Flash-drying: a suitable technology for bulk solids processing

HOTorNOT Seminar

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SOME BASIC CONCEPTS

**Thermal separation:** to form homogeneous groups of substances whichever mixed with other ones, applying heating energy.

**Mix:** Combination of 2 or more substances where all ingredients are keeping its own physical identity. In a mix substances can be combined in any proportion. The properties of the mix are the combined properties of all ingredients and these component can be recovered with no alteration from the mix without a chemical reaction.

**Drying operation is a contact mass transference** (solid/liquid), where moisture mix will be transferred by means evaporation to the gaseous phase, based to the vapour pressure coming from the mix and the partial vapour pressure of the gas flow.
More CONCEPTS

Vaporization: Running of molecules from liquid phase to gas. The molecules which run off are the more close to the hot surface. So, evaporation is fastest; at same pressure level, when the temperature is higher, due a large fraction of molecules have enough energy to run off.

Effect of pressure:

```
<table>
<thead>
<tr>
<th>Temp.</th>
<th>Presión</th>
</tr>
</thead>
<tbody>
<tr>
<td>°C</td>
<td>bar</td>
</tr>
<tr>
<td>0,2</td>
<td>60</td>
</tr>
<tr>
<td>0,4</td>
<td>75</td>
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<tr>
<td>0,6</td>
<td>86</td>
</tr>
<tr>
<td>0,8</td>
<td>93</td>
</tr>
<tr>
<td>1,0</td>
<td>99</td>
</tr>
</tbody>
</table>
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Boiling temperatures of H₂O at different pressures:

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CONCEPT

Heat transfer: process where there is energy interchange among several parts or among different elements of one body whose are at same temperature. The heat is transferred by means of convection, radiation or conduction. These three processes can be carried out simultaneously, but it can occur that one of the mechanisms will be predominant on the other ones.
When is used a thermal solid-liquid separation process?

When the specs. for separation of final products are no possible to reach by means mechanical methods: centrifugation, decanting, filtration, …

When product value permits it.

Potential Secondary Effects of Drying

Tension and shrinkage (constriction) of dried material) (i.e. ceramic materials)

Chemical changes (pirolisis, oxidations, ….)

Bio-chemical changes (food, proteins, …)

Estructural changes (modification on crystalline phase, shape, particle size,…)

Solid – liquid relation

Surface moisture | Interstice moisture | Solvation moisture

- Easy drying | Difficult drying +
POWER NEEDED BY A DRYER:

\[ Q_{\text{total}} = Q_{\text{sólido}} + Q_{\text{líquido}} + Q_{\text{evaporation}} + Q_{\text{others}} \]

\[ Q_{\text{sólido}} = m_s \cdot C_{e_s} \cdot \Delta T \]

\[ Q_{\text{líquido}} = m_l \cdot (C_{e_l} \cdot \Delta T + C_{e_v} \cdot \Delta T') \]

\[ Q_{\text{evap}} = m_l \cdot \Delta H_{\text{vap}} \]

\[ Q_{\text{others}} \] if there are dispersion fluid, agitation, no isolation looses, heating of drying from outside, ....

TYPE OF DRYERS

FLUID BED
TYPE OF DRYERS

FLUID BED

- Batch and continuous
- Product cooling if needed.
- Only drying of wet solids
- OK for eliminate interstice and solvation moisture.
- Low thermal efficiency.

TYPE OF DRYERS

PADDLE DRYER
**TYPE OF DRYERS**

**PADDLE DRYER**

- Batch and continuous.
- Only Drying of wet solids
- Lumps formation during drying (not desired)
- Low thermal efficiency.
- No possible drying of solutions/ suspensions
TYPE OF DRYERS

BICONE DRYER

• Batch
• Wet solids drying only.
• Low drying temperatures
• Vacuum application
• Lumps formation during drying (not desired)
• Sterilization permitted

TYPE OF DRYER

CONE DRYER

• Batch
• Wet solids drying only.
• Low drying temperatures
• Vacuum application
• Lumps formation during drying (not desired)
• Sterilization permitted
• Possibility of particle coating
TYPE OF DRYERS
SPRAY-DRYER

- Continuous drying
- Pump able solutions/suspensions could be dried
- High temperatures for drying possible
- Large surface and volume for drying
- Possible to obtain granules, powder.
TIPOS DE SECADORES

SECADOR DE BANDEJAS

• Trabajo por batch
• Secado de sólidos húmedos
• Inversión económica
• Posibilidad de utilización de vacío
• Secado no homogéneo
• Precisa molturación / disgregación posterior

TYPES OF DRYERS

TURBULENCE DRYING

• Continuous drying
• Wearing effect
• Wet solids drying
• Obtaining fine powder
• High temperatures for drying
• Milling effect as complementary
TYPES OF DRYERS
LIOFILIZERS

- Batch operation.
- High operation cost
- Drying temperature very low.
- Freeze drying
- Sterile conditions
- Evaporation capacity quite limited.

TIPOS DE SECADORES
FLASH-DRYER
TYPES OF DRYERS

FLASH-DRYER
- Continuous process
  - Wet solids and solutions and suspensions able to be dried.
  - Short residence time
  - Nice for thermosensible products
  - Possibility of sieving pneumatically

- Fine powder obtention
- Deagglomeration of initial lumps
- Large surface of drying.
- Low operation cost
- Possibility of sterilization w/ steam

RINA - JET DRYER (TOROIDAL TYPE – HIGH TURBULENCE)
RINA-JET type S1008 unit

RINA-JET S3632 type evap 7/8 tn/h
RINA-JET (Straight type - low turbulence)

RINA-JET type S1008 R unit
RINA-JET  Slurry/suspension feeding nozzle

RINA-JET  Slurry feeding system
**RINA-JET**  Operation cost calculation

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 1</td>
<td>123</td>
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<tr>
<td>Item 2</td>
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<td>Item 3</td>
<td>789</td>
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<td>Item 4</td>
<td>234</td>
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<td>Item 5</td>
<td>567</td>
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**RINA-JET**  Operation cost calculation

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</table>
RINA-JET  Internal heating recuperation

RINA-JET  External heating recuperation
RINA-JET  Heating recuperation. Lower operation cost and low CO2 emission

RINA-JET  Special performances
RINA-JET Complete Centrifugation+Drying+JetMilling set

RINA-JET ZrO-AA lining. Wearing protection.
### TABLE WITH PARAMETERS COMPARISON OF DRYERS

<table>
<thead>
<tr>
<th>Dryer Type</th>
<th>Thermal power</th>
<th>Initial moisture</th>
<th>Final moisture</th>
<th>Evap. capacity</th>
<th>Type of process</th>
<th>Vacuum necessary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid Bed</td>
<td>Med</td>
<td>5-50 %</td>
<td>0.1-5 %</td>
<td>5-1.000</td>
<td>Batch/Continuo</td>
<td>Sí / No</td>
</tr>
<tr>
<td>Paddle dryer</td>
<td>Med</td>
<td>5-50 %</td>
<td>0.1-5 %</td>
<td>10-5000</td>
<td>Batch/Continuo</td>
<td>Sí / No</td>
</tr>
<tr>
<td>Bicone</td>
<td>Low</td>
<td>5-50 %</td>
<td>ppm</td>
<td>10-100</td>
<td>Batch</td>
<td>Sí</td>
</tr>
<tr>
<td>Cone</td>
<td>Low</td>
<td>5-50 %</td>
<td>ppm</td>
<td>10-100</td>
<td>Batch</td>
<td>Sí</td>
</tr>
<tr>
<td>Spray dryer</td>
<td>High</td>
<td>20-98 %</td>
<td>0.1-5 %</td>
<td>10-10.000</td>
<td>Continuo</td>
<td>No</td>
</tr>
<tr>
<td>Tray dryer</td>
<td>Low</td>
<td>10-70 %</td>
<td>0.1-2 %</td>
<td>10-100</td>
<td>Batch</td>
<td>Sí</td>
</tr>
<tr>
<td>Flash dryer</td>
<td>High</td>
<td>5-98 %</td>
<td>0.1-1 %</td>
<td>10-10.000</td>
<td>Continuo</td>
<td>No</td>
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<tr>
<td>Turbulence dryer</td>
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<td>5-80 %</td>
<td>0.1-1 %</td>
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<td>No</td>
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<td>Liofilizer</td>
<td>Low</td>
<td>5-90 %</td>
<td>ppm</td>
<td>0.1-10</td>
<td>Batch</td>
<td>Sí</td>
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</tbody>
</table>

### CHOICE AND SIZING OF A DRYING SYSTEM

Physical properties of materials to be dried and dried product:

- **Presentation** (wet solid, slurry, solution)
- Viscosity,
- Particle size distribution
- Thermal conductivity,
- Latent heat of liquid to evaporate,
- Wearing (abrasion effect)
- Porosity,
- Fusion point - melting -,
- Etc.
CHOICE AND SIZING OF A DRYING SYSTEM

Chemical properties of dry solid and liquid:

- Odour,
- Thermal stability,
- Flammability,
- Reactivity in front drying gases,
- Corrosion effect,
- Existence of several crystalline phases,
- Proportion solid – liquid
- Etc.

Properties of flow of material to be dried:

- Quantity of product to be dried per time unit,
- Quantity of liquid to be separated,
- Continuous or discontinuous process,
- Material handling
- Etc.

Drying kinetics

Lugar de instalación
- Size of building or area to be sited.
- ATEX area
CHOICE AND SIZING OF A DRYING SYSTEM

Environmental conditions:

- Noise restrictions,
- Dangerous emission vapours of liquid to atmosphere.
- Dangerous leakages of dried product by exhaust.
- Etc.

Tech specs for dried product:

- Bulk density,
- Particle size distribution,
- Crystalline structure,
- Residual (final) moisture
- Sterilization
- Etc.

Economical considerations:

- Value (added) of the product,
- Operation cost (man power, energy costs, etc.)
- Heat recovery possibilities,
- Heat from exhausts to be used (cogeneration)
- Etc.

Validation and certification:

- Process validation FDA
- GMP/GAMP
- Certification CE-ATEX
- HazOp studies
- CIP Validation Riboflavin tests
- SIP Validation
### SOME PRACTICAL APPLICATIONS

<table>
<thead>
<tr>
<th></th>
<th>Fluid bed</th>
<th>Paddle dryer</th>
<th>Bicone</th>
<th>Cone</th>
<th>Spray dryer</th>
<th>Tray d.</th>
<th>Flash dryer</th>
<th>Turb. dryer</th>
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<tr>
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<td>Kaolin</td>
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<td>Starch</td>
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Some questions ...  

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