Drying Basics and Principles

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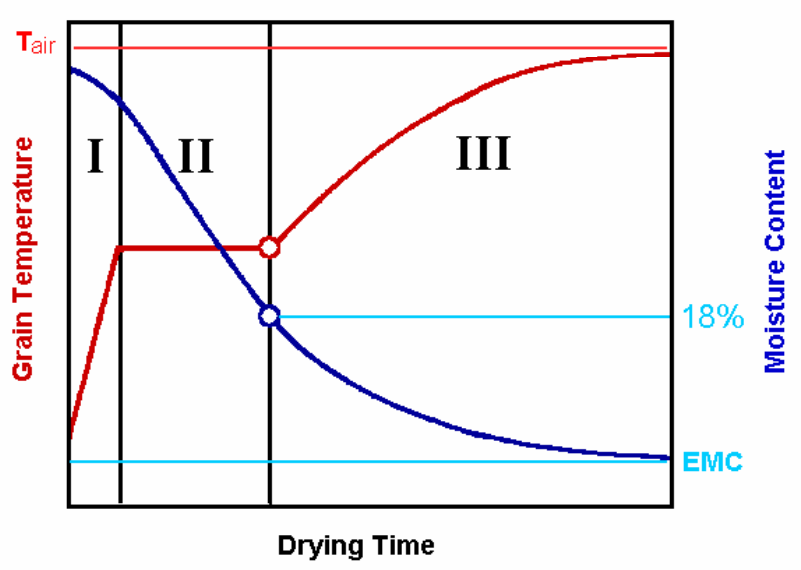
Content

- Drying process
- Moisture gradient
- Tempering
- Heated air drying and low temperature drying

Drying process

- **I Preheating period**
  - drying rate is slowly increasing
  - only a very slight change in MC
- **II Constant-rate period**
  - drying rate is constant in time
  - removal of surface water
  - grain temperature is constant
  - energy used to evaporate water
- **III Falling-rate period**
  - drying rate declines over time
  - transfer of internal moisture to the surface
  - drying rate declines
  - grain heats up (danger)
  - for paddy grain starts at 18%



-> Temperatures for drying paddy

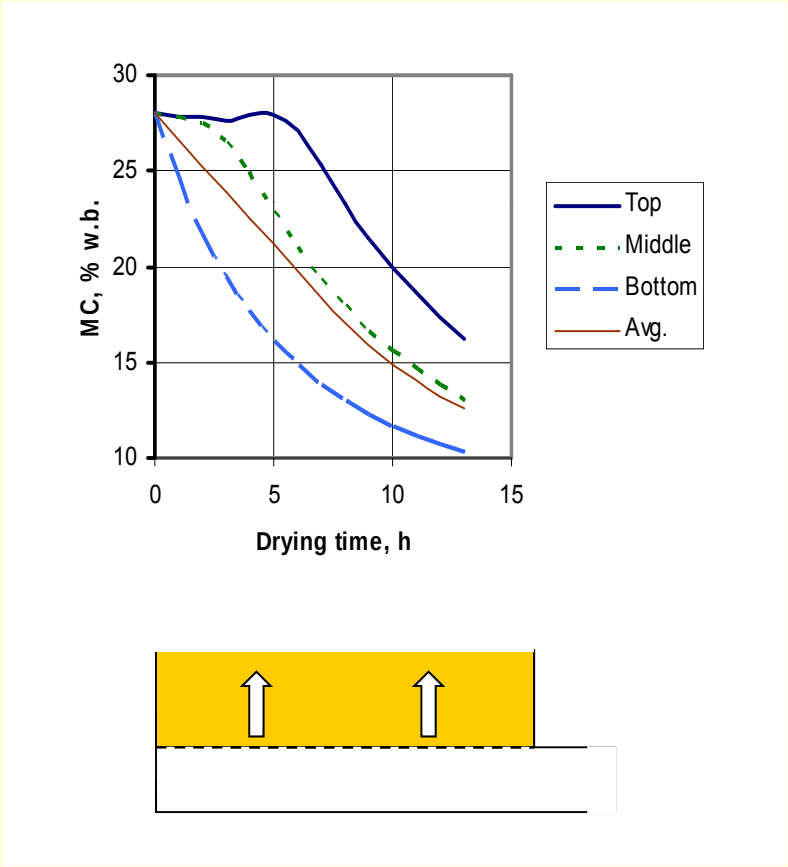
- Seeds
  - Maximum of 43 ºC
- For milling
  - During constant-rate period: > 100°C
  - During falling-rate period: < 55 °C (depends on drying system)

Drying rate

- Stated in percent moisture removed per hour
- Affected by:
  - Temperature and relative humidity of the drying air
    - Seeds: max. 43°C
    - Fist stage drying: max. 120°C
    - Second stage drying: max. 55°C
  - Air velocity
    - Too low -> air is saturated before leaving the dryer
    - Too high -> faster drying but wast of energy
    - Low-temperature drying: 0.1 m/s
    - Heated air drying: 0.15-0.25 m/s
    - Fluidized bed drying: 2.3 m/s

Uniform drying

- **Moisture gradient**
  - grain at the air inlet dries faster
  - moisture gradient
  - unloading - dry grains are mixed with wet grains
  - Re-wetting -> cracks in dry grains
- **For even drying**
  - sun drying: stir every 30 minutes
  - mix grain in fixed bed dryers
  - use re-circulating batch dryers
  - use low temperature for more even drying

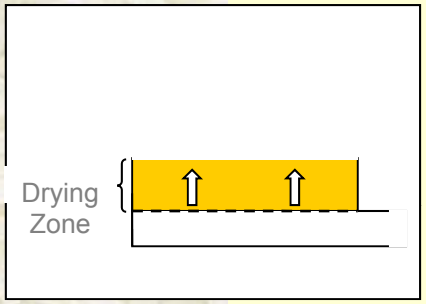


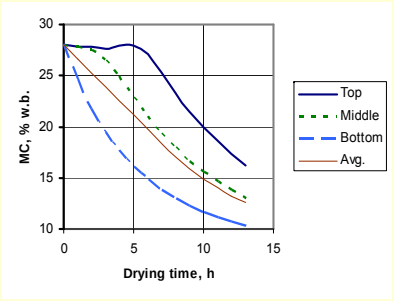
Tempering

- Temporary stopping of drying (tempering)
  - moisture will equalize inside the grains
  - moisture between grains will equalize (reduces the moisture gradient)
- Re-start drying
  - drying rate will be higher
  - reduced energy requirement
- Application
  - re-circulating batch dryers, grain goes through cycles of drying followed by tempering
  - tempering bins in continuous flow dryer plants

Mechanical drying Methods

Heated-air drying



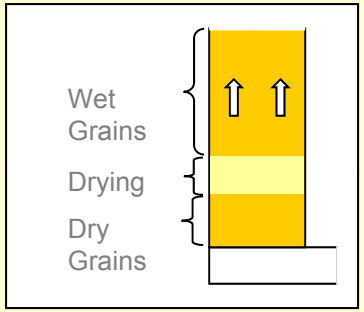


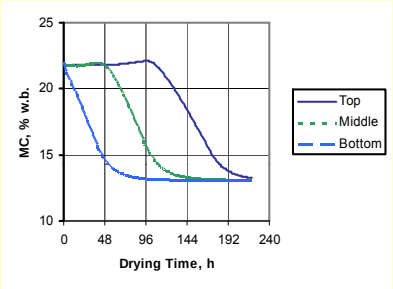
Drying air temp.: 43ºC
Air velocity: 0.15-0.25 m/s
Airflow rate per t grain: >0.7 m³/s
Power requirement: 1.5-2.5kW/t grain
Layer depth: < 40 cm
Drying time: 6-12 h
Initial MC: up to 30%+

Advantages:
Simple management
Fast drying
Affordable
Low level of integration

Disadvantages:
3-4% moisture gradient in final product, requires mixing or reduced layer depth
Reduction in milling yield
Danger of killing seeds

Low-Temperature Drying





Drying air temperature: Δ T = 0-6 ºK
Air velocity: 0.1 m/s
Airflow rate per t grain: >0.05-0.4 m³/s
Power requirement: 0.05-0.15 kW/t grain
Layer depth: < 2 m
Drying time: days to weeks
Initial MC: 18% (28%)

Advantages:
Very energy efficient
Bins can be filled at harvest rate
Maintains grain quality optimally
Drying in storage structures

Disadvantages:
Increased risk with poor power supplies
Requires bulk handling system (high level of integration in postharvest system)
Long drying time

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Drying
Storage
Milling
Packaging
Marketing

Sun drying

- **Advantages**
  - Free energy
  - Low capital investment
- **Disadvantages**
  - Weather risk
  - Temperature control difficult
  - High qualitative and quantitative losses
  - High labor requirement

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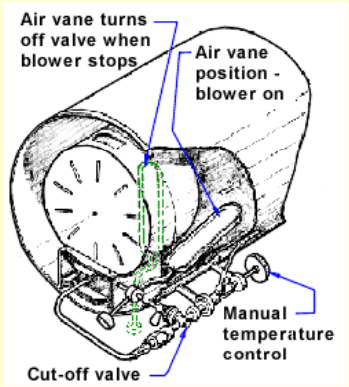
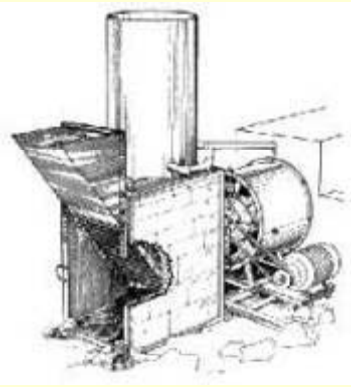
IRRI Flat-bed dryer

Capacity	1 – 2 metric tons/batch
Price	US$ 1000-2000
Drying time	6-8h
Grain Quality	Medium quality, uneven drying of bottom and top layer
Heater	Drying air temperature: 43°C A.) Kerosene burner, 2.0 l kerosene/h B.) Rice hull furnace, 3-4 kg rice hull/h
Fan	Axial flow fan, 2200 rpm 1800 cfm at 20mm H2O A.) Electric motor, 2.5 kW B.) Gasoline engine, 0.75l gasoline/h
Dimensions **Weight**	L: 3.2m; W: 2.5m; H: 1m; bin: 220 kg; furnace: 290kg
Advantage	Simple design, can be locally made, can handle very wet crop
Disadvantage	Moisture gradient, mixing necessary, dust when unloading, kerosene smell



Kerosene burner



Rice hull furnace

Vietnam: Reversible airflow flat bed dryer..

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Vietnamese 4t Flat Bed Dryer in Battambang, Cambodia

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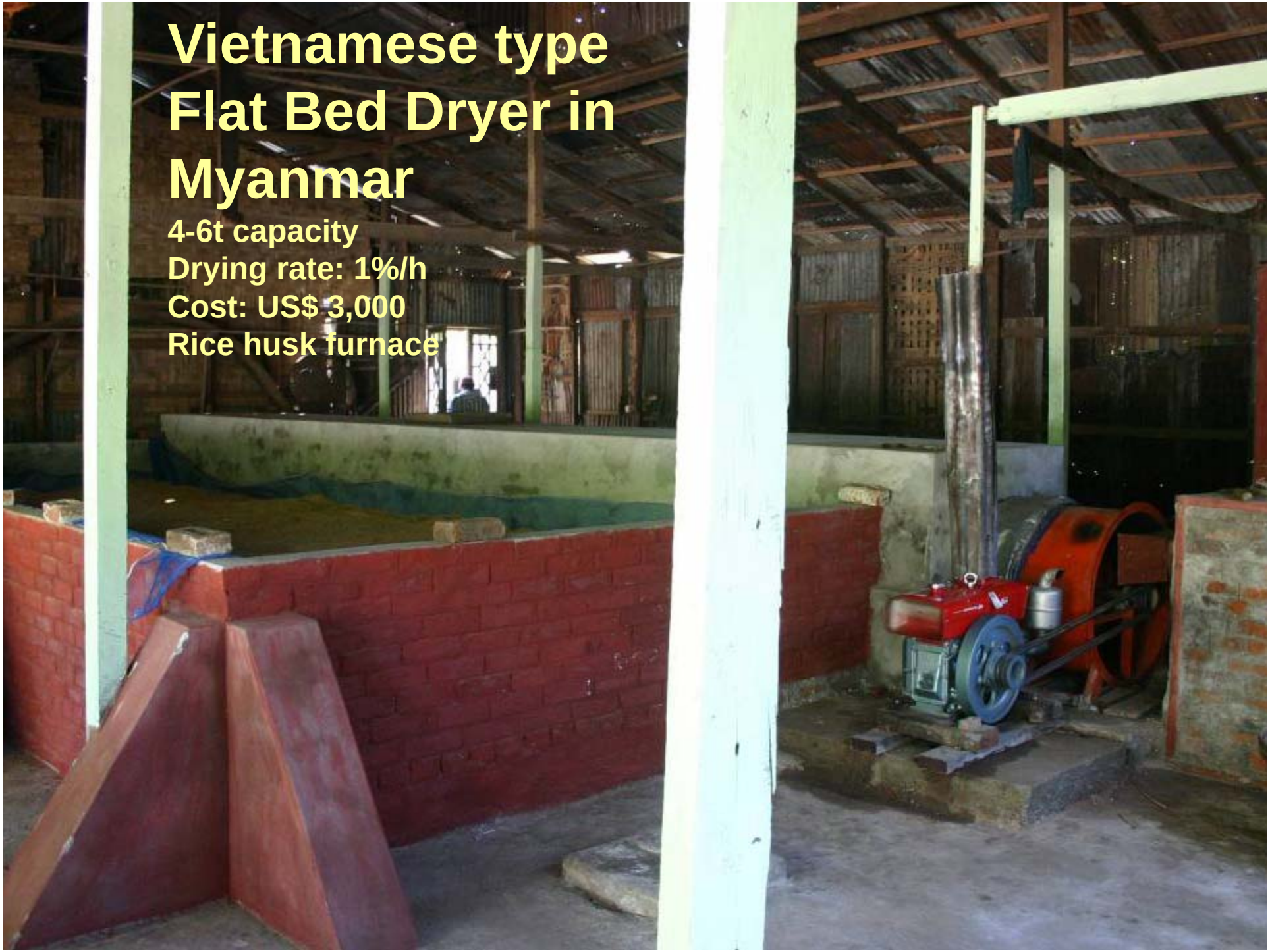
Vietnamese type Flat Bed Dryer in Myanmar

4-6t capacity
Drying rate: 1%/h
Cost: US$ 3,000
Rice husk furnace



Vietnamese Low-cost dryer

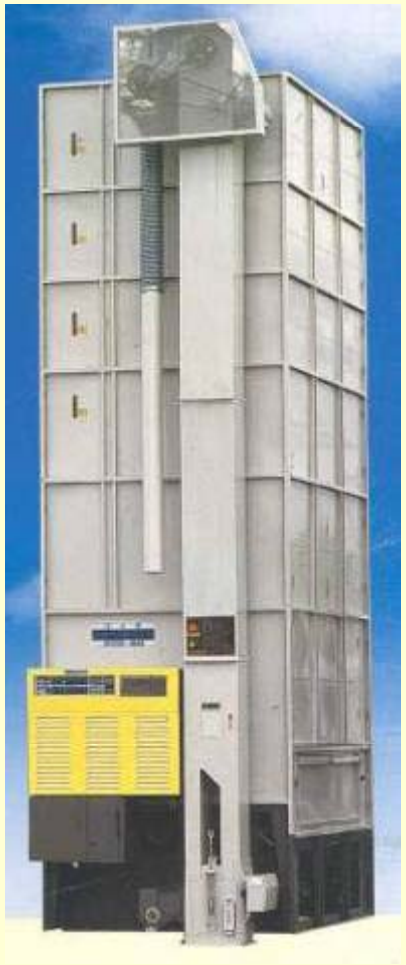
Capacity	1 t/batch
Price	US$ 150-200
Drying time	2-4 days
Grain Quality	Good, low temperature drying principle
Heater	Drying air temperature: 6°C above ambient, if weather is bad A.) Coal stove, 0.9-1 kg/h B.) Electric heater, 1 kW
Fan	Axial flow fan, 1750 rpm blowers from automotive coolers Electric motor, 0.5 kW
Advantage	Very cheap, simple design, can be locally made, can utilize traditional storage structures, highly mobile
Disadvantage	Small moisture gradient, long drying time

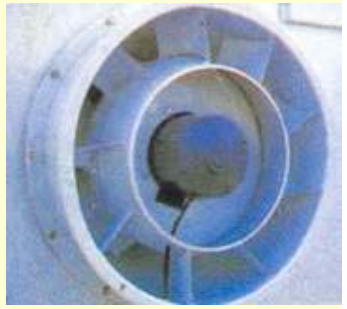
Low-cost seed dryer

Capacity	100-250 kg
Price	US$ 150-200
Drying time	6-9h (initial MC of 22%)
Grain Quality	Good seed quality
Heater	Drying air temperature: 43°C Rice hull stove, 1-1.5 kg rice hull/h
Fan	Centrifugal fan, 3200 rpm 0.11 m^3/s Electric motor, 220W
Advantage	Simple design, can be locally made, affordable, mobile
Disadvantage	Moisture gradient

Re-circulating batch dryer

Capacity	10 metric tons/batch
Price	US$ 10,000
Drying time	6-8 h, 55 min circulation period
Grain Quality	Best quality, continuous mixing, tempering – drying cycles
Heater	Drying air temperature: adjustable, Kerosene burner, 15.4 l/h
Fan	2 axial flow fans, 1730 rpm 1800 cfm at 20mm H2O A.) Electric motor, 2.5 kW B.) Gasoline engine, 0.75l gasoline/h
Dimensions	L: 3.5 m; W: 2.5 m; H: 8.3 m; 2,110kg
Electricity cons.	7.2 kW for blower, conveyors, electronic control
Advantage	Automatic operation, excellent quality, Automatic safety features
Disadvantage	Problems with very wet crop (>30%)





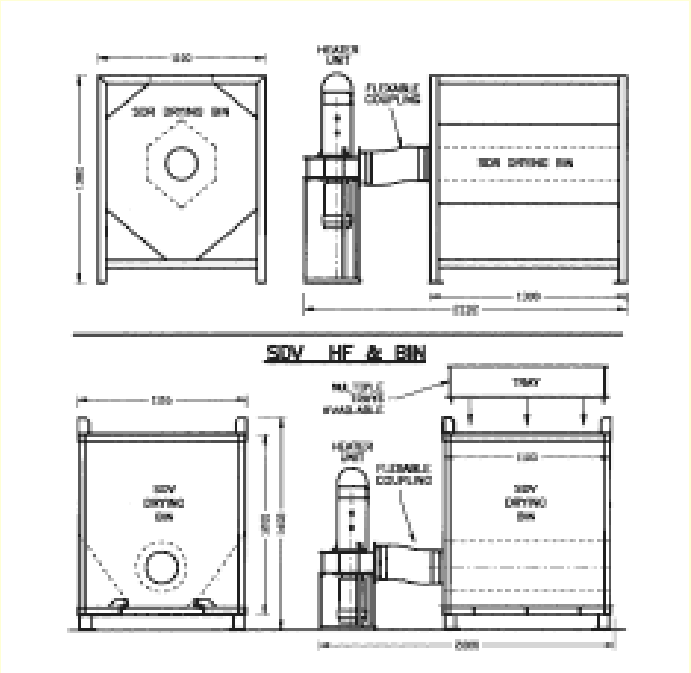
Axial-flow blower

Kerosene burner

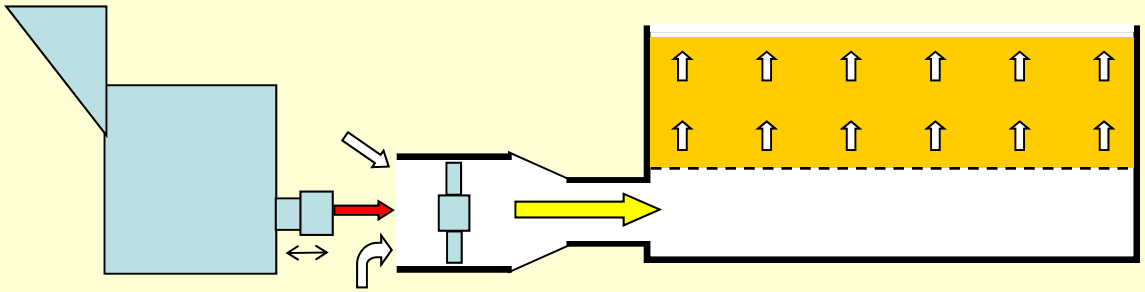
Control panel

Agridry seed dryer

Capacity	0.6 t/batch (1m³)
Price	US$ 1,350
Drying time	3.5 hours from 21.5% to 12.5% Drying rate: 2.3%/h
Grain Quality	See quality analysis
Heater	LPG gas, 20 MJ/h
Fan	Centrifugal fan Electric motor, 1.5 kW
Advantage	Mobile, convenient operation, automatic temperature control, high drying rate
Disadvantage	Uneven grain bed thickness Bin needs to be totally filled Inconvenient unloading



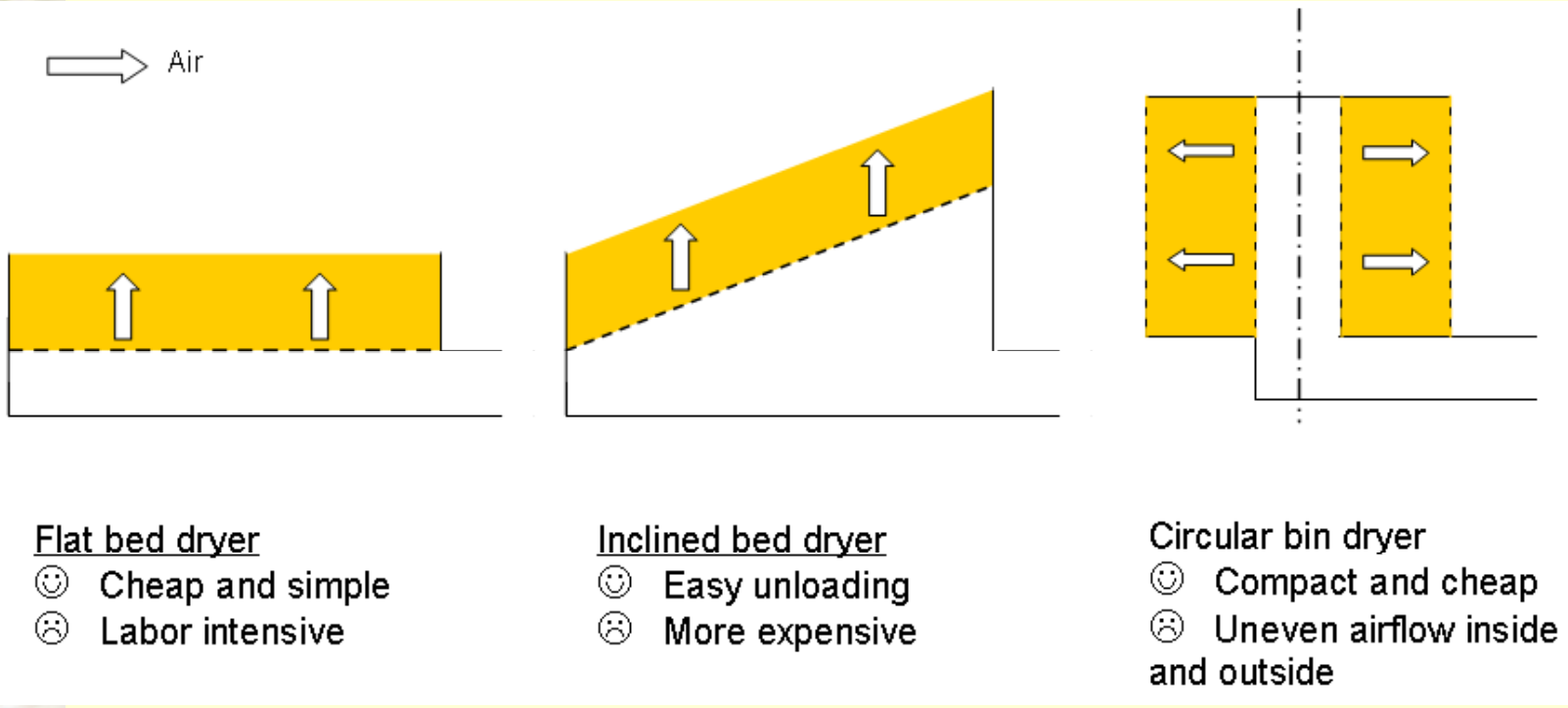
Components of a flat bed dryer



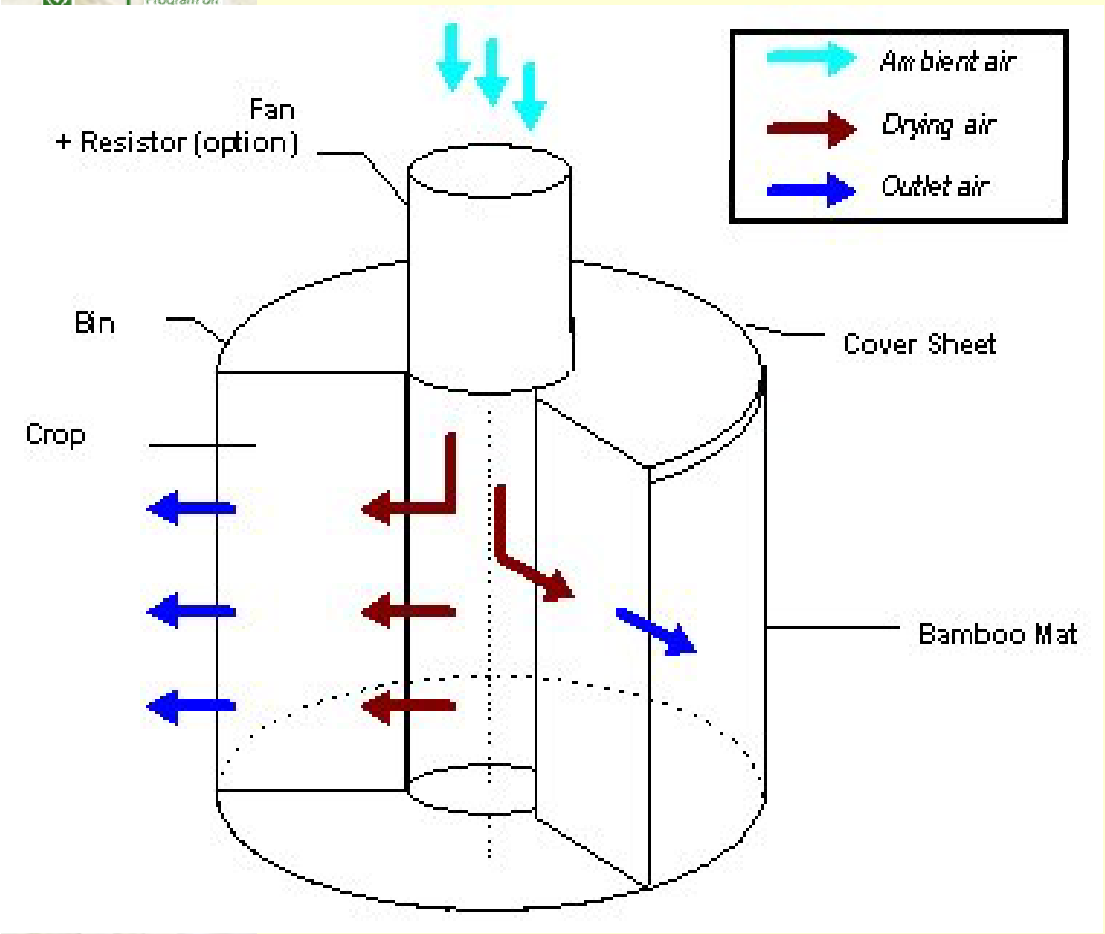
Components of a dryer and their function

- **Main components**
  - **Drying bin** - holds the grain
  - **Air distribution system** – provide drying air, remove water
  - **Fan** – create pressure and air flow
  - **Air heater** – reduce relative humidity of air
- **Optional**
  - **Conveyors** – loading and unloading
- **Accessories**
  - **Moisture meter** – monitor drying process
  - **Dust separator** – clean exhaust air

Drying bin and plenum chamber

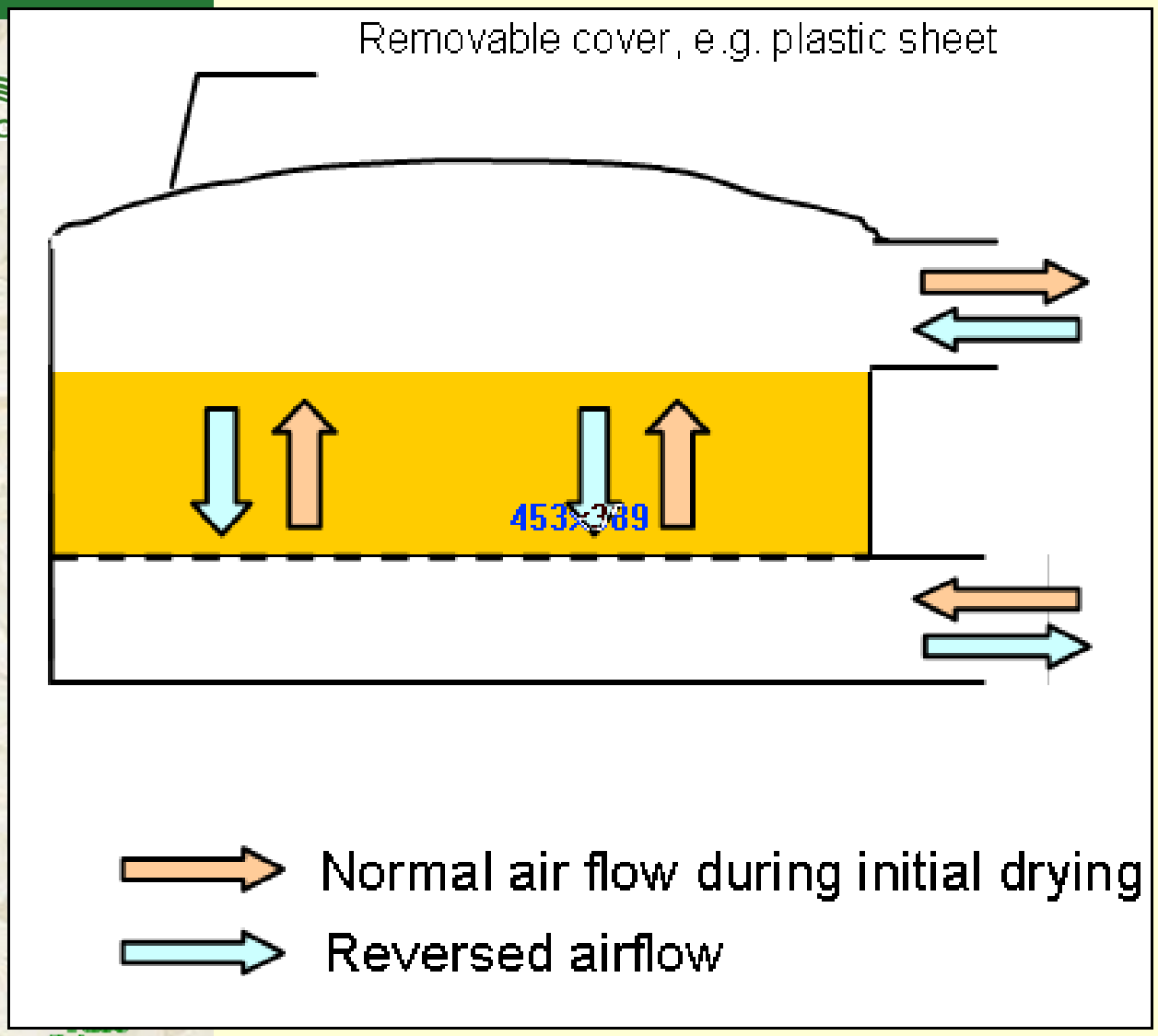


Circular drying bin



- Advantages
  - Self supporting structure
  - Simple plenum chamber
  - Short air delivery pathways
- Disadvantage
  - Uneven air velocity
  - Air velocity highest at the inlet

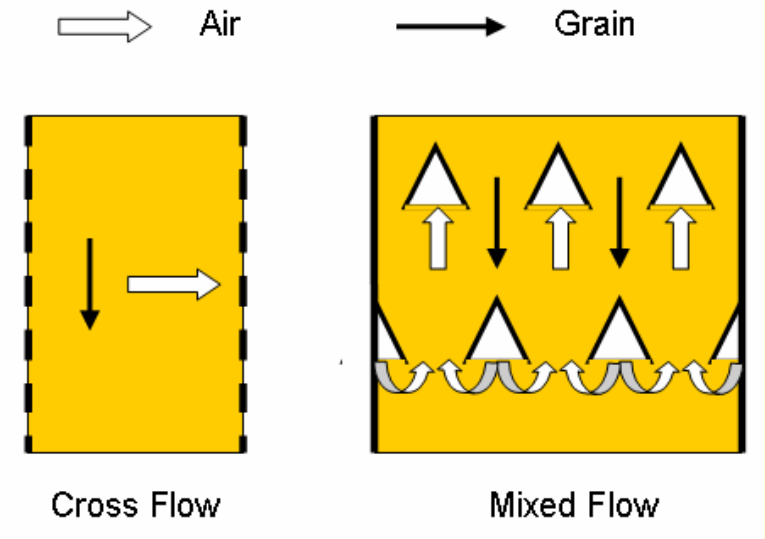
Reversible air flow dryer



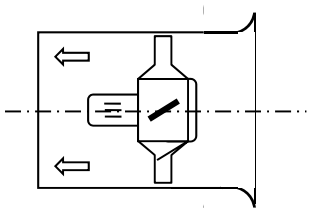
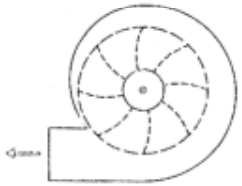
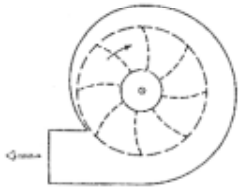
- Reversal of air flow
- Reduced moisture gradient
- No mixing needed
- Increased capacity

Air distribution system
Re-circulating batch dryers

- Cross flow
  - Grain moves downwards, air across
  - Less hindrance of grain flow, works better with wet paddy with high amount of straw and chaff
- Mixed flow
  - Air flows from inlet to outlet ducts
  - Ducts are shaped so that they mix the grain
  - Better mixing leads to better quality



Fans

Fan type	Axial flow	Centrifugal, forwards curved	Centrifugal, backwards curved
			
Cost	Cheap	more expensive	most expensive
Characteristics[1]	non-overloading	overloading	Non-overloading
Pressure creation	10-15 cm water	0-15 cm water	0-30 cm water
Unstable region of operation	At high pressure	None	None
Construction	Sturdy	Light	Sturdy
Noise level	High	Low	Medium
Typical use	Aeration, recirculation batch dryer, batch dryer		In-store dryers

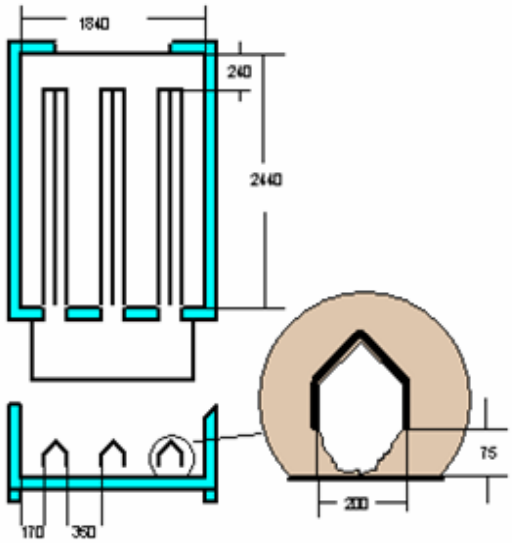
Air distribution system

Type of dryers	**Pressure system**	**Suction system**
	Fixed bed batch	Dryers with moving grain, re-circulating batch and continuous flow
Air tightness of bin	Fixed batch can be made airtight easily, large outlet	Moving mechanical parts make sealing difficult
Heater	Before fan	Before dryer inlet
Fan	High temperature resistance needed, sometimes exposed to flames	Lower temperature resistance
Dust	Stays mainly in fixed bed, set free when unloading	Sucked out with the drying air

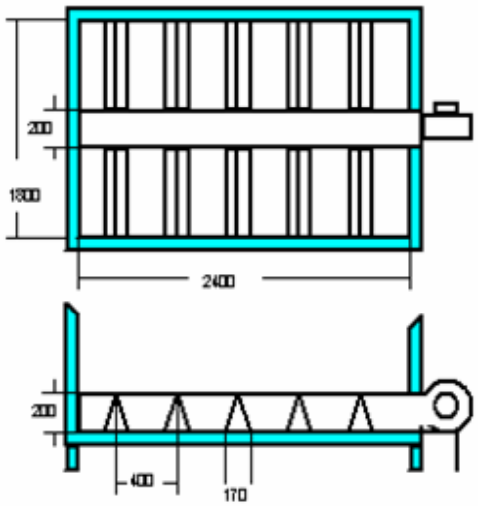
Air distribution system Options for batch dryers

System	Air ducts	Perforated false floor	Air-sweep floor
Cost	Low	Medium	High (grill shaped metal plus fan)
Air distribution	Uneven	Optimal	Optimal
Requirements	Sealed floor Additional plenum chamber needed	Stable support structure needs withstand walking on it	Support structure Strong fan for conveying
Constraints	Manual unloading Uneven drying at high MC	Manual unloading	Dust creation

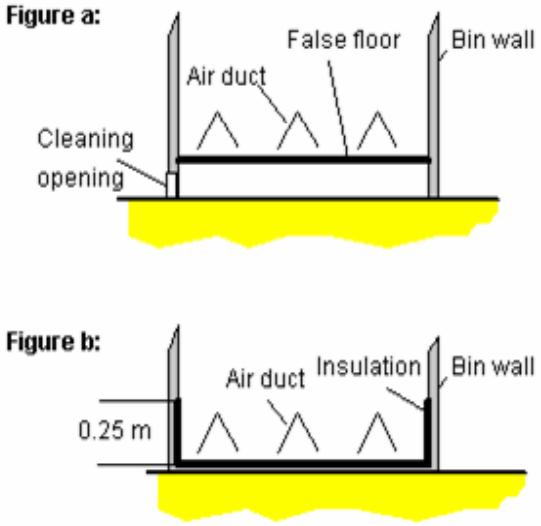
Air distribution systems
Air ducts for batch dryers



Air ducts with plenum chamber outside the drying bin

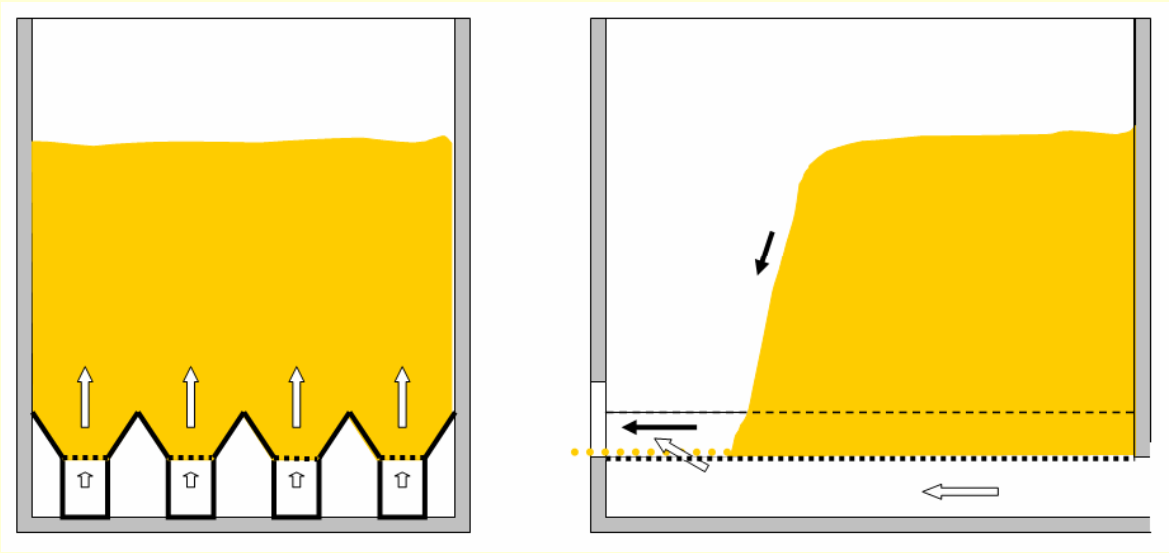


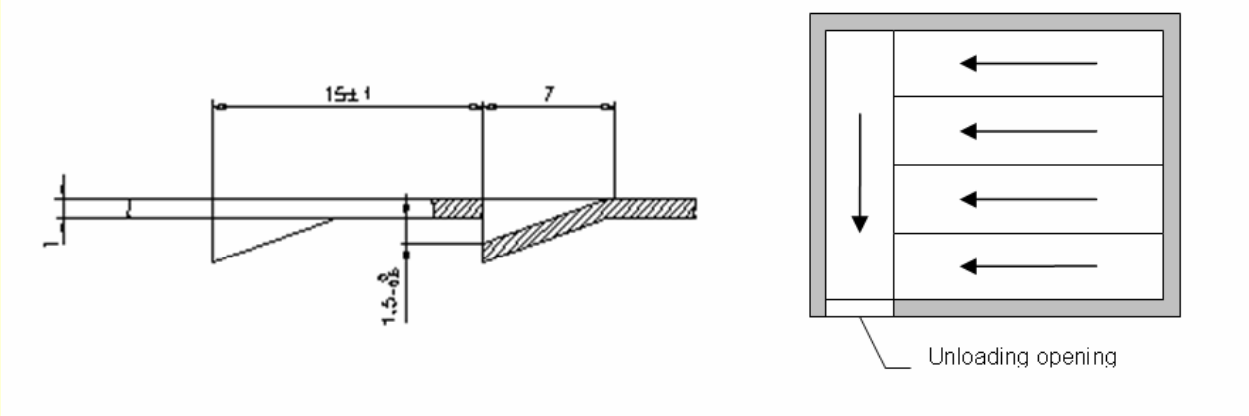
Air ducts with central plenum chamber



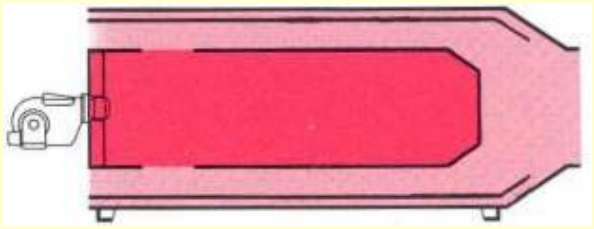
Protecting the grain bulk from ground moisture. Figure a: False floor. Figure b: Insulation

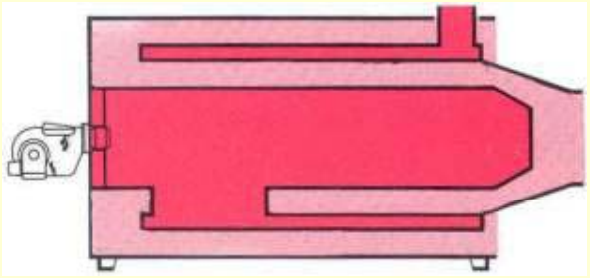
Air distribution systems
Air sweep floors





Heating systems





Heating Systems

	Kerosene / Diesel burner	Small Rice Hull Furnace	Automated Rice Hull Furnace	LPG burner	Electricity	Solar energy
Application	High	Medium	Low	Few	None	None
Capital cost	Low	Medium	High	Medium	Low	High
Operating cost	Medium	Low	Low	Medium-High	High	None
Advantages	• Easy fuel handlingAutomatic operation • High energy content	• Cheap fuel • CO2 neutral	• Cheap fuel • CO2 neutral	• Easy handling of fuel • Automatic operation • Clean flame	• Convenient • Easy to control • Clean	• CO2 neutral
Constraints	• Smell	• Labor intensive • Material difficult to convey • Bulky fuel	• High capital cost • Wear of components. • Bulky fuel	• Availability • Cost of fuel	• Expensive • Limited power load • Highest energy form	• Low heat generation

Accessories: Pre-cleaner

- Fines in rice create dust during the loading and drying process and reduce airflow through the rice grain.
- Pre-cleaners usually consist of
  - scalper that lets through the grain but retains straw
  - a smaller second screen that removes small stones and other impurities
  - air aspirator for sucking out dust and light empty grains

Accessories: Elevators and Conveyors

- For horizontal and vertical transport of grains:
  - Loading
  - Circulation
  - Discharge
- Need to be matched to the capacity of the dryer.
  - A properly designed bucket elevator for a re-circulating batch dryer can easily reach capacities of 10t/h.

Accessories: Moisture meter

- Monitoring grain moisture to avoid
  - over drying
  - incomplete drying
- Over drying
  - Unnecessary weight loss
  - Reduced milling yields
- Incomplete drying causes qualitative and quantitative losses from
  - fungal growth
  - insect activity
  - respiration

Accessories: Dust collection system

- Grain handling will create dust, making working around a grain drying hazardous.
- Need for dust collection systems
  - Cyclone
  - Need to be properly sized depending on the dryer specifications.