



# **Process Solid-Liquid Separation and Drying for Geothermal Brine, Battery Material Powder and Black Mass Recycling**

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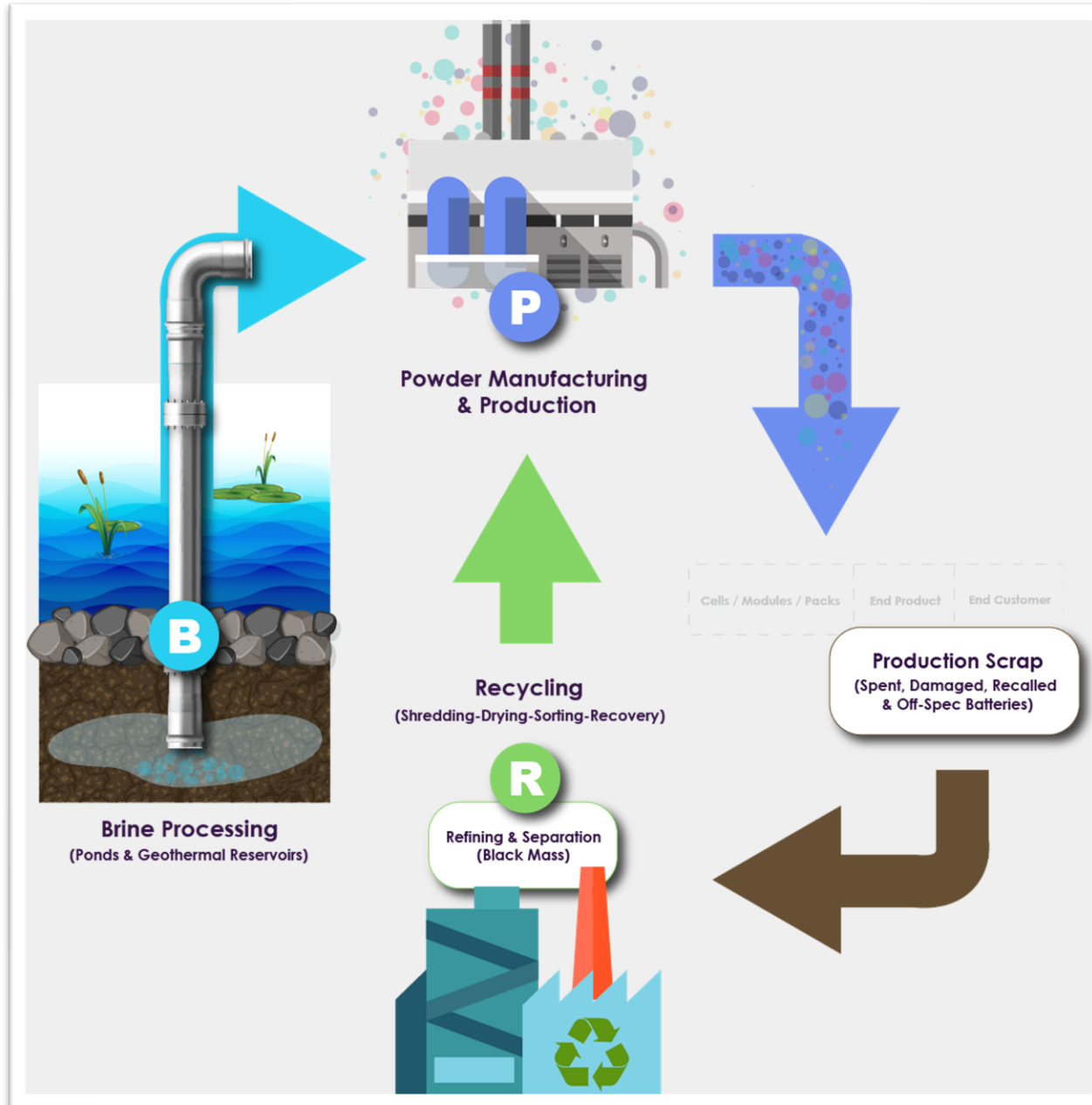
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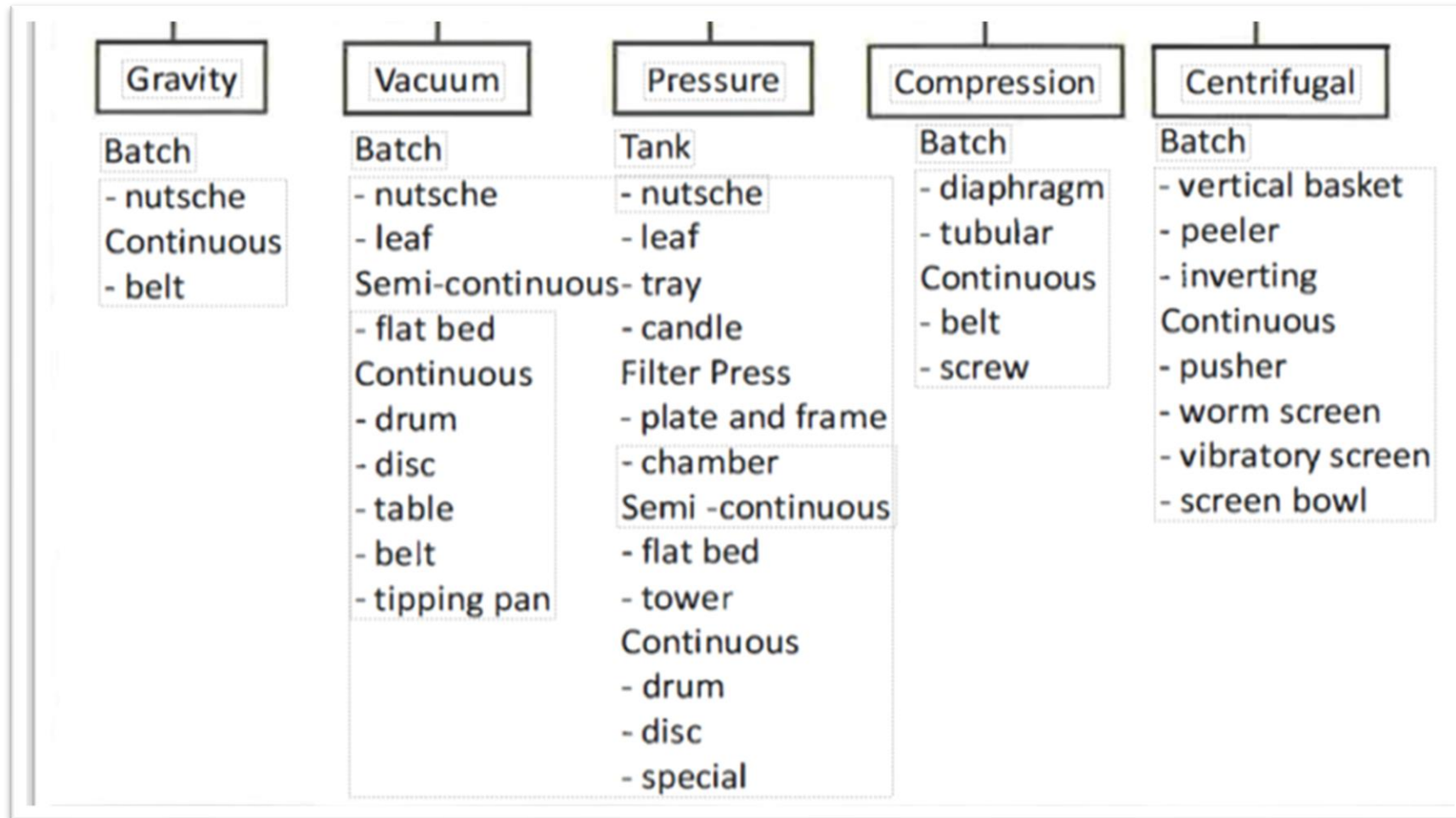
- 40 years of engineering and business marketing experience in the field of solid-liquid separation including filtration, centrifugation, drying, mixing & recycling
- Author of [“Solid Liquid Filtration Handbook” \(Elsevier, 2015\)](#)
- Editor of [“Integration & Optimization of Unit Operations” \(Elsevier, 2022\)](#)
- Professional skills focus on process solutions, innovation strategy, market expansion and business development.
- Published & presented worldwide on applications in the chemical, pharmaceutical, and energy/environmental industries
- Introducing European companies & technologies into the marketplace.

# PRESENTATION OVERVIEW



# PRESENTATION OVERVIEW

## Filtration Options



# **PRESENTATION OVERVIEW**

## **Drying Options**

### **Batch dryers:**

- Tray dryers
- Spray dryers
- Rotary dryers
- Vertical Vacuum dryers
- Pan dryers
- Spin Flash dryer

### **Continuous dryers:**

- Conveyor dryers
- Belt dryers
- Fluid bed dryers
- Spray dryers
- Horizontal paddle dryers
- Tunnel dryers
- Rotary dryers

# BRINE PROCESSING

## Lithium Extraction Technology

- Raw Material Sources for Lithium
  - Mining of Hardrock Ores (Spodumene, Pegmatites)
  - Clays
  - Evaporative Solar Ponds
- Other Sources: Direct Lithium Extraction (DLE) from Geothermal Brines
  - Adsorption
  - Ion exchange
  - Solvent extraction

# BRINE PROCESSING

## Lithium Extraction Technology

- Other Sources: Direct Lithium Extraction (DLE) from Geothermal Brines
  - Adsorption:
    - Physically adsorbs LiCl molecules onto the surface of a sorbent from a Li-loaded solution with water as a stripping solution
  - Ion exchange:
    - Takes Li ions from the solution by trading lithium ions for protons or other cations within the sorbent's structure. An acid solution is typically required for stripping and recovering the lithium
  - Solvent extraction:
    - Exchanges LiCl molecules or Li ions between brine and an organic liquid phase containing an extractant that complexes with lithium or lithium compounds in the brine

# BRINE PROCESSING

## Lithium Extraction Technology

- Process Steps
  - Precipitation followed by Solid-Liquid Separation
  - Cake Washing
  - Dissolution to Distillation followed by Drying
  - Leaching / Solid-Liquid Separation
  - Purification
    - Evaporation/Neutralization
    - Solid-Liquid Separation
    - Crystallization
    - Drying



# BRINE PROCESSING

## Lithium Extraction Technology

- Solid-Liquid Separation-Bulk Separation
  - Pusher Centrifuges
  - Indexing Vacuum Belt Filters
- Solid-Liquid Separation-Clarification / Polishing
  - Candle Filter
  - Pressure Plate Filter
  - Filter Press
- Drying
  - Fluid Bed
  - Spray

# BRINE PROCESSING

## Lithium Extraction Technology

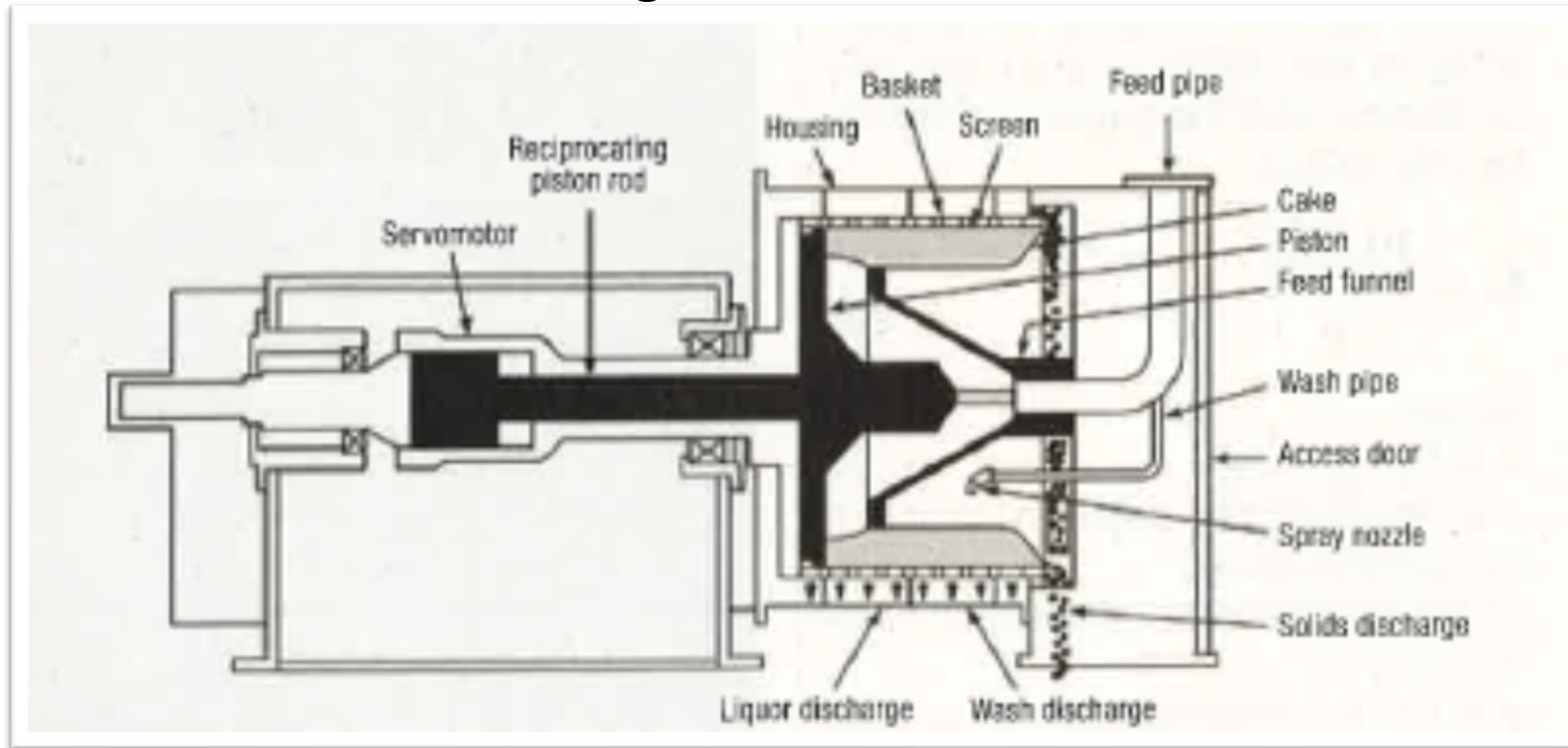
### Pusher Centrifuge

- Continuous Operation
- Ideal for particles 75 - 200 micron and up
- Particles can be granular, crystalline or fibrous
- Incompressible solids
- Solids should also be free-draining
- Cake Washing
- Concentrated Slurry Solids Discharge



# Pusher Centrifuge

- Solids are retained as a cake on a wedge wire basket from where they are transported by an oscillating pusher mechanism in the direction of the solids discharge



# BRINE PROCESSING

## Lithium Extraction Technology

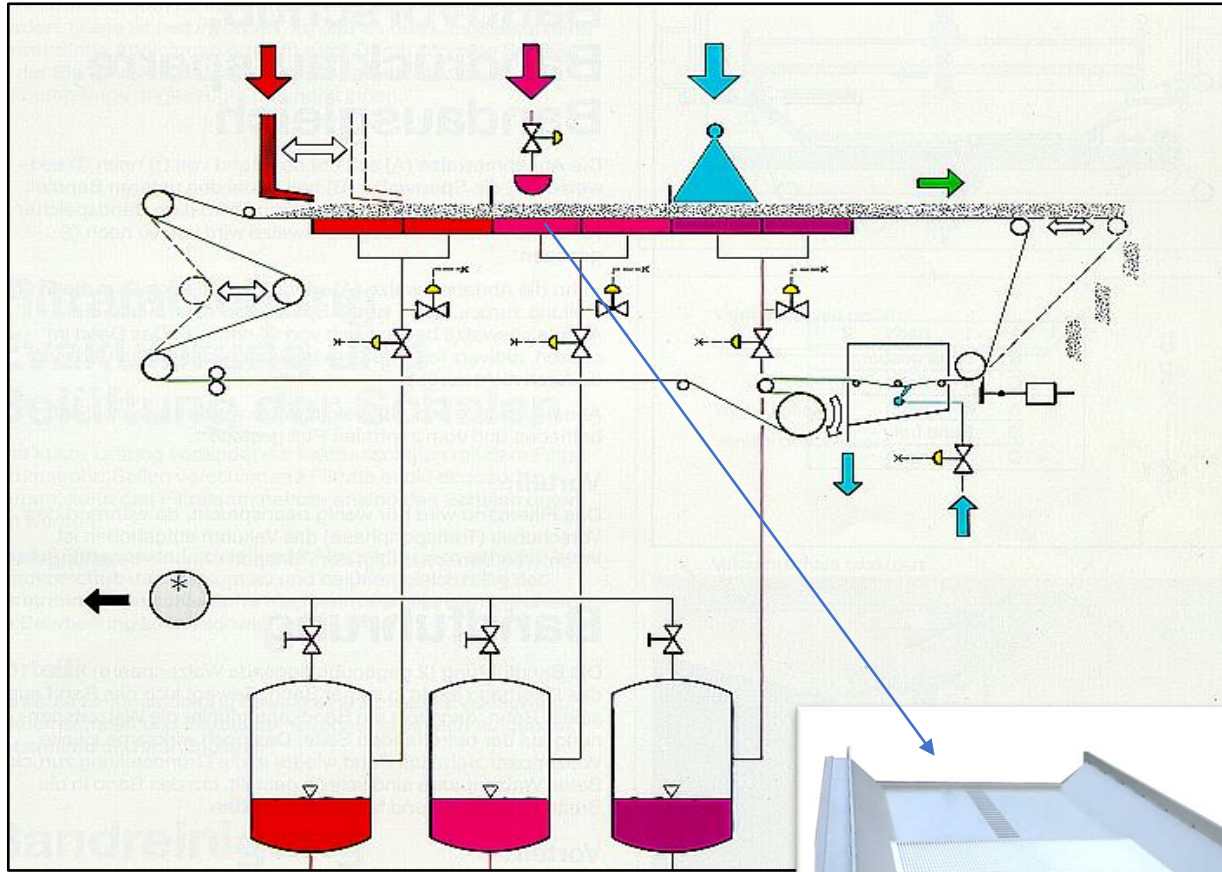
### Indexing Vacuum Belt Filter

- Slurry Feeding
- Filtering
- Cake Washing
  - Displacement
  - Counter-Current
- Dewatering/Drying
- Pressing
- Discharging

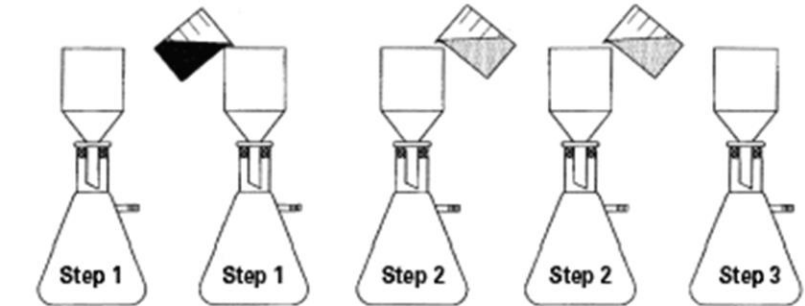
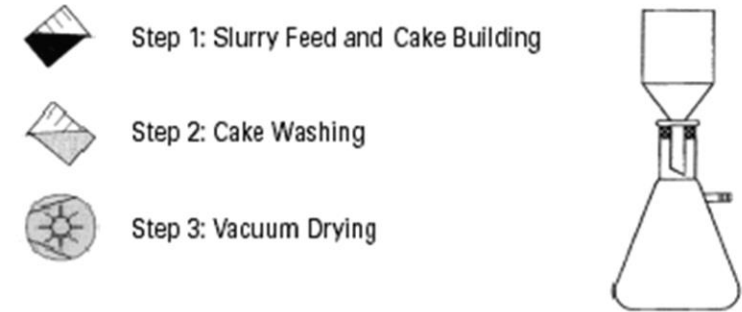




# Indexing Vacuum Belt Filter



## Think of a Buchner Funnel and Vacuum Flask



Now, combine these to a continuous process.  
The result is the **BHS Continuous Indexing Vacuum Belt Filter**.

# **BRINE PROCESSING**

## **Lithium Extraction Technology**

### **Chamber / Membrane Filter Press**

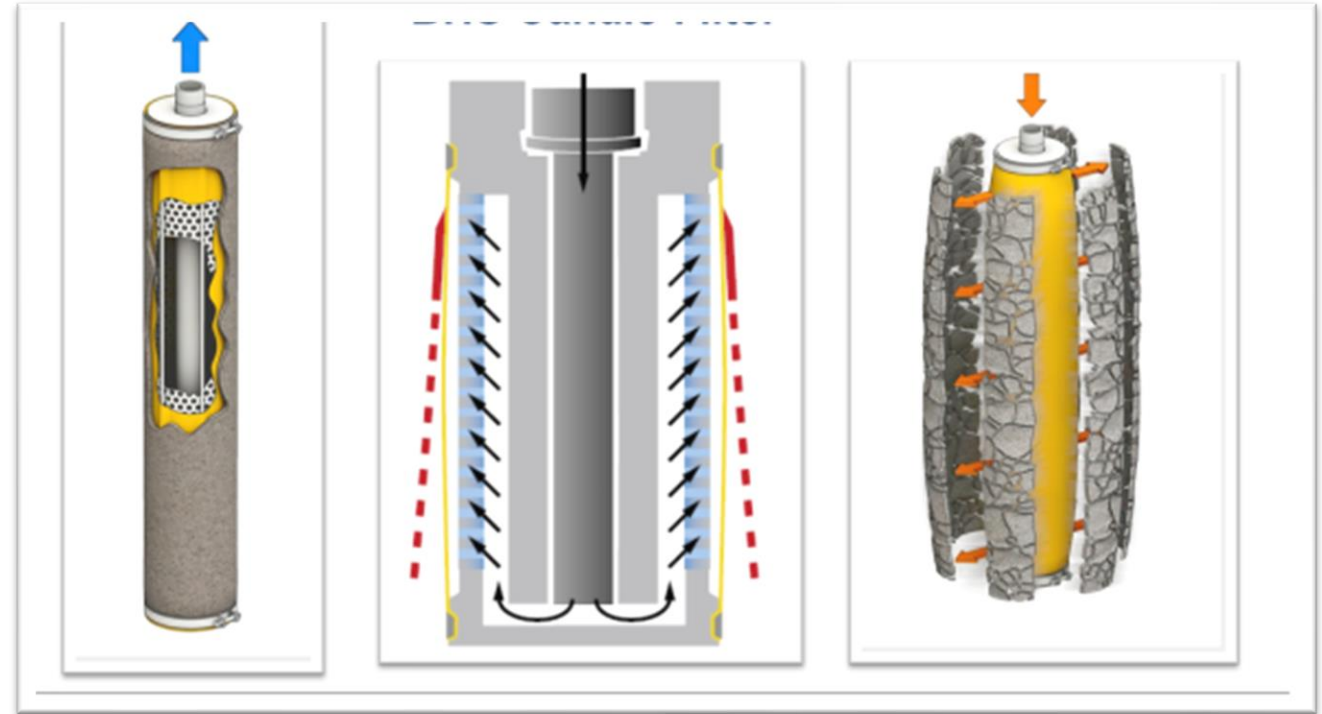
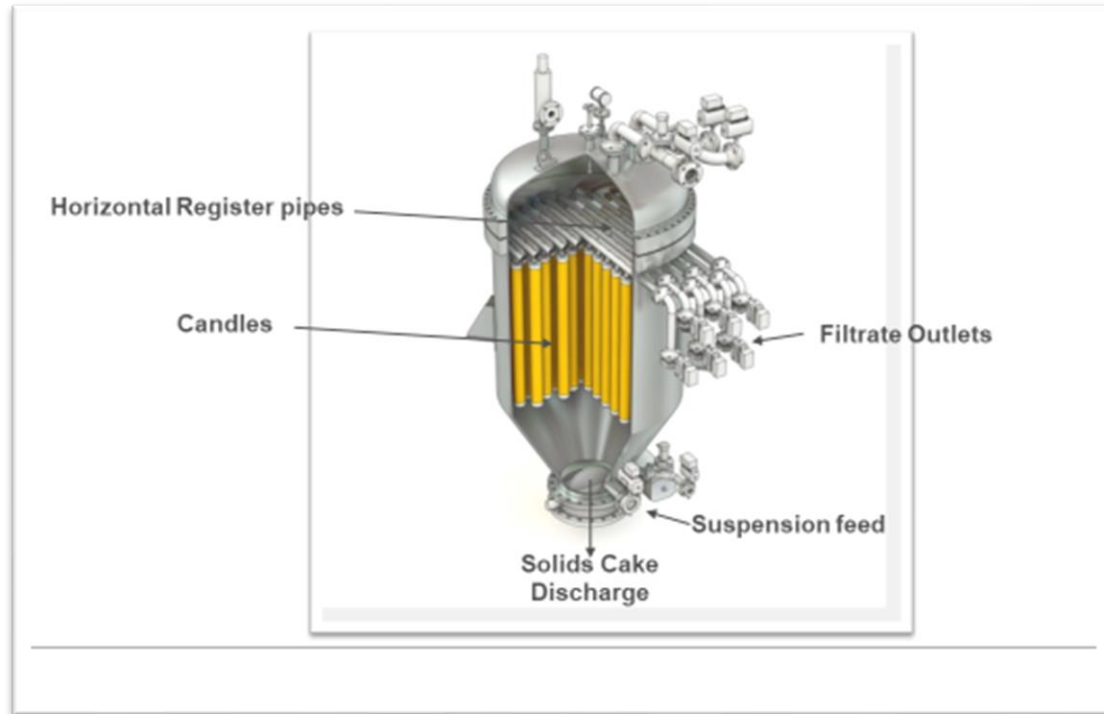
### **Side Beams-Enclosed or Open**



# BRINE PROCESSING

## Lithium Extraction Technology

### Candle Filter for Clarification

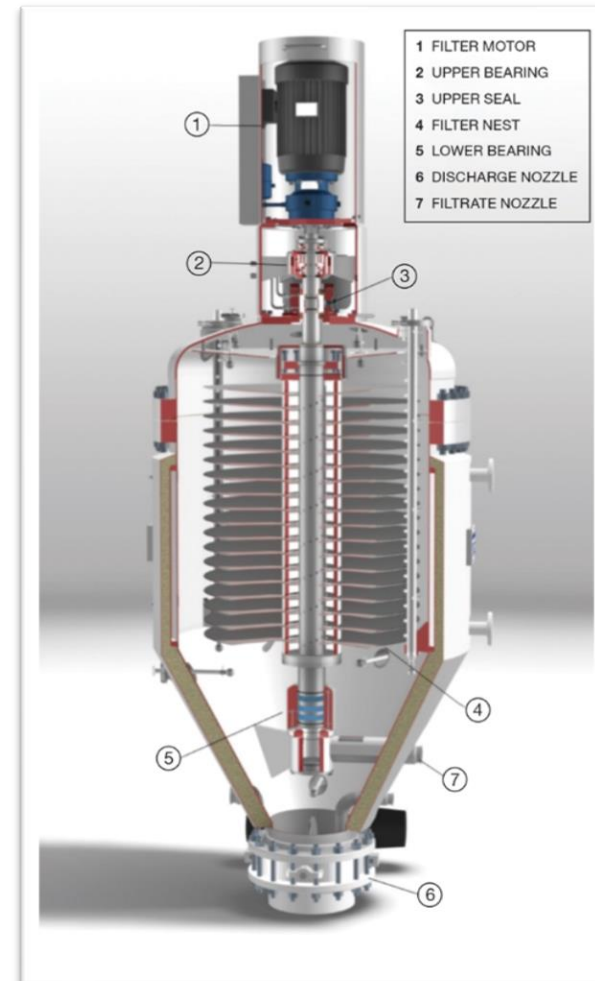
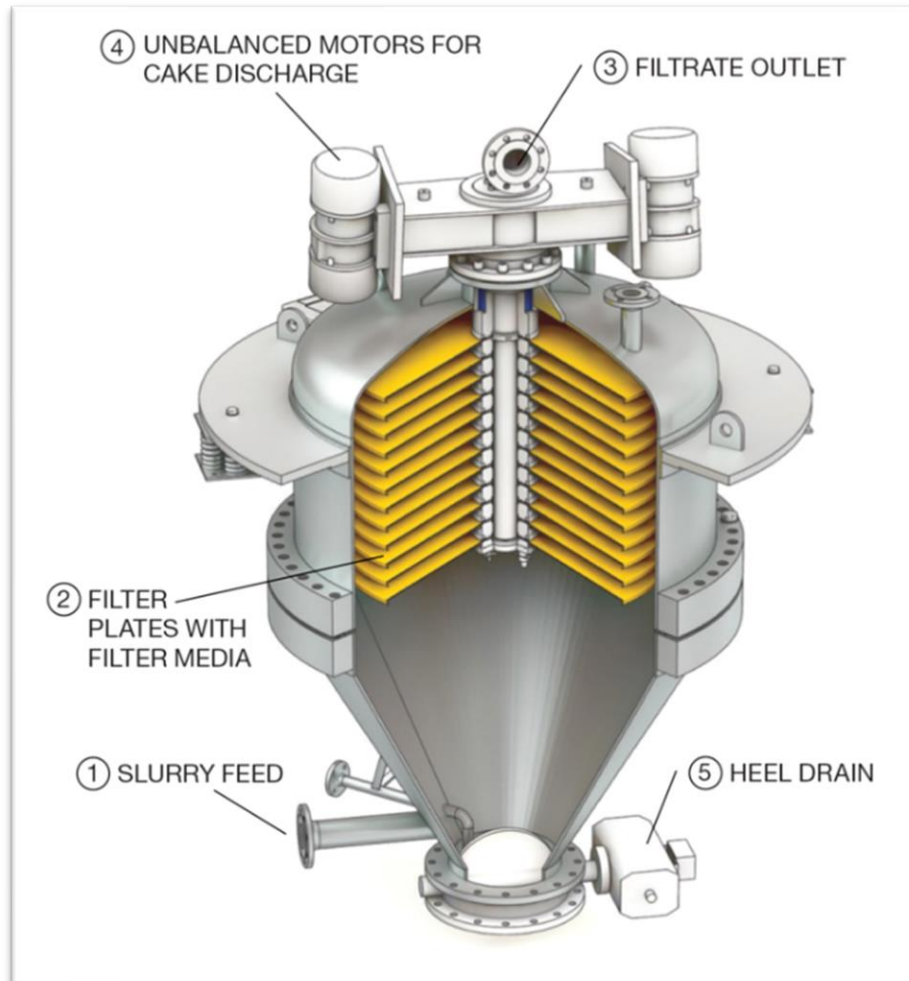




# BRINE PROCESSING

## Lithium Extraction Technology

### Pressure Plate Filter for Clarification

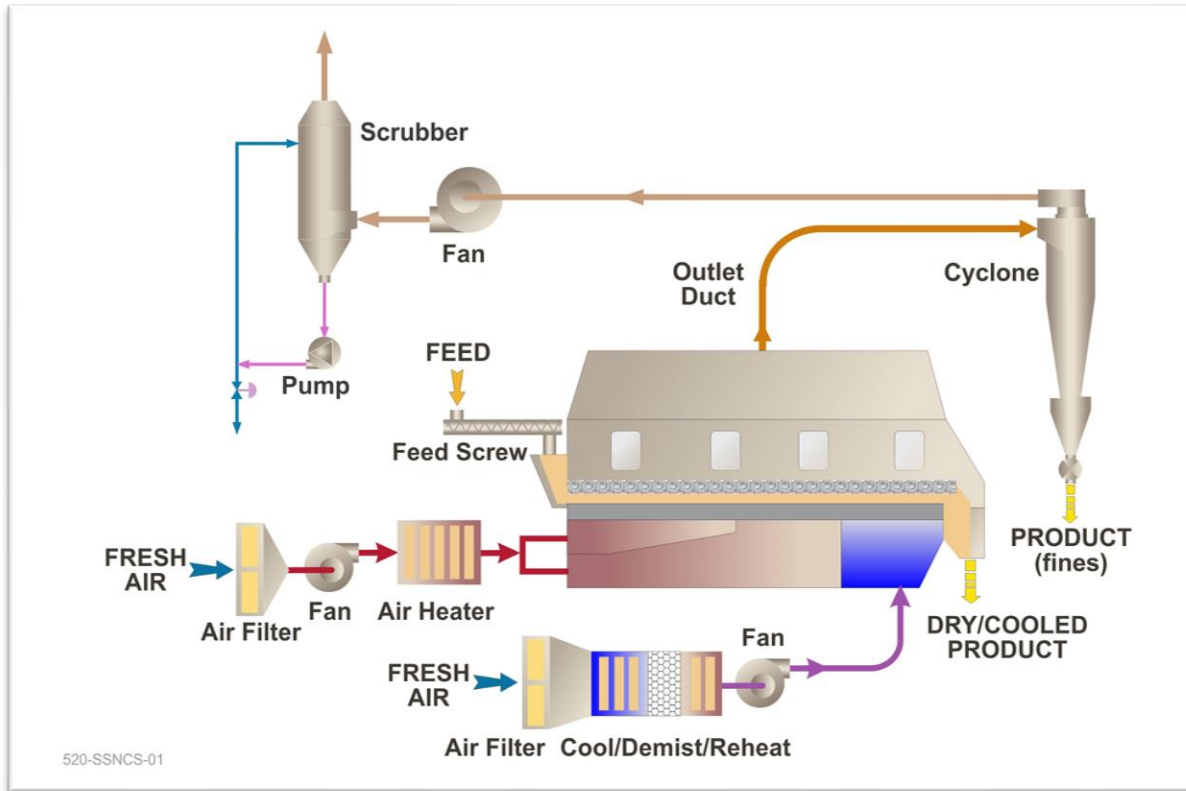




# BRINE PROCESSING

## Lithium Extraction Technology

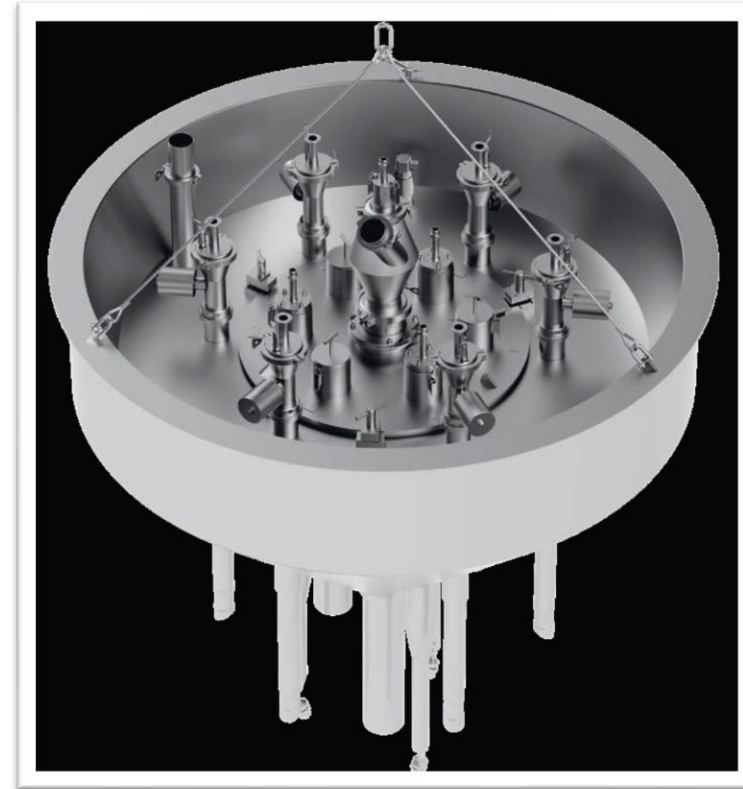
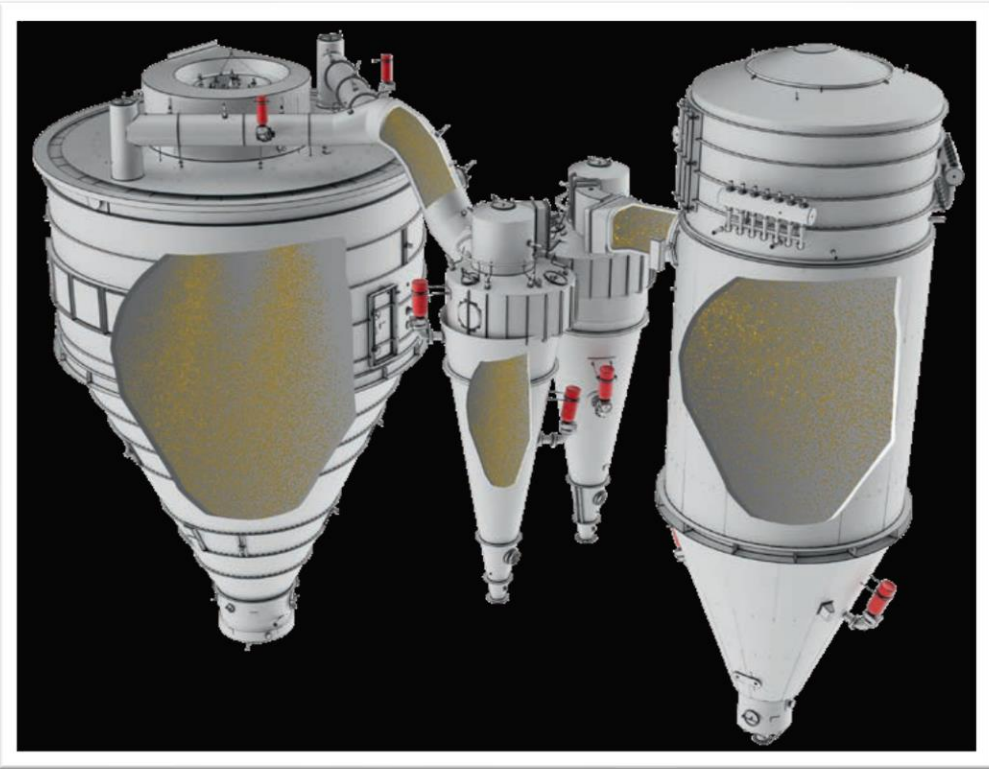
### Static Fluid Bed Dryer



# BRINE PROCESSING

## Lithium Extraction Technology

### Spray Dryer



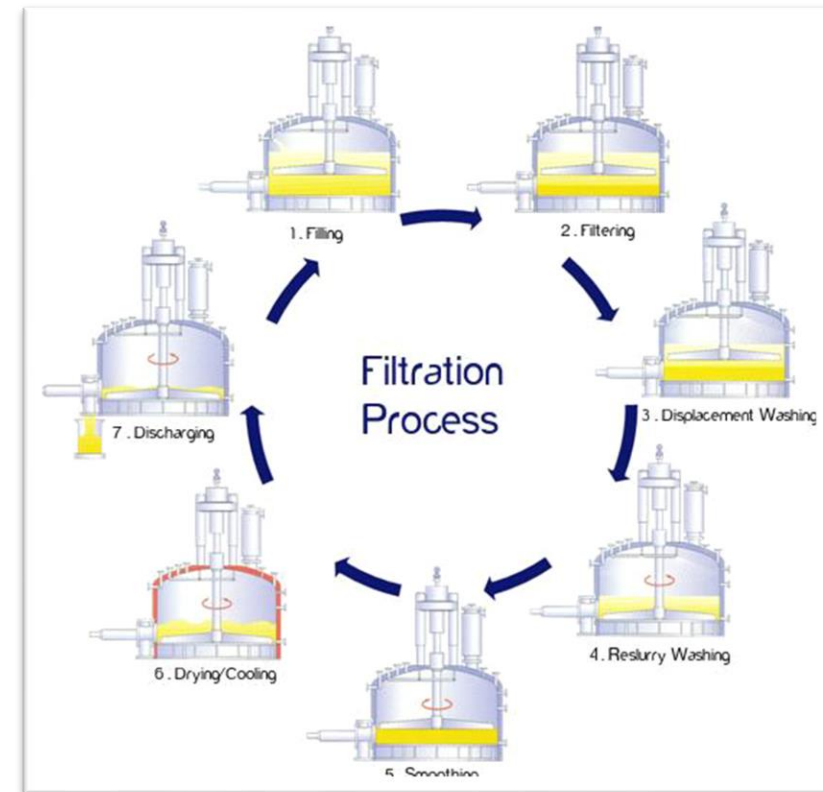
# BATTERY POWDER & MATERIALS MANUFACTURING

- Solid-Liquid Separation-Bulk Separation
  - Pusher Centrifuges, Indexing Vacuum Belt Filters
  - Agitated Nutsche Filter-Dryer
  - Peeler Centrifuge
- Solid-Liquid Separation-Clarification / Polishing
  - Candle Filter, Pressure Plate Filter, Filter Press
- Drying
  - Fluid Bed, Spray
  - Horizontal Paddle Dryer
  - Vertical Conical Dryer

# BATTERY POWDER & MATERIALS MANUFACTURING

## Agitated Nutsche Filter-Dryer Process Steps

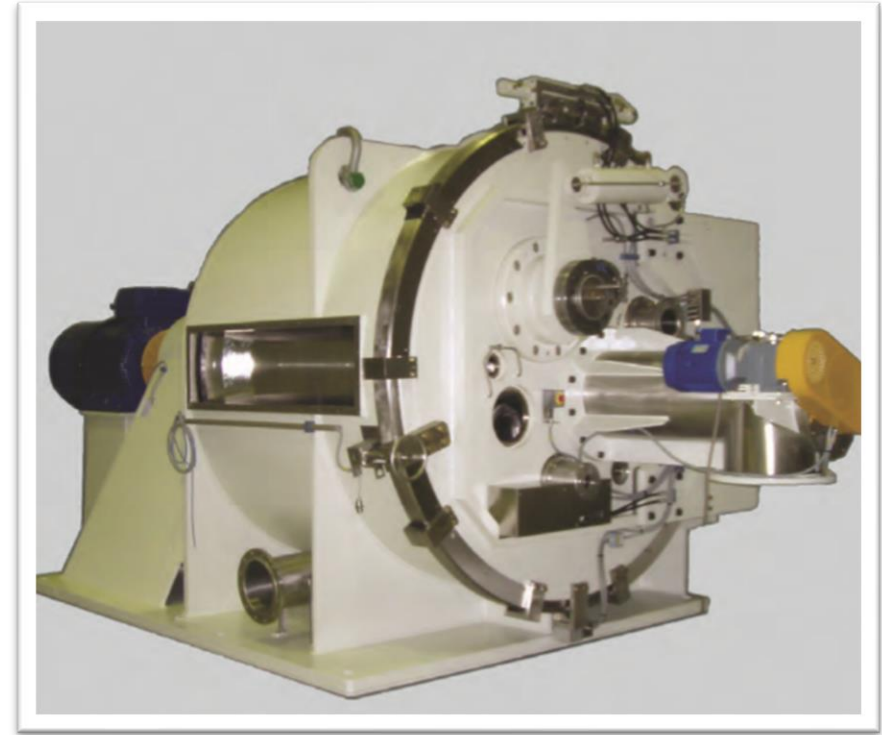
1. Filling/Charging
2. Filtering
3. Displacement Washing
4. Reslurry Washing
5. Smoothing
6. Dewatering/Drying
7. Discharging



# BATTERY POWDER & MATERIALS MANUFACTURING

## Horizontal Peeler Filtering Basket Centrifuge

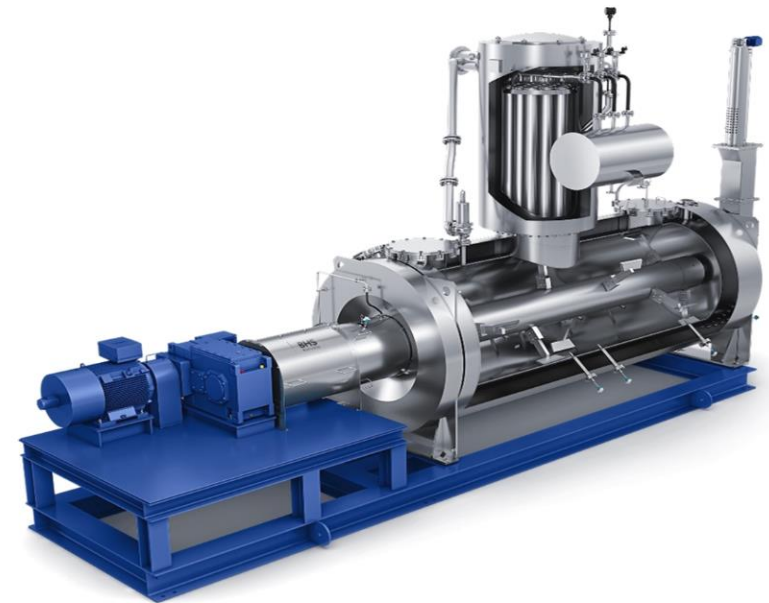
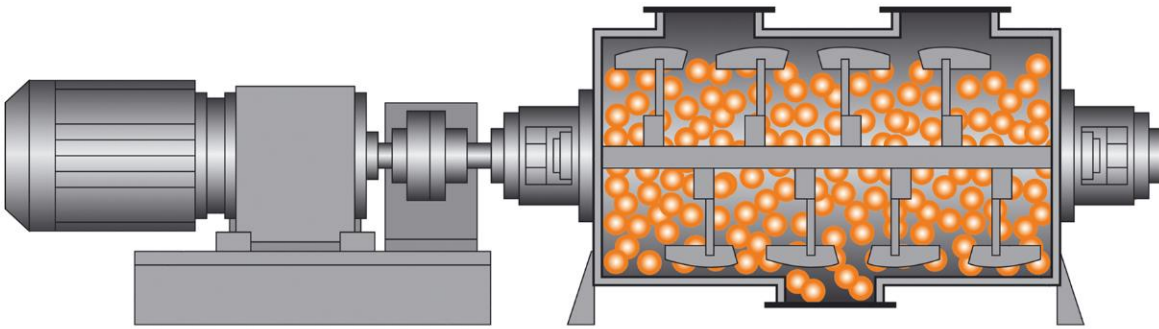
- Batch Operation
- Horizontal Axis with shaft support by front & rear bearings
- Plug-flow cake washing
- Cake removal peeler knife and mechanical auger





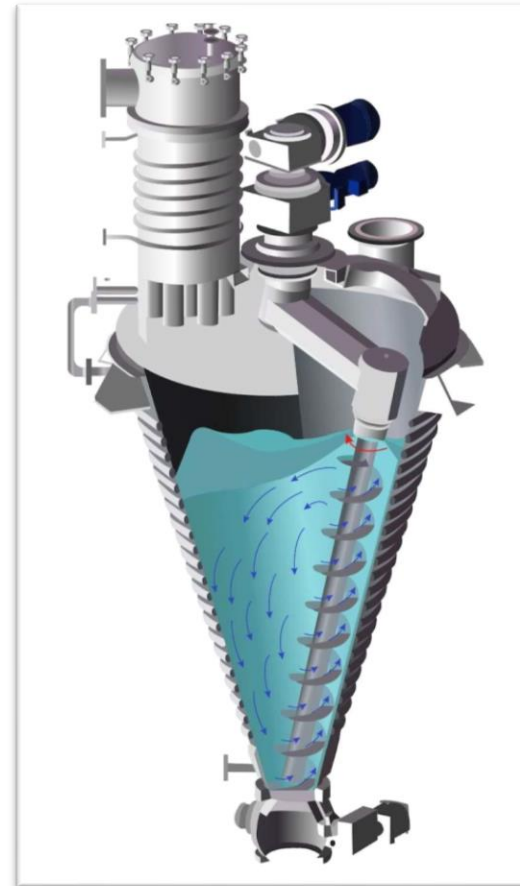
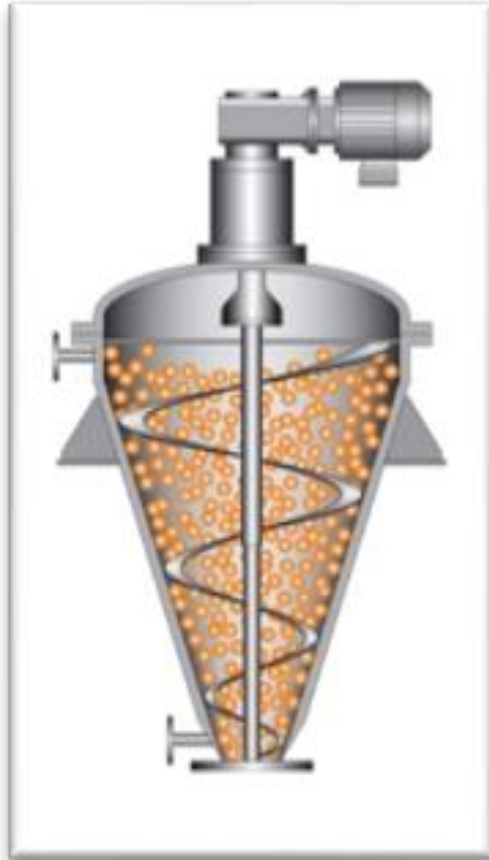
# BATTERY POWDER & MATERIALS MANUFACTURING

## Horizontal Paddle Dryer



# BATTERY POWDER & MATERIALS MANUFACTURING

## Vertical Conical Dryer



# RECYCLING OF PRODUCTION SCRAP & EOL /ESS BATTERIES

## Shredding-Drying-Sorting-Recovery/Refining

- Stage 1: Mechanical Size Reduction
- Stage 2: Drying of Black Mass
- Stage 3: Gas Treatment & Electrolyte Recovery
- Stage 4: Sorting & Separation
- Stage 5: Refining



# RECYCLING OF PRODUCTION SCRAP & EOL /ESS BATTERIES

## Shredding-Drying-Sorting-Recovery/Refining

- Solid-Liquid Separation-Bulk Separation
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  - Candle Filter, Pressure Plate Filter, Filter Press
- Drying of Black Mass
  - Fluid Bed, Spray
  - Horizontal Paddle Dryer
  - Vertical Conical Dryer

# **RECYCLING OF PRODUCTION SCRAP & EOL /ESS BATTERIES**

## **Shredding-Drying-Sorting-Recovery/Refining**

### **Stage 2: Benefits of Drying of Black Mass**

- Maximum Efficiency of Recovery Rate
  - Guaranteed to 95% from mechanical treatment
- Drying Evaporates the Electrolytes and VOCs
  - Sorting is conducted in a safe, non-explosion proof, environment
  - Easy installation from safety/health & environmental perspectives
- No Agglomeration as Drying is at Low Temperatures
  - No melting of plastics / polymers

# **LABORATORY TESTING FOR TECHNOLOGY SELECTION**

## **Cake Structure Determination & Process Parameters**

- **Feed Solids**
  - **Granular, particulate, sludge, crystalline, liquid, pasty, continuous flat sheets, sticky, lumpy**
  - **Size distribution, bulk density**
- **Filtration Pressure (or Vacuum) or Centrifugation**
- **Cake Thickness & Cake Structure**
- **Cake Washing**
- **Cake Dewatering / Drying**
- **Cake Discharge**
- **Cycle Times, Flux Rates & Drying Curves**

# SUMMARY & TAKEAWAYS

- **Lithium Market has many moving parts such as lithium production, geothermal brine, battery material powder and Black Mass Recycling/Separation/Refining**
- **There are many technology choices for process solid-liquid separation and process drying**
- **Testing (lab, pilot, demonstration, etc.) is critical for the optimum technology selection to de-risk the scale-up to full production**
- **Consideration must be given to upstream & downstream operations, solids handling and energy / environmental costs**
- **We have covered the main choices but there are many more possibilities for creative problem solving**

# **SUMMARY & TAKEAWAYS-FILTRATION CRITERIA**

- 1. Typical Solids Content of Slurry (% Solids)**
- 2. Process Characteristics**
- 3. Slurry Composition / Properties**
- 4. Solids Description, Range of PSD**
- 5. Cake Thickness/Structure/Formation**
- 6. Cake Washing**
- 7. Cake Pressing**
- 8. Cake Moisture**
- 9. Filtrate Quality**
- 10. Filtrate Discharge / Separation of filtrates**
- 11. Cake Discharge**
- 12. Cloth and Overall Cleaning**
- 13. Mechanical / Operational**
- 14. Other (Performance/Installation/Utilities  
/Ancillaries/ Filter Aid/Filter Media/MOC, etc.)**

# **SUMMARY & TAKEAWAYS-DRYER CRITERIA**

- 1. Dryer throughput; mode of feedstock production (batch/continuous)**
- 2. Physical, chemical & biochemical properties of the wet feed and final product spec**
- 3. Variability in feed characteristics, process parameters and downstream impacts**
- 4. Upstream and downstream processing operations**
- 5. Moisture content of the feed and product (Wet and Dry basis)**
- 6. Drying kinetics-isotherms, drying curves, drying times**
- 7. Heat sensitivity - Melting point, - Glass transition temperature**
- 8. Quality parameters (physical, chemical, biochemical)**
- 9. Safety aspects, e.g., fire hazard and explosion hazards, toxicity**
- 10. Value of the product**
- 11. Need for automatic control**
- 12. Toxicological properties of the product**
- 13. Turndown ratio, flexibility in capacity requirements**
- 14. Type and cost of fuel, cost of electricity**
- 15. Environmental regulations**
- 16. Space in plant**
- 17. Dryer Materials of Construction, Seals, etc.**



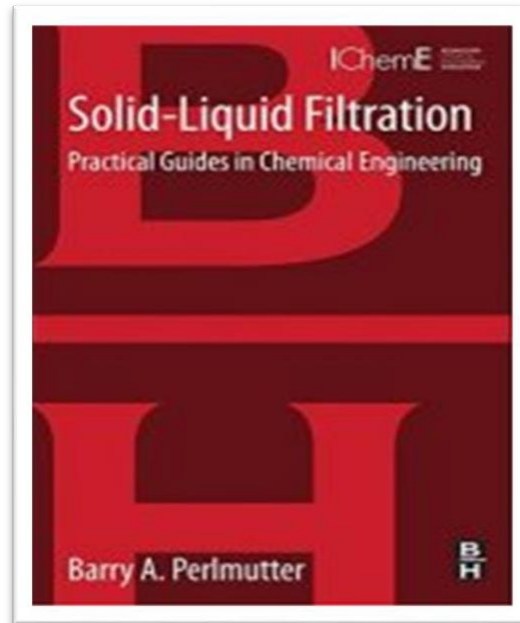
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### Solid-Liquid Filtration



### Integration & Optimization of Unit Operations