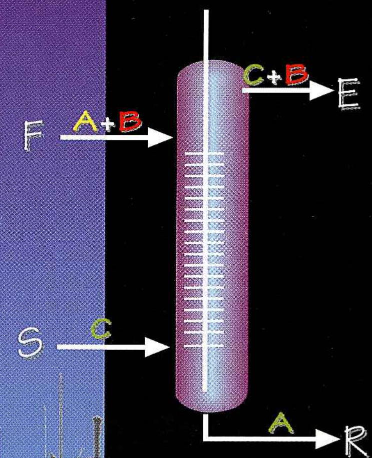
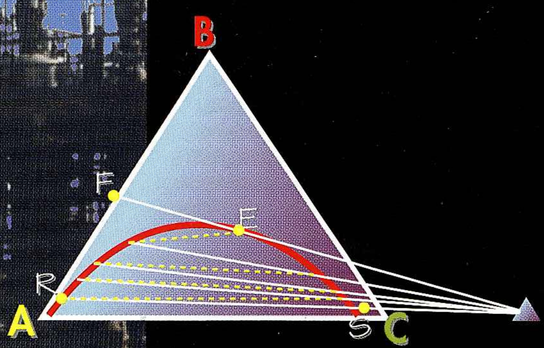
Liquid-Liquid Extraction





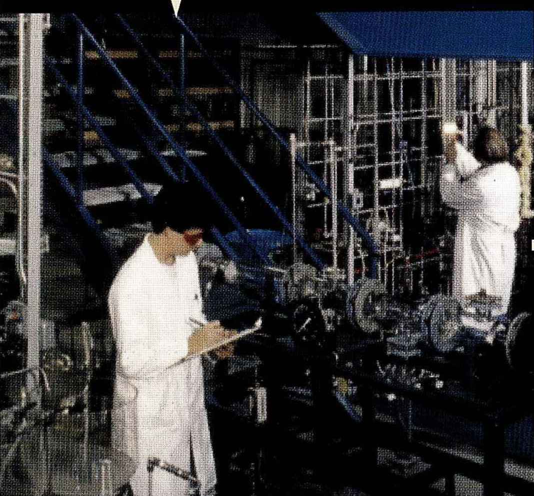
KOCH MODULAR PROCESS SYSTEMS, LLC

EXTRACTION TECHNOLOGY GROUP

Process Conceptualization

DESIGN STEPS

- **Process Conceptualization**
  -Determines overall process conditions
- **Process Development**
  -Provides pilot plant data for scaleup
- **Extractor Design**
  -Selects the proper extractor for the application
- **System Design**
  -Integrates the extractor with other process steps



Process Development

Extractor Design

System Design

Koch Process Technologies, Inc. (KPTI) has been involved in the development, design and supply of liquid-liquid extraction (LLE) technology and equipment for over forty years. At KPTI, we don't just sell extraction equipment, we supply solutions to your difficult separation applications.

This problem solving effort follows a logical sequence as presented below.

Drawing from our experience, KPTI first determines if LLE is the appropriate separation technology. If the answer is yes, initial studies are performed to identify possible solvents and operating conditions. This leads to the development of a conceptual process flow sheet.

KPTI next designs a laboratory and pilot plant program to fully evaluate the process and provide a sound basis for the scale-up to commercial size equipment. Tested are not only the extraction steps, but also the solvent recovery steps.

KPTI is a recognized world leader in the supply of LLE equipment. With a broad range of extractor designs ranging from static to agitated columns, we select the extractor best suited for the particular application.

KPTI then incorporates the extractor into an overall system which includes solvent recovery, and when appropriate, further product purification steps. These systems are delivered as modular units with a Process Performance Guarantee.

LLE is a powerful separation technique which falls right behind distillation in the hierarchy of separation methods (Figure 1).

The general rule: If a separation can be made economically by distillation, there is no reason to consider extraction. However, in situations where distillation is not feasible for reasons such as a complex process sequence, high investment or operating costs, heat sensitive materials, or low volatility, extraction is often the best technology to use.

Extraction frequently involves additional steps to recover and recycle the solvent. A typical extraction process is shown in Figure 2. Since most investment and operating costs are associated with the solvent recovery steps, it is very important to consider and study this aspect when designing the process.

In a typical extraction process, about 15% of the capital investment is in the extractor itself, with the remaining 85% in the solvent recovery steps. Likewise, about 3% of the operating cost is in the extractor, with the remaining 97% in solvent recovery. Therefore, it is extremely important to consider the solvent recovery aspects early in the project since they play such an important role in overall process economics.

REASONS TO USE EXTRACTION

- **Separation not feasible by distillation**
- **Energy requirements of distillation are prohibitive**
- **A complex distillation sequence is required**
- **The material is heat sensitive**
- **The material is non-volatile**

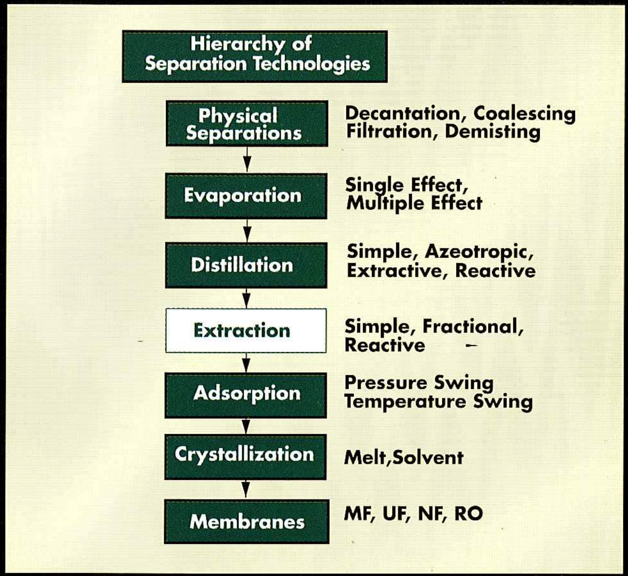


Figure 1: Hierarchy of Separation Technologies

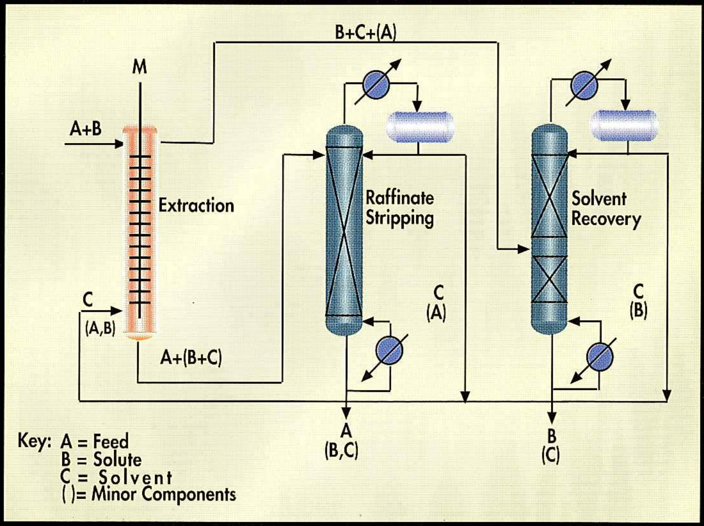


Figure 2: Typical Extraction Process Flowsheet

APPLICATIONS

While distillation works on the principal of boiling point difference, LLE works on the principle of chemical structure difference. This makes LLE ideally suited for separation problems such as:

Recovery of tightly hydrogen-bonded organics from water such as formaldehyde, formic acid, acetic acid.

Purification of heat sensitive materials such as pharmaceuticals, flavors, fragrances and food products.

Recovery of products from reactions such as caprolactam and adiponitrile (for nylon production), acrylic acids and agricultural chemicals.

Purification of non-volatile materials such as phosphoric acid, polymer solutions and metals.

Separation of petroleum fractions and isomers such as aromatics/aliphatics, butadiene/butene, and m/p-cresol.

Removal of high boiling organics from wastewater such as phenol, aniline, nitrated aromatics.

INDUSTRIAL APPLICATIONS

- **Refining**
  - -Lube Oils
  - -Aromatics
- **Pharmaceuticals**
  - -Antibiotics
  - -Vitamins
- **Foods**
  - -Lactic Acid
  - -Flavors/Fragrances
- **Metals**
  - -Copper
  - -Cobalt/Nickel
- **Polymers**
  - -Caprolactam
  - -Adiponitrile

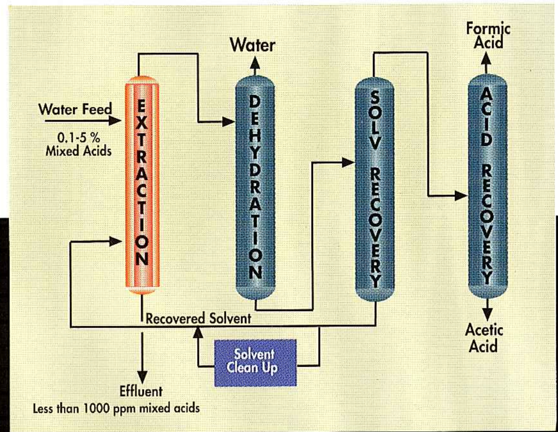


Figure 3: Recovery of Carboxylic Acids

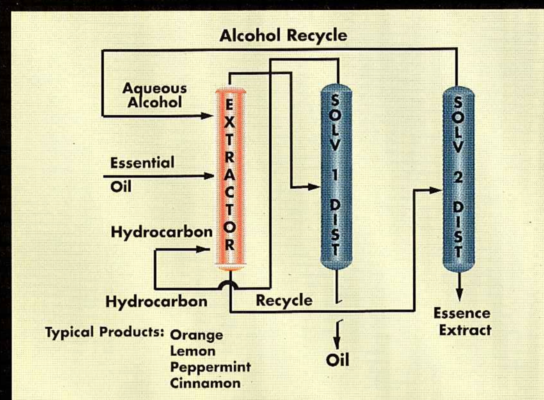


Figure 4: Extracton of Flavors and Aromas

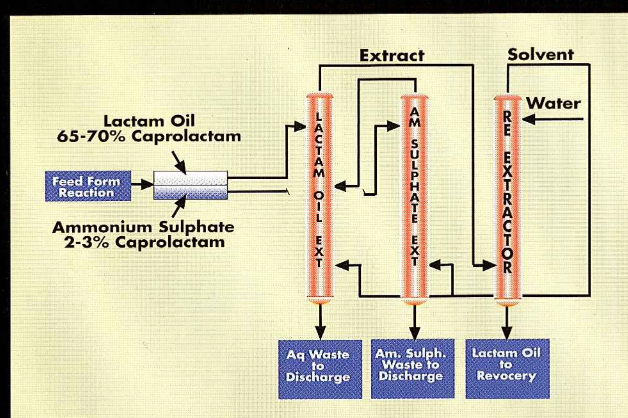


Figure 5: Recovery of Caprolactam

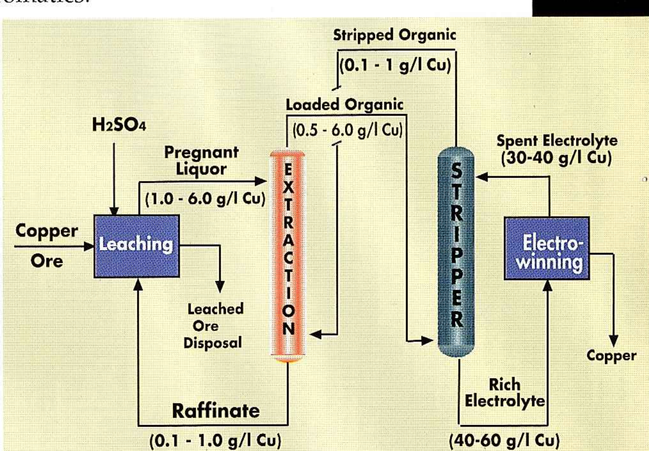


Figure 6: Production of Copper

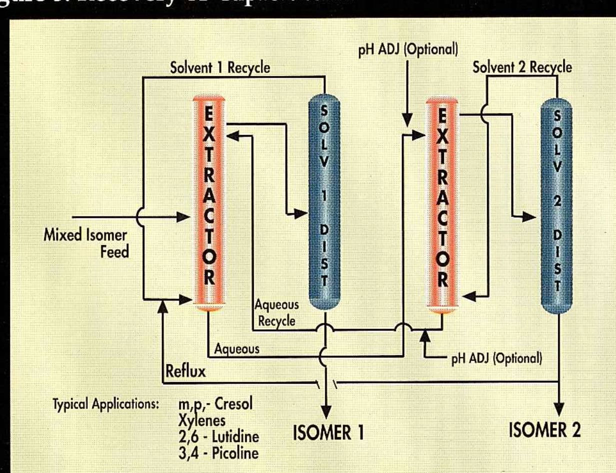


Figure 7: Separation of Structural Isomers

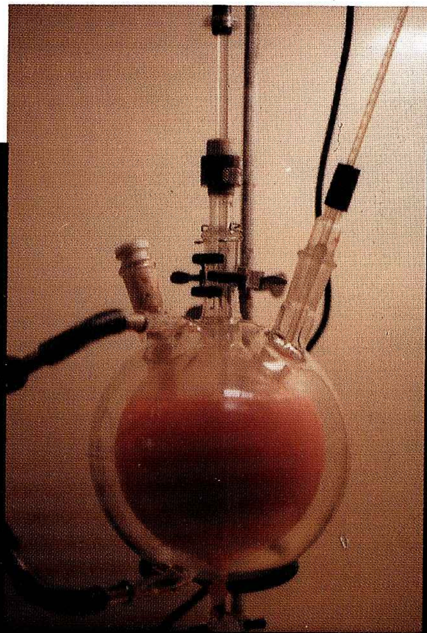


Figure 8: Bench Scale Apparatus

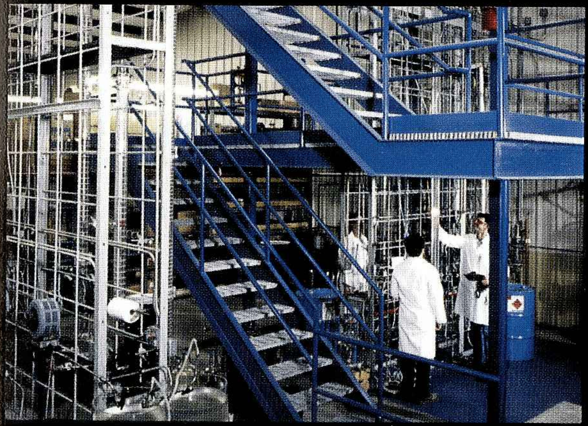


Figure 9: Pilot Plant

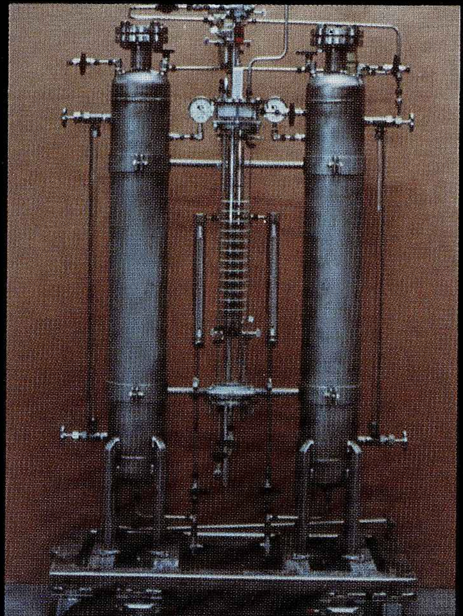


Figure 10: Extraction Screening Unit (ESU)

INFORMATION FROM TESTING

- **Bench Scale Tests Provide**
  - -Equilibrium data
  - -Mixing characteristics
  - -Settling times
- **Pilot Scale Tests Provide**
  - -Data for scaleup
  - -Demonstration of the entire process
  - -Process optimization
  - -Basis for performance guarantee

Almost every LLE project involves a pilot test to provide the basis for commercial plant design. Unlike distillation, which can often be designed by simulations alone, LLE usually has many unknown factors such as equilibrium, efficiency and capacity data. Small trace impurities can have a significant impact on all of the above. For this reason, only actual plant solutions are used for these tests.

The first step is usually bench scale tests to generate the liquid-liquid equilibrium data. The typical bench scale apparatus is shown in Figure 8. Besides supplying the equilibrium data, these tests can reveal information on emulsions or entrainment which help guide extractor selection.

We select the appropriate extractor based on our review of each application. Pilot tests are then run to demonstrate the process performance as well as provide data for scale-up (Figure 9). These pilot tests are performed in the same type of extractor planned for the commercial scale. Often, more than one type of extractor will be tested to compare performance.

Sometimes the nature of process materials being handled prohibits shipping to the pilot plant. In these cases, KPTI can deliver **portable units** and operating personnel to the plant for on-site testing. Figure 10 shows our portable Extraction Screening Unit (ESU) ideally suited for this purpose.

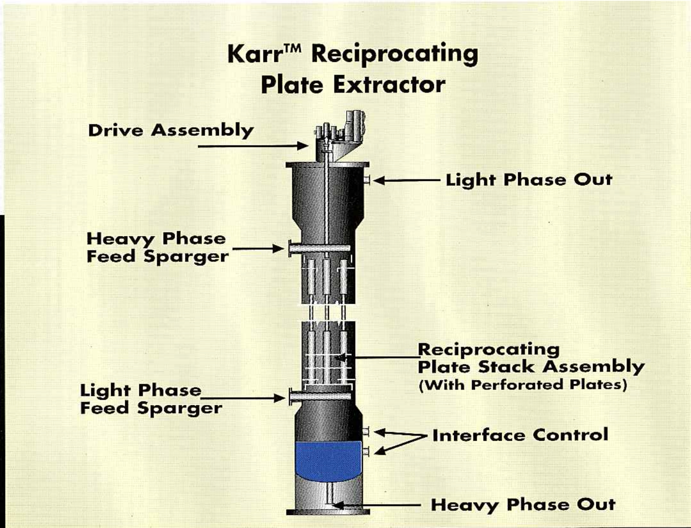


Figure 11: Karr™ Column

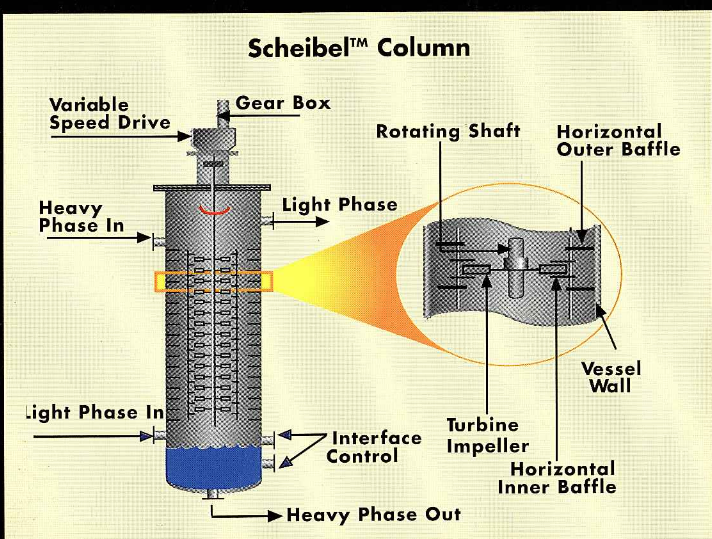


Figure 12: Scheibel™ Column

A RANGE OF EXTRACTORS

KPTI has a wide range of extractors to choose from, both static and agitated columns.

- **Static Columns**
  - Sieve trays
  - Random packing
  - SMVP™ packing
- **Agitated Columns**
  - Karr™ Column
  - Scheibel™ Column
  - RDC
  - Pulsed Column
  - AP™ Column
  - Special Designs

During the pilot plant tests, the extractor is run over a range of flow rates and agitation speeds, and the separation performance is measured. At each flow rate, the agitation is increased until the flood point is reached. From this data, the conditions which give the optimum volumetric efficiency are determined.

Next comes scale-up to commercial size. Any scale-up procedure must determine (1) how diameter varies with throughput and (2) how height varies with diameter. For the agitated columns, there is an additional parameter to be determined, namely, (3) how the power input varies with column size.

Finally, the extractor is sized with the active zone height, together with the top and bottom settler zones and instrumentation for control of the column interface.

Several features of the different agitated columns are shown in Figures 11-14. A typical column installed in an operating plant is shown in Figure 15.

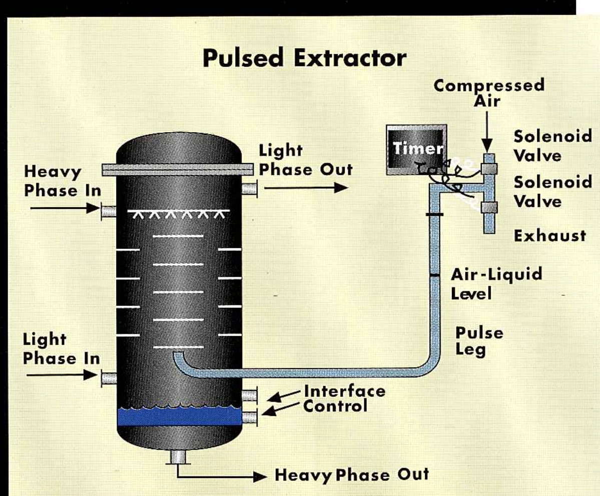


Figure 13: Pulsed Column

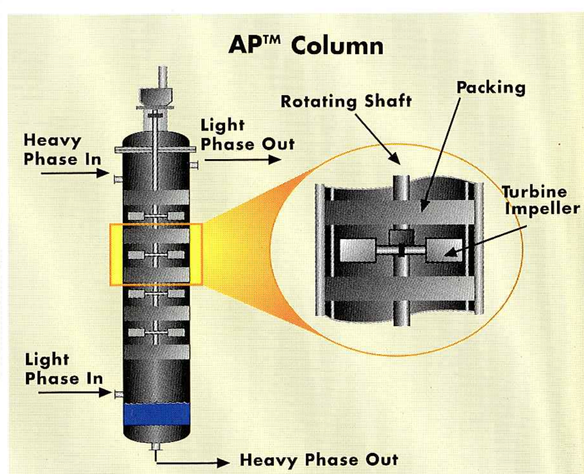


Figure 14: AP™ Column

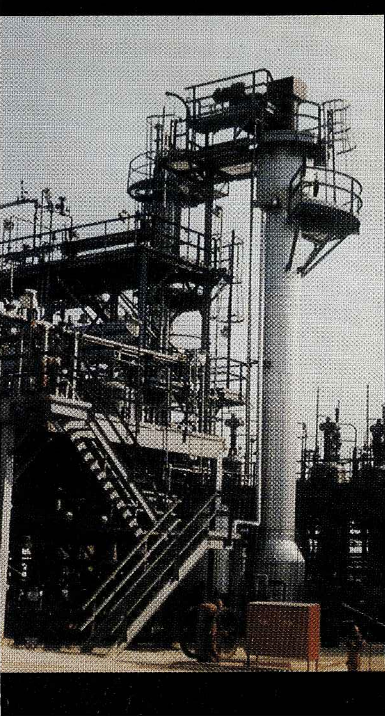


Figure 15: Column Installed in an Operating Plant

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