Biomass Drying Technology Update

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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/ heat exchangers

**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
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
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)
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**
**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
- WESP are expensive and require:
  - Quench duct or pre-scrubber
  - Water treatment equipment
  - Solids removal by centrifuge is typical
**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 m² – $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 m² 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 costs
    $10,000,000+
Furnace Capital & Operating Costs

• Equipment Costs
  • Reciprocating Grate Furnace Example
    • 32 MM Btu/hr (firing) or 12 m² – $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 m² – $500,000 + $500,000 for refractory

• Operating Costs - Reciprocating Grate Furnace
  • 12-15 m² 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 m² 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

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

**Total Power Demand**
860 HP to 1,480 HP
• 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
- FEESCO – 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!

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