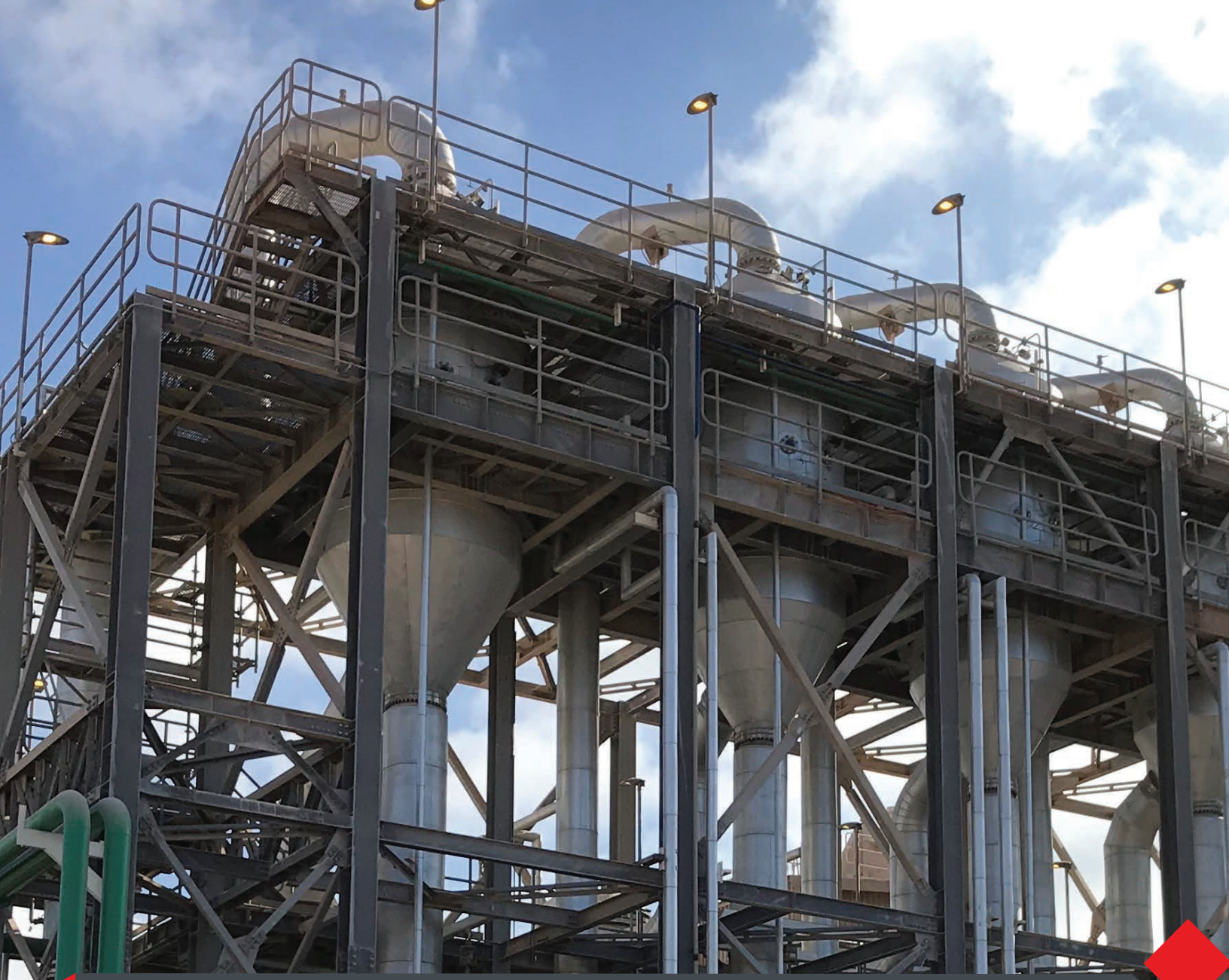


BATTERY GRADE LITHIUM PRODUCTION

SWENSON

WHITING

SINCE 1884

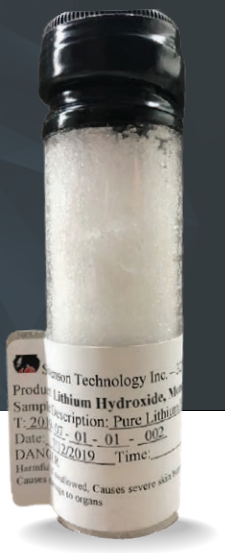
WHITING.CA/LITHIUM-REFINING

LITHIUM REFINING USING CRYSTALLIZATION

The global demand for lithium is skyrocketing, driven by increasing electric vehicle (EV) sales powered by lithium-ion batteries. However, pure lithium is not found in nature; it must be extracted and refined from liquid brines commonly found in salt lakes, oil field, geothermal brines, or from lithium-bearing minerals found in hard rock mines and some clay deposits.

The refining process isolates the lithium while removing contaminants and other chemicals to produce a pure, usable form of lithium. As lithium demand rises, so does the need for efficient, cost-effective lithium extraction and refining processes. Crystallization processes that are designed to form high purity lithium crystals by controlling how the crystal is formed and grown have been proven to produce valuable battery-grade lithium products and are core technology to the lithium refining industry.

Battery Grade Lithium
Pure $LiOH{\cdot}H_2O$
Crystal Product



HIGHER QUALITY CRYSTALS THROUGH INNOVATIVE SOLUTIONS

COMPLETE CUSTOMIZED SOLUTION

1 MODELING AND SIMULATION

Design starts with an understanding of the thermodynamics and chemical behavior to improve the process and economics. This is very important for efficient processing and contaminant removal.

2 BENCH TESTING

Process and flowsheet development.

Glassware testing provides:

- ✔ Proof of concept
- ✔ Physical data
- ✔ Crystal data:
  - Yield · Purity · Morphology

3 PILOT TESTING

Generate data for commercial plant design.

Pilot testing facilities include:

Evaporators

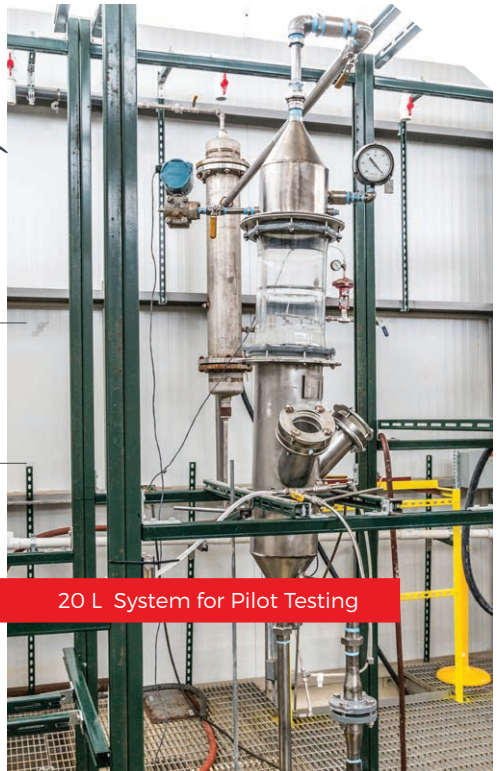
- ✔ Forced circulation ✔ Falling film

Crystallizers

- ✔ Draft tube baffle (DTB) ✔ Forced circulation
- ✔ Evaporative ✔ Cooling

Pilot testing provides:

- ✔ Fouling and scaling tendencies
- ✔ Crystal data:
  - Washing requirements
  - Centrifuge performance
  - Breakage



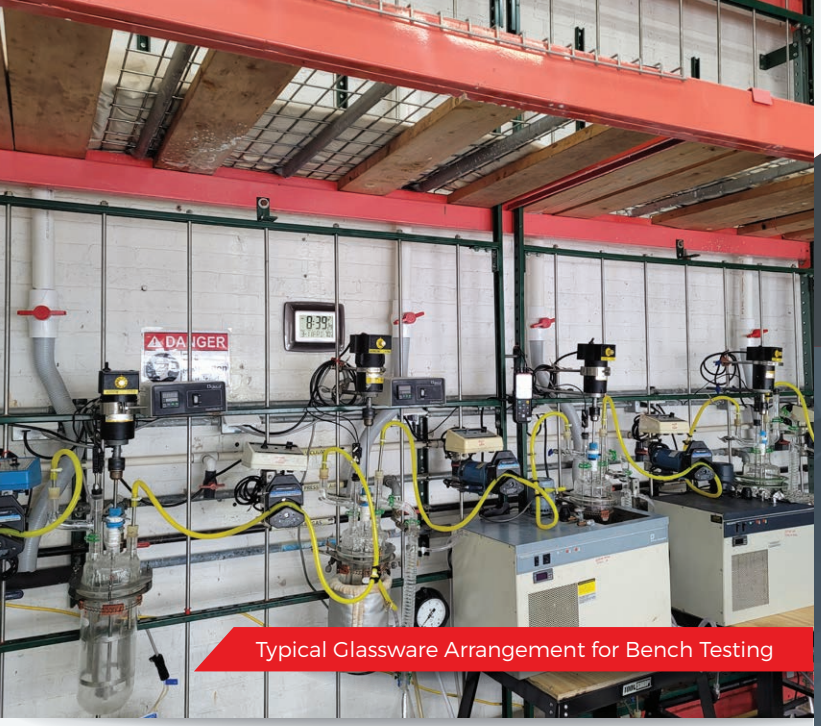
20 L System for Pilot Testing

4 PROCESS DESIGN, EQUIPMENT SIZING, AND COST ESTIMATION

Design commercial plant process and equipment, and evaluate costs.

5 FABRICATION, DELIVERY, AND COMMISSIONING

Implementation of successful commercial operation.



Typical Glassware Arrangement for Bench Testing

SWENSON HAS LITHIUM PURIFICATION AND PRODUCTION EXPERIENCE SINCE 1950s

BENEFITS OF LITHIUM CRYSTALLIZATION TECHNOLOGY FROM SWENSON

Swenson leverages decades of supplying lithium crystallization process equipment expertise and world class experience to design a lithium refining system that meets the unique demands of your lithium source and battery production purity demands. As a result, Swenson lithium refining crystallizers enable our clients to do the following:

- Maximize recovery of high purity, battery-grade lithium products
- Effectively and efficiently remove contaminants
- Reduce costs and increase revenue by improving process efficiency

LITHIUM REFINING CRYSTALLIZATION SYSTEMS

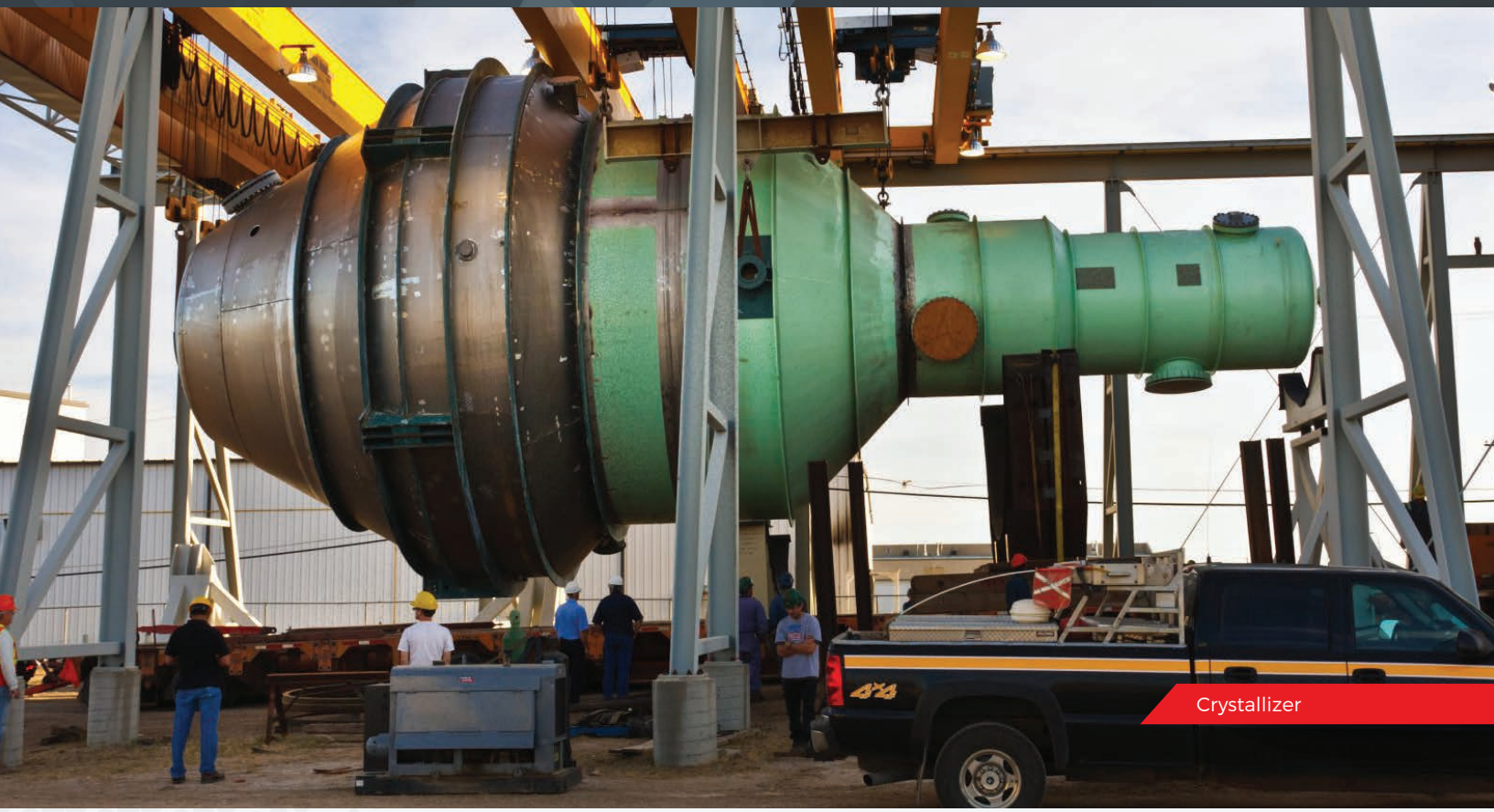
Crystallization of valuable, high purity products requires years of know-how and experience to properly engineer the process to control the formation of the crystals in a manner that effectively separates the impurities. Each lithium source stream, either produced from lithium brines or hard rock, has its own impurity profile that requires unique design approaches. Crystallizers can be used to effectively remove contaminants from lithium sources to improve the lithium recovery. It is important to work with an experienced crystallizer technology partner that provides the breadth of experience necessary to successfully address all challenges.

SWENSON'S DECADES OF LITHIUM EXPERIENCE:

Evaporators & Crystallizers Experience	1950	1960	1970	1980	1990	2000	2010	2020
$LiOH \cdot H_2O$	✓		✓		✓	✓	✓	✓
Li_2CO_3	✓	✓			✓	✓	✓	✓
LiCl	✓	✓	✓	✓			✓	✓
Li_2SO_4	✓		✓	✓		✓	✓	✓
$Na_2SO_4 \cdot 10H_2O$	✓	✓	✓	✓	✓	✓	✓	✓
Na_2SO_4	✓	✓	✓	✓	✓	✓	✓	✓

HIGHER QUALITY CRYSTALS
THROUGH INNOVATIVE SOLUTIONS

» WE TEST, DEVELOP, ENGINEER, AND MANUFACTURE YOUR SOLUTION.



Crystallizer

SWENSON

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