Harris Group Inc.

Biomass Drying Technology Update

BioPro Expo & Marketplace
Atlanta, GA, March 14-16, 2011

Matt Worley
Sr. Process Engineer
Harris Group Inc.

Benefits of Drying Fuel

- It depends on your process…
  - Pelletizing requires drying
  - Gasification and pyrolysis generally requires drying
  - Not required for direct combustion, but can result in the following benefits:
    - Improved efficiency: 5%-15%
    - Increased steam production: 50%-60%
    - Reduced ancillary power requirements
    - Reduced fuel use
    - Lower emissions
    - Improved boiler operation
  - An accurate and comprehensive cost/benefit analysis must be preformed!

Drawbacks of Using Dry Fuel

- Firing dry fuel can result in the following drawbacks:
- Flame temperature can approach the fusion temperature of the ash
- If drier is down must use fossil fuel backup in boiler
- May require expensive materials of construction if the hot flue gases are cooled below the dew point
- Lower excess air tends to decrease NOx emissions, but high flame temperatures can increase NOx formation

Typical / Mainstream Biomass Dryer Technologies

- Rotary Drum – *Most Common for wood*
- Belt/Conveyor – *Second Most Common for wood*
- Cascade/Fluidized Bed
- Flash /Pneumatic
- Superheated Steam
- Bed/Grate

Other Drying Technologies

- Open Air Drying
- Perforated Floor Bin Drying
- Electromagnetic radiation (microwave)
- Disk (Porcupine) Dryer
- Screw Heat Exchanger
- Tray Dryers

See presentation notes for details on these technologies

Rotary Dryers - Direct Fired Single Pass

Direct Fired Single Pass

- 800-1,200 °F feed temperature *(as low as 450 °F)* controlled with flue gas recirc. (FGR)
- 200-250 °F exhaust temperature *(full range of 160-300 °F)*, above 220 °F prevents condensation of acids and resins
- FGR improves heat transfer and reduces fire risk by increasing humidity
- Advanced flighting – air classify / more even drying
- Retention times
  - < 1 min for small particles
  - 10-30 min for larger material

Heat sources
- Waste gas
- Hot air
- Direct (flame)

Applications
- Sludge
- Bark/Wood chips
- Sawdust
- Wood Residues
- Bagasse

Rotary Dryers

Features

•Typical Production:

- 5-50+ ton/hr of dried product at ~10% MC

•Maximum dryer size "so far":

- 24' dia. x 140' (TSI) = 75 ton/hr product

•Minimum residual moisture typical is 3-5% with 2% possible

Advantages

•Greatest capacity

•Lowest electrical power

•Minimal steelwork for erection

•Good energy efficiency: 1,500 (w/ FGR) to 1,800 Btu/lb evaporation

•Feed size flexibility and can accept hottest flue gases

•Low O&M costs

Rotary Dryer

Disadvantages

•Greater PM emissions

- Typically use cyclone or multiclone followed by WESP
- Greater VOCs emissions
- Typically use RTO for VOC destruction
- Material moisture is harder to control
- Greatest fire hazard
- Relatively Large Footprint

Rotary Dryers – Other Types

Direct Fired Triple & Quad-Pass

- Dryer of choice form the 70’s-90’s
- Typically < 1” minus (sawmill residuals)
- Compared to *single pass* dryer
    - Higher fire hazard
    - Higher VOCs emissions
    - Higher capital & O&M costs
    - Higher electrical costs

Indirect, Steam-tube

- Less efficient
- Expensive
- Requires smaller/uniform material
- Prone to plugging
- Cannot process sticky materials

Others:

- **Rotary Batch**
- **Single Pass Indirect Closed Loop**
- **Hybrid Rotary SSD - discussed later**

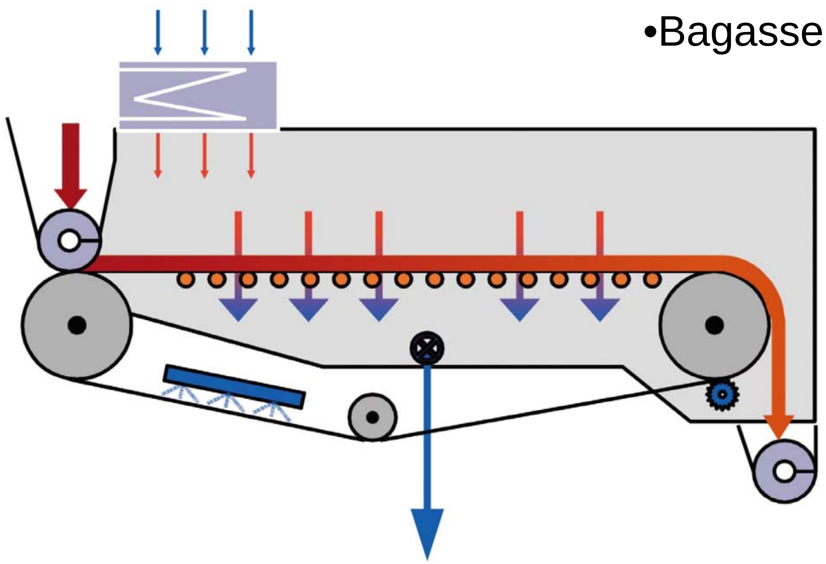
Belt / Conveyor Dryers

Advantages

- Material flexibility
- Utilization of waste heat (typical 140-250 °F limit)
- Non-destructive drying
- Low fire hazard
- Material is not agitated
- Lower emissions

Heat sources

- Low pressure steam
- Residual gas
- Hot water
- Hot air
- Can be fuel fired w/ heatx



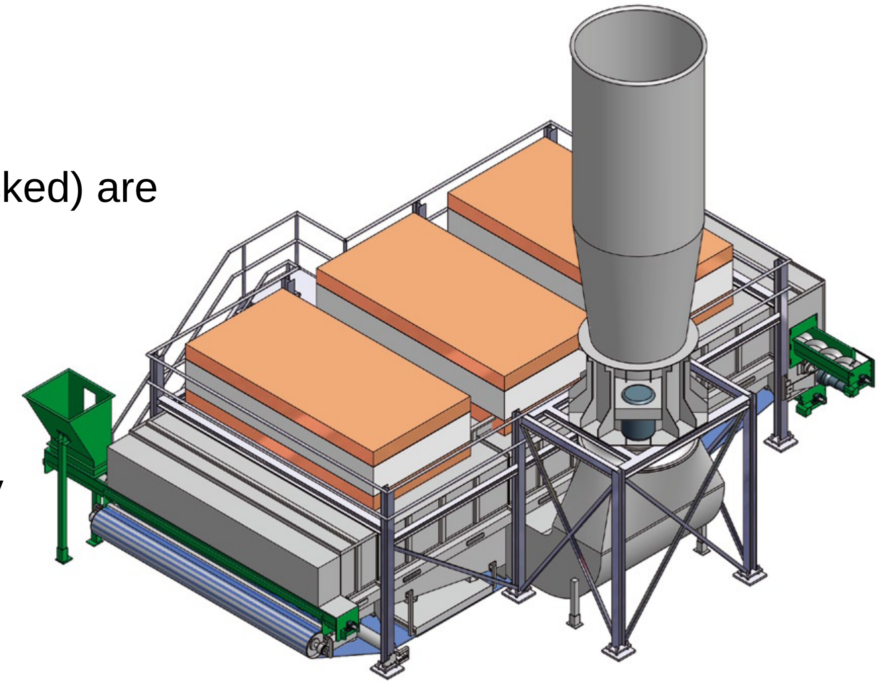
Applications

- Sludge
- Bark
- Wood chips
- Sawdust
- Wood residues
- Bagasse

Conveyor / Belt Dryers

Disadvantages

- Minimum residual moisture ~8%
- Large footprint, although multi-pass (stacked) are available
- Higher operating power
- Slightly greater O&M costs than rotary
- Capital (dryer alone) is higher than rotary
- Slightly more sensitive to operate
- Can have tar/fines build up issues
- No large machines to date in North America



Cascade & Fluidized Bed Dryer

Cascade is typically used for grain

•Can handle larger particles than flash dryers

Operation

•Intermediate temp between rotary and belt

•Residence time of 2-3 minutes

Advantages

•Smaller footprint than rotary and belt dryers

Disadvantages

•Prone to corrosion and erosion

•Higher O&M costs

•Must have *uniform* particle size

•Heat recovery is difficult

Flash / Ring Dryer

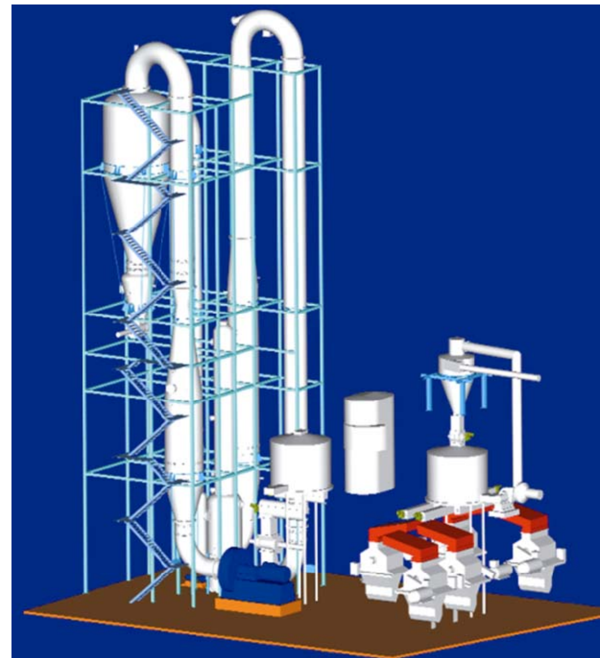
Features:

•Intimate contact with air / rapid drying / < 30 second retention time

•Wet or sticky materials can be recycled to improve material handling

•Slightly lower temperature compared to rotary

•Partially closed-circuit configuration



Advantages:

•Appropriate for a wide range of materials

•Simple design, reliable

•Good / consistent product quality

•Smallest footprint

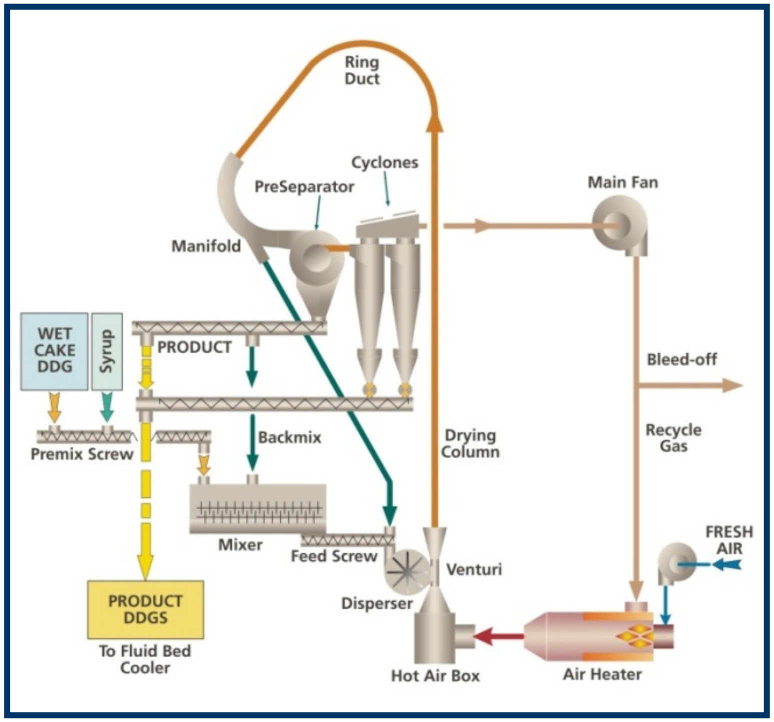
•Lower fire risk compared to rotary

•Easier to control as compared to rotary

•Higher humidity exhaust

•Short retention time / Lower VOCs emissions

Flash / Ring Dryer



Disadvantages

- Cost effective at larger scales only (higher installation costs)
- High electricity usage
- High heat requirements for drying
- Require small particle size…biomass would need to be hogged
- Subject to corrosion and erosion…higher O&M costs
- Heat recovery is difficult

Superheated Steam Dryer (SSD)

Features

•Similar to flash dryers (steam instead of air)

•Typically 90% steam is recirculated and 10% is condensed or reused

•Superheated steam

- Typically between 0 and 60 psig

•Pressurized

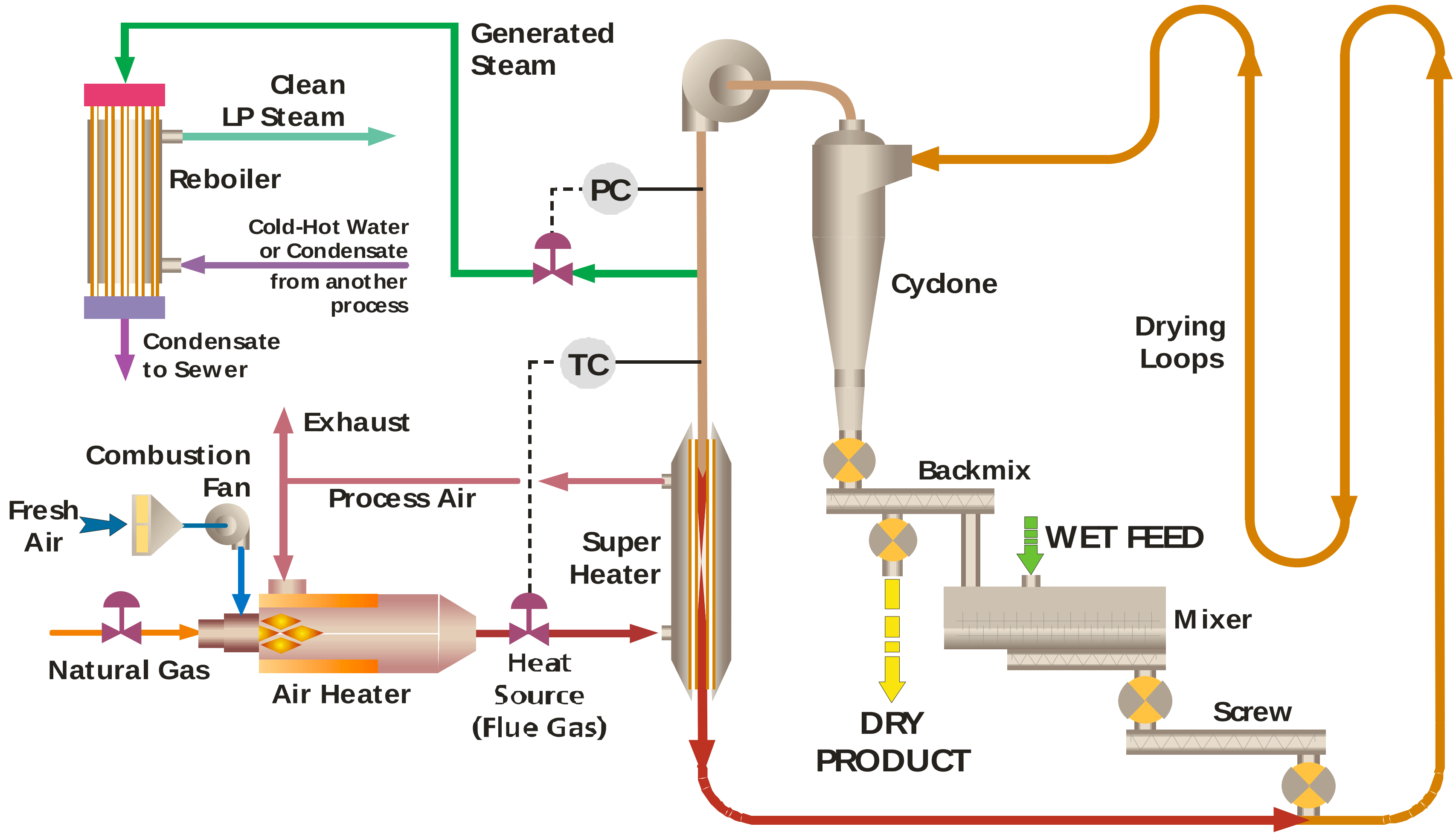
•Closed loop

•Low energy consumption

•Indirect heating

- Steam
- Hot air from natural gas burner
- Thermal oil
- Mechanical vapor recompression

Superheated Steam Dryer (SSD)



Superheated Steam Dryer (SSD)

Advantages

- Recover up to 70-80% of energy
- Zero air emissions to atmosphere *(depending on fuel used)*
- Accurate control of product moisture
- No risk of fire or explosion
- Small footprint
- Ease of operation
- High humidity exhaust (209°F WB)
- Smaller exhaust stream for RTO
- Multiple heat sources could be used; NG, coal, biomass

Applications

Biomass

Wood Waste

Animal Feed

Heat Treatment

Pulp and Fibers

Municipal Sludge

Industrial Sludge

Tobacco

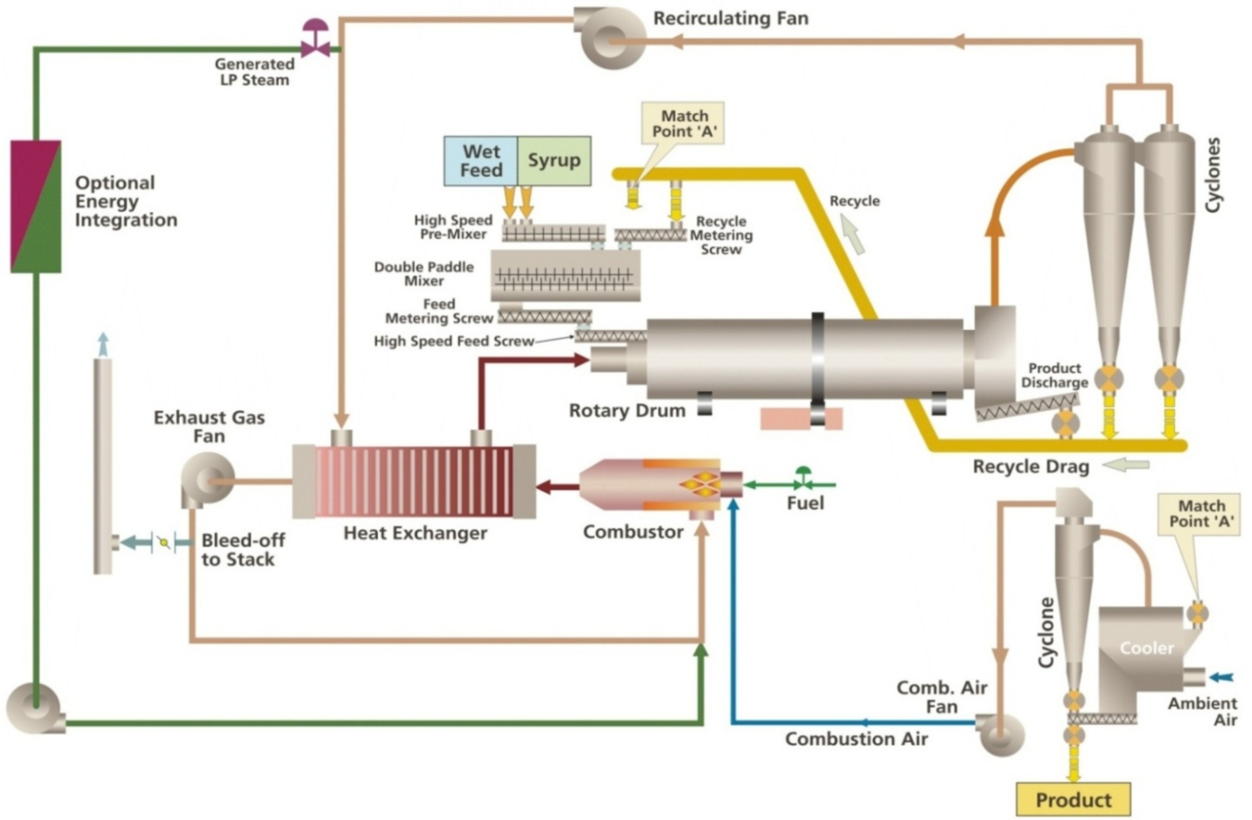
Superheated Steam Dryer (SSD)

Disadvantages

- Cannot dry larger material
- Condensate is corrosive / contains high BOD - must treat
- Terpenes and wood oils can be extracted
- Potential sealing / leakage problems
- High capital for SS pressure vessel

Hybrid SSD / Rotary

- Heat recovery
- Run near atm pressure
- Can handle larger material than standard SSD
- Low emissions
- Difficult heat-x design
- No commercial units yet



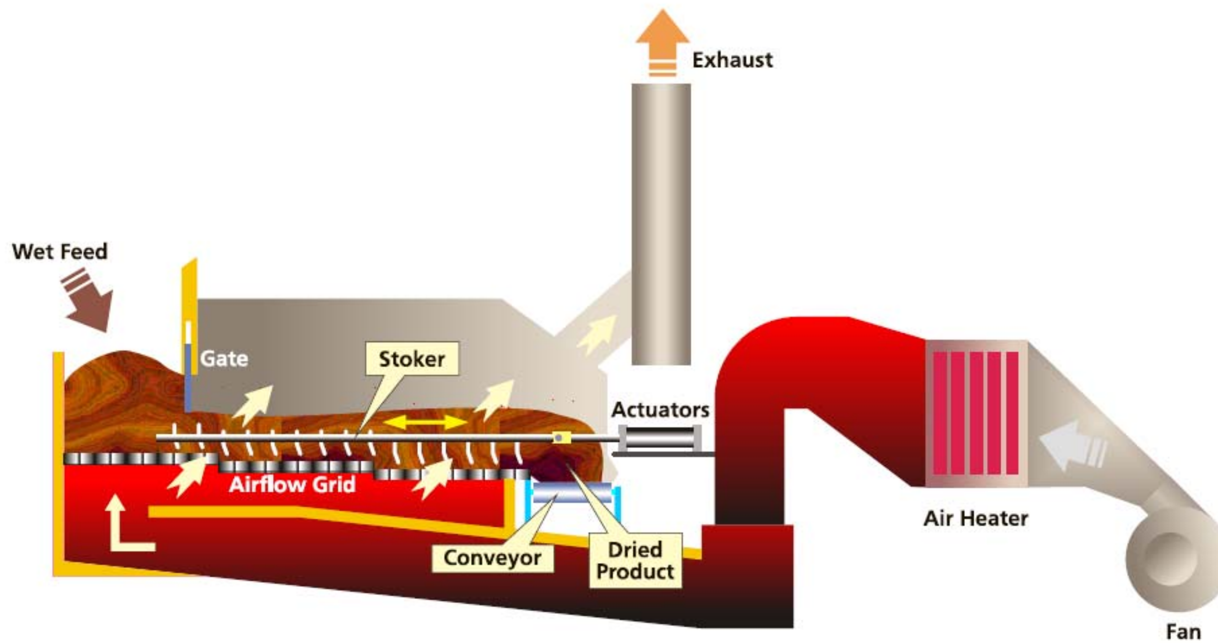
Bed / Grate Dryer

Advantages

- Can handle wide range of materials
- Utilization of waste heat w/ no temperature limit
- Robust design
- Ease of operations

Disadvantages

- Less efficient drying
- Particulate emissions can be high if fines are present
- Large footprint



Typical Emissions

- VOCs - Depends on biomass type, wood temp., res. time, & final moisture
  - Southern Pine
    - 8-9 lb/dry ton (assuming drying from 50% to 10-15% at ~1,000 °F)
  - Hardwood
    - 1-2 lb/dry ton (same assumptions)
- PM – Depends on biomass fines content and supplemental heat source etc.
  - w/ furnace
    - 3-5 lb/dry ton
  - w/o furnace
    - 0.5-2 lb/dry ton
- BACT will most likely be triggered for VOCs (40 tpy) and PM (25 tpy)

Emissions Limits

52.21(b)(23)(i) Significant means, in reference to a net emissions increase or the potential of a source to emit any of the following pollutants, a rate of emissions that would equal or exceed any of the following rates:

POLLUTANT AND EMISSIONS RATE

- Carbon monoxide: 100 tons per year (tpy)
- Nitrogen oxides: 40 tpy
- Sulfur dioxide: 40 tpy
- **Particulate matter: 25 tpy of particulate matter emissions**
- **PM10: 15 tpy**
- **PM2.5**: 10 tpy of direct PM2.5 emissions; 40 tpy of sulfur dioxide emissions; 40 tpy of nitrogen oxide emissions unless demonstrated not to be a PM2.5 precursor under paragraph (b)(50) of this section
- **Ozone: 40 tpy of volatile organic compounds or nitrogen oxides**
- Lead: 0.6 tpy
- Fluorides: 3 tpy
- Sulfuric acid mist: 7 tpy
- Hydrogen sulfide (H2S): 10 tpy
- Total reduced sulfur (including H2S): 10 tpy
- Reduced sulfur compounds (including H2S):10 tpy

Air Emissions Control - Particulate

Particulate

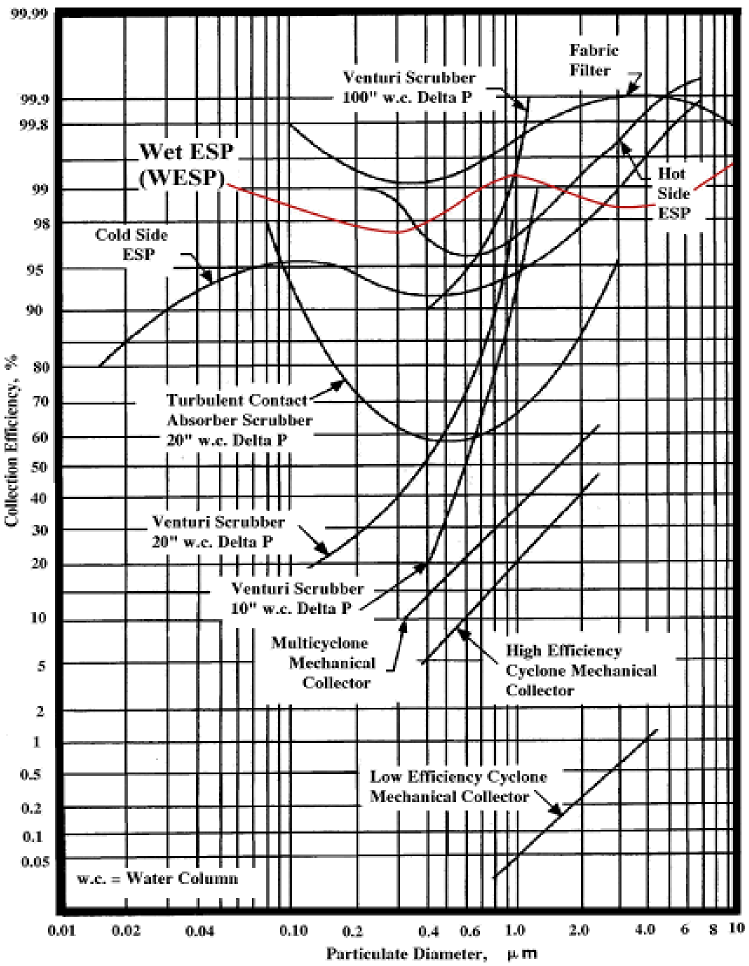
- Typically exhaust to drop box then cyclone or multiclone
- Further removal by scrubber and/or WESP
  (Typical BACT limit - 0.09-0.55 lb/ton)

•Condensable tars and pitches are problematic

- Insulation
- Heat tracing or double ducting

•WESPs are expensive and require:

- Quench duct or pre-scrubber
- Water treatment equipment
- Solids removal by centrifuge is typical



Air Emissions Control - VOCs

VOCs (terpenes, alcohols, organic acids, etc.)
Causes “blue haze” and opacity issues

- Hardwoods can contain <1% resins
- Softwoods can contain >10% resins

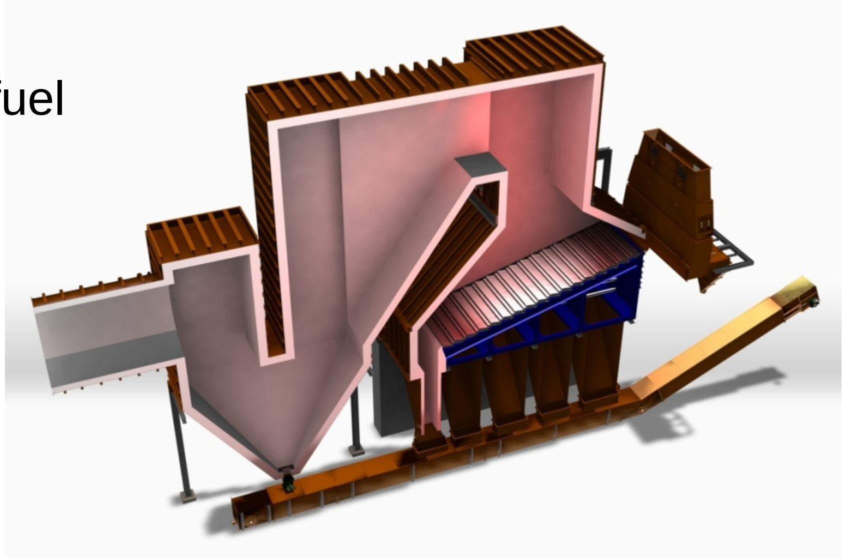
•VOC destruction typically required via…

(Typical BACT limit - 0.3-1.0 lb/ton)

- Regenerative thermal oxidizer (RTO)
  - 98% VOC and 100% CO removal, as well as 95% heat recovery
  - Bed material is expensive (protected by WESP)
- or Chemical Scrubber - 90% VOC and 30% CO removal
- or Biofilter - 90% VOC and 50% CO removal

Supplemental Heat Options (Direct Fire)

- Fines/Suspension Burner
  - ~10% moisture / ¼" minus biomass fuel
  - Manual ash clean out periodically
  - 60 MMBtu/hr (firing) – $350,000
- Reciprocating Grate Furnace
  - Wet fuel capable
  - Very fuel flexible (size and type)
  - Most reliable
  - 32 MMBtu/hr (firing) or 12 m^2 – $875,000 - $1,000,000



Dryer / Furnace Capital Costs

- Equipment Costs
  - Example Rotary Drum Dryer System Costs (no furnace)
    - 14’x60’ dryer – $2,200,000
    - 20’x100’ dryer – $3,700,000
  - Example Complete Uninstalled Equipment Costs (equipment, steel, instrumentation, PLC, motors, etc.) *(~650 odstpd, 50% MC down to 15% MC)*
    - 14’x60’ dryer (120k ACFM) and 30 m^2 furnace – **$5,200,000**
- Installation Costs
  - Mechanical erection only (no foundations, electrical, or controls)
    - Dryer (18’x80’) at ~ $500,000, plus Furnace at ~ $1,000,000
  - Total System Install ~ 1.5 to 2.0 times equipment costs
  - Grand Total w/ engineering, indirects etc. ~ 2.0 to 3.0 times equipment

$10,000,000+

Furnace Capital & Operating Costs

- Equipment Costs
  - Reciprocating Grate Furnace Example
    - 32 MM Btu/hr (firing) or 12 m^2 – $875,000 - $1,000,000
  - Fines/Suspension Burner Example
    - 60 MM Btu/hr (firing) – $350,000

- Installation Costs (mechanical erection only, no foundations, electrical, or controls)
  - Reciprocating Grate Furnace
    - 45 MM Btu/hr (firing) or 18 m^2 – $500,000 + $500,000 for refractory

- Operating Costs - Reciprocating Grate Furnace
    - 12-15 m^2 grate – 150-300 HP
    - Ash disposal

Dryer Operating Costs

- Example Rotary Drum Dryer System Connected Power (no furnace)
  - 14’x60’ dryer – 500 HP
  - 20’x100’ dryer – 1,000 HP

  - Cyclone design determines fan size
    - Cyclone system – 20 in WG (design for 25”)
    - Multiclone system – 12 in WG (design for 15”)

- Example Complete Systems Connected Power
  - 14’x60’ dryer w/ 120k ACFM fan & 30 m^2 furnace – 850-900 HP

Air Emissions Control Capital Costs

- Equipment Costs
  - Example Complete Uninstalled Equipment Costs (quench duct, WESP, water recycle system, RTO, burner, media, duct, fan, stack, steel, instrumentation, PLC, motors)
    - WESP and RTO (160,000 ACFM capacity) – **$4,600,000**
- Installation Costs
  - Mechanical erection only (no foundations, electrical, or controls)
    - WESP / RTO (~160,000 ACFM capacity) – $600,000
  - Total System Install ~ 1.5 to 2.0 times equipment costs
  - Grand Total w/ engineering, indirects etc. ~ 2.0 to 3.0 time equipment

$9,000,000

Air Emissions Control Operating Costs

- Natural Gas (RTO burner)
  - 3-5+ MMBtu/hr w/ VOCs heat included
  - VOCs Heat Value – 12,500-15,000 Btu/lb
- Transformer/Rectifiers (WESP)
  - WESP (70,000 ACFM capacity) – 210 kVA or 230 HP
  - WESP (160,000 ACFM capacity) – 315 kVA or 340 HP
- ID fan
  - RTO (70,000 ACFM capacity) – 400 HP
  - RTO (160,000 ACFM capacity) – 800 HP
- Misc. Power Demand
  - WESP and RTO (70,000 ACFM capacity) – 230 HP
  - WESP and RTO (160,000 ACFM capacity) – 340 HP

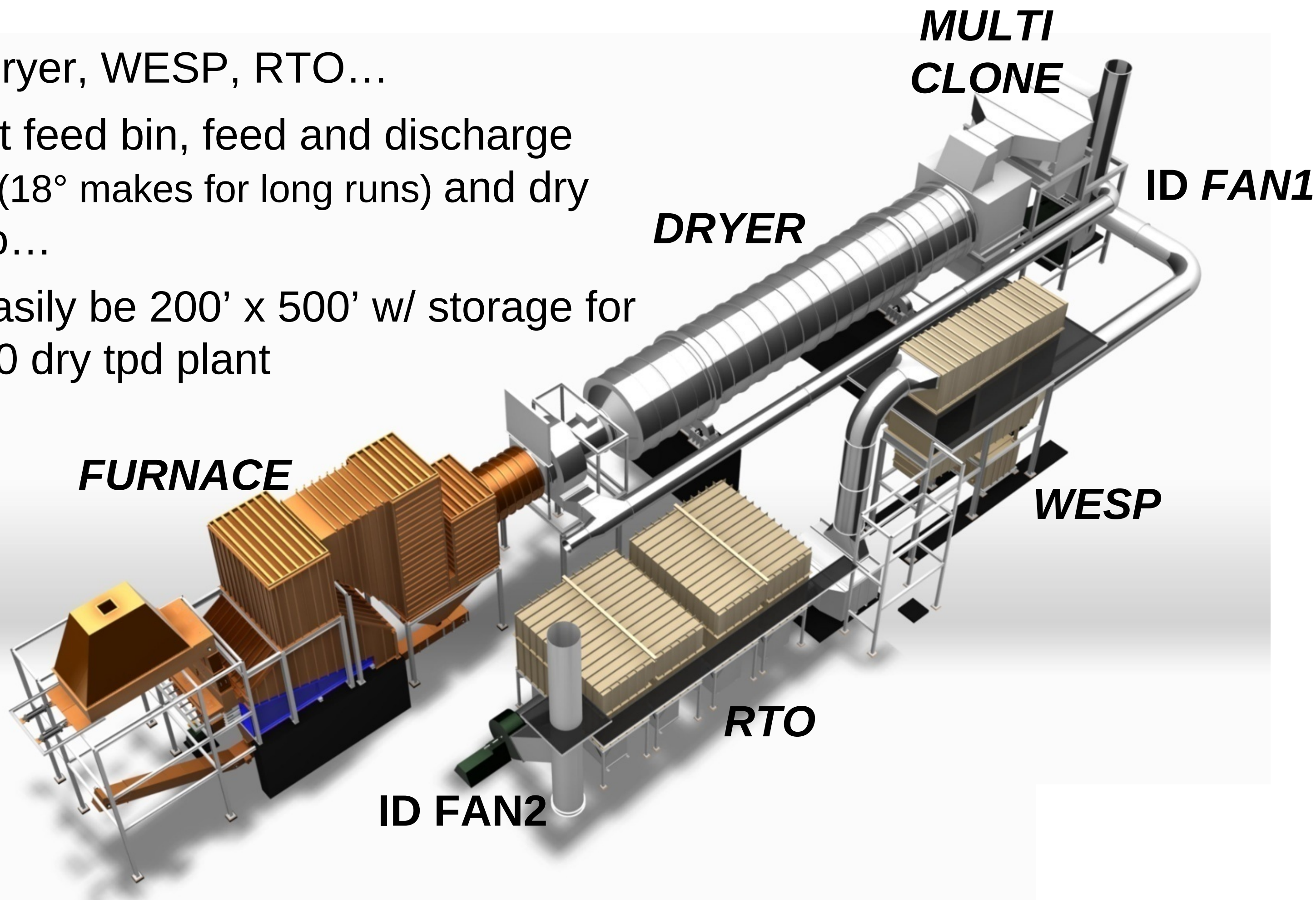
Total Power Demand

860 HP to 1,480 HP

- Don't forget
  - Water make-up
  - Defoamer
  - NaOH
  - Solids Disposal @ 50-60% moisture

Dryer System Footprint

- Furnace, Dryer, WESP, RTO…
- Don't forget feed bin, feed and discharge conveyors (18° makes for long runs) and dry storage silo…
    - Can easily be 200' x 500' w/ storage for a 1,000 dry tpd plant



Fire Detection and Suppression

- O_2 content should not exceed 10%, typicality control to ~8% in a rotary dryer
- Resins can condense and attract dust resulting in a very flammable mixture
- Double ducting (cyclone discharge & fan) or heat tracing works well to reduce condensation
- WESP protects outlet duct and RTO

Systems Should Include (GreCon, FireFly, Flamex) **:**

- Spark detectors
- Temperature indication
- Burner exhaust shutoff / bypass to emergency stack
- Feed shut off
- Auxiliary gas evacuation system if power is lost to ID Fan
- Load simulators
- Deluge showers
- Fire dump
- Dry storage considerations

Heat Recovery Options

- **Recirculation of exhaust gas to feed end of dryer** (typically done with direct fired systems)
- **Latent heat (and water) can be recovered from the moist exhaust gases**
  - **Flue-gas condensers**
  - **Run-around coil**
    - Antifreeze or oil through exhaust heat exchanger
    - Used elsewhere in process or at dryer feed end
  - **Industrial heat pump (refrigerant and compressor)**
    - Can recover part of latent heat of vaporization by condensing/dehumidifying exhaust
    - Energy efficient
    - High compressor energy usage
    - High capital cost
    - Limited to providing heat at 140-150 °F

Biomass Dryer Vendors

- **M-E-C** – Direct Fired Rotary
- **TSI** - Direct Fired Rotary
- **GEA - Barr-Rosin** – Rotary, Flash (ring) & SSD
- **Andritz** – Rotary, Belt
- **Buettner** – Direct & Indirect Rotary, Belt & Flash
- **Swiss Combi** (Anhydro – US rep) – Rotary & Belt
- **Ronning Engineering** – Direct & Indirect Fired Rotary
- **Louisville** – Steam Tube, Direct & Indirect Fired Rotary
- **Davenport** – Steam Tube Rotary
- **Aeroglide** – Rotary & Belt
- **Bruks** – Belt
- **Alstom Power**, Air Preheater Co. – Flash
- **Charles Brown** – Steam Tube, Direct & Indirect Fired Rotary
- **ESI Inc**. – Cascade
- **International Applied Engineering Inc**. – Cascade
- **The Onix Corp**. – Direct Fired Rotary
- **Wyssmont** – Tray
- **Thermal Energy International** – Low Temp Vacuum Belt
- **Williams Patent Crusher and Pulverizer Co.** – Impact Dryer Mills
- **Simon Dryers** – Steam Tube & Direct Fired Rotary
- **SSD Western** – Direct Fired Rotary
- **Stela** – Cascade, Belt & Direct Fired Rotary
- **Dupps** – Flash, Direct Fired Rotary & SSD
- **FEECO** – Direct Fired Rotary
- **Jining Tiannong Machinery** –
- **Teaford – Dieffenbacher** – Direct Fired Rotary & SSD
- **Bio-Gas** – Rotating Screw
- **DryTech Engineering** – Flash, Belt, Fluid Bed, Direct & Indirect Fired Rotary
- **Kinergy** – Vibratory Conveyor
- **Belt-O-Matic** – Belt
- **Metso (KUVO)** – Belt
- **Pulse Drying Systems** – Direct Fired Rotary
- **Raj** – Multiple Types

Cost Effectiveness

Scenarios that improve the cost effectiveness of a fuel dryer include:

- If drying reduces consumption of expensive fossil fuels
- If the wet fuel creates a bottleneck that drying can eliminate
- If boiler stack emissions of VOCs and particulates must be reduced to correct permitting problems
- If low temperature heat from the dryer is recovered and used in the facility
- If drying reduces disposal of materials
- If green power can be sold at a premium price
- If carbon offsets or Renewable Energy Credits (RECs) are sold

Thank you!

Matt Worley
Sr. Process Engineer
Harris Group, Inc.
matt.worley@harrisgroup.com
(404) 424-8889