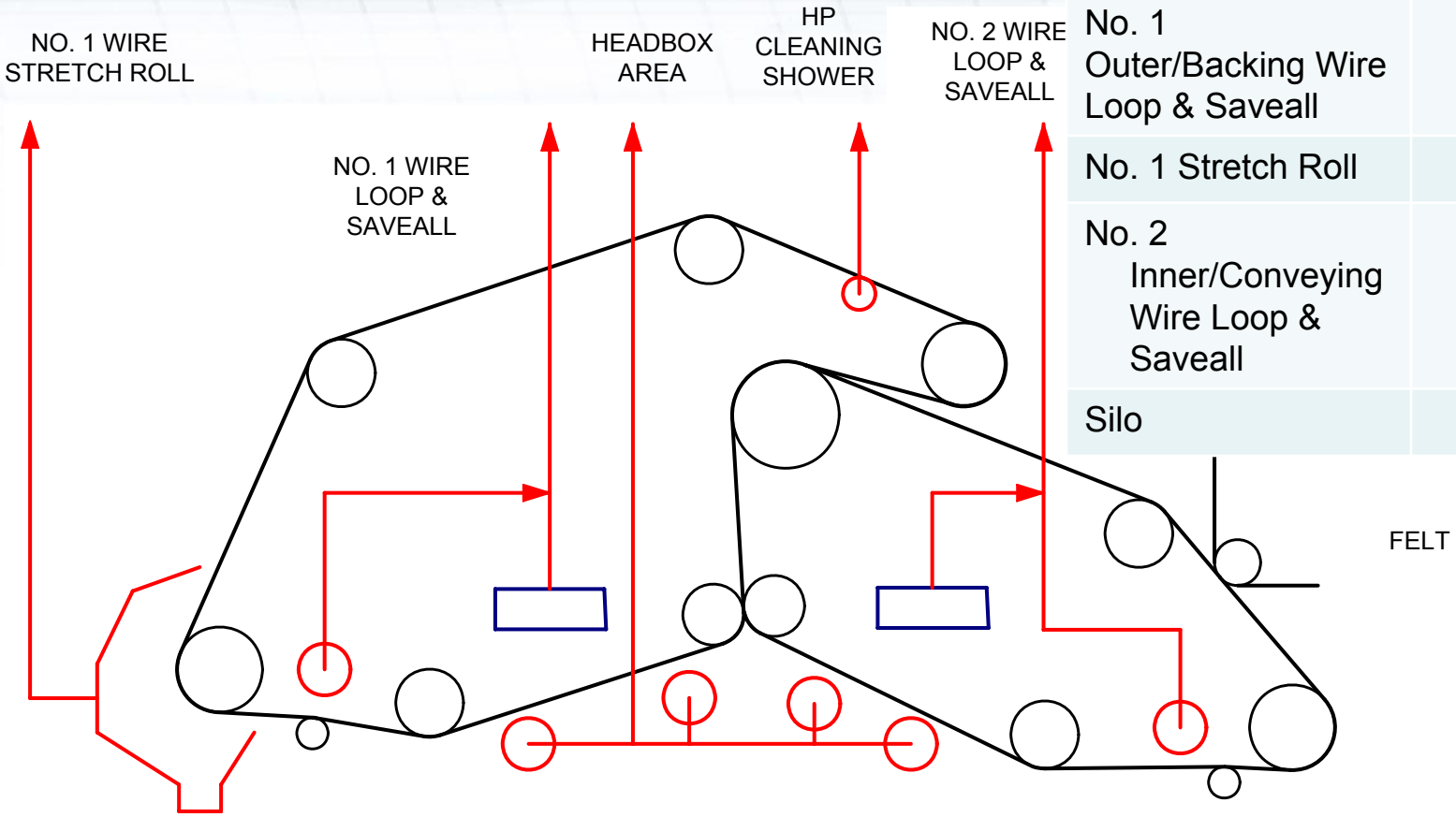
Exhaust Systems – *Top Wire*



Top Wire/Top Ply Pickup Location	Flow Factor, *F* ft	Flow Adjustment, *B* ft^3/min
Beneath top former headbox (Top Ply)	0.13	5,500
Inside top wire loop	0.21	0
After high pressure shower	0.16	0

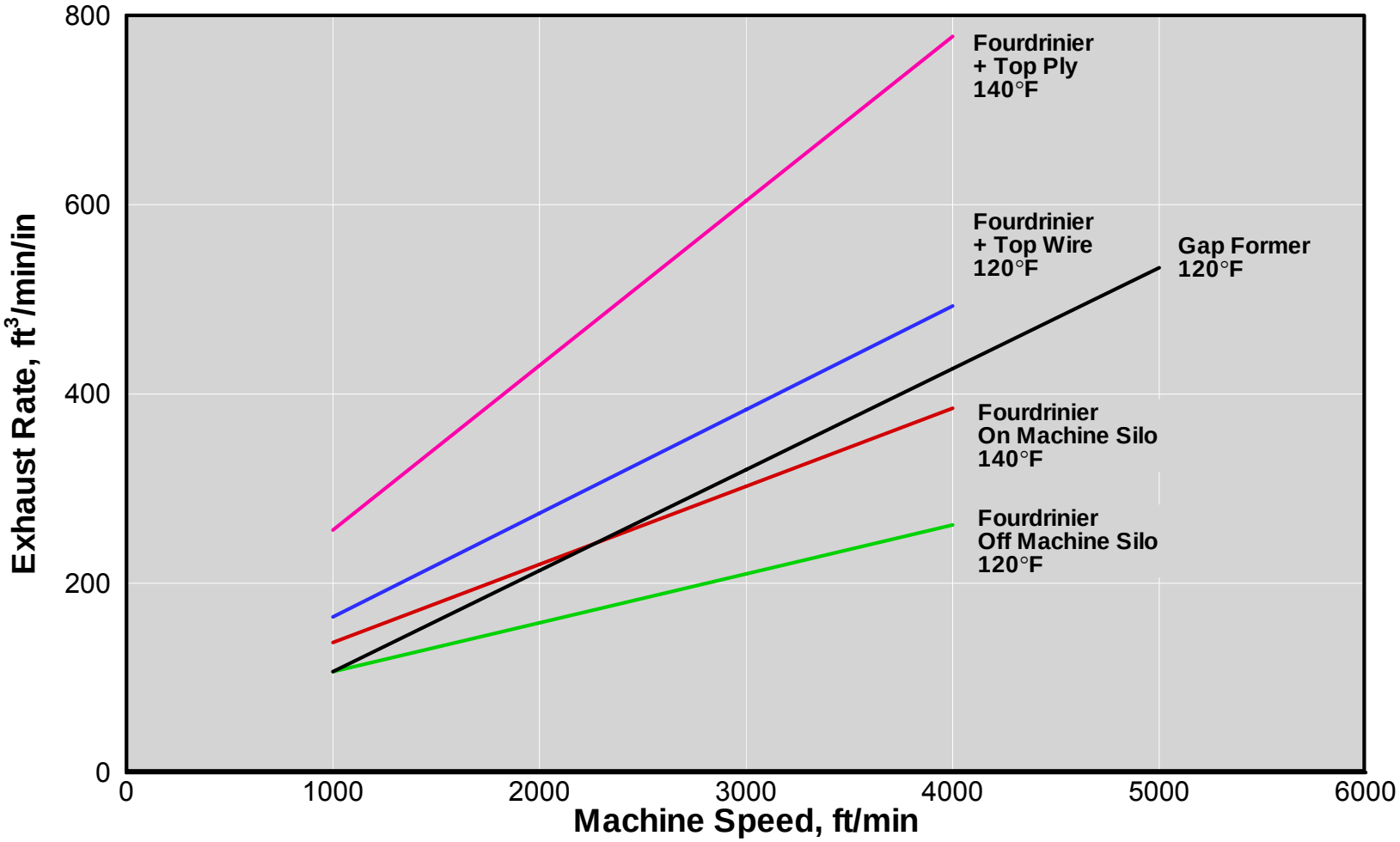
Exhaust Systems – *Gap Former*

Gap Former Pickup Location	Flow Factor, *F* ft
Headbox area	0.47
No. 1 Outer/Backing Wire Loop & Saveall	0.28
No. 1 Stretch Roll	0.24
No. 2 Inner/Conveying Wire Loop & Saveall	0.24
Silo	0.05



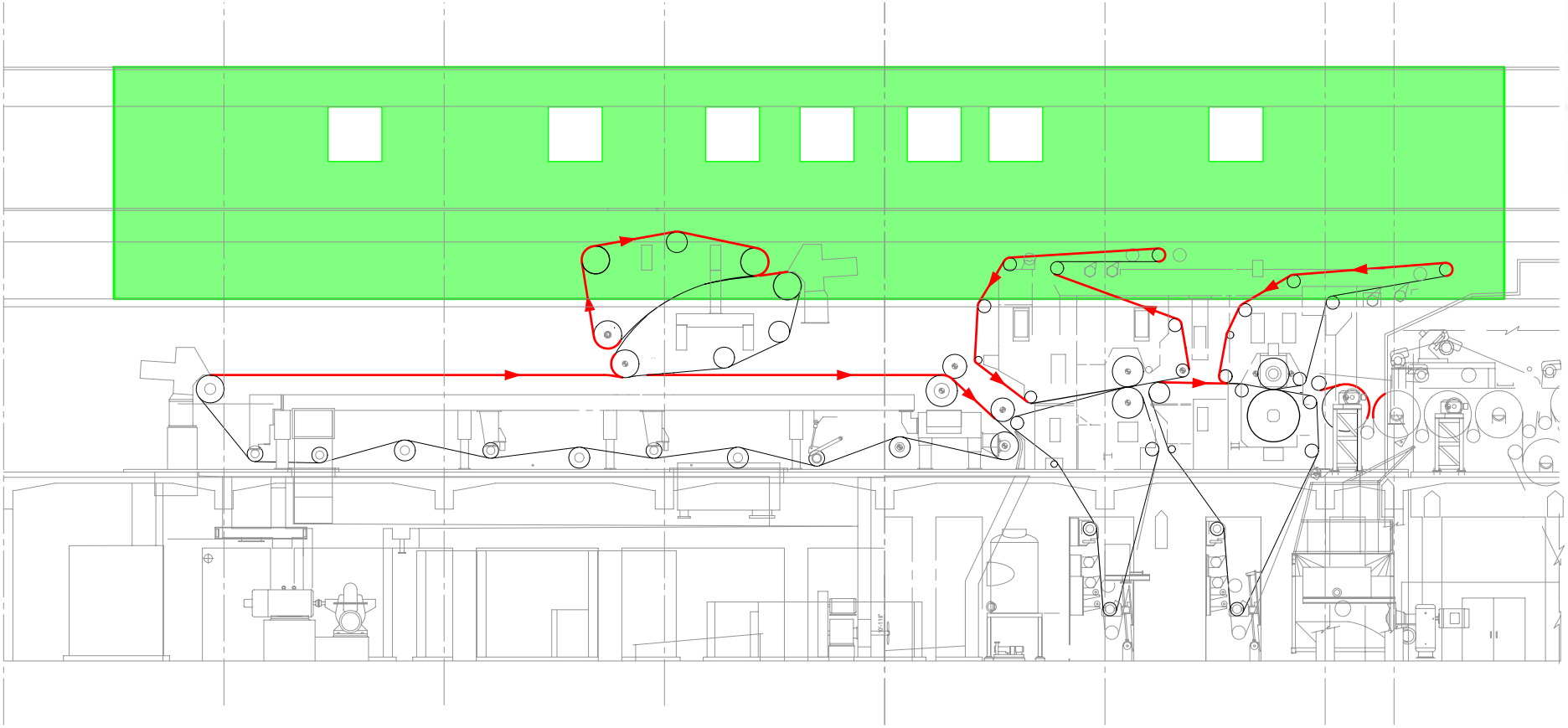
Exhaust Systems – *Former*

Exhaust rate versus former type and speed



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

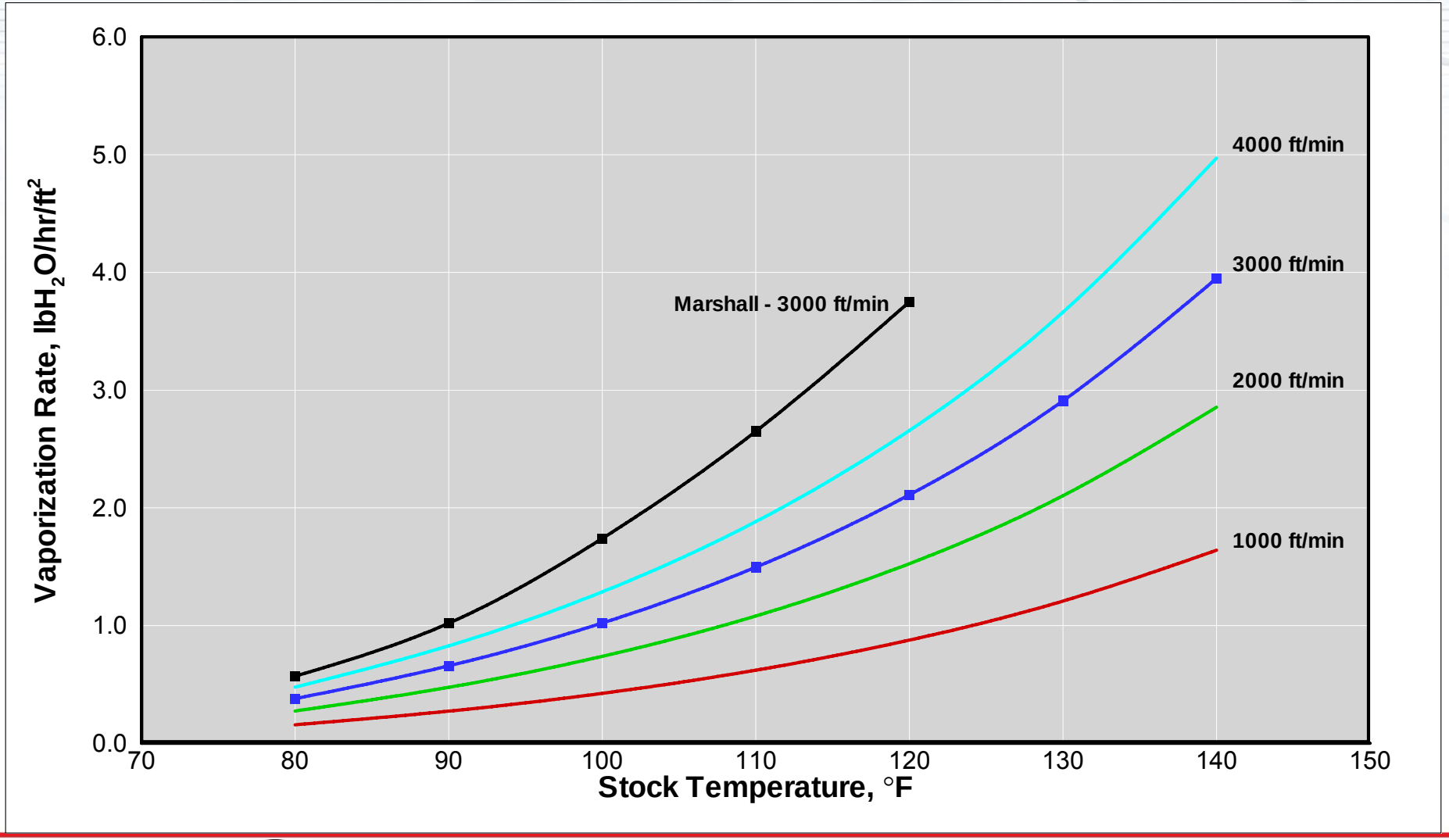
$$\dot{V} = \left[\underbrace{\left(0.0107\mathrm{v} + B\right)}_{} AC_t C_w + nDw \right] E$$

Exhaust Rate per Area
Machine Speed
Flow Constant
Surface Area
Temperature Correction
Wire surface area correction
Quantity
Steam box / lazy steam shower exhaust rate
Trim Width
Geometry factor

- 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



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

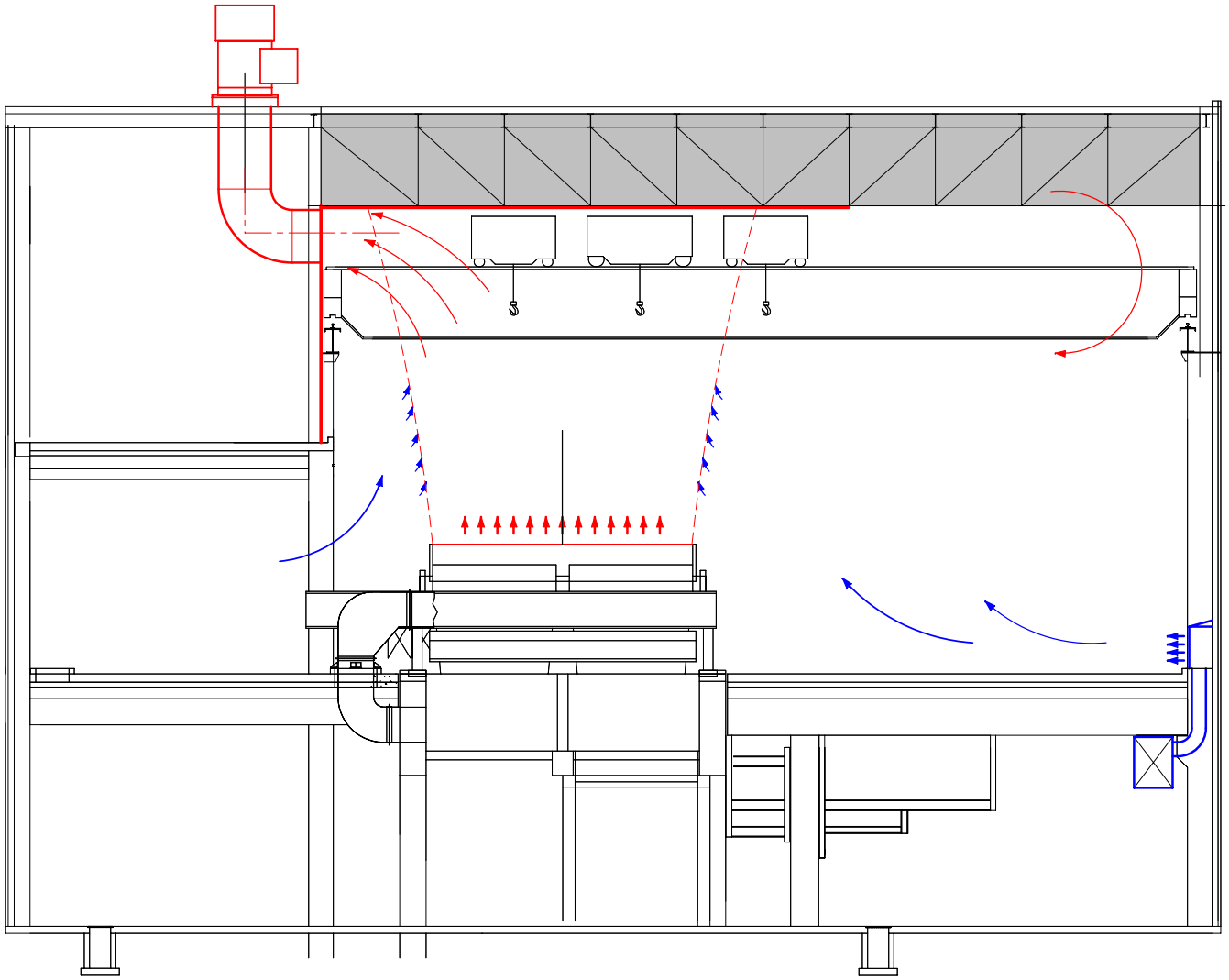
Supplemental Roof Exhaust – *Process Heat Gains*

Source	Floor Level	Heat 10^{-3} Btu/ton
Refiners	Operating	58 – 88
Cleaners	Operating	1,000 Btu/h/ft^2
Stock Prep – Pumps & Piping	Ground	20
Vacuum System	Operating	37
Forming & Press – Pumping & Piping	Ground	75
Forming & Press – PM Drives	Operating	51.6
Main Dryer – PM Drives	Operating	18.5
Winder – PM Drives	Operating	44.4

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-to70% 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

$$\frac{Total\ Winter\ Exhaust\ (\mathrm{ft}^3 \text{or } \mathrm{m}^3/\mathrm{min})}{Production\ Rate (\mathrm{lb} \text{ or } \mathrm{kg}/\mathrm{min})}$$

Paper Grade	ft³/lb paper	m³/kg paper
Bleached Board	545 – 645	36.4 – 43.1
Corrugating Medium	375 – 545	25.0 – 36.4
Fine	530 – 630	35.4 – 42.1
Linerboard	375 – 575	25.0 – 39.4

Performance Indices – *Wet End Exhaust*

- **Flow rate**

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

- **Temperature and Humidity**

$$Roof\ \ Exhaust\ DB - Operating\ Floor\ DB < 25^{\circ}\text{F}$$

$$Dry\ Bulb - Dew\ Point > 5^{\circ}\text{F}$$

$$Humidity\ \ Ratio\ \ Pick\ up < 150\ \text{grains}\ H_2O/\text{lbDA}$$

Performance Indices – *Building Make-up*

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

- **Air Distribution** (%)

Floor Level	Total	Tending Side	Drive Side
Mezzanine	0 – 5	-	0 – 5
Operating	70 – 80	50 – 60	10 – 20
Ground	20 – 30	10 – 20	5 – 10

Performance Indices – *Maintenance*

- **Equipment Performance**

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

  - 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.