ExxonMobil

# High-performance metal extraction diluents for lithium-ion battery recycling

With the continued growth in electric vehicle (EV) adoption, it's estimated that 2 million tons of lithium-ion batteries will be available for recycling by 2030[1]. Recycling offers an end-of-life option for used EV batteries by extracting valuable metals that can then be re-deployed.

**Efficient recovery**

Minimal diluent and extractant with consistent performance

**Higher production rate**

Enabled with faster separation speed

**Global scalability**

Enabling quick global ramp up of operations and quality consistency

**Solvent extraction is a highly effective approach for recovering metals from EV batteries, enabling ...**

metal recovery rates of **90+%** with **95+%** purity[2]

High purity, quality consistency, improved safety and a global supply make Escaid™ diluents an excellent choice for solvent extraction processes[3].

**Low viscosity, high density, and low aromatics content significantly impact the phase separation time.**

**40%** faster separation speed.

Escaid™ diluents are used for the solvent extraction of rare earth and noble metals including copper, nickel, cobalt, uranium and zinc. The Escaid portfolio features grades with narrow boiling ranges, low viscosities, high flash points, and low evaporation rates. Escaid products offer the right balance of good flow and phase separation with minimal diluent and extractant losses.[4]

1 Source: Bloomberg New Energy Finance (BNEF) – "Lithium-Ion Battery Recycling: 2 million tons by 2030". Jan 7th 2019.

2 Recovery rate and purity dependent on system variables. Source: Chagnesa A, Pospiech B – "A brief review on hydrometallurgical technologies for recycling spent lithium-ion batteries". Journal of Chemical Technology and Biotechnology. 88: 1191-1199 (2013)

3 Source: https://www.exxonmobilchemical.com/en/solutions-by-industry/industrial-applications/metal-solvent-extraction, "Selecting the right diluent" PDF

4 Source: https://www.exxonmobilchemical.com/en/solutions-by-industry/industrial-applications/metal-solvent-extraction, "High-performance diluents for metal extraction" PDF brochure

# Range of solutions

ExxonMobil is a leading global supplier in the solvent extraction market, with a diluent product slate that enables custom solutions for optimized performance across a wide range of operating temperatures and conditions. Escaid™ 110 has been the diluent of choice in the solvent extraction market for decades, and is well-suited for EV battery recycling. Contact your ExxonMobil sales representative for more information on our products.

| Key properties* | Escaid 110 fluid[1] | Escaid 120 fluid[2] |
|---|---|---|
| Distillation range (°C)[3] | 207 - 240 | 235 - 265 |
| Aromatics content (% wt)[4] | < 0.01 | < 0.1 |
| Viscosity at 25°C (cSt)[5] | 2.1 | 3.16 |
| Flash point (°C)[6] | 82 | 103 |
| Density at 15°C (kg/dm$^3$)[7] | 0.795 | 0.822 |
| Occupational exposure limit[3] (mg/m$^3$)[8] | 1200 | 1200 |

Source: Data from tests performed by or on behalf of ExxonMobil.
*All data provided are typicals from latest FAAG: (1) Singapore typicals; (2) Antwerp typicals. Test methods: (3) Distillation Range: Method "ASTM D86" for all grades; (4) Aromatics content: flash kerosene - Method "AMS 140.31" for Escaid 110 - Method "EM Test method UV1" for Escaid 120 and 120 ULA; (5) Viscosity at 25 C: Method "ASTM D445" for Escaid 110 - Method "ASTM D7042" for Escaid 120 and Escaid 120 ULA; (6) Flash Point: Methods "ASTM D93" for all grades; (7) Density at 15C: "ASTM D4052" for Escaid 110 and method "ISO 12185" for Escaid 120 ; (8) Source for Occupational Exposure Limits: RCP - TWA - ExxonMobil data.

# Performance comparison with a commercial product

**Kinematic viscosity and Aromatics content impact the phase separation time.**

| Property | Impact | Escaid™ 110 Diluent (typical values) | Comp. 1* |
|---|---|---|---|
| **Aromatics (wt%) UV/GC** | **Toxicity/ performance (odor, polarity, entrainment loss, phase separation, oxidation)** | **0.001** | **0.022** |
| **Kinematic viscosity 40°C, cSt, ASTM D445** | **Entrainment losses, fluidity, phase separation** | **1.60** | **2.26** |
| Bromine index mg/100g, ASTM D2710 | Inert/reactivity | <1 | 5 |
| Aniline point, °C, ASTM D611 | Solubility | 76 | 92 |

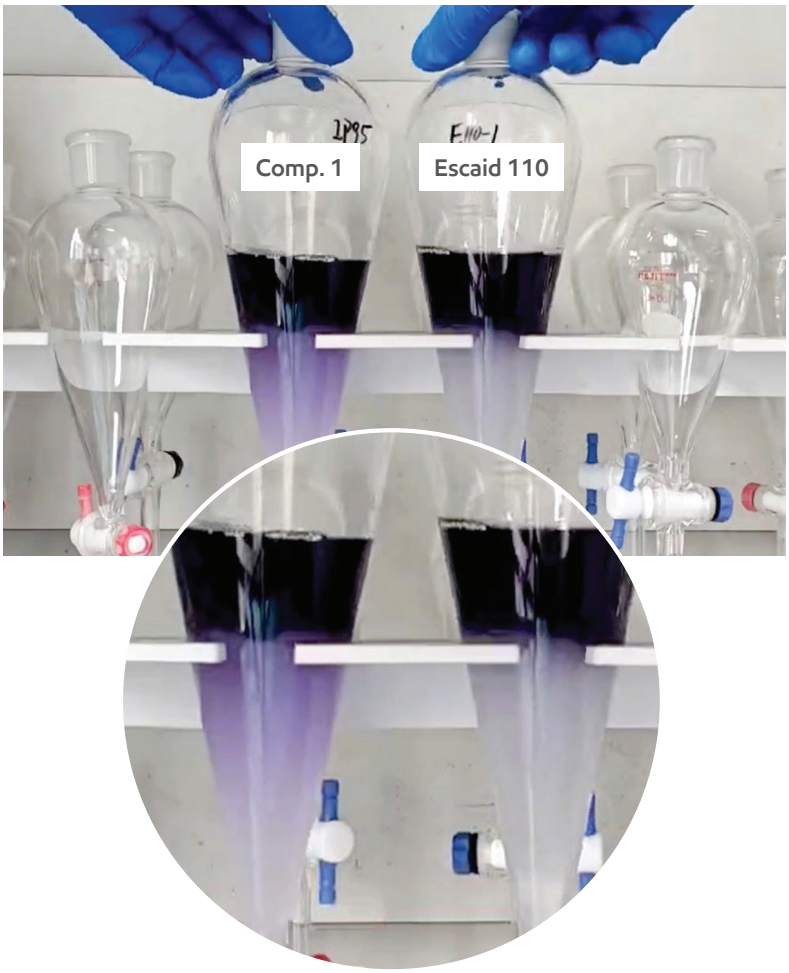
*Based on single sample test in a third party lab on comparative fluid provided by customer

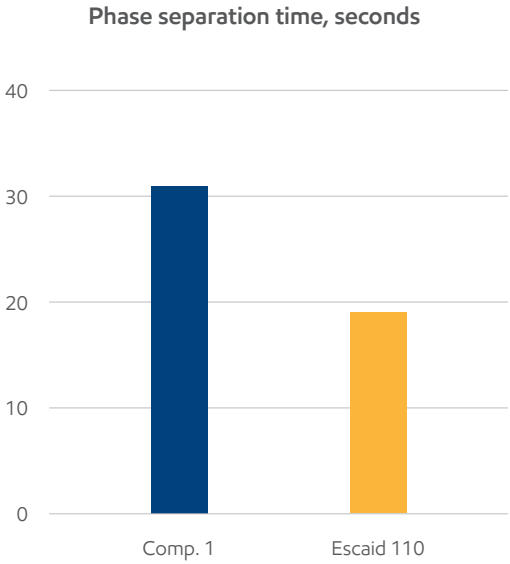
# Opportunity to increase production rate and manufacturing efficiency

Low viscosity, high density, and low aromatics content collectively contribute to a shorter phase separation time, which leads to improved overall efficiency. Faster phase separation time was observed in trials with Escaid™ 110 Diluent. Furthermore, global supply also ensure that the benefits of optimized phase separation are fully realized.

**Faster phase separation time was observed in trials with Escaid™ 110 Diluent (19s) [1] ,**

**40% faster** **than the result by using the Comp. 1 (31s).[2] [3]**




(1) Standard Deviation for 4 repeated tests: 8s
(2) Standard Deviation for 4 repeated tests: 13s.
(3) In scaled up production the performance may differ due to various factors

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