Selecting Dryer Type

Tray Drying Before 1920
Stack Dryer

- Energy efficient
- High capital cost

Pothole

- For small lots
- High labor cost

Hopper-bottom Trailer

- Low capital cost
- Need to operate in a building to recirculate air
- Separate fan & burner for each 12 ton unit.
Stadium

- Low labor cost
- High capacity - 25 ton increments

Grain Bin

- Large Lots
- No air recirculation

Dryer size

- Handle peak harvest
  - Nut volume = 80 - 85 ft³/ton
  - Large dryers are built in trailer load increments (12 to 13 tons)
- Number of lots
Bin Geometry

Self unloading Pallet bin Self unloading

25 Ton Dryer Design

Holding Volume for 25 tons of nuts:

\[25t \times 80\text{ft}^3/\text{ton} = 2000\text{ft}^3\]

Fan Selection

- Fan type
- Airflow
- Static pressure
Fan Selection

- Centrifugal (squirrel cage)
  - High Volume
  - Slow speed = low energy use
- Axial
  - Noisy
  - Portable

Fan Selection

- Fan type
- Airflow
- Static pressure

Airflow Capacity

- High airflow
  - Faster drying
  - Less MC variability
  - Higher fuel cost
  - Higher electricity cost
  - Higher capital cost
Airflow Controls Drying Time

Effect of Airflow on Costs

25 Ton Dryer Design

Airflow for 2000 ft³ of nuts:

2000 ft³ x 20 cfm/ft³ = 40,000 cfm
### Static Pressure (in w.c.)

<table>
<thead>
<tr>
<th>Airflow (cfm/ft³)</th>
<th>Nut depth (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4'</td>
</tr>
<tr>
<td>10</td>
<td>0.1</td>
</tr>
<tr>
<td>20</td>
<td>0.4</td>
</tr>
<tr>
<td>30</td>
<td>0.9</td>
</tr>
</tbody>
</table>

*Plus pressure drop at fan inlet and in plenum (<1/2” w.c.)*

### Fan Curve - Table

![Fan Curve - Table Image]

### Fan Curve - Graph

![Fan Curve - Graph Image]
Inlet Designs

Burner before fan

Burner after fan

Air Pollution Regulations

- Air Quality Management Districts increasingly strict applying NOx regulations to agricultural applications.
- Each AQMD has different requirements.
- Check with your local AQMD before building a new dryer.
- Low NOx burners readily available but more expensive.
**Burner Capacity**

- Minimum air temperature during drying season is about 50°F.
- Air recirculation increases minimum to about 70°F.
- Maximum outside air temperature during drying = 100+ °F.
- Turn-down ratio, at least 10 to 1

**Burner Control System**

- Modulating gas flow control.
- Flame out detection.
- Excellent digital controls now better and cheaper than analog or gas bulb.
- Should meet Safety Codes!
- Must have PID to use with VFD.
- Digital communication a plus.

**25 Ton Dryer Design**

Burner capacity for 40,000 cfm:

\[ 40,000 \text{ cfm} \times 60,000 \text{ Btuh/1,000 cfm} = 2.4 \text{ million Btuh} \]

60,000 Btuh/1000 cfm is a rule of thumb for California conditions, assuming a maximum temperature rise of 80°F.
Air Plenum Dimensions

- Maximum air speed = 1500 fpm

25 Ton Dryer Design

Air plenum area:

40,000 cfm / 1500fpm = 27 ft²

Uniformity of Airflow and Temperature

Low airflow to first bin
Relative Humidity

In typical drying weather air heated to 110°F has an RH = 15%.

Effects of Air Recirculation

Recirculation System
Air Recirculation

Daytime operation - minimal recirculation

Door open

Cold air drops out

Nighttime operation - Recirculate 50% when air when off nuts is 10°F cooler than outside air.

Partially close door

Warm air rises

Drying Costs

6 ft bin
25% initial moist.
110°F air temp.
16.7 cfm/ft³

overdrying

natural gas

electricity

Cost ($/ton)

Time (hours)
Recirculation Myths

- It rains inside the dryer at night. The air is too wet. Recirculation is useless.
- If I add some exhaust fans in the roof I can get rid of that wet air and dry better.
- I do not have a wall between the fan and bins but recirculation works fine.
- Recirculation is complicated and expensive.

Psychrometric Chart

Recirculation Psychrometrics
Recirculation Myths

• It rains inside the dryer at night. The air is too wet. Recirculation is useless.
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Hot Air Rises (Really…)

Recirculation Myths

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- **Recirculation is complicated and expensive.**

Recirculation Instrumentation

- Outside Temperature
- Temperature at Roof Inside
- Monitor Recirculated Air Flow
- Keep Plenum Humidity Below 40%
Recirculation Myths

- It rains inside the dryer at night. The air is too wet. Recirculation is useless.
- If I add some exhaust fans in the roof I can get rid of that wet air and dry better.
- I do not have a wall between the fan and bins but recirculation works fine.
- Recirculation is complicated and expensive.
- Got anymore??

Do Not Over Dry

Nut MC variability caused by
- Differences in maturity
- Position in bin
- Airflow

Incoming Moisture Content Variability

![Incoming Moisture Content Variability Chart]

Moisture Content (%wb)
Simulated MC after 25h of Drying

<table>
<thead>
<tr>
<th>Nut Depth</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velocity</td>
<td>80 ft/min</td>
<td>160 ft/min</td>
</tr>
<tr>
<td>Pressure</td>
<td>0.4 in wc</td>
<td>3.5 in wc</td>
</tr>
<tr>
<td>Motor</td>
<td>2.0 HP</td>
<td>8.0 HP</td>
</tr>
</tbody>
</table>

Nut Depth

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velocity</td>
<td>80 fpm</td>
</tr>
<tr>
<td>Drying Time</td>
<td>21 hr</td>
</tr>
<tr>
<td>Top Moisture</td>
<td>10%</td>
</tr>
<tr>
<td>Bottom Moisture</td>
<td>5%</td>
</tr>
</tbody>
</table>
Moisture Uniformity

- Velocity
  - 80 ft/min
  - 160 ft/min

- cfm/ft³
  - 10
  - 20

- CFM
  - 4000
  - 8000

- Pressure
  - 1.0 in wc
  - 3.5 in wc

- Motor
  - 1.2 hp
  - 8.0 hp

Moisture Uniformity

- Velocity
  - 80 ft/min
  - 160 ft/min

- Drying Time
  - 31 hrs
  - 21 hrs

- Top MC
  - 10%
  - 10%

- Bottom MC
  - 3.5%
  - 5%

- Average
  - 5.5%
  - 7.5%

Initial MC Effects Uniformity

- 8% Moisture
  - Drying Top Nuts to 8% Moisture
  - Drying to 8% Average Moisture

- 13% Moisture
  - Drying Top Nuts to 8% Moisture
  - Drying to 8% Average Moisture
Moisture Uniformity

Moisture Content At Top of Bin Which Corresponds To An 8% Average Moisture

<table>
<thead>
<tr>
<th>Bin depth</th>
<th>4 foot</th>
<th>6 foot</th>
<th>8 foot</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 foot</td>
<td>50</td>
<td>100</td>
<td>150</td>
</tr>
<tr>
<td>Air velocity (fpm)</td>
<td>100</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>Initial moisture</td>
<td>15%</td>
<td>9.4</td>
<td>12.8</td>
</tr>
<tr>
<td></td>
<td>25%</td>
<td>11.3</td>
<td>15.9</td>
</tr>
<tr>
<td></td>
<td>35%</td>
<td>12.8</td>
<td>20.4</td>
</tr>
</tbody>
</table>

Define Moisture Content

Wet Basis Moisture (Industry Standard)

<table>
<thead>
<tr>
<th>mwb%</th>
<th>Water Pounds</th>
<th>Nuts Pounds</th>
<th>mdb%</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>10</td>
<td>90</td>
<td>11.1</td>
</tr>
<tr>
<td>40</td>
<td>60</td>
<td>90</td>
<td>66.6</td>
</tr>
<tr>
<td>60</td>
<td>135</td>
<td>90</td>
<td>150</td>
</tr>
</tbody>
</table>

What is 1% Worth?

At 8% MC a lot weighs 25 tons, what does it weigh at 7%, 6%, 5%?

<table>
<thead>
<tr>
<th>MC wb%</th>
<th>Weight tons</th>
<th>Weight difference</th>
<th>Weight difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>25.0</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>7</td>
<td>24.7</td>
<td>-1.1%</td>
<td>-538 lb</td>
</tr>
<tr>
<td>6</td>
<td>24.5</td>
<td>-2.1%</td>
<td>-1064 lb</td>
</tr>
<tr>
<td>5</td>
<td>24.2</td>
<td>-3.2%</td>
<td>-1579 lb</td>
</tr>
</tbody>
</table>
Moisture Meters

- Hand-held
  - Dickey-John
  - John Deere
- Membrane test
  - Usually brittle at 6%.

Applied Instrumentation

Minimize Drying in Early Morning

- Keep burner on during the day
Solar Heating

- Expensive

Fire Safety

- Prevent fire by regularly cleaning air plenum.
- Adjust and control burner to produce short flame.
- Adequate transition length.
- Have a water supply available.

Extinguish a Fire

1. Turn off burner.
2. Direct a spray of water into fan inlet.
Dryer Designs

Trends, Problems, Possibilities

Trends

• Shrinking Season Requires More Capacity.
• Capital costs drive move to longer rows, larger fans & burners.
• VFDs now cost effective.
• Electronics allows automation of many tasks.

Variable Speed Drives

• Variable speed or variable frequency drives now readily available.
• Huge advantage for outdoor dryers.
• Recirculation better for indoor dryers.
• Require different burners with combustion air supply. These burners are more expensive and less flexible.
Specify Variable Speed Drive

- Specify Carefully!
- Must do PID.
- Someone must program and provide user interface. May cost more than the drive!
- MUST have proper burner and burner controls!

Problems

- Longer rows, shorter transitions, bigger burners, higher plenum velocities make temperature and air flow uniformity MUCH worse.
- Pushing burners too hard may increase flame length beyond safe limit.
- Processors struggling with shorter season also are having increasing problems with moisture variability.
- Industry needs more dry storage and lot traceability.

Uniformity of Airflow and Temperature

![Diagram showing airflow and temperature control with labels: Low airflow to first bin, Turning vane, Burner]
Temperature & Airflow Solutions

• Profile plates for burners.
• “H”, “Box”, “T”, or other burner configurations.
• Must RAMP burner up slowly on startup or when setpoint changes.
• One or more baffles to create turbulence and mixing
• Tunnel in a tunnel?

Possibilities

• Find better ways to use electronics.
• Field to package traceability?
• Automate dryer tasks like air doors & recirculation.
• Bin level detection.
• Automated grading.
• Computer model can fine-tune dryers.

Thank You!