COUNTERCURRENT VS. CROSSCURRENT SOLVENT EXTRACTION

Rousselet-Robatel manufactures centrifugal extractors adapted to many solvent extraction processes in the chemical, metallurgical, and pharmaceutical industries. Rousselet-Robatel extractors operate based on countercurrent phase flow.

Prior to incorporating Rousselet-Robatel equipment into an extraction process, laboratory and developmental extraction work is commonly performed using crosscurrent phase flow. On an industrial scale, batch wise extractions are frequently performed in gravity decanters using crosscurrent phase flow.

An explanation demonstrating the principles of operation of both countercurrent and crosscurrent extraction has been included to identify the key benefits of countercurrent operation.

CROSSCURRENT EXTRACTION

In a crosscurrent extraction process, the feed containing the solutes is contacted with fresh solvent for each extraction stage. The extracts can be collected separately or combined for further processing. Please refer to Figure 1.

---

**CROSSCURRENT EXTRACTION SCHEMATIC**

**FRESH SOLVENT**

**FEED** (Containing Solutes(s))

Stage #1 → Stage #2 → Stage #3

**EXTRACTS** (Solvent Containing Desired Solute(s))

**RAFFINATE** (Depleted of Solute(s))

---

Figure 1: Crosscurrent Extraction
COUNTERCURRENT EXTRACTION

In a countercurrent extraction process, the feed to each stage is contacted with solvent from the preceding stage. For example, the feed to Stage #1 is contacted with the extract from Stage #2, and the feed to Stage #2 is contacted with the extract from Stage #3, and so forth. This countercurrent contact results in the gradual enrichment of the solute in the solvent phase across the extraction process. Due to the high efficiency of countercurrent flow, the quantity of solvent required for the process is reduced, resulting in a more concentrated extract. Please refer to Figure 2.

![Countercurrent Extraction Schematic](image)

Figure 2: Countercurrent Extraction

COMPARISON OF EFFICIENCY AND SOLVENT CONSUMPTION

To demonstrate the advantage of countercurrent extraction, we have a sample process in which acetic acid is to be extracted from water using n-butanol as the solvent.

- The initial concentration of acetic acid in the water phase is 15% by weight.
- The goal is to extract 96% of the acetic acid from the water into the n-butanol solvent at standard temperature and pressure.
- The solvent / feed flowrate ratio is 2:1 by weight.
- The desired concentration of acetic acid in the raffinate should be less than 0.56% wt.

Using equilibrium data, and constructing a McCabe-Thiel diagram, it is determined that three theoretical stages of extraction are required to achieve the desired solute recovery.
For a crosscurrent extraction, the McCabe-Thiel diagram is as follows:

Equilibrium Data for Acetic Acid in Water vs. n-Butanol at STP (Crosscurrent Operation)
For a countercurrent extraction, the McCabe-Thiel diagram is as follows:

**Equilibrium Data for Acetic Acid in Water vs. n-Butanol at STP**
(Countercurrent Operation)

**Graph Key**
- Equilibrium Line
- Operating Line (KG Feed / KG Solvent)
- Initial Solute Concentration in Feed
- Desired Solute Concentration in Raffinate
- Theoretical Stage(s)
CONCLUSIONS

As shown on the McCabe-Thiel diagrams, three theoretical stages are required for both extraction methods.

Crosscurrent system
- 6 kg of solvent is required to extract the solute from 1 kg of feed (3 stages with each stage using 2 kg of fresh solvent).

Countercurrent system
- 2 kg of solvent is required to extract the solute from 1 kg of feed.

Benefits of Countercurrent Extraction
- Approximately 67% less solvent is consumed in the countercurrent process. Please note that specific reductions in solvent consumption depend upon the distribution coefficient and the solvent to feed ratio selected.
- A significantly more concentrated extract obtained using the countercurrent method.
- Downstream processing costs are reduced.

ROUSSELET-ROBATEL PROCESS DEVELOPMENT

Rousselet-Robatel can evaluate your specific extraction process to identify the benefits of applying countercurrent extraction. In order for Rousselet-Robatel to perform an evaluation, we would require the following information:

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Solute concentration in raffinate from each extraction stage</td>
</tr>
<tr>
<td>2</td>
<td>Solute concentration in extract from each stage</td>
</tr>
<tr>
<td>3</td>
<td>Initial concentration of solute in the feed phase</td>
</tr>
<tr>
<td>4</td>
<td>Solvent / Feed ratio for each extraction stage (please specify if by volume or weight basis)</td>
</tr>
<tr>
<td>5</td>
<td>Desired % recovery of solute</td>
</tr>
<tr>
<td>6</td>
<td>If more than one solute is to be recovered, please specify items 1-5 for each solute. If there are multiple extraction processes (main extraction, scrubbing, back-extraction, etc.), please specify items 1-5 for each extraction process.</td>
</tr>
</tbody>
</table>

For more details including the principle of operation of the Rousselet-Robatel range of centrifugal extractors, application questionnaires, and equipment specifications, visit our home page on the web at [www.rousselet-robotel.com](http://www.rousselet-robotel.com).

Please note that all process information provided is treated confidentially.