Selection of Industrial Dryer

Being an energy intensive unit equipment, dryers involve significant investment in their operation. Therefore selection of right dryer for a particular process becomes important for minimizing the long term impact on the economies of a plant.

This article outlines important points in dryer selection with suitable examples.

Selecting the right dryer is one of the most complex areas in drying technology. Major costs for dryers are in their operation rather than in their initial investment costs as found in conventional dryers. Minimum cost is often taken to mean minimum capital cost, but this ignores expenditure on fuel, which, in the case of convective dryers, dominates the lifetime cost of the drying operation. Since dryer life is typically 25-40 years, selection of inefficient dryer can have a long-term impact on the economic health of the plant. Therefore, optimum dryer selection is very much important. Dryer vendors are not necessarily specialized and normally offer only a narrow range of drying equipments. The buyer must therefore be reasonable conversant with the wide assortment of dryers and be able to decide on an informal preliminary selection before going to the vendors (1).

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The selection of drying equipment remains predominately an art in which knowledge, experience and science all play important roles. Because of the complexity of the drying process, many factors needs to be considered and weighed upon and still there is “no” right answer due to varied technical and economical viability. According to survey conducted by SPIN (Solid Processing Industrial Network), U K, selection of dryer is a key problem faced by all companies. Over 90% of the companies have made errors in selection of their new dryers (2). The optimal choice can be defined as the dryer that satisfies all designated quality parameters. Figure 1 illustrates a structured technique for dryer selection (5).

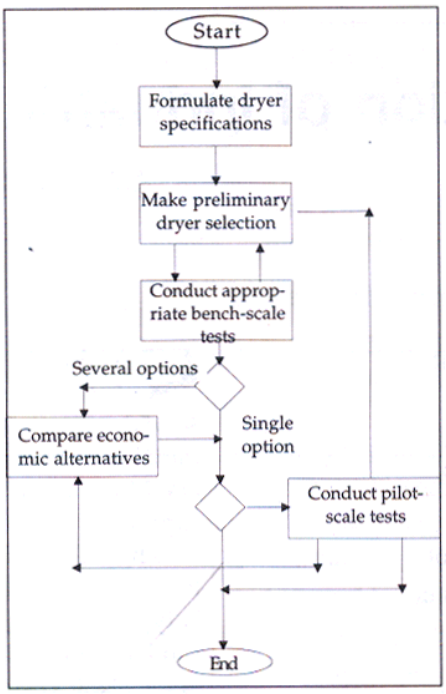

Fig 1: Iterative approach to dryer selection

Checklist for Selection of Industrial Dryers

Following data need to be collected before selection of dryers (Papagiannes, 1992; Van't Land, 1991)–

1. Physical form of feed – Liquid, slurry, pasty, free flowing powders, granular, crystalline, continuous sheet, discontinuous sheet.
2. Dryer throughput (Kg/hr).
3. Upstream/Downstream equipment – batch or continuous.
4. For particulate feed products, mean particle size and size distribution.
5. Inlet/outlet moisture content of product.
6. Maximum allowable product temperature.
7. Drying curve.
8. Feed cohesiveness.
9. Product fragility.
10. Contamination by drying gas.
11. Explosion characteristics (vapor/air and dust/air).
12. Toxicological properties.
13. Corrosion aspects.
14. Product value.
15. Experience already gained.

Factors to be considered in Selection of Industrial Dryers.

Selection of dryers can be made based on following characteristic information:

Feed property

Physical nature of the material to be handled is the primary consideration for dryer selection. Slurry will demand a different type of dryer from that required by a coarse crystalline solid which, in turn, will be different from that required by a sheet material. Spray dryers or film drum dryers may be chosen if the isolation of a solid from a solution or slurry via conventional crystallization is either impossible or too complicated. However, feed modification or product post processing must also be considered and can increase the range of possible drying operations. E.g. a sticky paste or difficult to handle wet solid may be back mixed with be used for eliminating some of the dryers from selection list (9).

Product Specification

Product specification may strongly affect the choice of dryer. For example, a flaked product is readily obtained from a drum dryer, while a highly porous, agglomerated product of low bulk density is often produced by spray dryers. If such product is greatly desired, a particulate feed may be reslurried to produce a suitable feed for a drum or spray dryer.

Some time, spray dryer is selected if the characteristic spherical particle shape is desired (as in making instant coffee). Typically, the average particle size falls in the range of 50 to 200 mm. Because of short residence time this dryers cab be used for heat-sensitive products e.g. milk powder. Proper selection of design as it is affected by the type of feed, abrasive property of the feed, feed rate, desired particle size and size distribution. Table 2 gives atomizer selection criteria (2).

Table 1: Classification of Commercial dryers based on materials handled

Type of Dryer	Liquid	slurries	Pastes & sludges	Free-flowing powder	Granular, crystalline or fibrous solids	Large solids, special forms and shapes	Continuous sheets	Discontinu-ous sheets
Tray & compartment. Direct type. Batch operation	X	?	?	?	?	?	X	?
Batch Through circulation. Direct type batch of operation	X	X	?	X	?	?	X	X
Tunnel. Continuous tray. Direct type, continuous operation	X	X	?	?	?	?	X	?
Continuous Through-circulation.	X	?	?	?	?	?	X	?

Direct type, continuous operation								
Direct rotary. Direct type, continuous operation	?	?	?	?	?	X	X	X
Pneumatic conveying. Direct type, continuous operation	?	?	?	?	?	X	X	X
Spray. Direct type, continuous operation	?	?	?	X	X	X	X	X
Continuous sheeting. Direct type, continuous operation.	X	X	X	X	X	X	?	X
Vacuum shelf. Indirect type, batch operation.	X	?	?	?	?	?	X	?
Vacuum freeze. Indirect type, batch or continuous operation.	?	?	?	?	?	?	?	?
Pan. Indirect type, batch operation.	?	?	?	?	?	X	X	X
Vacuum rotary. Indirect type, batch operation.	X	?	?	?	?	X	X	X
Screw conveyor & Indirect rotary. Indirect type, continuous operation.	?	?	?	?	?	X	X	X
Fluid bed. Batch, continuous, direct & indirect.	?	?	?	?	?	X	?	?
Vibrating tray. Indirect type, continuous operation.	X	X	X	?	?	X	X	X
Drum. Indirect type, continuous operation.	?	?	?	X	X	X	X	X
Cylinder. Indirect type, continuous operation.	X	X	X	X	X	X	?	?
Infrared. Batch or continuous operation.	?	?	?	?	?	?	?	?
Dielectric. Batch or continuous operation.	?	?	?	?	?	?	?	?

If the mean size of the product exceeds that of the feed, the choice is automatically restricted to those dryers that promote granulation such as fluidized bed granulators and vibrofluidised bed dryers. An alternative may be the use of High Shear Mixer which are Maceutical industries. If the mean size of the products is less than that of the feed, the milling of the product post drying is required.

Table 2 – Automiser selection criteria

	Rotary wheel	**Pressure nozzle**	**Two-fluid nozzle**
Type of chamber			
1.Cucurrent	?	?	?
2.Counter-current	X	?	X
3.Mixed (fountain)	X	?	?
Feed type			
1.Solution/slurries	X	X	?
2.Low viscosity	?	?	?
3.High Viscosity	?	X	?
Slurries			
1.Non-abrasive	?	?	?
2.Slightly abrasive	?	?	?
3.Highly abrasive	?	X	X
Feed rate			
1. <3 m3 per h	?	?	?
2. >3 m3 per h	?	?*	?*
Droplet size			
1. 30-120 µm	?	X	X
2. 120-150 µm	X	?	X

***** Multi-nozzle assembly

Mode of operation

Batch dryers tend to be of smaller size and are more labor-intensive since each batch must be loaded and unloaded. Hence the use of batch dryers is favored by a low throughput, a low drying rate, batch upstream and down stream equipment and multiple products. For product capacity below 100 kg/hr, batch dryers are mostly used where as the production capacities exceeding 1000 kg/hr often require a continuous dryer (Kiranoudis et al., 1996). For in between cases, the choice of batch and continuous dose depends solely on the upstream and downstream requirements.

If material is friable, then 'layer dryers' should be preferred e.g. conveyor dryer (either belt or screw type), tray dryer etc. where as if material is not friable then 'dispersion dryers' can also used for drying.

Mode of heating

Convective dryers (especially dispersion dryers) use higher gas flows and achieve higher heat transfer rates than contact dryers. Hence, they can achieve much faster drying, especially in the unhindered drying stage. Convective dryers are effective in higher temperature application and can use exhaust gases from a burner, containment is required, or gaseous particulate emission are tightly restricted, conduction dryers should be favoured. If feed contains fine particles, the indirect mode of heat transfer in normally preferred.
If a solvent must be evaporated and then recovered, it is usually not available to choose a convection dryer. Since solvent must be condensers and other equipment becomes rather large.

If the contact with products of combustion from fossil fuel adversely affects our product's quality, then indirect heat drying like steam-tube rotary dryer or multi coil dryer can be used. Another alternative is a direct-heat dryer using ambient air that is indirectly heated by steam, electricity, fossil-fuel-burning or by high temperature waste gas. Flash, rotary, fluid-bed, spray dryers etc can utilize these air heating methods. If the risk of fire, explosion or other oxidative damage is very high (e.g. Coal, pulp), superheated steam drying (SHSD) may be considered (8). SHSD are already in operation in several industries and finds huge application in wood and baggage drying.

Table 3 – Residence time of material in dryers

Dryers	Typical residence time within dryer			
	0-10 (sec)	10-30 (sec)	10-60 (sec)	1-6 (hr)
Convection				
Belt conveyor dryer			?	
Flash dryer	?			
Fluid bed dryer			?	
Rotary dryer			?	
Spray dryer		?		
Tray dryer (batch)				?
Tray dryer (continuous)			?	
Conduction				
Drum dryer		?		
Steam jacket rotary dryer			?	
Steam tube rotary dryer			?	
Screw conveyor dryer			?	
Tray dryer (batch)				?
Tray dryer (continuous)			?	

The other modes of heating are more specialized. Radiative heating, either at high temperature (e.g. direct fired rotary dryers with the flame in the drum) or low temperature (solar collectors) is usually combined with convection. Dielectric (RF and Microwave) dryers release energy within the material,

speeding drying of product, but have a high capital and energy cost, however, they can be beneficially used to provide a small amount (say 5%) of energy with rest being supplied by conventional thermal means.

For drying of very high heat-sensitive products such as those of a biological nature, freeze-drying can be done at typically – 30 to – 10^{o}C. An alternative may be the use of heat-pump assisted drying in the temperature range of 5 to 50^{o}C.

Vacuum operation

If the maximum product temperature is lower than or equal to 30oC, it is worthwhile to look at vacuum dryers. A good driving force for evaporation can be created while keeping the temperature low.

Table 4: Fluidized bed dryer selection criteria.

Selection criterion	WMFBD	PFFBD	VFBD	SBI
▪ **Feed liquid/suspension/slurry**	**Inter particle bed**	**X**	**Inert particle bed**	**Inert particle**
▪ Wet particles				
a. Free flowing	**?**	**?**	**?**	**?**
b. Cohesive	**X**	**X**	**X**	**X**
▪ Particle size				
a. small	**?**	**?**	**?**	**X**
b. Medium	**?**	**?**	**?**	**?**
c. Large	**X**	**X**	**?**	**X**
d. Polydisperse	**X**	**X**	**?**	**X**
▪ Moisture				
a. Surface	**?**	**?**	**?**	**?**
b. Internal	**?**	**?**	**?**	**?**
▪ Product speciation				
a. Uniform moisture	**X**	**?**	**?**	**X**
b. Low moisture	**X**	**?**	**?**	**X**
c. Fragile	**X**	**X**	**X**	**X**
d. Heat-sensitive	**?**	**X**	**X**	**X**
▪ Drying time				
a. 5-10 min	**?**	**X**	**X**	**X**
b. 10-60 min	**?**	**?**	**?**	**?**
c. 60 min	**X**	**?**	**X**	**?**
▪ Throughput				
a. Low	**?**	**?**	**?**	**?**
b. Medium	**?**	**?**	**?**	**?**
c. High	**?**	**?**	**?**	**X**
▪ Immersed heating	**?**	**X**	**X**	**X**
▪ Temperature zoning	**X**	**?**	**?**	**X**
▪ Flexibility in operation	**X**	**?**	**?**	**X**

WMFBD : Well-mixed fluidized bed dryer
PFFBD : Plug flow fluidized bed dryer
VFBD : Vibrofluidized bed dryer
SBD : Spouted bed dryer

Vacuum operation

If the maximum product temperature is lower than or equal to 30^{o}C, it is worthwhile to look at vacuum dryers. A good driving force for evaporation can be created while keeping the temperature low.

If the product is oxidized by air during drying, consider either vacuum drying or inert gas drying or inert gas drying. If the evaporated solvent needs to be recovered, vacuum dryer is a better choice. If either the product or the removed liquid is toxic, the equipment must be operated in a closed loop, vacuum dryer can give good service in this situation. It also avoids dust formation and fire hazards. Agitated vacuum dryer may be considered as an advanced version.

Drying time

The moisture may be surface (free), inherent or both. Surface moisture can be easily removed and required less drying time. The inherent moisture requires a higher temperature and a longer retention time. Table 3 gives typical residence time within some dryers, (6).

Flash dryer can be used for removing surface moisture. It can be used as pre-dryer. Materials that require a longer contact time with the hot gases and have particle size distributions that do not allow them to be easily conveyed in a hot gas stream are usually dried in a direct-heat rotary dryer, but crystal breakage may be a problematic area. Crystal- line materials or polymers that are relatively fragile can be dried successfully in steam-tube rotary dryer. It also provides precise temperature control. For materials that are more fragile 'Rotolouvre dryer' cab be used (4).

Two dyers with different characteristic may be used in series. This is most frequently used where either the drying rate or the handling characteristic of the feed change markedly during the drying process. In the firs case, dispersion dryer (e.g. spray, pneumatic conveying dryer) may be used before a long residence time dryer (e.g. fluidized bed), with the transition coming at or below the critical moisture content. An example of second case is a multistage fluid bed with a well-mixed stage followed by a plug-flow section, with the transition occurring where the solid becomes sufficiently free-flowing. A final cooling stage may also be added, if desired.

For coarse particles (i.e. over 5 to 10 mm), band (belt) dryers is chosen when it is not possible to suspend the particles in the drying gas. When particle size exceeds 0.1 mm, fluidized bed may be a good choice because of its high heat and mass transfer rates between gas and particles. Tables 4 summarize a selection guide for various fluidized bed dryer types based on their operating characteristics (7).

Two – stage drying

Two dryers with different characteristic may be used in series. This is most frequently used where either the drying rate or the handling characteristic of the feed change markedly during the drying process. In the first case, dispersion dryer (e.g. spray, pneumatic conveying dryer) may be used before a long residence time dryer (e.g. fluidized bed), with the transition coming at or below the critical moisture content. An example of second case is multi-stage fluid bed with a well-mixed stage followed by a plug-flow section, with the transition occurring where the solid becomes sufficiently free-flowing. A final cooling stage may also be added, if desired.

Product value

If the Product value is low, this eliminates consideration of freeze and microwave dryers, which are unlikely to be economically viable under these circum-stances.

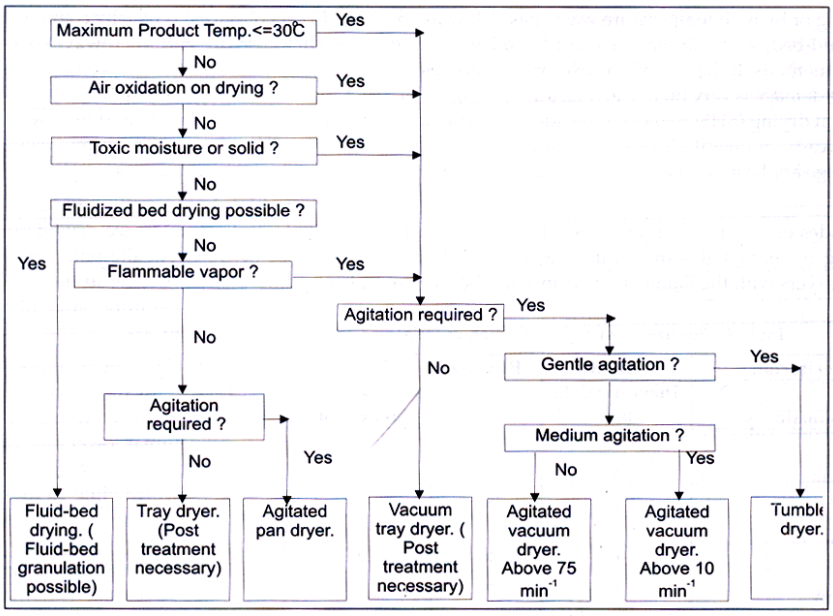

Fig2: Decision tree for the selection of a batch dryer

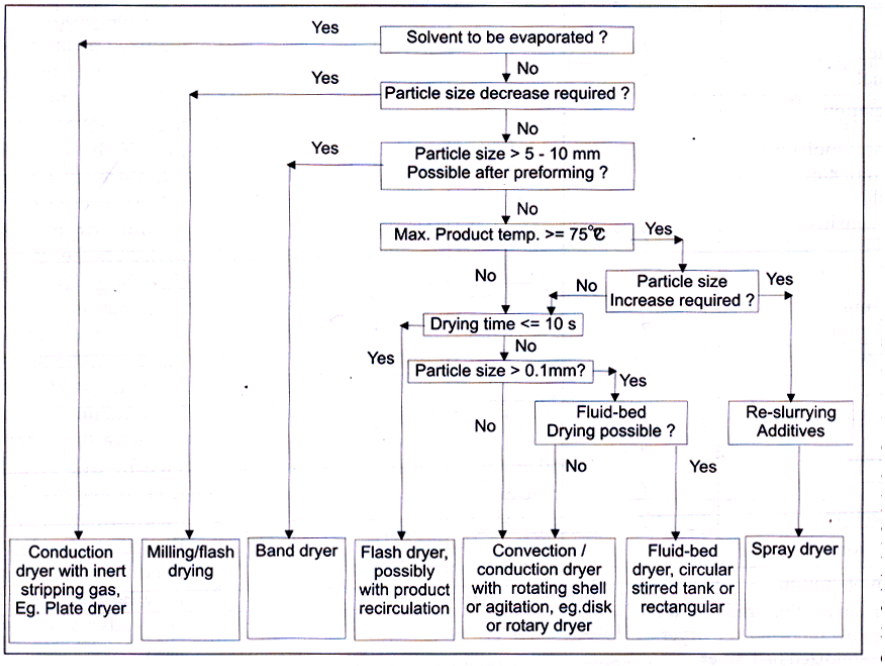

Fig 3: Decision tree for the selection of a continuous dryer

Decision trees (fig 2 and fig 3) can be for dryer selection. Fig 3 is a decision tree for the selection of batch dryers suitable for any particular process and fig 4 is a decision tree for the selection of continuous dryers. The final selection of the dryer will usually represent a compromise between the total cost, operating cost, equality of the product, safety consideration and convenience of installation.

Conclusion

Optimum dryer selection being critical issue and have major impact on economic health of plant, it is not recommended to solely depend on vendors recommendation but buyer should come up with preliminary dryer selection before referring to any vendor. Decision trees for selection of batch and continuous dryers can be used during initial assortment of large number of dryers. Factors to be considered during final dryer selection are also explained.

Reference Book:

Chemical Industry Digest
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