iFormulate

Introduces…

Fluid Bed Processing

iFormulate Webinar
30th October 2018

In association with:

iFormulate *Skills* UNIVERSITY OF LEEDS

Fluid Bed Processing
16th-18th January 2019

Overview:

1. Why Choose Fluid Bed Technology?
2. What is a Fluidised Bed?
3. How does it work?
4. What are its properties?
   – The importance of particle properties
5. What is it used for?
6. Different Fluid Bed designs
7. Summary
8. Learning More

This webinar is being recorded and will be made available

The audience is muted and you may ask questions using question function in GoToWebinar

This webinar will last about 40 minutes

Your Speakers

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iFormulate Ltd

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A Little About iFormulate

- A company founded in 2012 by two experienced industry professionals…
- Combining diverse experiences, knowledge and wide range of contacts:
- …polymers, materials science, chemistry, imaging, dyes, pigments, emulsion polymerisation, biocides, anti-counterfeiting, environmental, formulation, consultancy, marketing, business development, strategy, regulatory, training, events, R&D, innovation
- Complementary network of Associates

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Our Services

iFormulate Consult

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1. Why Choose Fluid Beds?

First of all: Why do you dry products?

- Usually comes at the end of a production process
- Involves removal of a solvent, often water
- Can reduce transportation cost
- Can make materials more suitable for handling
- Helps avoid moisture that could lead to corrosion
- Can be used to mix ingredients in solution or slurry and so make consistent products
- Can increase shelf life of products

Drying and Other Things

But drying your product is probably not the only thing you're trying to do…

Some Other Things You Might Want From Drying

- Not to harm your materials, like sensitive actives
- Good yield and economics
- Product that flows well or product that isn't dusty
- Particles that redisperse well
- Particles that can be compressed, e.g. in a tablet press
- A product with defined particle size - fine or large
- Particles with defined strength - strong or weak
- Engineered particles?

What Is Particle Engineering?

- Designing and creating the particles you want to have at the end of the process
- Giving the final product the desired properties
- By controlling:
  - Particle size - and size distribution
  - Particle morphology (shape)
  - Mechanical strength of particles – redispersibility, friability
  - Internal structure of particles – e.g. encapsulation

So You Want To Dry: What Choice Have You Got?

Source: http://www.solidsforum.com/Drying

Absorption Dryers
Active Freeze Dryers
Adsorption Dryers
After Cooling Dryers
Agitated Dryers
Air Classifier Dryers
Air Dispersion Dryers
Air Dryers
Air Impingement Dryers
Airswept Turbo Dryers
Apron Dryers
Aseptic Filter Dryers
Auto Dryers
Automated Batch Dryers
Back Mix Dryers
Back Mix Feeding Dryers
Back Mix Flow Fluid Bed Dr
Ball Dryers
Band Dryers
Batch Agitated Dryers
Batch Dryers
Batch Rotating Dryers
Batch Tray Dryers
Belt Dryers
Bench Top Dryers
Brazing Furnaces
Calciner Dryers
Calciners
Carousel Dryers
Cascading Rotary Dryers
Centrifugal Dryers
Centrifugally Agitated Bed I
Classifying Dryers
Closed Loop Dryers
Compressed Air Dryers
Conduction Dryers
Conical Dryers
Conical Screw Dryers
Contact Fluidizer Dryers
Continuous Band Dryers
Continuous Dryers
Continuous Flow Dryers
Continuous Gravity Dryers
Continuous Tray Dryers
Continuous Tunnel Dryers
Convection Dryers
Conveyor Dryers
Counter Current Dryers
Counterflow Dryers
Cross Flow Dryers
Crystallizing Dryers
Dehumidificators
Dehydration Systems
Deliquescent Dryers
Delta Dryers
Desiccant Dryers
Direct Fired Dryers
Direct Heated Dryers
Disc Dryers
Dispersion Dryers
Drum Dryers
Dry Roasters
Dryers
Drying Cabinets
Drying Installations
Drying Ovens
Dual Plenum Dryers
Dual Plenum Roasters
Dust Tight Dryers
Even Flow Dryers
Festoon Dryers
Filter Dryers
Flaker Dryers
Flash Dryers
Flat Bed Through Air Dryers
Flotation Dryers
Fluid Bed Dryers
Fluidized Bed Calciners
Fluidized Bed Dryers
Freeze Dryers
Gas Dryers
Gas Tight Dryers
Heat Pump Dryers
Heated Dryers
Heatless Dryers
High Frequency Dryers
High Velocity Air Impingem
Highly Turbulent Bed Dryer
Hopper Dryers
Horizontal Band Dryers
Horizontal Paddle Dryers
Impingement Dryers
Impingement Ovens
Indirect Heated Dryers
Infrared Dryers
Infrared Zone Dryers
Inline Dryers
Jacketed Dryers
Kilns
Laboratory Dryers
Laboratory Spray Dryers
Loop Dryers
Lyophilizers
Membrane Dryers
Microwave Dryers
Mill Dryers
Mixer Dryers
Mobile Dryers
Moving Bed Dryers
Multi Pass Dryers
Multi Stage Dryers
Multi Tier Fluid Bed Dryers
Multi Zoned Dryers
Paddle Dryers
Pan Dryers
Paste Dryers
Pharmaceutical Dryers
Plate Dryers
Plug Flow Dryers
Plug Flow Fluid Bed Dryers
Pneumatic Dryers
Post Bake Equilibration Dry
Predryers
Press Dryers
Pressure Swing Dryers
Pulse Jet Dryers
Pulverised Air Dryers
Radiant Heating Dryers
Rapid Dryers
Refractance Window Dryer
Refractory Lined Dryers
Refrigerated Air Dryers
Refrigerated Dryers
Regenerative Desiccant Dry
Regens
Ribbon Dryers
Ring Dryers
Roaster Dryers
Roasters
Roller Dryers
Rolling Bed Dryers
Rotary Calciners
Rotary Drum Dryers
Rotary Dryers
Roto Cone Dryers
Rotor Dryers
Scraped Surface Dryers
Screw Dryers
Second Stage Dryers
Single Pass Dryers
Single Stage Dryers
Sludge Dryers
Slurry Dryers
Solids Drying Equipment
Spin Dryers
Spin Flash Dryers
Spiral Dryers
Spouted Bed Dryers
Spray Dryers
Stationary Bed Dryers
Steam Tube Dryers
Suction Drum Dryers
Suction Dryers
Supercritical Dryers
Superheated Steam Dryers
Superheated Vapor Dryers
Suspension Dryers
Thermal Disc Dryers
Thin Film Dryers
Through Air Dryers
Toasters
Tornesh Dryers
Tower Dryers
Tray Dryers
Truck Dryers
Tube Bundle Dryers
Tubular Dryers
Tumble Dryers
Tunnel Dryers
Turbo Dryers
Turbo Tray Dryers
Twin Tower Dryers
V-Cone Dryers
Vacuum Band Dryers
Vacuum Dryers
Vertical Dryers
Vertical Paddle Dryers
Vertical Ribbon Dryers
Vibrating Fluid Bed Dryers
Vibratory Dryers

Focus on a Few Types of Dryers

Dryer Type	Advantages	Disadvantages
Tray/Shelf Dryer	Low losses, versatile, small batches, uniform heating	Slow manual load/unload. Little opportunity for particle engineering
Rotary Dryer	Can uses for pastes, wet solids	
Freeze Dryer	Good for heat sensitive materials. Porous redispersible product	Slow, complex, expensive. Limited opportunity for particle engineering
Drum Dryer	Use viscous feeds. Relatively cost-effective and simple. Rapid drying	Maintenance requirement. Control of film thickness
Microwave Dryer	Dry sensitive materials, bulk, viscous, rapid	Less suitable for larger batches. Little opportunity for particle engineering
Vacuum Dryer	Low risk of oxidation, heat damage. Small batch sizes	Less suitable for larger batches. Little opportunity for control and particle engineering
Spray Dryer	Rapid, good heat and mass transfer Opportunities for particle engineering	Can be complex and capital intensive Have to start with a pumpable liquid feed
Fluid Bed Dryer	→	→

Some Typical Applications of Fluid Bed Processing

Chemical	• Synthesis reactions • Cracking • Calcination, Combustion and Incineration
Drying	• Specialty chemicals • Foods - e.g. grains • Foods – cooking and freezing
Granulation	• Pharmaceuticals – granules for tableting • Agrochemicals – water dispersible granules • Detergents
Encapsulation **Particle Coating**	• Foods - probiotics • Agrochemicals – top spray • Pharmaceuticals – Wurster coating

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Fluid Bed Drying

Advantages:

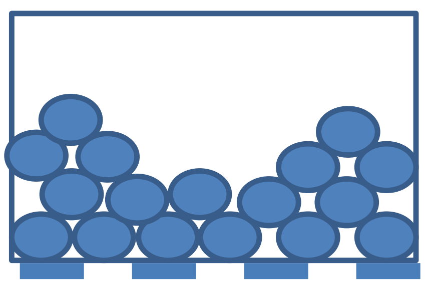
- Rapid drying via large surface area and good contact, high mass and heat transfer → uniform product
- Batch or continuous process
- Possibility to use with heat sensitive materials
- Particles can be engineered to disperse and flow well in application
- Can create granular material for subsequent processing
- Can be used to encapsulate and coat particles

Disadvantages:

- Need to be able to fluidise the input material – need to be 250µm or larger
- Risk of particle attrition which creates dust
- Potentially high energy consumption – high pressure drops
- Less suitable for flammable or toxic material

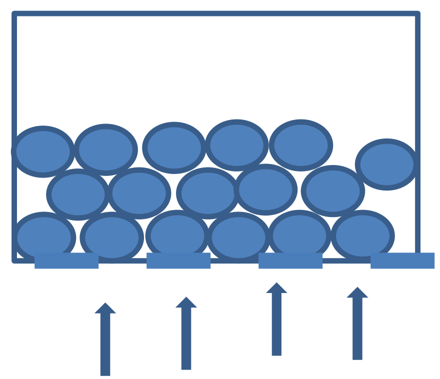
2. What is a Fluidised Bed?

- Basically a packed bed of particles that are brought to a state of random movement by pressurised air.
- Behaves like a fluid
- Simplified to particles in air.



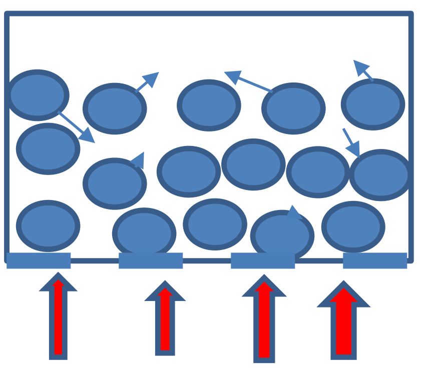
Very low air flow

Static packed bed



Low air flow

Minimum state of fluidisation



High air flow

Fully fluidised bed

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3. Mechanism

- Air flows over the particles in upward direction
- Causes a pressure drop over each particle
- When this supports the weight the particle, minimum fluidisation is reached, maximum pressure drop.
- Bed behaves as a liquid, has a defined surface and can flow if not contained.
- Higher air flow gives higher movement of particles

4. Properties

- Has a defined pressure drop across the height of the bed
- Lots of movement in random directions
- Has a bubbling surface like boiling water.

- ***Lots of mixing.***
  - ***Particle/air and particle/particle***
- ***Good mass transfer***
- ***Good heat transfer***

Minimum Fluidisation Velocity

The minimum or incipient fluidisation velocity is obtained by equating the **pressure drop** of the bed to the **buoyed weight** of the solids.

Carman-Kozeny:

$$u_{mf} = \frac{(\rho_p - \rho_f) g \, \phi^2 \, d_v^2 \, \varepsilon_{mf}^3}{\mu \, (1 - \varepsilon_{mf})}$$

Minimum fluidisation velocity is a function of density difference and particle diameter squared

Bed voidage and sphericity are difficult to estimate. $\varepsilon \approx 0.4$ for spherical particles, but with irregular ones it depends on shape as well as size. Φ is a correction for non spherical particles.

It is also important to determine voidage under minimum fluidisation, provided that the height H_{mf}, solid mass M and column cross sectional area A are known:

$$\varepsilon_{mf} = 1 - \frac{M}{\rho_p A H_{mf}}$$

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Maximum Fluid Velocity

- Occurs when the particles can be blown out of the bed.
- That's why you need air separation devices such as cyclones and filters.
- Various equations exist, depending on shape for terminal velocity.
- Ut:Umf ranges
- From 9:1 to 90:1

$$u_t = 1.75\sqrt{\frac{\left(\rho_p - \rho_f\right) g\, d_p}{\rho_f}}$$

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Consequences of the Models

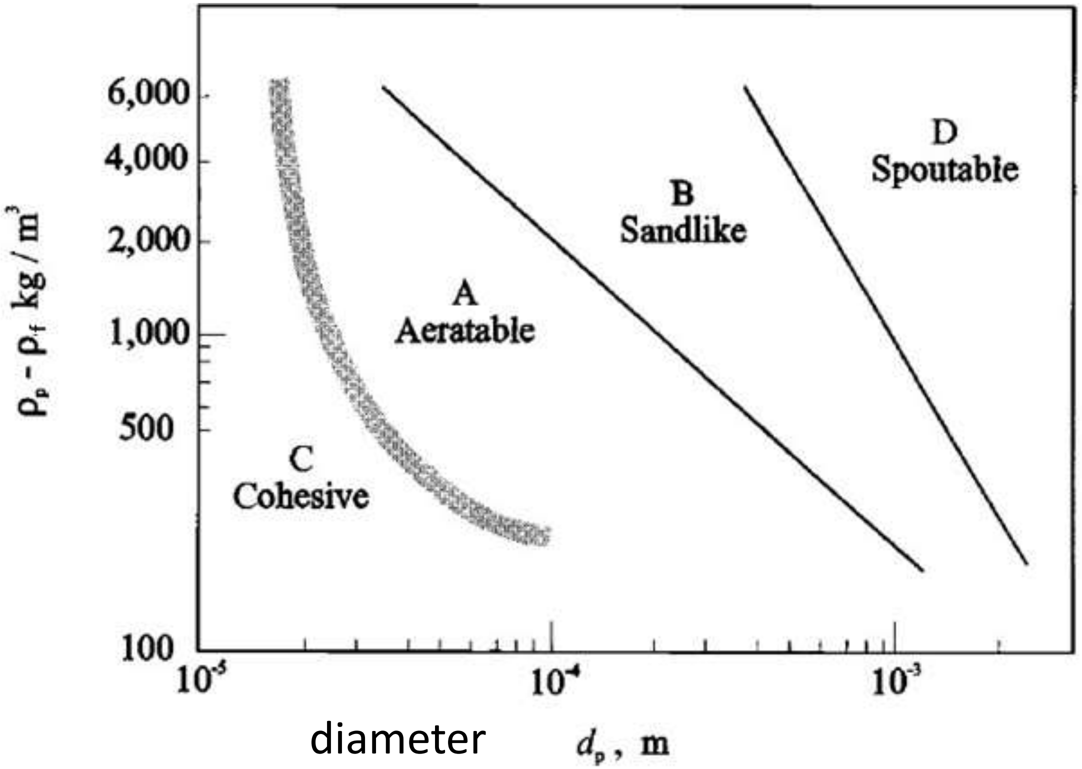
- Particles of different sizes will need different air velocities
- Can segregate particles of different sizes or densities in the fluid bed
- Need to ensure sufficient velocity of air to fluidise largest/densest particle
- Beds can be used to “screen off fine particles”

5. Uses of Fluidised Beds

1. **Heterogeneous reactions**
   - Coal burning in powder stations
   - Catalytic reactors-hydrocarbon cracking
2. **Drying**
   - Good control of residence time and temperature
   - Sometimes used with spray drying to increase capacity or temperature sensitive materials
3. **Cooling**
   - After fluid bed drying
4. **Coating**
   - Encapsulation using polymeric solutions
5. **Agglomeration**
   - Low density particles with raspberry structure
   - Used to “instantise” food such as coffee and milk powders

Some powders are easier than others: Geldart's Classification

density



diameter

Based on air at ambient conditions as fluidising medium.
Geldart, D. (1973). Types of gas fluidization.
Most cited paper in fluidisation literature (1184 citations)

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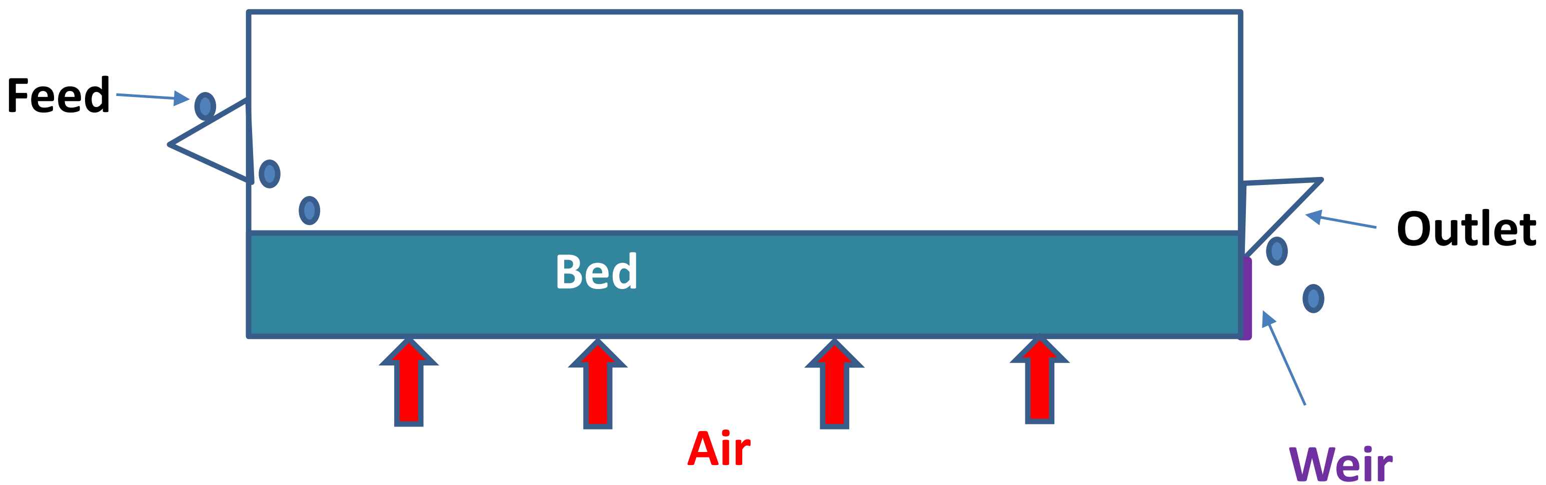
6. Different Bed Designs

- Batch, continuous, spouted
- Static or vibrating
  - Vibration is good for slightly cohesive/sticky particles
  - Allows for easier fluidisation

Continuous Fluidised Beds

- Fills like a liquid bath, flows downhill.
- Weir controls depth of bed, hence residence time
- Particles have a distribution of residence time in bed
- Can add internal weirs to control time in each section



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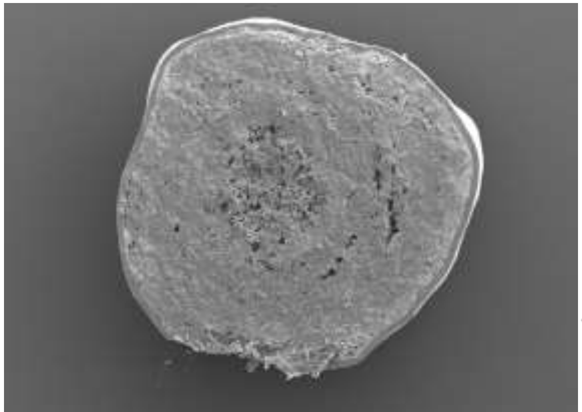
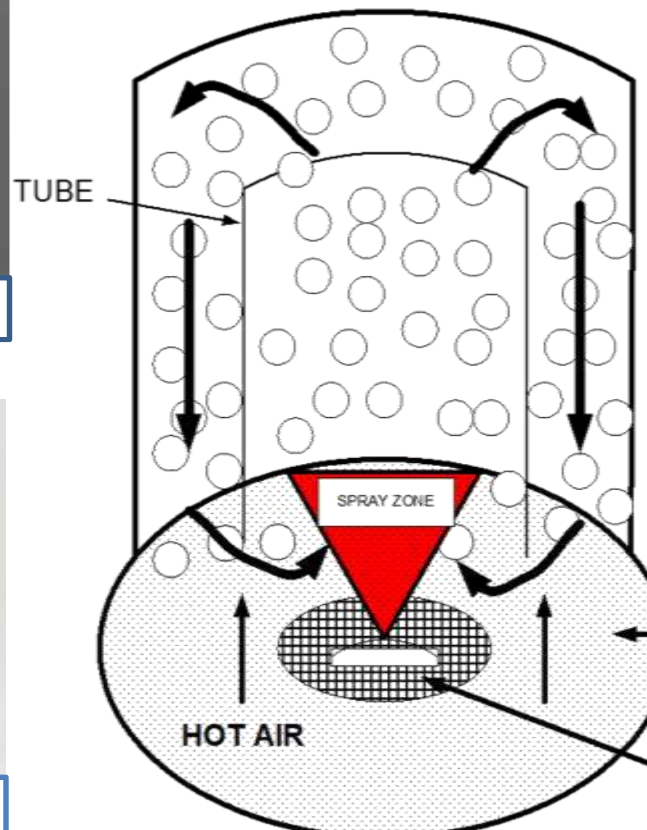
Wurster Coater Chamber



Coated particle

Agglomerate shape



Fluidised Bed

- Particles circulate repeatedly through the coating zone defined by the tube
- Particle Temperature close to exhaust temperature
- 6 to 10 second cycle
- 15 min to several hour batch time

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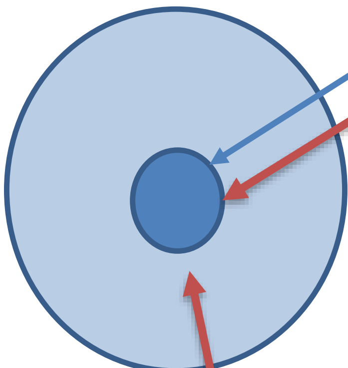
Spouted Beds

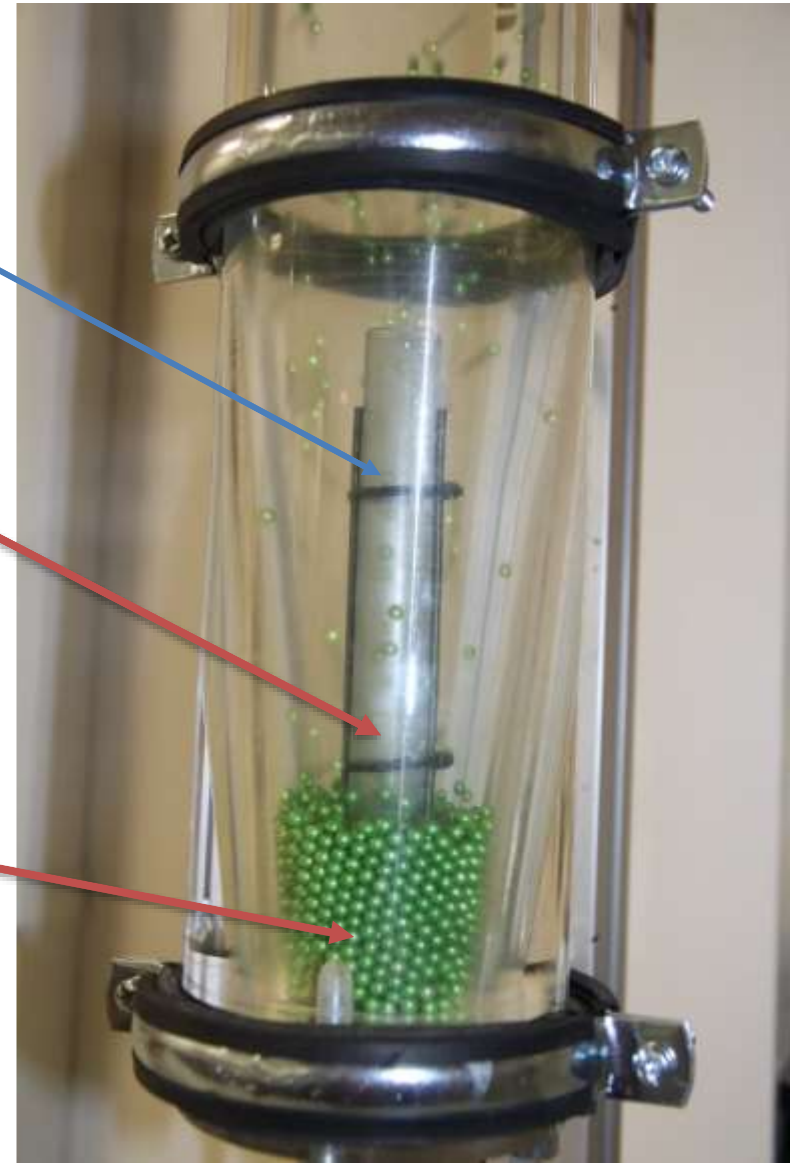
Particles move up the core and then fall down in the annulus

Plan view



Central core has high air velocity

Outer ring has lower velocity of air



- Coating solution is sprayed onto particles in central core
- Hot, drying air is fed into outer annulus

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7. Fluidised Beds: Summary

- **Very versatile**
  - Can have lots of different functions
  - Lots of different designs
- **Behaviour dependent of particle properties**
- **What we have not covered:**
  - Challenge of fragile particles and particle shape
  - Potential for make up
  - Importance of distributor plate design for air feeds
  - Start up and shut down procedures
  - Developments to cope with difficult materials

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8. Fluid Bed Processing: Learning More

Fluid Bed Processing

16th-18th January 2019

https://engineering.leeds.ac.uk/short-course/2769

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Image courtesy of NEUHAUS NEOTEC

Day 1. Fluidisation Basics:

What causes powder beds to fluidise?

Properties of powders

What are the watch-outs?

Engineering particles with different properties

Practical demonstrations

Day 2. Industry Case Studies

The importance of the bed design on how it operates

The key operating parameters from starting up to steady state

Real-life case studies examples from a range of industries

Further practical demonstrations

Day 3. New Developments and Innovations

Latest developments in fluid bed applications from industry and academia

Problem solving forum

Any Questions?

- Participants remain muted
- Please use the GoToWebinar question/chat boxes
- Any follow up questions or other enquiries:

  E: info@iformulate.biz
- Participants will be sent details of how to access a recording of this webinar
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