Introduction

Evaporators are used in the food and beverage sector primarily for the removal of water or solvent from liquid products. The purpose of evaporation is to reduce volume, enhance microbial stability or to decrease energy consumption in downstream processes particularly if the product is to be dried. Desirable characteristics of an evaporator include short product residence time, low evaporation temperature and high evaporation capacity.

Evaporators are also used for the distillation of non-aqueous materials. These devices are often quite specialized and typically operate at higher temperatures and higher vacuums than evaporators used for processing aqueous materials.

The newly developed RM series Centritherm® Short Path evaporator from FT Technologies was designed specifically for high vacuum, short path operation (molecular distillation) where vacuums of 0.5 to 0.001 mbar and temperatures in excess of 150°C are required.

The Centritherm® evaporator is a thin-film, spinning cone system with a very short residence time (approximately 1 second over the heating surface) and small hold-up volume.

Centritherm CTRM Design benefits

Key benefits of the centrifugal nature of the CTRM series is that they produce a thin, fast moving liquid film. Most other thin film evaporators use mechanical action in the form of
wiper blades ("wiped film") to control film thickness and distribution of the product. The centrifugally induced thin film provides the following benefits in improving product quality:

- **Short residence time:** around 1 second on the heat transfer surface
- **High heat transfer efficiency:** a thin fast-moving liquid film promotes efficient heat transfer and reduces fouling of the heated surface
- **Ability to handle viscous products:** up to 20,000 cP
- **Low hold up volume:** because the liquid film is thin the volume of product on the heat transfer surface is small so there is minimal loss of product during start up and shut down

The CTRM evaporator places no reliance on gravity flow so it is more compact than competing wiped film units. The film thickness is thin (generally <1mm) and the internal condenser is only millimeters away from the heating surface ensuring the distillate condenses as quickly as possible providing a higher quality product.

The clever design also allows easy validation of product heating surfaces in those cases in which frequent inspections are required. The modular system allows for multiple units to be placed on a common base, either enabling multi-stage operation or providing increased evaporation capacity whilst minimizing the amount of floor space required. The unit can also function as a highly efficient reboiler – to generate vapor feed to a distillation column.

The CTRM evaporator can be designed to operate with a variety of heating systems, including steam, thermal oil or direct infrared heating elements. Internal or external condensers or a combination of both provide maximum flexibility.

As the hold up volume is so small and the heat transfer so effective, the CTRM series evaporator rapidly reaches steady-state operating conditions on start-up and shut-down. This makes it particularly suitable for:

- Multiple products with rapid turnaround to change from one product to another.
- Small batches: Easy to process a series of small batches of product.
- High value products where it can process valuable product with minimal loss during the shut down and cleaning of the unit or if the operation is interrupted.

**Applications**

Some of the applications that the CTRM evaporator can be used for in the oils and fats industry include:

- Low temperature refining of edible oils to remove dissolved gas, moisture and other volatile compounds while also removing remaining free fatty acids and odor compounds
- Removal of pesticides from citrus and vegetable oils
- Removal of waxes such as lanolin
- Purification of essential oils i.e. removing residual solvents and separating a pure aromatic distillate from waxes, colors and other non-volatile impurities
- Squalene distillation to purity of above 99% from shark liver oil
- Refining and deodorization of fish oils
- Concentration of Omega-3 fatty acid esters
- Fractionation of Milk Fat
- Distillation of re-cycled lubricating oils

Two applications of particular interest at the moment are:

**Citrus Oils** – Commercial applications using CTRM evaporator technology for processing of citrus oils include:

1. **Oil Folding:** Oil folding is the separation of low boiling mono-

<table>
<thead>
<tr>
<th>Pass 1</th>
<th>Pass 2</th>
<th>Reconstituted</th>
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</thead>
<tbody>
<tr>
<td>Feed (kg)</td>
<td>1000</td>
<td>50</td>
</tr>
<tr>
<td>Distillate (kg)</td>
<td>950</td>
<td>33</td>
</tr>
<tr>
<td>Residue (kg)</td>
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<td>17</td>
</tr>
<tr>
<td>Distillation ratio (%)</td>
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<td>67</td>
</tr>
<tr>
<td>Reduction in Agricultural Residues (%)</td>
<td>&gt;95</td>
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Table 1: Short path distillation of single strength orange oil in two passes. Courtesy FT Technologies R&D.
terpenes, particularly d-limonene, to create concentrated oils containing a higher concentration of the compounds that contribute to typical citrus flavor. The process normally involves an evaporation unit (reboiler) coupled to a rectifying column in order to increase the recovery of the high boiling flavor compounds. The CTRM has the ability to evaporate approximately 95% of citrus peel oil in a single pass.

2. Separation of agricultural residues: Fungicides and parasiticides are used to control such problems as mould, blight and other fungal diseases. These compounds can be left as residues on the fruit and finally end up in the extracted peel oil. As many of these compounds are high molecular weight, high boiling compounds they are less volatile than most of the desired flavor compounds that companies wish to retain in their product.

Using the CTRM evaporator to treat citrus oil enables the isolation of these unwanted compounds in the final residue while the required flavor compounds are recovered in the distillate. Using short path distillation generally requires two to three passes where the residue from the first or second pass is redistilled and the subsequent distillates are recombined. The combined yields of some compounds are shown in figure 1 for orange oil. The final result is dependent on the volatility difference between the agricultural residues and the important flavor compounds in the particular variety of citrus. Actual results show that where the combined distillation ratio of multiple passes is >98% of the feed oil (single strength) it is possible to remove >95% of the contaminants in orange oil and >80% for lemon oil (Table 1). At the same time the bulk of the important flavor compounds are recovered in the distillate.

Fish Oils – Commercial applications using the Centritherm CTRM evaporator for processing of fish oils include:

1. Refining and deodorizing of fish oils. Fish oils are generally recovered by heating or cooking the milled fish and then separating the oil from the cooked flesh. The raw material is often the processed waste from fish that has been canned or frozen. Fish oil has a characteristic smell that must be removed if the final product is to have an acceptable aroma. Depending on the treatment of the raw material there can also be an objectionable smell or odor that will contaminate the final product whether it is the oil or derivatives of the oil such as omega-3 fatty acids.

Fish oils may also contain free fatty acids (FFA) which need to be removed if a refined oil is required. The CTRM evaporator is an ideal system to refine and deodorize fish oils. The system shown in figure 2 uses two stages. In the first stage the oil is processed at approximately 150°C and 1 mbar. Moisture, dissolved gasses and some short chain free fatty acids are removed, thereby allowing the second stage to operate at high vacuums.

The second stage is a short path unit that operates at around 200°C and 0.01 mbar. It evaporates the free fatty acids and other molecules that contribute to the odor of the oil producing a preferred bland refined oil.

2. Concentration of omega-3 fatty acid esters. Omega-3 fatty acids are unsaturated essential fatty acids that need to be included in the diet as they cannot be created in the human body from other fatty acids. Various fish oils contain high
levels of omega-3 fatty acids with the most common being eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA).

Fish oil can be processed to produce a concentrated distillate of omega-3 fatty acids using short path distillation. This is done by creating ethyl esters from the oil which enables separation of the omega-3 fractions by distillation. The process comprises the following steps:

1. Ethyl trans-esterification: The oil is reacted with an excess of ethanol and a catalyst at around 120°C for several hours. The omega-3 concentrations vary in the original oil depending on the source and species of fish. Generally the resultant esters will have in the region of 20% to 30% omega-3’s (12 to 20% DHA and 6 to 10% EPA).

2. Removal of Glycerol: The esterification reaction releases glycerol which is removed either by settling or by centrifugation.

3. Removal of excess ethanol: Excess ethanol is removed using a standard low-vacuum Centritherm evaporator operating at 50 to 60 mbar and approximately 40°C.

4. Distillation of omega-3 fatty acid esters: The esters are subjected to three processing stages. The first, commonly known as the degassing stage removes final traces of ethanol, moisture and dissolved gasses. This is followed by two further distillations, the first removing lower boiling short chain esters and other volatile compounds and the second recovering a concentrated distillate containing the omega-3 esters at a concentration generally in excess of 50%.

Our company can supply suitable omega-3 processing equipment to suit a range of production requirements from a simple batch operation to a fully integrated, continuous processing line.

Example 3: Squalene distillation from shark liver oil

Squalene is a unique substance high in Vitamins A, D and E. Squalene occurs naturally within the human body where it supports natural lubrication for the skin and supports oxygen delivery and toxin removal from all the body’s cells.

Squalene is extracted from a number of source materials with shark liver oil having the highest squalene concentration (ranges from 25% to 80%). Squalene is also present in some vegetable oils such as amaranth seed oil (6 to 8%), olive oil (0.3 to 1.2%) and rice bran oil (0.1 to 0.3%). It is used for its many medical benefits that include: support of the immune system, joint mobility, wound healing, respiratory health.

The Centritherm CTRM evaporator can be used to recover squalene from oils such as shark liver oil where the aim is to obtain a clear distillate that has a squalene content of >99%.

The system incorporates two CTRM Centritherm evaporators operating in series; one as a heater/degasser followed by a second operating as a short path distillation device. The set up is as shown in figure 2 above. Degassing/heating stage: operates at 140°C to 150°C and 1 to 2 mbar. This step preheats the oil, removes any traces of moisture, and non-condensable gases. This step can also remove short-chain low-boiling compounds that may contribute to an undesirable odor in the oil and prevent them from ending up in the final squalene distillate.

Short path distillation stage: operates at approximately 170°C to 180°C and at 0.01 mbar. In this step a clear distillate is recovered which is normally >99% pure squalene (figure 3).

With oils in their various forms being a stable part of our everyday life the challenge for manufacturers is to be able to improve the quality of their product and to meet their client’s demands. At the same time they need to achieve, if possible, higher yields, cleaner product (i.e. removal of pesticides), lower energy costs and more flexibility from their equipment. The Centritherm CTRM evaporator can assist them in achieving their goals.

Key No. 75171

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Figure 3: Squalene distillation: feed shark oil (left), residue (middle), squalene distillate (right). Courtesy FT Technologies R&D

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