DRYER PERFORMANCE AND METHODS OF DRYING

Dryer Performance

- The performance of any dryer depends upon the design of overall drying system, plant maintenance and its operational method.

- The desired performance objectives of the drying systems are

Contd…

Dryer Performance

1. The grain quality must be preserved.

2. The grain should be uniformly dried.

3. The grain should dry fast enough to arrest moulding and germination.

4. The dryer should be efficient in utilization.

5. The drying potential of the heated air should be maximized.

Indicators of Dryer Performance

To evaluate the performance of dryer, the design specifications should be known or estimated and compared with measured indicators given below:

1. Static pressure at the plenum chamber, this gives an indication of air delivery of the fan and can be roughly cross-checked with an air-velocity meter.

2. The moisture content of grain at the top and bottom layers, and at various point in the dryer bed area to monitor drying progress and its uniformity.

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Indicators of Dryer Performance

3. The temperature and relative humidity of exit air, this gives an indication of utilization of drying potential of heated air.

4. The blower speed.

5. The amount of fuel used by the burner or energy consumption of the heater. This gives an indication about efficiency of fuel combustion.

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Indicators of Dryer Performance

6. Dry-bulb temperature and relative humidity of the ambient air.

7. The actual drying period.

8. The milling quality of dried products.

Efficiency of drying

If the drying system is efficiently designed, the drying of product will be faster and uniform. Drying of product will take place within desirable time and quality products will be obtainable.

Efficiency of drying

Overall thermal efficiency of drying system can be expressed in the following manner.

$$\text{Overall thermal efficiency} = \frac{\text{Amount of heat utilised}}{\text{Amount of heat available}}$$

The overall thermal efficiency of a drying system can be estimated by the following equation.

Overall thermal efficiency, %

$$= \frac{(\text{amount of water vapour removed, kg}) \times (\text{latent heat of evaporation, kcal/kg})}{(\text{amount of fuel, kg}) \times (\text{net calorific value of fuel, kcal/kg})} \times 100$$

Heat utilization factor

- The utilization factor of a drying system is the ratio of drop in temperature of drying air by drying process and the increase in the temperature of ambient air by heating.

Heat utilization factor

$$\text{Heat utilization factor} = \frac{\text{Drop in dry bulb temperature of drying air, °C}}{\text{Increase in dry bulb temperature of ambient air, °C}}$$

$$= \frac{t_2 - t_3}{t_2 - t_1}$$

Where,

t_1 = Dry – bulb temperature of ambient air,
t_2 = Dry – bulb temperature of heated air,
t_3 = Dry – bulb temperature of exit air,

COP & Effective heat efficiency

Coefficient of performance = $\frac{t_3 - t_1}{t_2 - t_1}$

Heat utilization factor = 1 - coefficient of performance

Effective heat efficiency = $\frac{t_2 - t_3}{t_2 - tw_2}$

$tw_2 =$ Wet – bulb temperature of the drying air, ℃

For calculation of effective heat efficiency of the drying system, the sensible heat of heated air is taken into consideration.

Different drying methods

Sun/solar drying

A. Drying of standing crops.
B. Drying of grains on stalk.
C. Drying of thrashed grain.

Artificial drying with Mechanical means.

A. Contact drying.
B. Convective drying.
C. Freeze drying.
D. Radiation drying.
E. Super heated steam drying.
F. Osmotic drying.
G. Fluidized bed drying.
H. Desiccated air drying.

Solar drying

1. This is traditional method of drying of crops and probably being followed by farmers since man has developed art of cultivation.
2. Sun is very large nuclear fusion reactor which converts 40 lakh tones of hydrogen into helium in one second.
3. Earth absorbs a minute portion of sun energy, but the amount of energy received is approximately of 5.4×10^{24} joule/year.
4. This amount of energy is equivalent to 27,000 times the total energy produced by man.

Solar drying

❑ Features of sun/solar drying.

1. Uncontrolled and non-uniform drying results in crack in kernels. Such grains yield large quantity of broken during milling.
2. The process is dependent on the sun energy, hence the crop harvested during monsoon season can not be dried.
3. It required a large number of unskilled labours.
4. About 1-2% grain is lost due to birds, insects and rodent attack.
5. It requires no fuel or mechanical energy, drying cost is low as compared to mechanical drying.
6. It requires very large area for drying.

Solar drying

A. Drying of standing crops.

1. Grains are dried on the plant till proper moisture content is attained.
2. Then the crop is harvested and threshed.
3. There is considerable quantity is lost due to shattering.
4. This drying process is slow and takes about 2-3 weeks after the grains have attained biological maturity.

Solar drying

B. Drying of grains on stalk.

1. This is an improvement over the previous methods.
2. The crop is harvested at higher moisture content and is left in the field or on bunds of the field till it has dried to proper moisture content.
3. Another method is to dry the harvested crop on racks.
4. Crop is bundled near the ears and hung on a rope exposing to the sun.

Solar drying

C. Drying of threshed grains.

1. The harvested crop at a higher moisture content is threshed and the grains are spread on the floor in 1 to 3 cm thick layer.
2. It is continuously stirred manually till it has attained the desirable moisture content.
3. In this process , the grains are subjected to under controlled drying causing cracks in the kernels.

Mechanical drying

“Rate of drying of grains can be controlled by controlling the temperature of hot air ventilating through grain mass”.

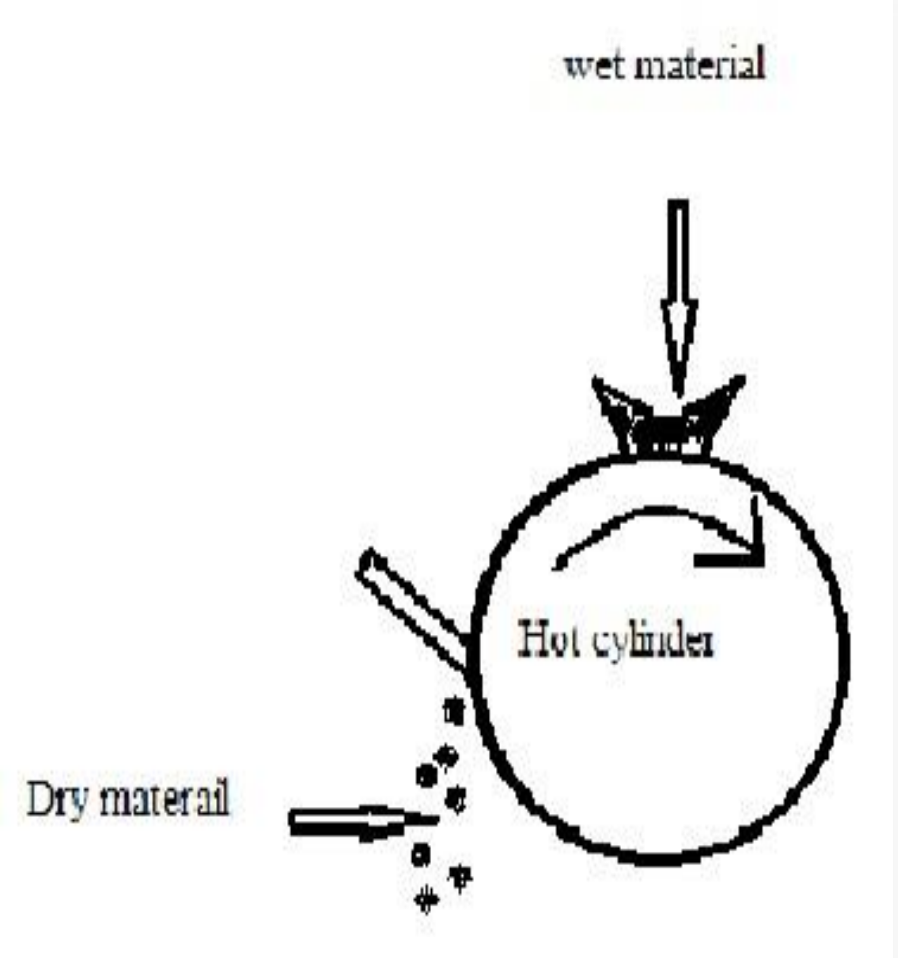
❑ Features of mechanical drying.

1. Grains can be dried in all seasons and also during night.
2. The process is automatic and requires a small number of un skilled labors, however , a trained person is required to operate the dryer.
3. Losses due to insects, birds and rodents are avoided.
4. The process required little space for operation and its suitable for big meals.
5. Mechanical drying in conjunction with early harvest improves the milling quality of grains.

Mechanical drying

A. Contact drying

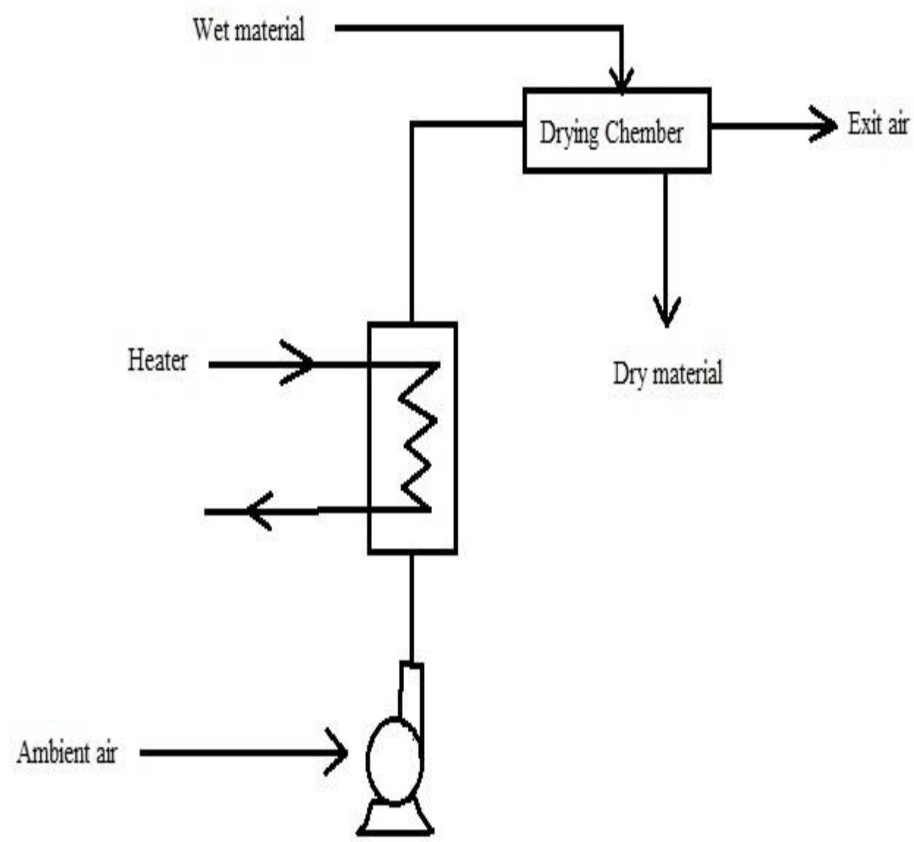
1. In this method of drying, heat is supplied to wet products by conduction. For heat transfer, a heated surface like plate, cylinder, dryer wall is used.
2. The rate of heat transfer is dependent upon the thermal conductivity of the heated surface and also depends on the heat transfer coefficient from the heating medium to the surface.
3. The commonly used heating medium in conduction drying are steam, organic liquids, metals and other materials with high values of heat transfer coefficient.
4. Since all the heat which passes through the material is utilised for moisture evaporation, thermal efficiency of contact drying is higher.



Mechanical drying

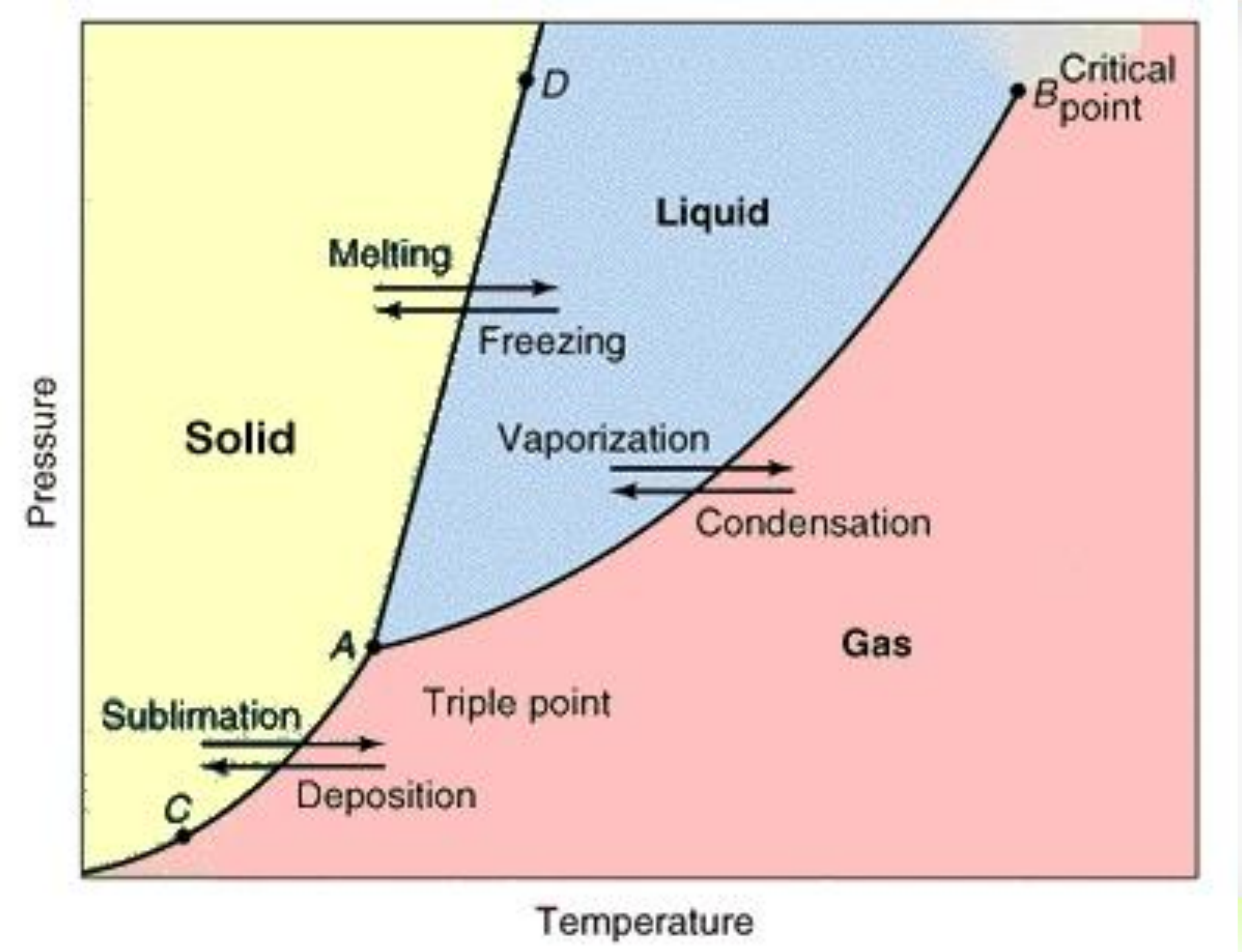
B. Convective drying.

1. In this method the sensible heat of heated air is transferred to the wet product by convection.
2. Heated gaseous medium (usually air) is ventilated through a mass of wet materials and carries with it the water-vapour evaporated from the material.
3. To save energy, sometimes the exit air from dryer is recirculated .
4. The partially dried material is recalculated for further drying.
5. In such situation the system is known as recirculatory dryer.



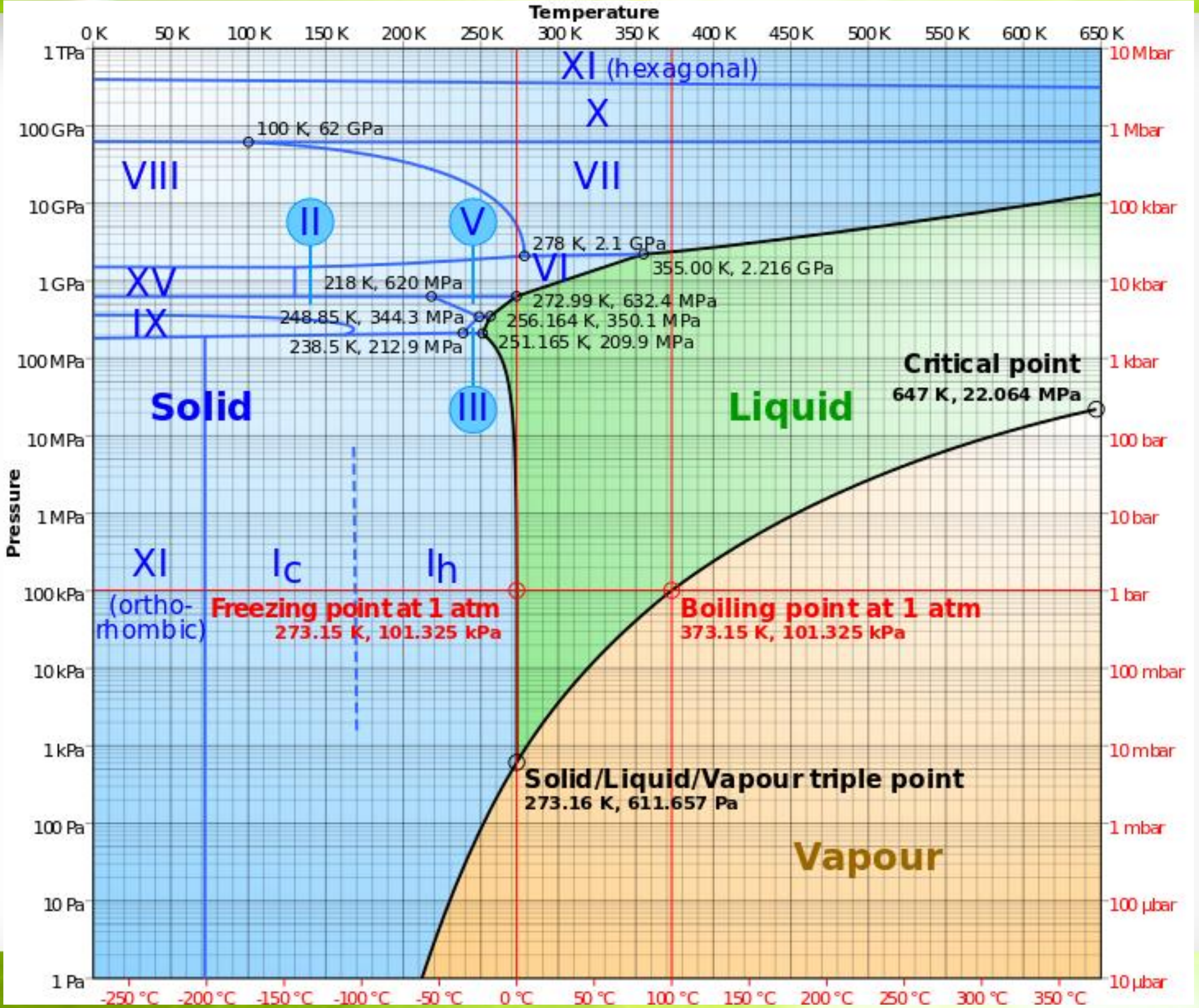
Mechanical drying

C. Freeze drying.



Mechanical drying

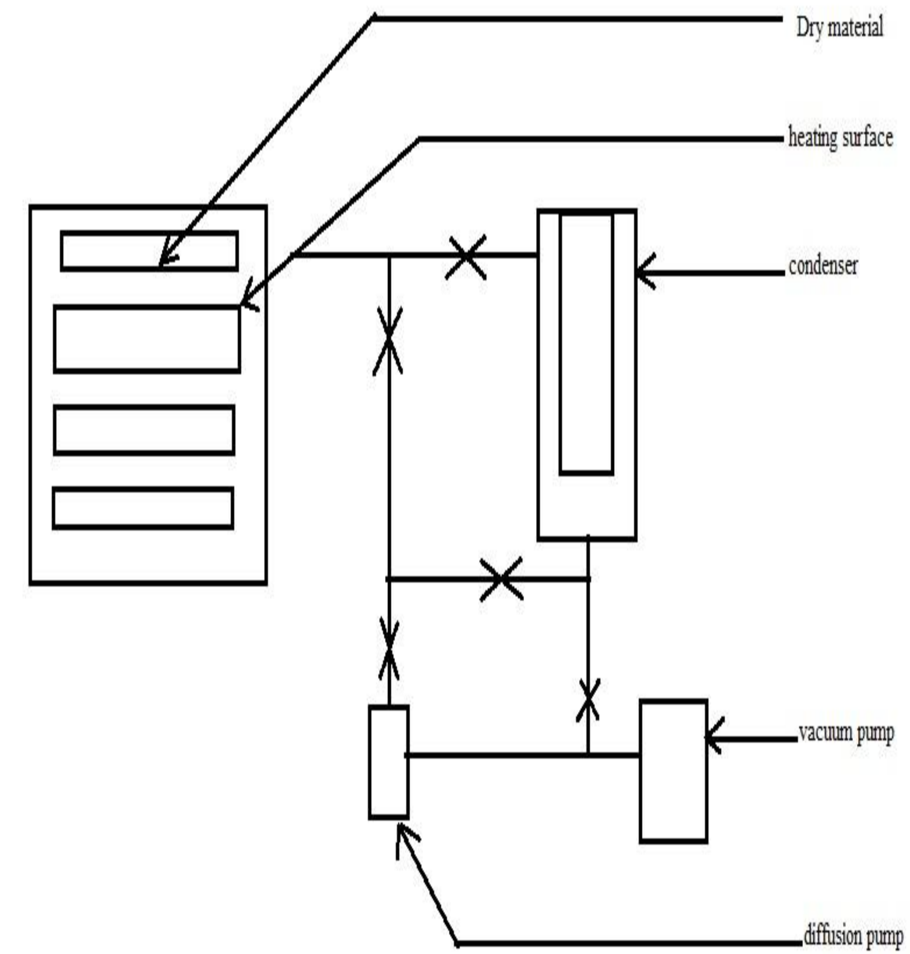
C. Freeze drying.



Mechanical drying

C. Freeze drying.

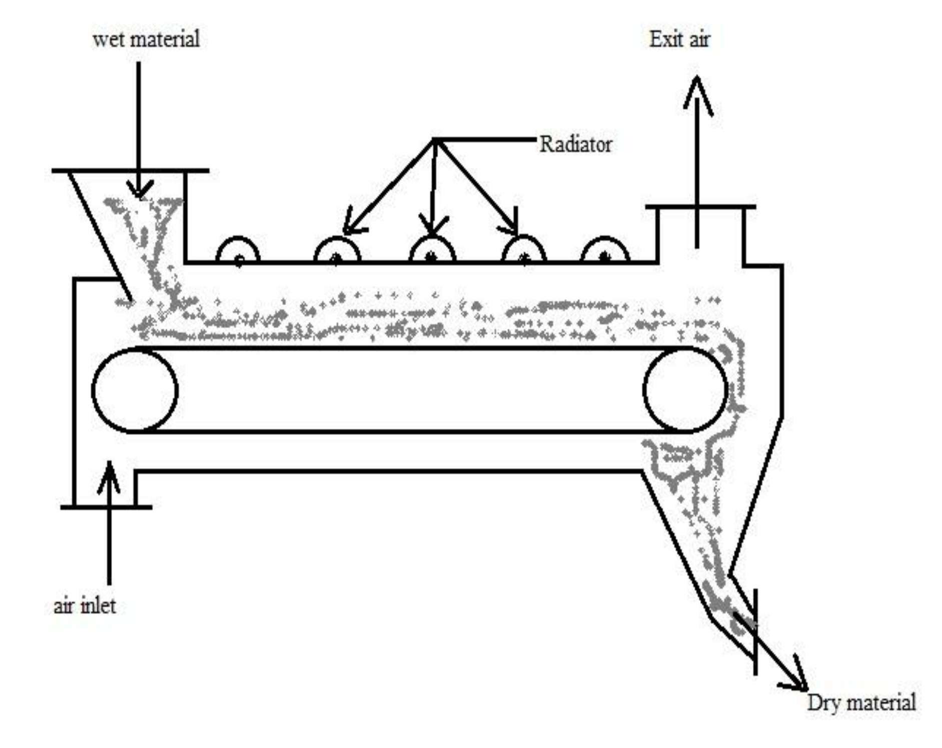
1. This method of drying is based on the sublimation of frozen moisture from the wet product placed in a drying chamber.
2. The pressure in the drying chamber is low.
3. Heat is supplied by radiation or conduction from heated trays and the temperature of product is not raised above 0^oC.
4. The sublimated moisture is condensed on refrigerated plates in the drying chamber but these plates do not come in contact with products.



Mechanical drying

D. Radiation drying.

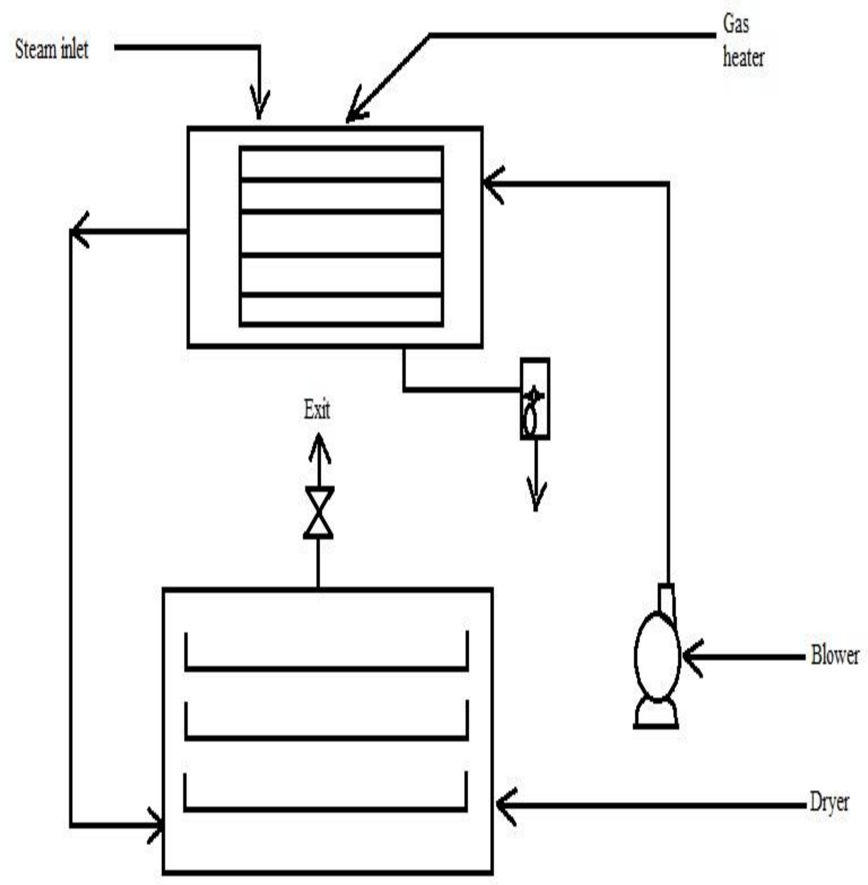
1. Heat energy can be supplied to wet products by electro-magnetic waves.
2. The wave length of radiation lies between 0.76 to 400µm.
3. The radiation within this wave length is also called as infra-red radiation.
4. The infra-red penetrates the surface of wet material and causes vibrations of molecular, which crates thermal effect.
5. Since the penetration depth of infra-red waves is relatively small, this method of draying is commonly used for drying of thin material.
6. The moisture migration inside the material and diffusion of vapour follows the same lows as in convective or drying.



Mechanical drying

E. Super heated steam drying

1. In this method of draying, as shown in, first of all dryer is fitted with hot air and normal convection draying takes place.
2. The water vapour evaporated during draying operation starts to circulate with hot air over pressure is realised by a presser control valve and the air is gradually replaced by water vapour.
3. At the end of draying water vapour with a small amount of air is circulated.



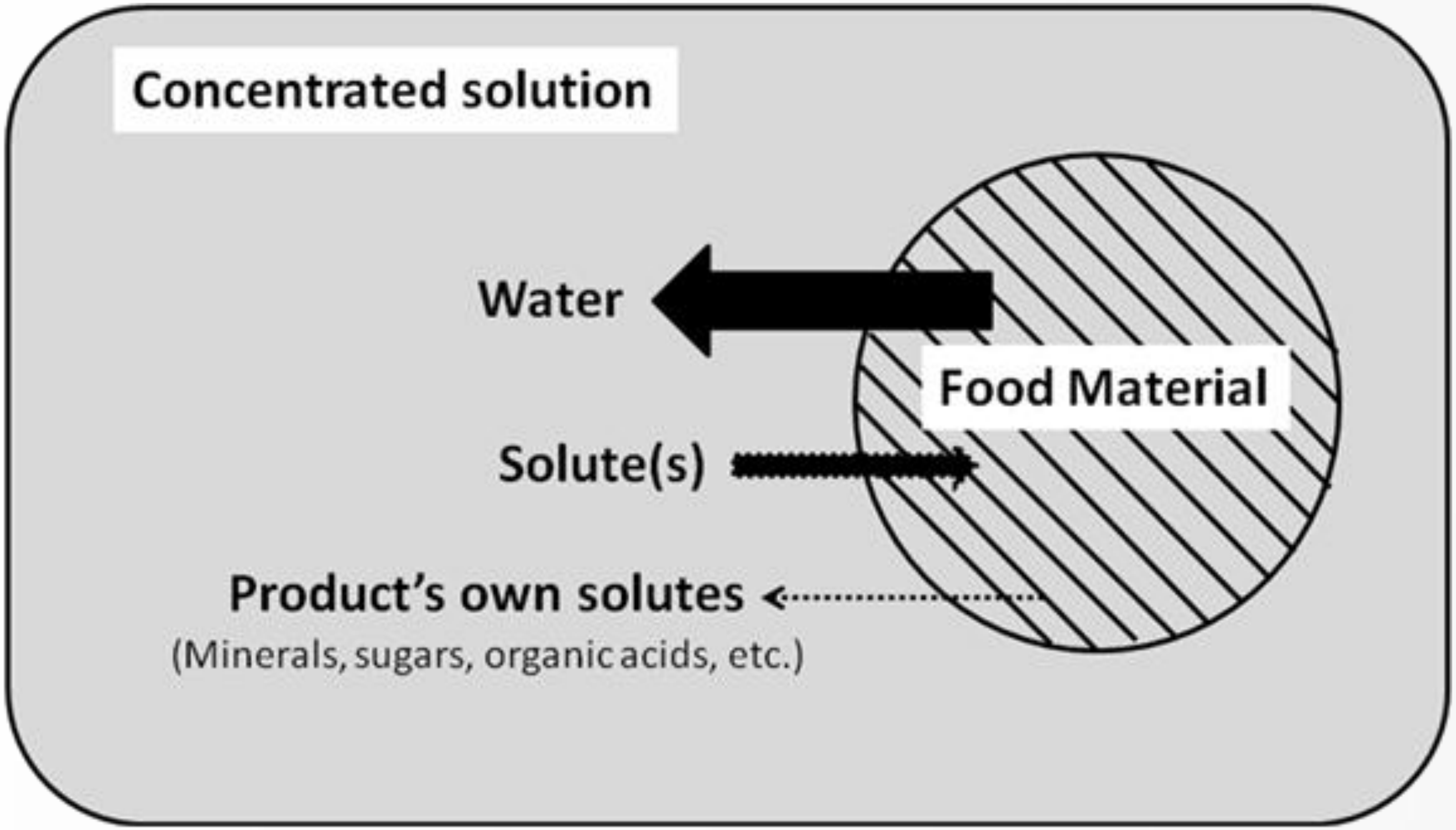
Mechanical drying

F. Osmotic drying

1. This method of drying can be successfully applied for dewatering of cellular products such as fruits, vegetables, meat etc.
2. For the moisture removal, osmo-active substances like; 60% aqueous solution of saccharose or 25% aqueous solution of sodium chloride is used.
3. The difference in osmotic pressure on both side of the cell wall having properties of a semi permeable membrane causes moisture removal from the products.
4. The semi-permeable property of cell wall permits migration of water and low molecular molecules to the osmo-active liquid having higher osmotic pressure. Thus, thinner cell sap causes increase in water activity of the medium.

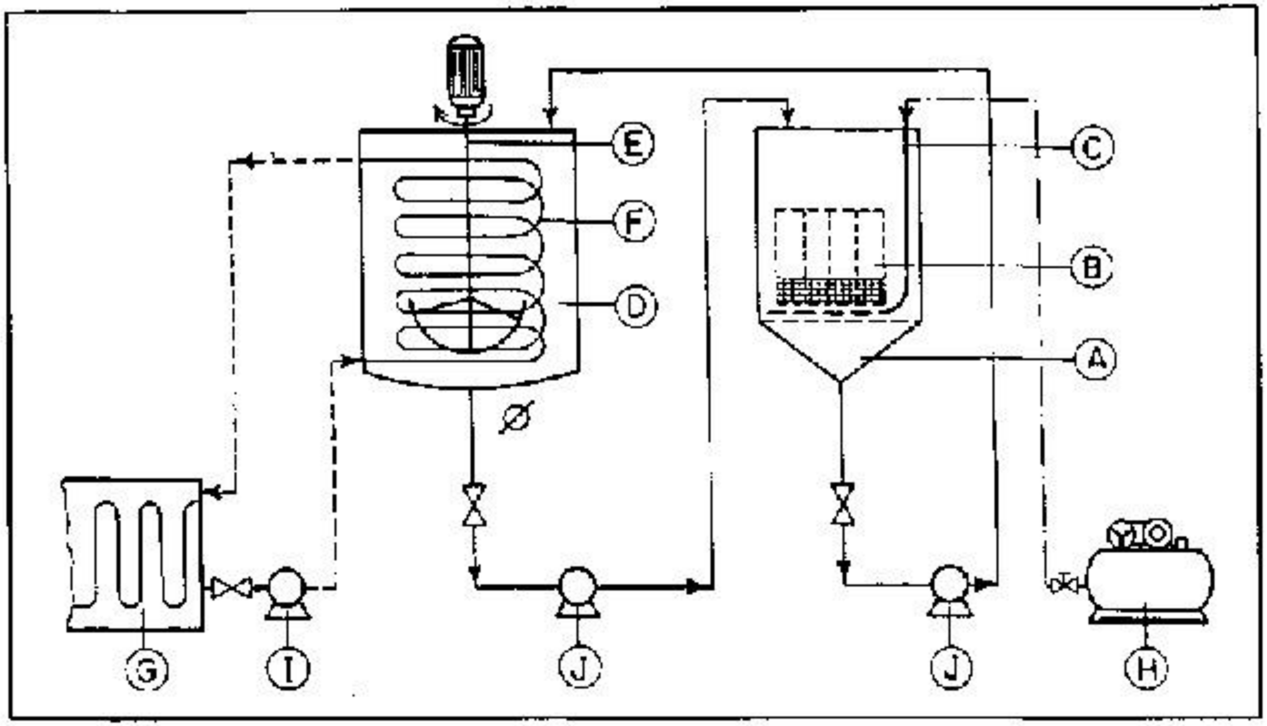
Mechanical drying

F. Osmotic drying



Mechanical drying

F. Osmotic drying figure.

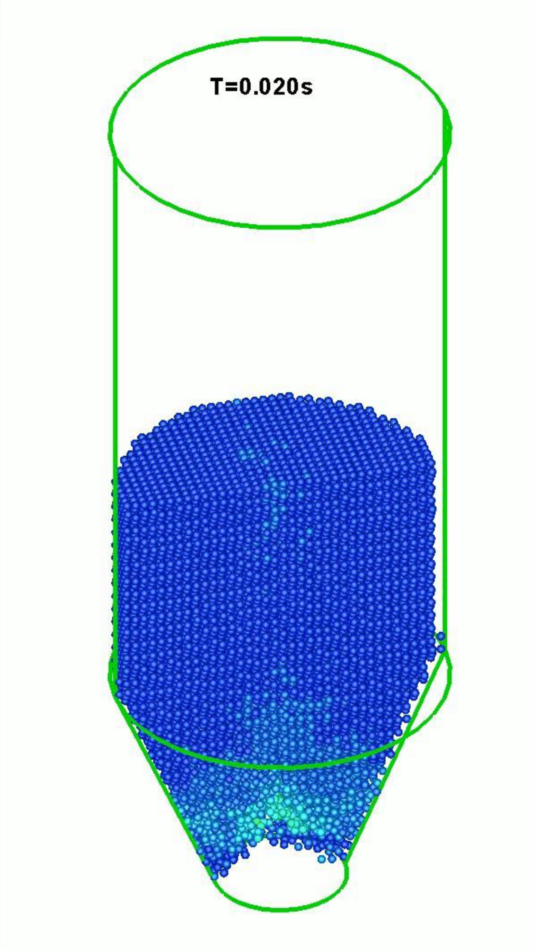


A: osmotic concentration tank; B: baskets with fruit samples; C: compressed air; D: syrup tank; E: agitator; F: refrigerating coil; G: ice tank; H: air compressor; I: centrifugal pump; J: gear pumps. ( ) Sucrose syrup; (-------) Cooling water; (------) Air.

Mechanical drying

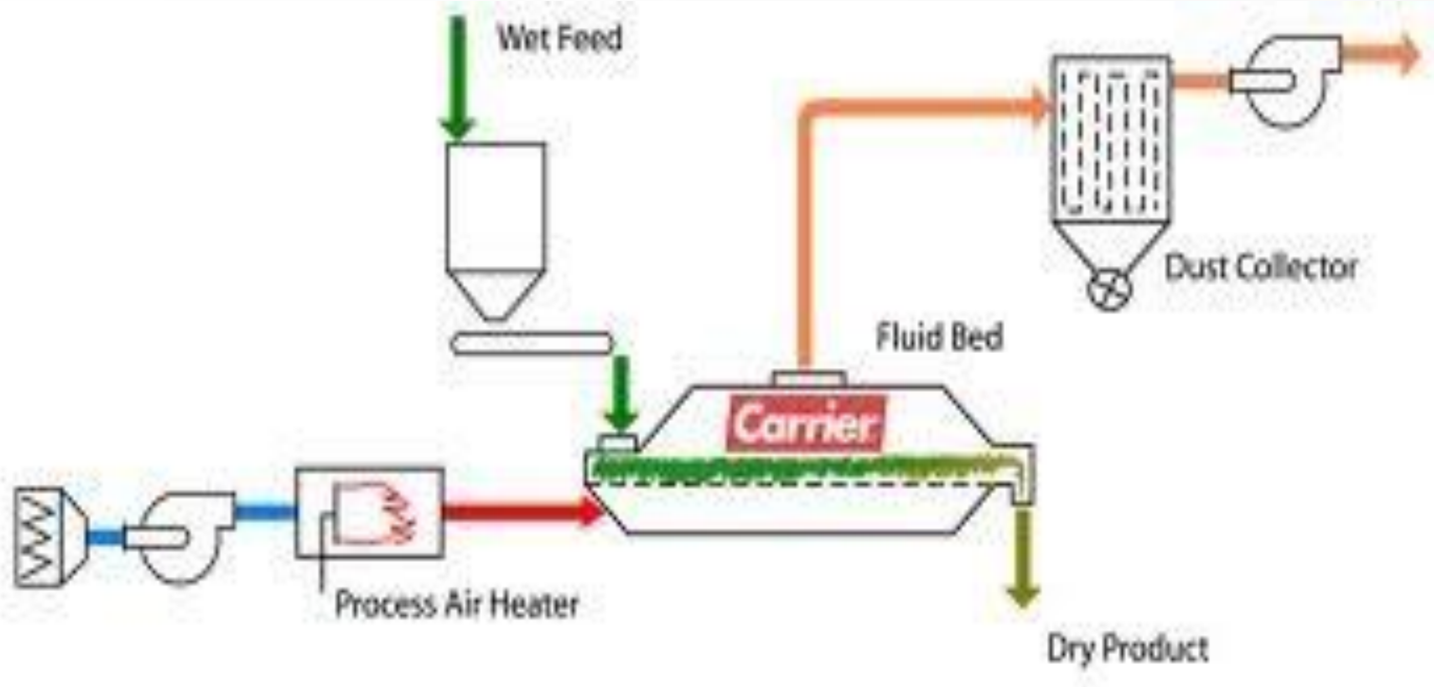
G. Fluidised bed drying

1. In this method of drying, products are being dried under fluidised condition in a dryer.
2. The materials are fluidised by drying air with sufficiently high velocity to cause suspension.
3. In this drying process, higher rates of moisture migration take place.
4. Since every surface of product is in contact with drying air, uniform drying of products takes place.
5. This method is normally used for the materials which have high initial moisture content and are lighter and at the same time requires to be dried quickly such as vegetable seeds.



Mechanical drying

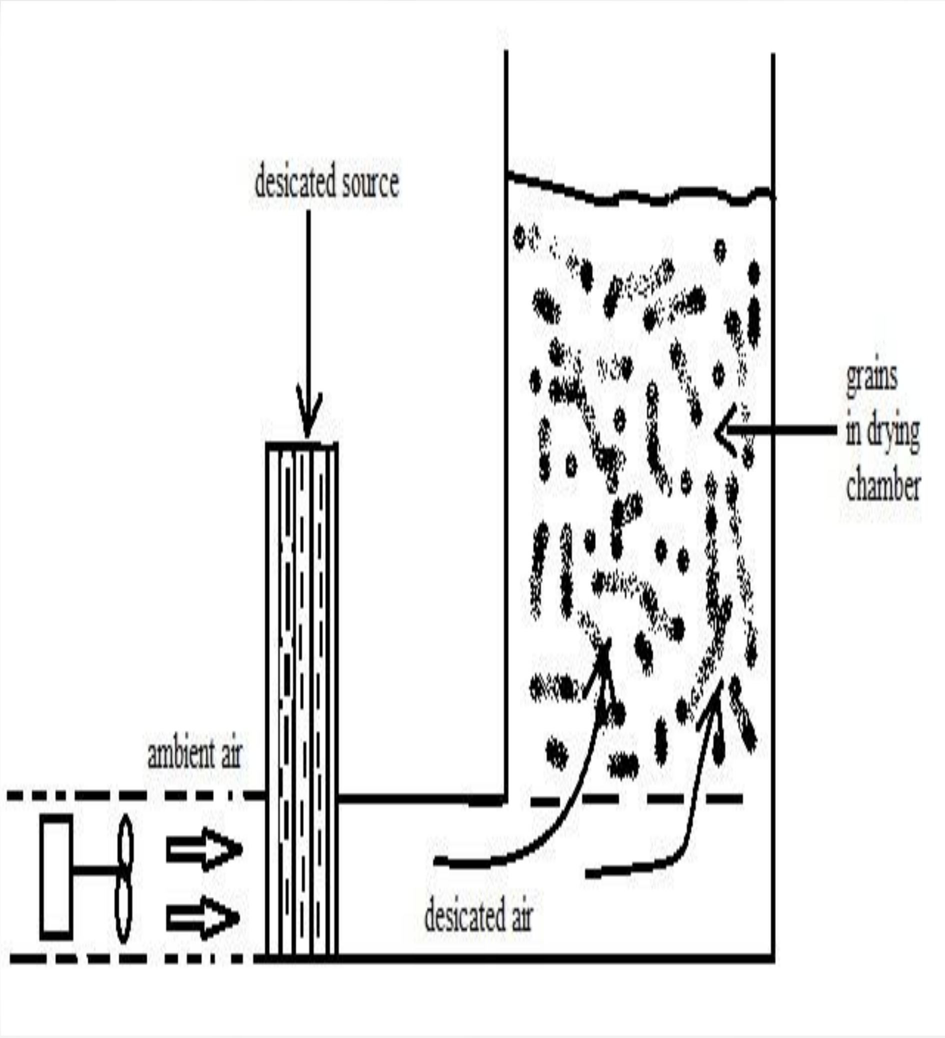
G. Fluidised bed drying



Mechanical drying

H. Desiccated air drying.

1. In this method of drying, the ambient air is passed through a desiccated medium or source e.g. silica gel.
2. The desiccators absorbs moisture from the air, as a result, the relative humidity of air is reduced and at the same time there is an increase in its temperature.
3. When such air comes in contact with wet grains, transfer of moisture from wet grains to drying air takes place.
4. The drying action occurs due to convective heat transfer. Schematic diagram of desiccated air drying is given in fig.



Spray drying

- Method

  :atomized (form small droplet)→ droplets contact with hot gas→liquid is rapidly evaporated →final product.

- Usage

  :liquids, instant tea, coffee.

- Advantage

  :spherical product.

- Disadvantages

  :quality loss,

  not all materials can be dried in this way

Other drying methods.

Explosive puffing

-Combination of high temperature and high pressure.

-Usage : small particle, honeycomb structure.

-Advantage : rapid.

-Disadvantage : High heat.

Explosion puffing is a processing system which facilitates hot air drying of fruits and vegetables. Explosion puffed foods are easily rehydrated and have excellent sensory properties. The process costs are similar to the cost of conventional hot air drying.

Application: carrots, potatoes, apples, blueberries, mushrooms, celery, onions, peppers, rutabagas, beets, yams, pears, pineapples, strawberries, and cranberries

Novel dehydration techniques

1. Microwave drying and dielectric drying.
2. Microwave-augmented freeze drying.
3. Centrifugal fluidized-bed drying.
4. Ball drying.
5. Ultrasonic drying of liquids.

Microwave drying and dielectric drying

- Use the electromagnetic wavelength spectrum.
- Frequency -Microwave drying:300-300000MHz.

  -Dielectric drying:1-100MHz.
- Usage:high value-added products.

  -Microwave drying (dry paste products)

  -Dielectric drying (cereal products)
- Advantages

  -low temperature, batch or continuous operation, good quality.
- Disadvantage-slow, expensive.

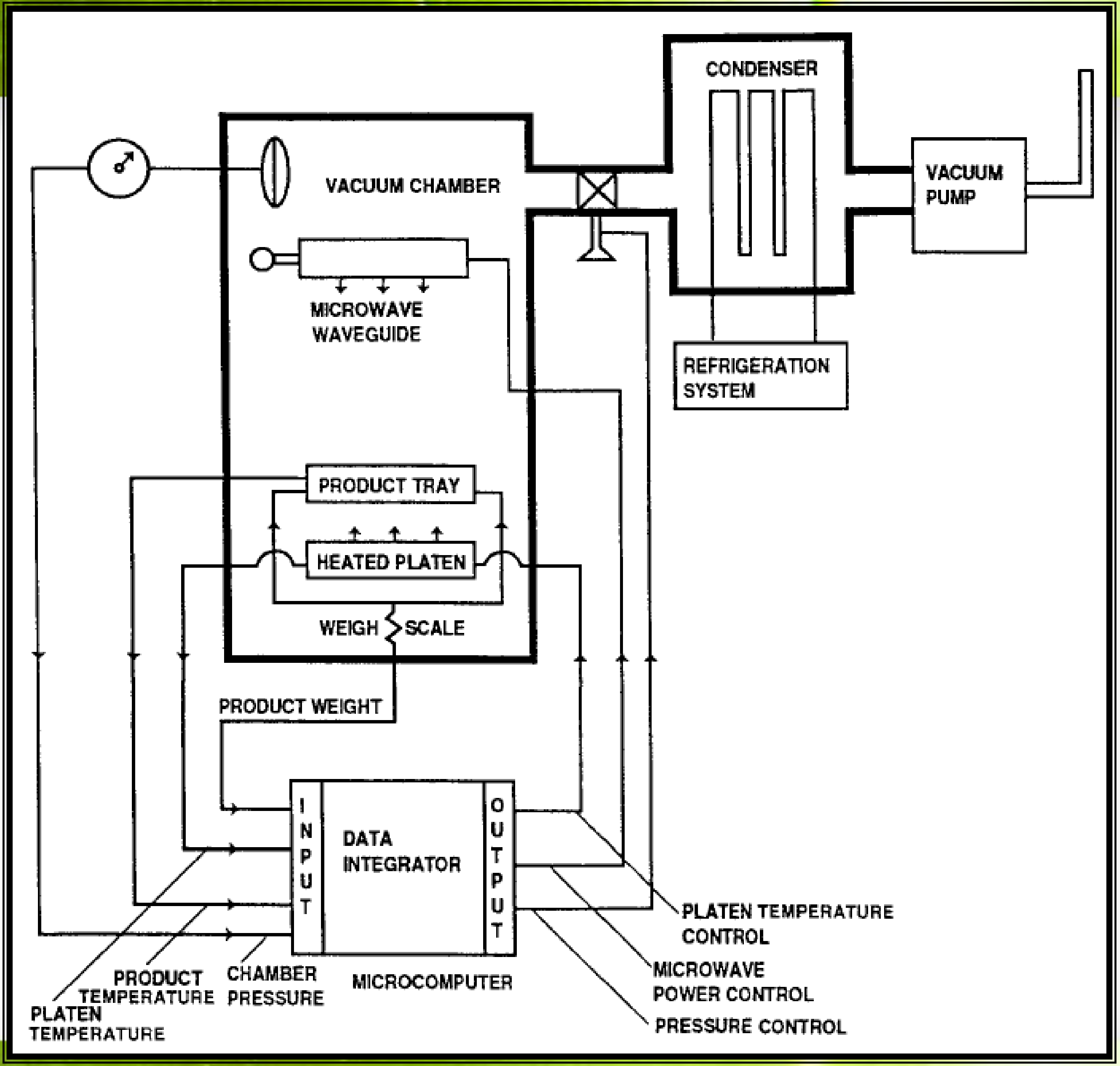
Microwave-augmented freeze drying.

Conventional freeze drying
+
Using microwaves

- Using microwave energy
  →Freeze drying rate increase.
- Usage:high value-added products.

Schematic diagram of a microwave-augmented freeze dryer.

Microwave-augmented freeze drying.



- Advantage & Disadvantage

- ◂ Costs of the this equipment are expensive.
  - ☞But more efficient.
- ◂ Non-uniformity of energy within the chamber.
  - ☞Use of waveguides and a rotating tray.
- ◂ Variety of food products can be dries using this method.
- ◂ Rapid : 1/3~1/2 time required.
- ◂ Low temperature.

Centrifugal fluidized-bed drying.

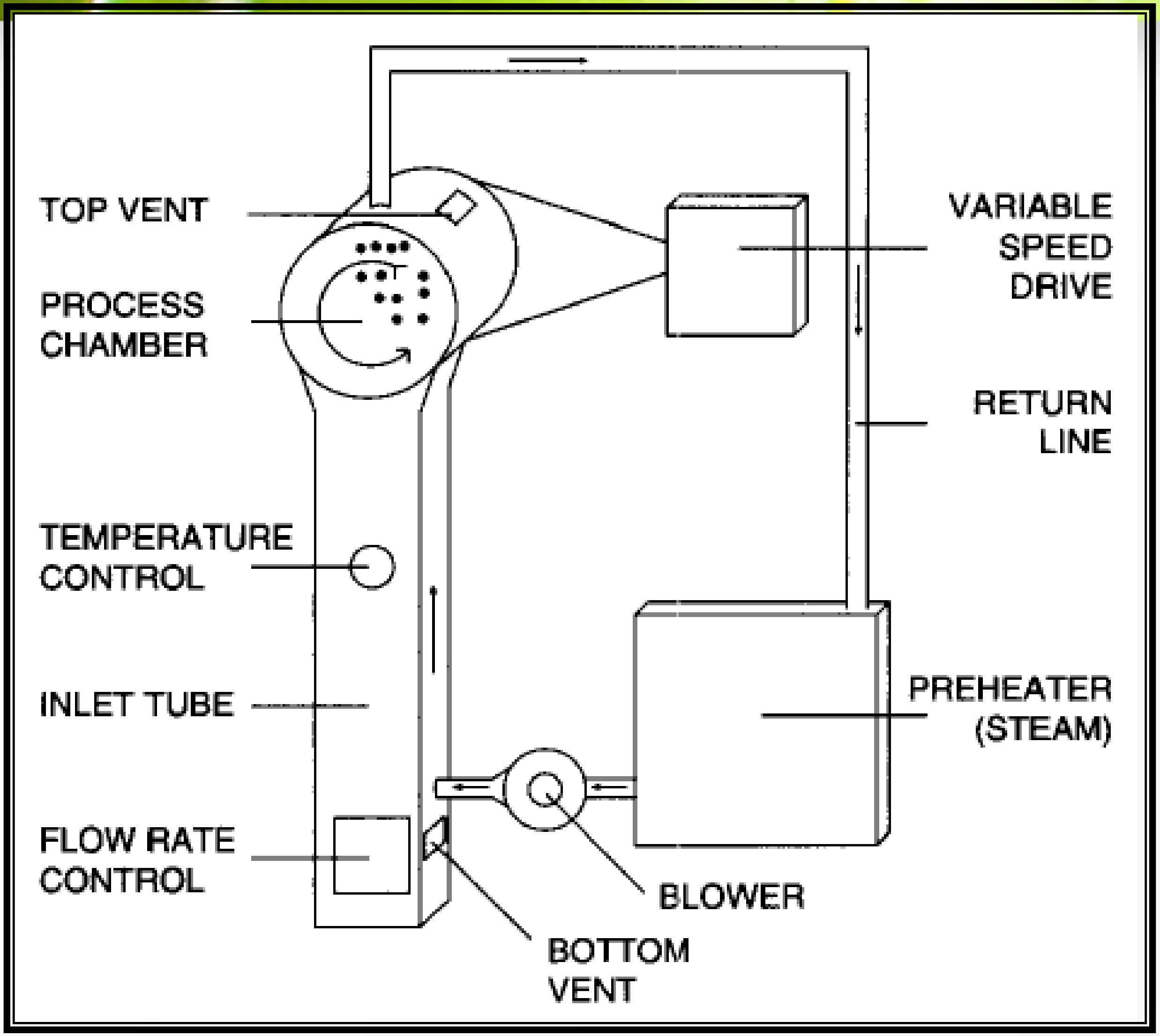
- Same principle as the conventional fluidized-bed dryer except that a rotating chamber is used.
- Usage

  :Small particle, vegetable piece, powders.
- Advantages

  :rapid, easy to control.
- Disadvantages

  :loss of product integrity, noisy.

Schematic diagram of a Centrifugal fluidized-bed dryer



Fluidized beds have been employed for various kinds of processes in the industries owing to their several advantages such as simplicity of design, intimate gas-to-particle contact, uniform particle exposure without mechanical agitation etc. However, the application of the fluidized beds has been limited, because they have to be operated at the gas velocity in the range between the minimum fluidization velocity and the terminal velocity of the particles, which are usually determined from the properties of the fluidized particles.

The centrifugal fluidized beds can overcome the limitations of the vertical conventional fluidized bed by adjusting the centrifugal force or rotating speed, which can increase apparently the velocity or density of gas in the bed. The centrifugal fluidized bed can also allow the smooth and homogeneous fluidization in the bed at any desired gas velocity, since the centrifugal force let the bed operating parameters set independently of the physical properties of the materials being treated [Fan, 1978; Kroger et al., 1979; Chen, 1987]

Ball drying

In this method, the material to be dried is added at the top of the drying chamber through a screw conveyor. The material within the drying chamber comes into direct contact with heated balls made from ceramic or other heat-conductive material. Drying occurs primarily by conduction. Hot air is passed through the bottom side of the chamber. When the product arrives at the bottom of the chamber, it is separated from the balls and collected [25].

- Usage

  :Small particle, vegetable piece.

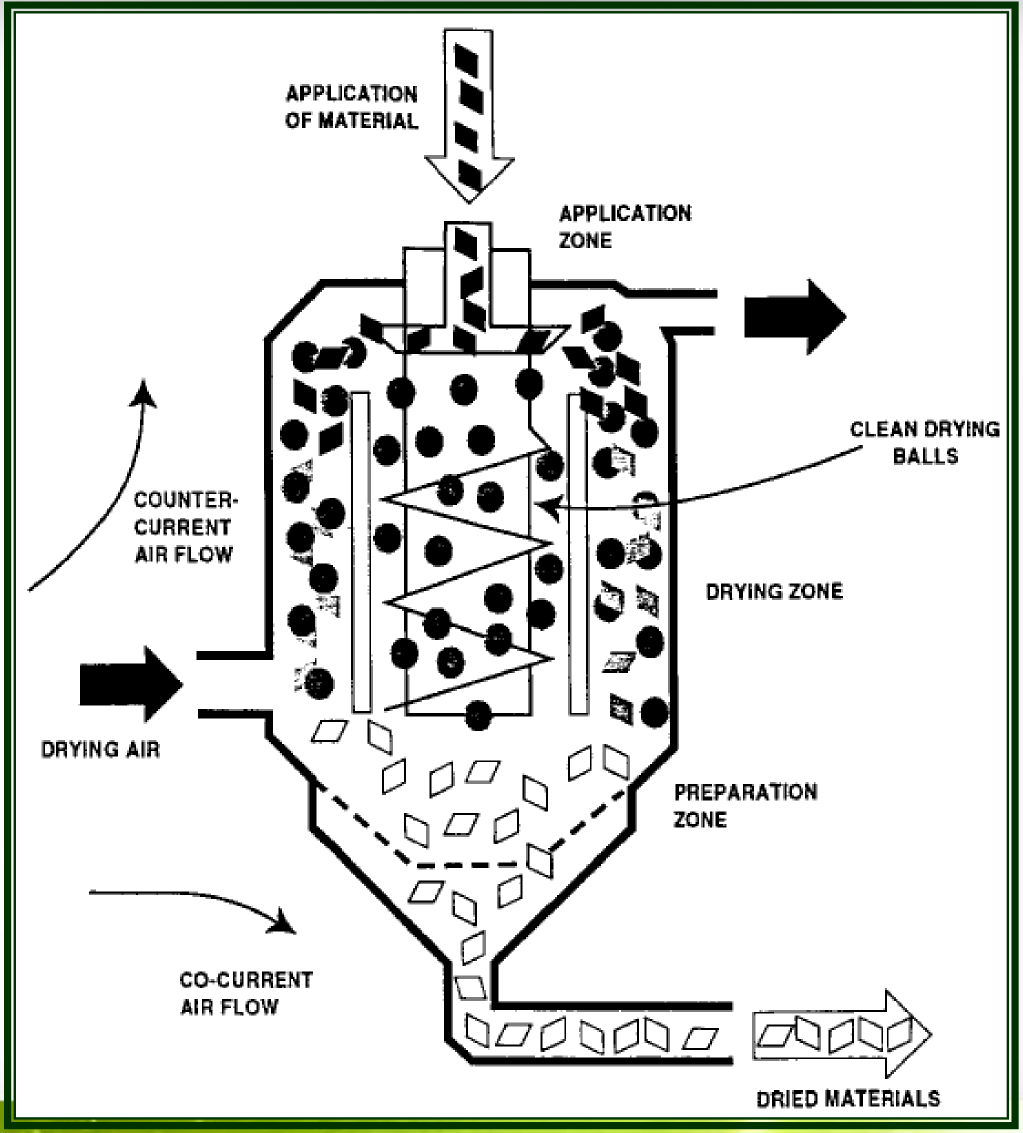
- Advantage

  :Relatively low temperature (70℃), continuous, rapid.

- Disadvantage

  :Loss of product integrity, difficult to control.

Ball drying



APPLICATION
OF MATERIAL
APPLICATION
ZONE
CLEAN DRYING
BALLS
COUNTER-
CURRENT
AIR FLOW
DRYING ZONE
DRYING AIR
PREPARATION
ZONE
CO-CURRENT
AIR FLOW
DRIED MATERIALS

Ultrasonic drying of liquids.

- High power ultrasound represents a means for food dehydration without affecting the main characteristics and quality of the product.
- High-intensity ultrasonic vibrations are capable of affecting mass transfer processes with the result of increasing the drying rate of materials.
- <u>Usage</u>

  :Liquids.
- <u>Advantage</u>

  :Rapid.
- <u>Disadvantage</u>

  :Require low-fat solution.

Schematic diagram of an experimental ultrasonic dryer.