gPROMS
Application areas

Heat-Integrated Distillation (HIDiC)

Modelling minimises risks and accelerates implementation

Heat integration brings a step-change in energy efficiency to distillation operations.

PSE's gPROMS can be used to investigate novel column design in order to:

- Minimise risk
- Verify designs and establish viability
- Accelerate implementation
- Optimise safe and effective start-up procedures
- Define operating envelopes
- Perform control design
- Maximise operational flexibility
- Troubleshoot poor operation.

Distillation operations are responsible for 40% of the energy used in the Chemical Process Industries. The technology that can reduce this energy requirement significantly will represent a major breakthrough in energy efficiency, and give significant competitive edge to the companies that adopt it.

Heat-Integrated Distillation Columns (HIDiCs) are such a technology. By combining rectifying and stripping columns in an annular (or similar suitable) arrangement so that they exchange heat along their lengths, and elevating pressure in the rectifying section, energy savings of nearly 50% can be achieved.

However, despite the obvious potential, this very promising concept has not yet developed into successful industrial-scale applications. This is partly because it is difficult to test its applicability to specific mixtures to be separated, leading to a high perceived risk in deploying such innovative technology.

In particular, the practical deployment of HiDiC technology is hampered by the difficulty of proving that it is possible to start up and operate the unit as intended. There is a relatively narrow window of feasible operation, outside which the HiDiC system is either not fully efficient or suffers from liquid drying in certain regions.

A model-based solution

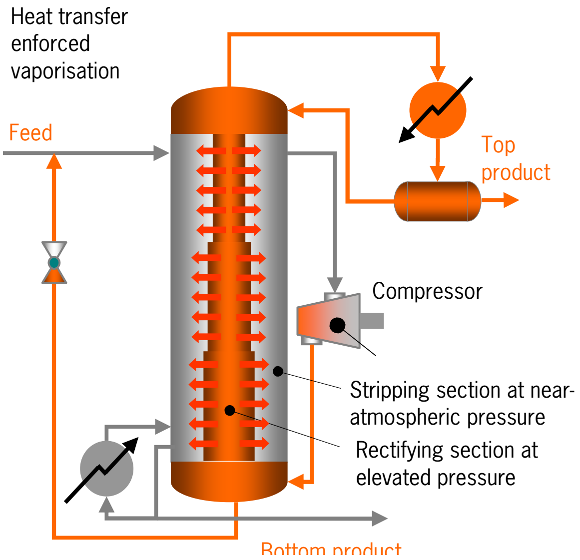


Fig. 1 HIDIC concentric tube column

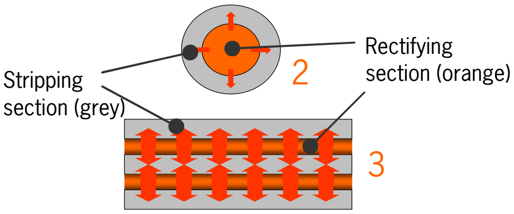


Fig. 2 Different HIDiC configurations

The resolution to these challenges is quite simple. Unlike complex reactors, HIDiC systems can be accurately modelled using only information available in the literature. No specific laboratory or pilot data is required. However, there are two complicating factors:

- The vaporisation in the stripping section and condensation in the rectifying section depart significantly from equilibrium. This calls for a rigorous rate-based approach.
- The heat transferred across the partition separating the low and high pressure sections must be modelled in a spatially distributed manner to correctly co-ordinate with the distributed energy balances of phases on either side.

PSE's Advanced Model Library for Gas Liquid Contactors (AML:GLC) addresses both of these aspects.

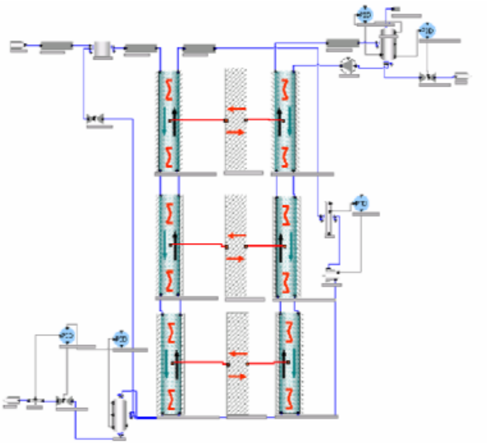
The library contains component models that can be assembled to cover a wide variety of configurations (including both conventional ones and a variety of HiDIC systems) with minimal effort. At its heart is a solution of the differential formulation of the Maxwell-Stefan equations for multicomponent mass and energy transfer over 2-dimensional distributed domains.

Example: separation of benzene and toluene

The separation of a mixture of benzene, toluene and a small amount of ethylbenzene was modelled for three separation processes: **[1]** A conventional distillation column **[2]** a HIDIC concentric tube column (see Fig. 2) and **[3]** a HiDiC compact heat/mass exchanger, in which the rectifying section comprises the tubes within a shell-and-tube heat exchanger configuration.

The gPROMS flowsheets for all the processes were constructed from AML:GLC and standard Process Model Library (PML) components. The flowsheet for the concentric tube HIDiC process [2] is shown on the right.

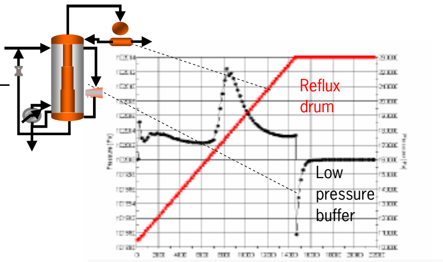
The resulting models were used to study the performance of the system during start-up and at steady-state operation.



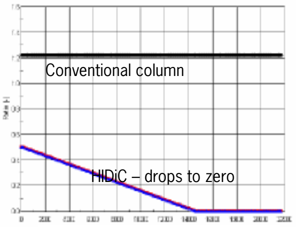
Results

Excellent agreement was achieved with experimental data obtained from the Tsukuba National Laboratory (AIST), Japan by using purely predictive models, without any parameter fitting.

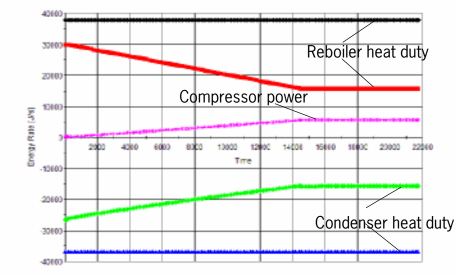
The start-up dynamic simulation quantified the pressure and heat exchange during the transition from cold and empty to full operation, as shown in the plots on the right. This verified that the equipment could be started up as planned. Further runs could then be performed to minimise the start-up time to full production.



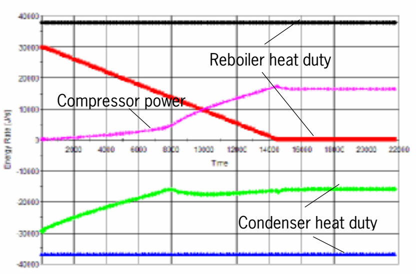
Pressure variation during start-up



Reflux ratio variation

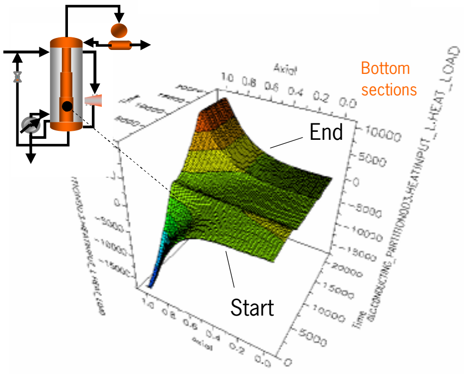


Energy input – conventional column vs. HIDiC concentric columns



Energy input – conventional column vs. HIDiC compact exchanger

The plots above show the energy input into the system through start-up to steady-state operation. It can be clearly seen that the reboiler and condenser duties for both HIDiC configurations are substantially less than for the conventional column, while the additional compression energy requirement is relatively small.



Distribution of heat exchanged between stripping and rectifying sections

Conclusions

Performance comparisons between the different configurations are shown in the table on the right.

These indicate that the HIDiC system, if properly designed, can save *up to 60%* of the energy required for separation. In addition, the condenser duty, and consequently the condenser size, can be reduced by up to 60 %.

Separation equipment	**Total energy input (MJ/h)**	**Condenser duty (MJ/h)**
[1] Conventional column	136.8	132.7
[2] HIDiC – concentric columns	76.6	56.8
[3] HIDiC – compact exchanger	59.7	57.5