Introduction to the Short-Process Recycling Technology for Scrapped Lithium Batteries

Section 1 - Process Overview

UniRec's short-process recycling technology for scrapped lithium batteries consists of a roasting-free dry dismantling process and an extraction-free hydrometallurgy processing segment. These two segments can be operated in tandem or independently.

Roasting-Free Dry Dismantling Process

1. **Process Features**

The dry dismantling process operates entirely in a closed, automatic environment protected by inert gas, without a pyrolysis step. This enables:

- High recovery rates for black powder.
- Low impurity content in black powder.

2. **Comparison with Industry Practices**

Most domestic and international processes include a pyrolysis stage, requiring materials to be heated in a rotary kiln above 650°C for a specific duration. This step:

- Decomposes PVDF (a binder) for separation of copper and aluminum foil from cathode and anode materials.
- Involves significant energy consumption, generates large amounts of gas and atmospheric pollutants, and has the risk of dioxin formation.

By contrast, UniRec's process:

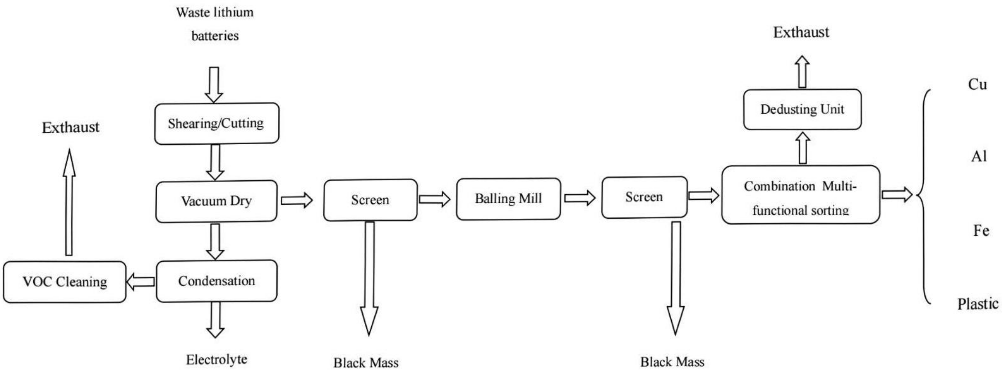
- Avoids high-temperature steps, significantly reducing energy use.
- Recovers nearly all the electrolyte for subsequent reuse.
- Emits lower concentrations of VOCs, HF, and particulates, meeting stringent EU standards.
- Supports CO2 emission reductions.

Data from demonstration line operations show:

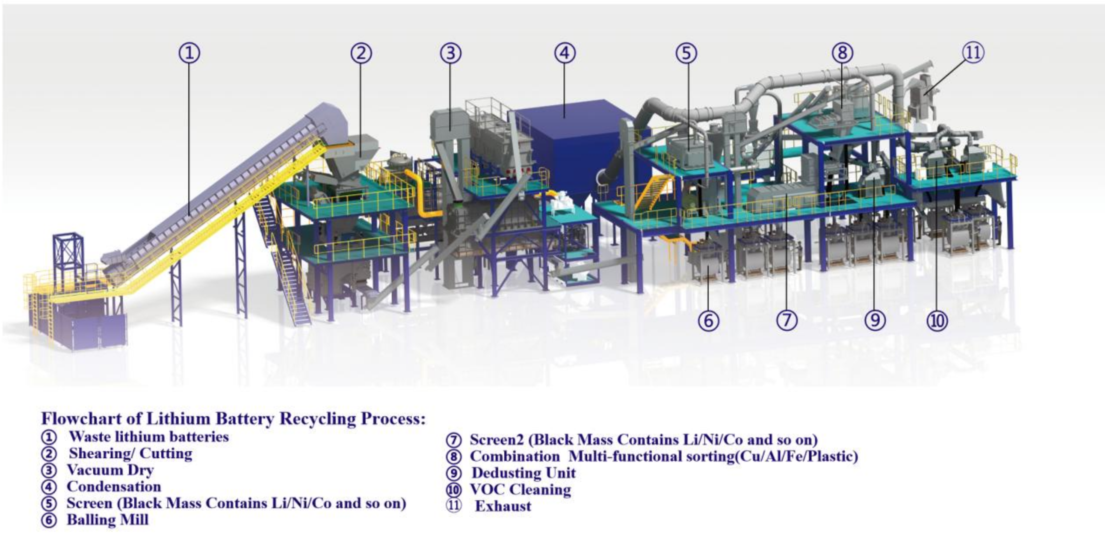
- **Black mass recovery rate:** 99% (industry average: below 96%).
- **Impurity content in black powder:** Copper and aluminum impurities below 0.5% (industry average: above 3%).
- **Cost efficiency:** Similar investment costs to competitors (with normal emission permits), but less investment (with strict emission permits) , and 20–30% lower operational costs (excluding raw battery purchases).

3. **Process Flow Diagram**

The document includes a **flowchart for the roasting-free dry dismantling process**, which outlines each step from battery disassembly to material recovery.



Flowchart of UniRec Roasting-Free Dry Dismantling Process



Section 2: Solvent Extraction-Free Wet Process

1. Process Features

The extraction-free hydrometallurgy process utilizes waste battery black powder and positive electrode powder as raw materials. Through a reduction leaching process, it directly yields:

- Leachate containing nickel (Ni), cobalt (Co), manganese (Mn), and lithium (Li).
- Recycled graphite powder from the negative electrode.

Key steps:

- Purification of the recycled graphite powder enables its reuse as raw material for battery anode.

- Nickel, cobalt, manganese, and lithium are recovered from the leachate to produce:
  - Battery-grade nickel-cobalt mixed salts, or
  - Precursors for ternary lithium battery production.
- Lithium-rich solutions are further processed to produce battery-grade lithium hydroxide or lithium carbonate.

This method achieves the purification and recovery of critical materials without the use of solvent extraction techniques.

2. Comparison with Industry Practices

Conventional industry methods often employ "sulfuric acid + hydrogen peroxide" leaching, followed by solvent extraction and precipitation to separate nickel, cobalt, manganese, and lithium. These methods typically result in:

- High reagent costs.
- Complex processes requiring over ten extraction stages.
- High equipment investment and operational costs.
- Material losses and limited recovery efficiency for Ni, Co, Mn, and Li.

Advantages of UniRec's Extraction-Free Wet Process:

- **Green Leaching Technology:**
  - Uses specialized, cost-effective reductants with high utilization rates.
  - Reduces reagent costs by over 50% compared to hydrogen peroxide.
  - Balances water usage within the system, minimizing wastewater discharge.

- **Integrated Purification Technology:**
  - Simultaneously removes impurities like copper, aluminum, phosphorus, and fluorine.
  - Compared to traditional methods, generates less waste residue and reduces loss of Ni, Co, Mn, and Li.
  - Achieves recovery rates of 99% or higher for Ni, Co, and Mn.

- **Direct Recovery of Ternary Solutions:**
  - Employs proprietary technology to separate cobalt, manganese, and lithium solutions.
  - Produces battery-grade nickel-cobalt-manganese mixed salts directly usable in lithium battery manufacturing.
  - Avoids solvent extraction, shortens process flows, and reduces material consumption.
  - Ensures high metal recovery rates with minimal waste or oily residues.

- **Performance Results**

  Data from demonstration lines validate the superiority of UniRec's wet process:

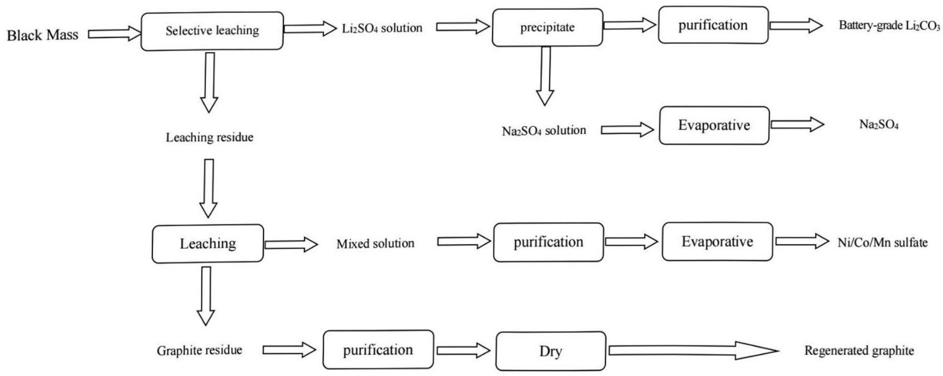
  Recovery rates:
  - Ni, Co, and Mn: 99% (industry average: below 98%).
  - Li: 95% (industry average: below 87%).

Cost efficiency:

- Fixed asset investment is over 30% lower than conventional plants for similar scale.
- Operating costs (excluding black powder purchases) are reduced by 15–20%.

3. Process Flow Diagram

The document includes a **flowchart for the extraction-free wet process**, illustrating stages from raw material leaching to purification and final product recovery.



Flowchart of UniRec Solvent Extraction-Free Wet Process

Section 3: Main Products

Dry Process Output

1. Main Product Yields and Recovery Rates

The dry dismantling stage processes 10,000 tons of battery packs, or 7,200 tons of cells annually, producing the following outputs:

Product	Recovery Rate (%)	Output (tons)
Black powder	99	3,600
Copper	95	570
Aluminum	95	360
Steel casings	99	1,290
Separators (including insulation pieces and plastic films ,etc.)	99	720
Electrolyte	95	610

2. Black Powder (Black Mass)

Black powder is a crucial material extracted from batteries, and its quality indicators include:

Indicator	Content (%)
Ni + Co + Mn	>30
Li	>3.6
Cu	<0.3
Al	<0.5
Fe	<0.3

3. Copper

Recovered copper powder's quality indicators:

Indicator	Content (%)
Cu	>93

4. Aluminum

Recovered aluminum powder's quality indicators:

Indicator	Content (%)
Al	>85

5. Steel Casings

Steel casings recovered from battery dismantling are considered a by-product for external sale.

6. Electrolyte

Electrolyte is nearly fully recovered during dismantling, ensuring its potential reuse.

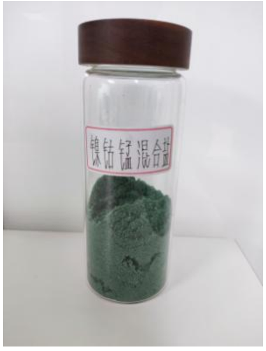
hydrometallurgy Process Output

1. **Main Product Yields and Recovery Rates**

This process handles 8,000 tons of black powder annually and produces the following:

Element	Recovery Rate (%)	Product	Output (tons/year)	Notes
Ni + Co + Mn	99	Nickel-cobalt-manganese sulfate	12,000	Convertible to ternary recursors
		Ternary precursor	3,870	Ni, Co, Mn totals remain constant
Li	95	Battery-grade lithium carbonate	1,450	Convertible to lithium hydroxide
		Battery-grade lithium hydroxide	1,625	Li total remains constant
Na	98	Industrial-grade sodium sulfate	11,000	-
Graphite	98	Recycled graphite powder	3,136	Meets requirements for battery applications

2. Battery-Grade Nickel-Cobalt-Manganese Sulfate



Quality indicators:

Indicator	Content (%)
Ni + Co + Mn	>20
Na	<0.1
Mg	<0.0016
Al	<0.0008
Ca	<0.0016
Fe	<0.0008
Cu	<0.0005
Zn	<0.0005
Cr	<0.0005
Cd	<0.0008
Pb	<0.0005
P	<0.0010
F	<0.0020
Si	<0.0010
Magnetic substances	<0.00001
Oil	<0.0010

3. Ternary Precursor Quality indicators:

Indicator	Content (%)
Ni + Co + Mn	60.00–64.00
Na	0.0300
Mg	0.0030
Al	0.0050
Ca	0.0030
Fe	0.0020
Cu	0.0010
Zn	0.0020
Cr	0.0030
Cd	0.0030
Pb	0.0030
Si	0.0050
Magnetic substances	0.00001
Tap Density	1.10 (g/cm^3)

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4. Battery-Grade Lithium Carbonate
Quality indicators:

Indicator	Content (%)
Li_2CO_3	99.5
Na	0.0250
Mg	0.0030
Ca	0.0030
K	0.0010
Fe	0.0010
Zn	0.0003
Cu	0.0003
Pb	0.0003
Si	0.0030
Al	0.0010
Mn	0.0003
Ni	0.0010
SO_4^{2-}	0.0800
Cl^-	0.0030

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5. Battery-Grade Lithium Hydroxide

Quality indicators:

Indicator	Content (%)
LiOH	56.5–57.5
Na	0.0050
Mg	0.0010
Ca	0.0020
K	0.0030
Fe	0.0007
CO_3^{2-}	0.4000
Cu	0.0001
Si	0.0500
Mn	0.0010
Insoluble matter	0.0050
Cl^-	0.0020
SO_4^{2-}	0.0080

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6. By-Product: Sodium Sulfate

Quality indicators:

Indicator	Content (%)
Na_2SO_4	99.6
Insoluble matter	0.0050
Ca	0.0100
Mg	0.0100
Cl^-	0.0500
Fe	0.0005
Moisture	0.05
Whiteness (R457)	88

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7. Graphite The graphite recovered through this process meets the quality requirements for lithium battery anode.

Section 4: Project Phases

Phase 1: Initial Construction

1. **Objective:**
   Construct a production line with a processing capacity of 1 ton of cells per hour.
2. **Annual Capacity:**
   - Battery packs: Approximately 10,000 tons, or
   - Cells: 7,200 tons.
3. **Process Details:**
   - If local regulations, like those in the U.S. and Europe, permit the external sale of metal casings, copper foil, and aluminum foil mixtures, the **Module IV** section in the process flowchart can be simplified.
   - This modularity reduces investment and operational complexity.

Phase 2: Expansion with Wet Processing Facilities

- **Objective:**
  Add hydrometallurgy processing facilities with an annual black mass processing capacity of 8,000 tons.

- **Raw Material Supply:**
  - Black powder shortage can be addressed by:
    1. Expanding the dismantling line to 2 ton/hour capacity, or
    2. Purchasing black mass from external sources.
- **Final Product Options:**
  - Depending on market demand and investment conditions, choose between:
    - **Battery-grade nickel-cobalt-manganese mixed salts** or **ternary precursors**.
    - **Lithium salts**, including:
      - Industrial-grade lithium carbonate.
      - Battery-grade lithium hydroxide.
      - Battery-grade lithium carbonate.

This phased approach allows for flexible scalability based on market and regulatory conditions while optimizing investment efficiency.

Section 5: Pollutant Emissions

Dry Low-Temperature Dismantling Process (1 Ton/Hour Cell Capacity)

1. **Air Emissions**
   - **Condensed Exhaust Gases:**
     - Generated during electrolyte recovery.
     - Major pollutants: VOCs and fluorides.
     - Treated exhaust gases meet discharge standards after deep treatment.
   - **Sorting Exhaust Gases:**
     - Generated by the airflow sorting machine during the separation of battery components post-crushing.
     - Major pollutants: particulates.
     - Treated with bag filtration to meet discharge standards.

   Emission Data:
   - Condensed Exhaust Gases:
     - Volume: 150 Nm^3/h.
     - Non-methane hydrocarbons: <25 g/m^3.
     - HF: <2.5 mg/m^3.
   - Sorting Exhaust Gases:
     - Volume: 36,000 Nm^3/h.
     - Particulates: <10 mg/m^3 (10 kg/h).
     - Nickel and its compounds: <5 mg/m^3.
     - Cobalt and its compounds: <5 mg/m^3.

2. **Wastewater**
   - **Dry Process:**
     - Does not use water, hence no wastewater discharge.
     - Electrolyte is recovered for reuse.

- **Residual Wastewater:**
    - Only spray washing water is produced, amounting to 7.2 m³ annually.
    - Properly handled by qualified facilities with no direct discharge.

3. **Solid Waste**
    - Battery dismantling generates solid waste, such as:
        - **Battery casings, steel casings, copper foil, and aluminum foil:**
            - Converted into by-products for sale.
        - **Separator/plastic casings/insulation pieces:**
            - Approximately 500 tons/year.
            - Regularly transported to qualified disposal facilities.

Short-Process Wet Recycling Technology (8,000 Tons/Year Black Powder)

1. **Air Emissions**
    - Nickel, cobalt, and manganese are extracted using specialized reductants, resulting in no significant gas emissions.
    - Minor acidic vapor emissions are fully absorbed and reused within the system.
    - Emission concentrations comply with atmospheric pollutant discharge standards.

2. **Wastewater**
    - **Recycling:**
        - Evaporative condensate and washing water are recirculated within the production process.
    - **Minimal Discharge:**
        - Small amounts of cleaning and laboratory wastewater are treated to meet discharge standards.
        - Total wastewater discharge: 1 m³/day.

3. **Solid Waste**
    - **Graphite Residue:**
        - Generated after extracting nickel, cobalt, manganese, and lithium.
        - Annual production: 3,136 tons.
        - Considered general solid waste but can potentially be sold as recycled graphite.
    - **Iron-Aluminum Residue:**
        - Produced during leachate purification.
        - Annual production: Approximately 320 tons.
        - Regularly transported to qualified disposal facilities as general industrial waste.

This section demonstrates UniRec's commitment to environmentally responsible operations, with minimal emissions, effective waste recycling, and strict compliance with pollutant standards.