PASS-THROUGH DISTILLATION, A NEW PLAYER IN SEPARATION TECHNOLOGY

EFFICIENT COMBINATION OF DISTILLATION AND ABSORPTION

Distillation remains the most used separation technology in the chemical industry, in spite of its large energy demands caused by low thermodynamic efficiency. Pass-through distillation (PTD) is an emerging hybrid separation technology that efficiently combines distillation with absorption. The basic idea of PTD involves the decoupling of the evaporation and condensation steps of a distillation process, by means of an absorption-desorption loop that passes through the component to be separated and thus allows the use of different pressures and types of heating/cooling utilities. Its main applications are in areas where conventional distillation does not work, and other methods are either too costly or prone to fouling.

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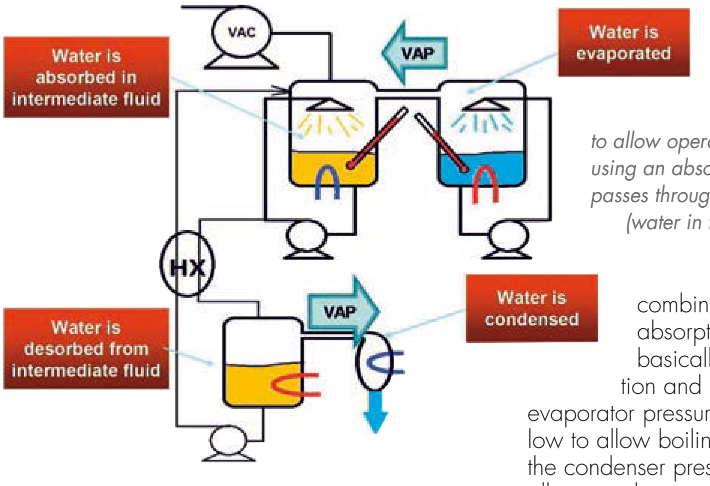

Fig 1: *Working principle of pass-through distillation (PTD): the evaporation and condensation steps are decoupled to allow operation at different pressures, by using an absorption/desorption loop that passes through the component to be removed (water in this case)*

PROBLEM STATEMENT

In conventional distillation, evaporation and condensation are carried out at the same operating pressure. Clearly, the selection of pressure in distillation is a fundamental step in the design, as the pressure will set both the boiling and condensation temperatures, and thereby the type of heating and cooling utilities required. Preferably, the evaporation temperature should be lower than that of high-pressure steam, and the condensation temperature should be higher than that of cooling water. However, setting one pressure to satisfy two temperature-constraints is not always possible, for instance in vacuum distillation, which is often used to separate heat-sensitive materials. Here the problem is that lowering the pressure also results in low condensation temperatures, requiring expensive refrigeration utilities instead of cheap cooling water. This issue can be solved conveniently by pass-through distillation which combines distillation with an absorption-desorption loop that basically decouples the evaporation and condensation steps. The evaporator pressure can now be sufficiently low to allow boiling at below 30 °C, while the condenser pressure is high enough to allow condensation at above 50 °C using conventional utilities.

PASS-THROUGH DISTILLATION

The working principle of pass-through distillation (PTD) is illustrated in **Fig 1**. Evaporation and condensation can take place at different pressures by using an absorption-desorption loop.
When water must be removed, a concentrated LiBr solution is used as hygroscopic working fluid. This brine absorbs the water vapor coming from the evaporator where the saturated feed is evaporated at low pressure. The diluted working fluid is pumped to the desorber, where the passed-through component (water) is evaporated at a higher pressure (using external heat) and then condensed using regular cooling water. Energy savings are also possible since the heat of absorption can be re-used for the evaporation step and the desorber can be replaced by multi-effect distillation (MED).

Remarkably, the evaporation and absorption operations can be fully integrated into a single unit, known as stripping-absorption module (SAM), shown schematically in **Fig 2** – which uses heat-pipes to transfer the heat released by absorption in-situ to the evaporation section of the unit. **Fig 3** renders the SAM equipment and the heat-pipe internals. Note that a similar setup can also be used for hybrid pervaporation-absorption systems suitable for dehydration of organic compounds.

The main advantages of pass-through distillation are applicability to heat-sensitive materials, low operating costs by avoiding expensive refrigeration utilities, similar or lower energy requirements compared to distillation, and low capital costs due to smaller equipment size compared to vacuum distillation technologies. A potential limitation,

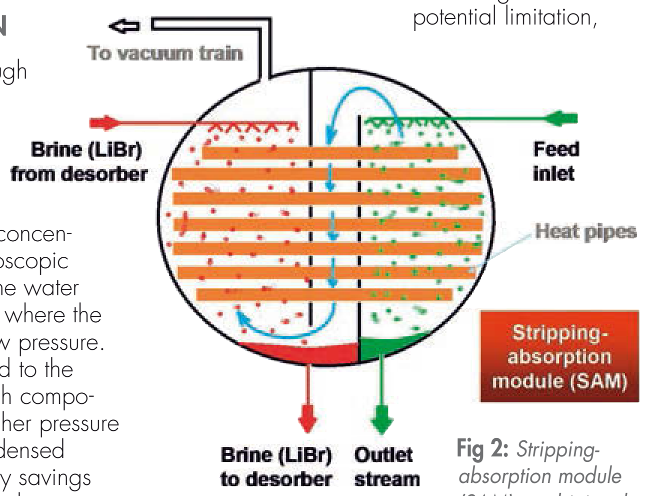

Fig 2: *Stripping-absorption module (SAM) combining the evaporation and absorption steps into a single efficient unit (see www.passthroughdistillation.com for detailed explanations)*

Fig 3: *Stripping-absorption module, rendering of equipment and internals designed by Drystill*

however, might be in finding a suitable working fluid for systems in which the component to be removed is not water, but another compound with different properties.

INDUSTRIAL APPLICATIONS

Distillation must have a heat sink in order to operate. At industrial scale most processing plants use evaporative cooling towers. Cooling water is typically used in condensers, at a temperature of about 30 °C, which means that the boiling point of the distillate is normally around 50 °C or higher. Still, there are applications that demand lower temperatures, and here refrigerated condensers are used to reduce the condensing temperature and thus allow lower boil-up temperatures in the top. Moreover, as refrigeration is too costly to be applied to large scale production, MED is used instead to reduce the energy cost. However, as more stages are added, the temperature in the first distillation stage increases, and therefore many MED installations suffer from thermally induced fouling, managed through redundant equipment and/or chemical cleaning. Although MED can reduce the energy requirements (at the expense of higher temperatures), while refrigerated condensation can reduce boil-up temperatures (while incurring a substantial energy penalty), these methods are mutually exclusive as their combined benefits and costs would cancel each other in the same process.

Pass-through distillation is a new method that should be added to the separation technologies toolbox, being useful in applications where classic distillation is not suitable and other methods are either too costly or too prone to fouling. PTD can be applied to the processing of complex aqueous waste streams, which are too contaminated to be treated and are presently incinerated at great cost. By using PTD most of the water can be removed, leaving a residue that can become auxiliary fuel for cement kilns for example. Other applications include: organic solvents recovery, water removal for drying of chemicals, aroma recovery in the food industry, concentrating orange-juice, separation of heat-sensitive materials, purification of pharmaceutical products, etc. Pass-through distillation can also be coupled with MED to offer reduced energy requirements and low boil-up temperature simultaneously, thus being useful for several classes of applications:

- It makes MED possible for distillations where refrigerated condensers are now used.
- It can improve consistency in product quality for single effect distillations that do not use refrigeration, but are periodically affected by thermal degradation of chemicals.
- It can eliminate fouling of the heating surface in distillations presently using MED.
- It can enable new commercial processes, e.g. ethanol recovery from live fermentation broth.

PTD may not be applicable everywhere, but it has been proven to work with water vapour and lithium bromide solution as the absorbent fluid. Further research is needed to determine other combinations of volatile components and absorbent fluids.

Fig 4 illustrates the first pass-through distillation pilot unit, in operation at Fielding Chemical Technologies (www.fieldchem.com), which was built together with the Canadian technology provider and inventor Drystill (www.drystill.ca) and with funding assistance from the Industrial Research Assistance Program (IRAP). ❑

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Fig 4: *Pass-through distillation pilot-scale unit (left) in operation at Fielding Chemical Technologies, where the stripping-absorption module built by Drystill (right) plays a central role*

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