

UNIT II: PSYCHROMETRY AND DRYING

CO2: To perform drying of agricultural products and analyze performance of dryers.

Design of Dryers

1) Design parameters for Dryers

Thermal Design:

a) Heat required, $Q = m_w \times h_{fg}$

Where, m_w – Mass of the water to be evaporated,

h_{fg} – Latent heat of vaporization

b) Air heating requirement, $Q = (m_a \times C_p \times \Delta T) = m_a \times C_p \times (T_{out} - T_{in})$

Where, m_a – Mass flow rate of air,

C_p – Specific heat of air

Psychrometric considerations:

- Dry Bulb Temperature (DBT or T_{db})
- Wet Bulb Temperature (WBT or T_{wb})
- Relative Humidity (RH)
- Humidity Ratio (ω)

Use psychrometric chart to determine the air properties.

Drying time calculation:

$$\text{Thin layer drying equation} = \frac{M - M_e}{M_o - M_e} = e^{-kt}$$

Where, M – Moisture at the time t,

M_e – Equilibrium moisture content,

M_0 – Initial moisture content,

k – Drying constant,

t – Drying time (in seconds)

- Deep Bed Drying: Requires numerical simulation due to non-uniform drying.

2) Components of a dryer system

a) Air flow and fan design

- Estimation of airflow requirement.
- Static pressure losses in ducts and drying bed.
- Selection of blower or fan type.

b) Heating system design

- Types of heating systems: direct and indirect heating.
- Electric, steam, gas, and biomass heaters.
- Temperature control and regulation devices.
- Heat energy requirement calculation.

c) Drying chamber and structural design

- Design of drying chamber, trays, or beds.
- Material selection for construction.
- Insulation and heat loss reduction.
- Design for easy loading and unloading.

d) Moisture removal and exhaust system

- Moist air removal and ventilation.
- Exhaust duct design and moisture control.
- Prevention of condensation inside the dryer.

e) Control and instrumentation

- Temperature and humidity measurement devices.

- Moisture content monitoring methods.
- Automation and control systems in modern dryers. Safety controls and alarms.

3) Selection of a dryer type

Based on:

- Crop sensitivity (temperature, agitation).
- Scale of operation (small farm to commercial).
- Capital and operating costs.

4) Quality considerations in dryer design

- Effect of drying temperature on product quality.
- Prevention of case hardening, cracking, and discoloration.
- Design features for uniform drying.
- Retention of nutritional and sensory properties.

5) Performance evaluation of Dryers

Key performance indicators:

- Thermal efficiency, $\eta_{th} = \frac{\text{Energy used for evaporation}}{\text{Total energy given as input}}$,
- Drying efficiency, $\eta_d = \frac{\text{Actual moisture removed}}{\text{Theoretical moisture removed}}$,
- Uniformity of Drying: Moisture variation across batch.
- Specific Energy Consumption: Energy (kWh) per kg of water (moisture) evaporated.

Testing standards:

- Follow ASAE/ISO standards for dryer testing.
- Measure: Temperature profiles, air velocity, fuel consumption, final moisture content.

6) Safety and maintenance

Safety considerations:

- i. Fire hazards (dust, overheating).
- ii. Electrical safety, proper grounding.
- iii. Ventilation to prevent CO buildup (if using combustion heaters).

Maintenance schedule:

- i. Regular cleaning of filters, ducts, trays.
- ii. Fan and heater inspection.
- iii. Calibration of sensors and controls.