Walnut Drying
Design and Operation

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Jim Thompson

Selecting Dryer Type

Tray Drying Before 1920

Fig. 2.—Sidwell drying house, outer walls made of slats to give good ventilation.

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

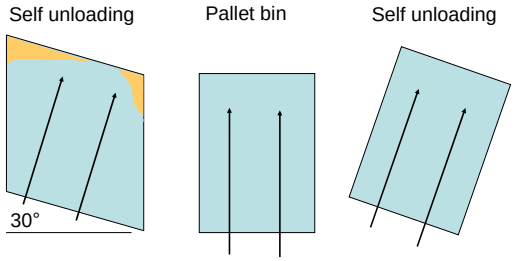
Grain Bin

•Large Lots
•No air recirculation

Dryer size

- Handle peak harvest
  - Nut volume = 80 - 85 ft^3/ton
  - Large dryers are built in trailer load increments (12 to 13 tons)
- Number of lots

Bin Geometry



25 Ton Dryer Design

Holding Volume for 25 tons of nuts:

$25t \times 80ft^3/ton = 2000ft^3$

Fan Selection

- **Fan type**
- Airflow
- Static pressure

Fan Selection

Centrifugal (squirrel cage)

•High Volume
•Slow speed = low energy use

Axial

•Noisy
•Portable

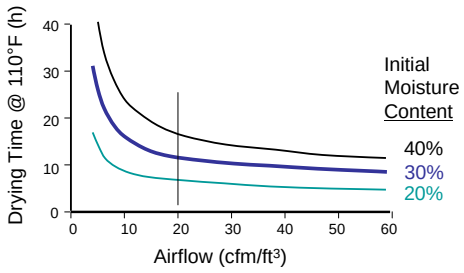
Fan Selection

- Fan type
- **Airflow**
- Static pressure

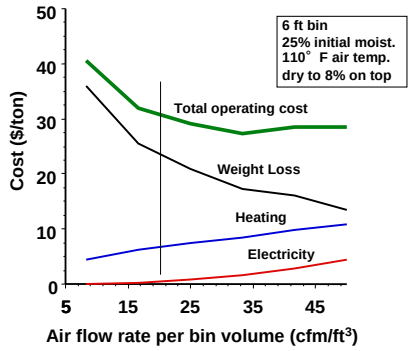
Airflow Capacity

- 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 ft^3 of nuts:

2000 ft^3 x 20 cfm/ ft^3 = 40,000 cfm

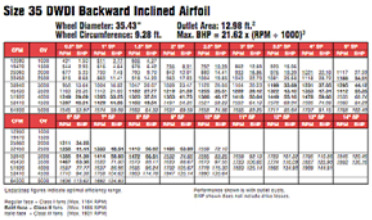
Static Pressure (in w.c.)

. Thru nuts

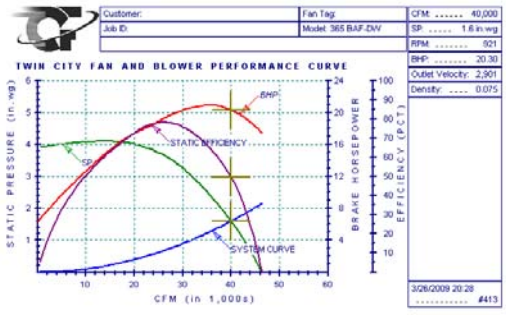
Airflow (cfm/ft^3)	Nut depth (ft)		
	4’	6’	8’
10	0.1	0.4	0.8
20	0.4	1.3	2.9
30	0.9	2.7	6.1

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

Fan Curve - Table



Fan Curve - Graph



Inlet Designs

Burner before fan

Burner after fan

Burners

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 cfm x 60,000 Btuh/1,000 cfm = 2.4 million Btuh

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

Air Plenum Dimensions

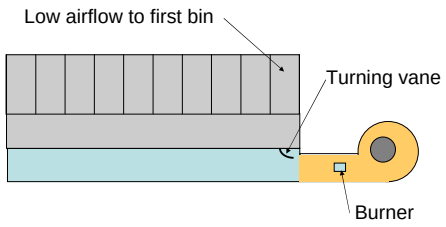
- Maximum air speed = 1500 fpm

25 Ton Dryer Design

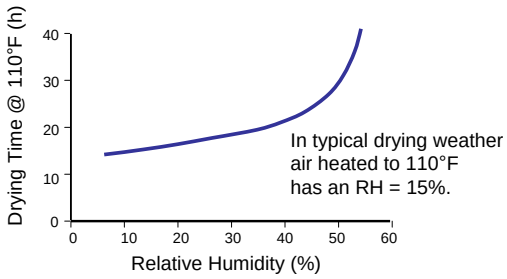
Air plenum area:

40,000 cfm / 1500fpm = 27 ft^2

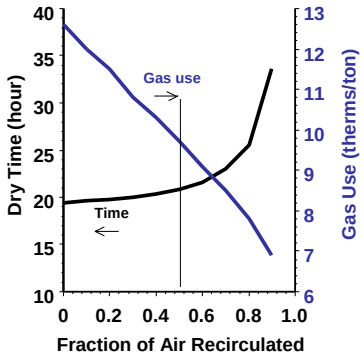
Uniformity of Airflow and Temperature



Relative Humidity



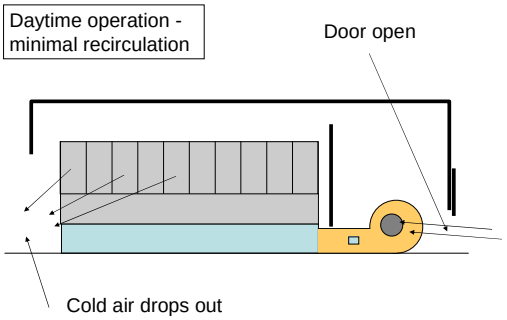
Effects of Air Recirculation



Recirculation System

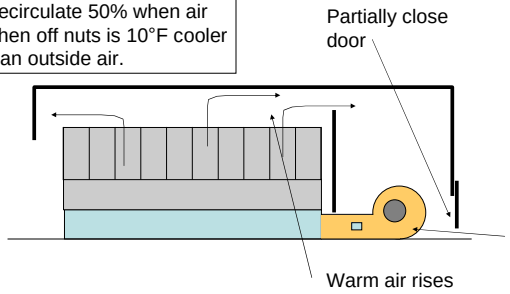
Air Recirculation

Daytime operation - minimal recirculation

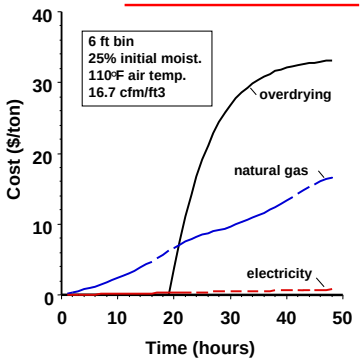


Air Recirculation

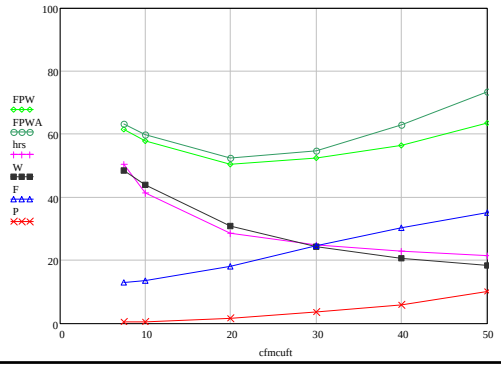
Nighttime operation - Recirculate 50% when air when off nuts is 10°F cooler than outside air.



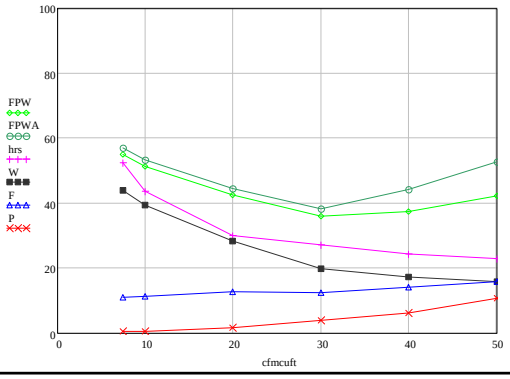
Drying Costs



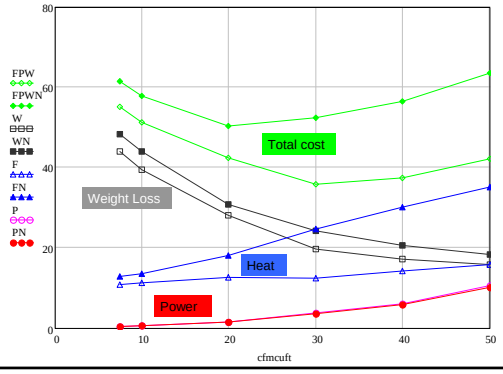
Drying Costs – No Recirculation



Drying Costs – With Recirculation



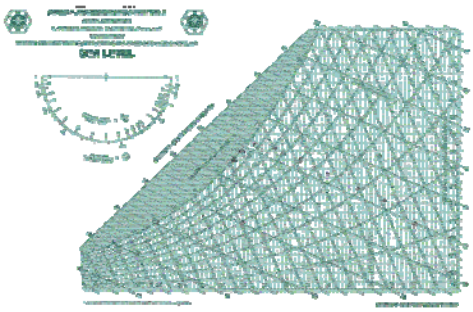
Drying Costs – w & wo Recirculation



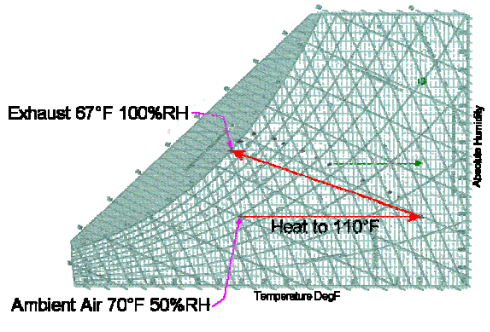
Recirculation Myths

- **It <u>rains</u> 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



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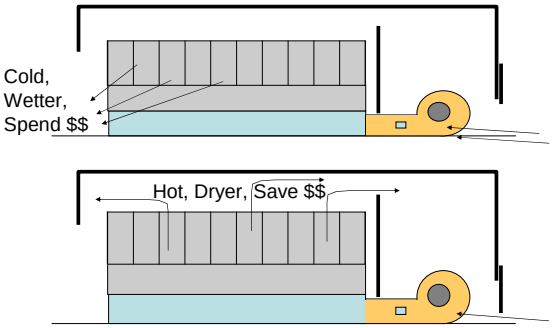
Hot Air Rises (Really…)



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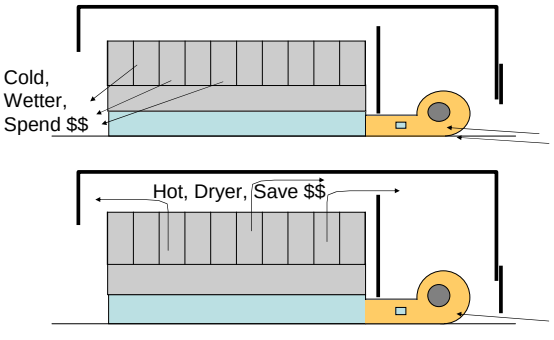
Hot Air Rises - Still



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Recirculation Instrumentation

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

Recirculation Myths

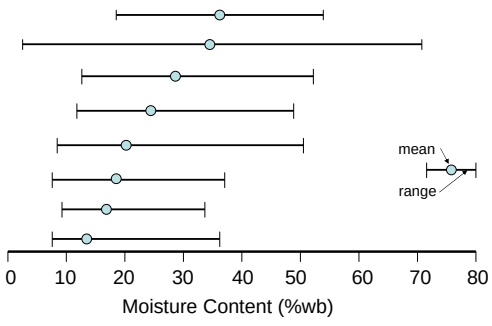
- It rains inside the dryer at night. The air is too wet. Recirculation is useless.
- If I add some exhaust fans in the roof I can get rid of that wet air and dry better.
- I do not have a wall between the fan and bins but recirculation works fine.
- Recirculation is complicated and expensive.
- Got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

Do Not Over Dry

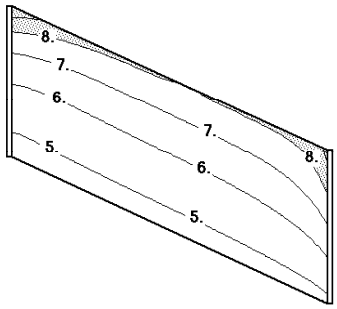
Nut MC variability caused by

- Differences in maturity
- Position in bin
- Airflow

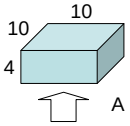
Incoming Moisture Content Variability



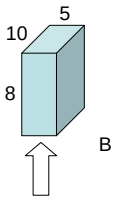
Simulated MC after 25h of Drying



Nut Depth

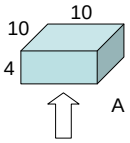


- 400 ft³
- 5 tons
- 20 cfm/ft³
- 8000 cfm



	A	B
• Velocity	80 ft/min	160 ft/min
• Pressure	0.4 in wc	3.5 in wc
• Motor	2.0 HP	8.0 HP

Nut Depth



- 400 cuft
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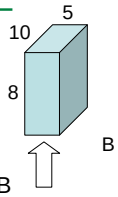
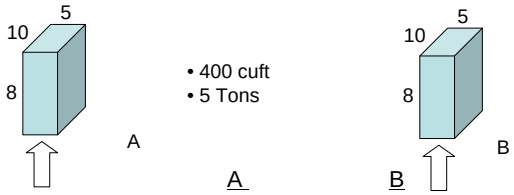


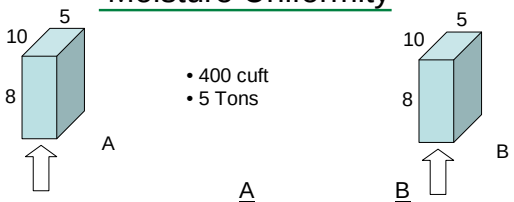
	A	B
• Air velocity	80 fpm	160 fpm
• Drying Time	21 hr	21 hr
• Top Moisture	10%	10%
• Bottom Moisture	5%	5%

Moisture Uniformity



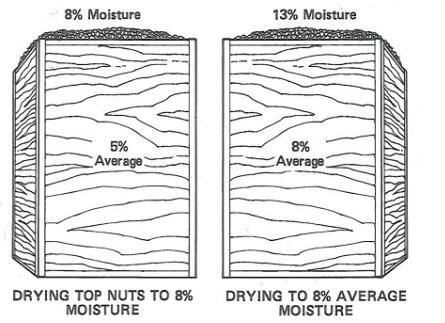
	A	B
• Velocity	80 ft/min	160 ft/min
• cfm/ft³	10	20
• CFM	4000	8000
• Pressure	1.0 in wc	3.5 in wc
• Motor	1.2 hp	8.0 hp

Moisture Uniformity



	A	B
• 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



Moisture Uniformity

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

Bin depth	4 foot			6 foot			8 foot		
Air velocity (fpm)	50	100	150	50	100	150	50	100	150
Initial moisture									
15%	11.6	9.9	9.4	12.8	10.8	9.9	13.7	11.7	10.7
25%	14.0	11.3	10.4	16.9	12.7	11.4	19.0	14.2	12.2
35%	16.7	12.6	11.1	20.4	14.9	12.7	23.8	17.2	14.4

Define Moisture Content

Wet Basis Moisture
(Industry Standard)

$$\frac{\text{Water}}{\text{DryNuts} + \text{Water}} \cdot 100$$

Dry Basis Moisture

$$\frac{\text{Water}}{\text{DryNuts}} \cdot 100$$

mwb%	Water Pounds	Nuts Pounds	mdb%
10	10	90	11.1
40	60	90	66.6
60	135	90	150

What is 1% Worth?

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

MC wb%	Weight tons	Weight difference	Weight difference
8	25.0	---	---
7	24.7	-1.1%	-538 lb
6	24.5	-2.1%	-1064 lb
5	24.2	-3.2%	-1579 lb

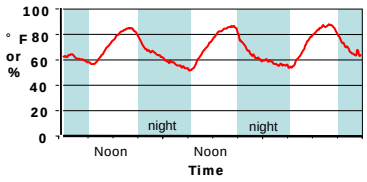
Moisture Meters

- 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

Figure 9: SOLARWALL panels on roof of dryer building

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.

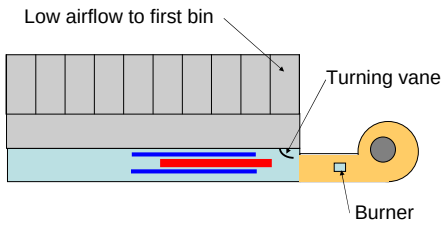
Specify Variable Speed Drive

- 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



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!