

The CONTACTOR™

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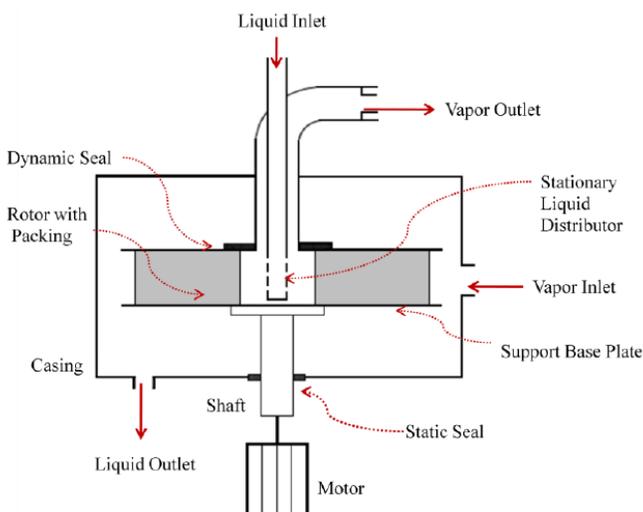
Centrifugal Processing: So Just What is HIGEE?

This issue of The Contactor is a departure from our usual case study with cold, hard data. It's a speculative piece about HIGEE processing which proposes uses a Rotating Packed Bed (RPB) in

- Floating ship and barge offshore applications where rocking motion induced by wave and swell action can have a highly detrimental effect on the performance of conventional packed (and especially trayed) columns, and in
- CO₂ capture applications where non-reactive but cheaply-regenerable solvents like MDEA cannot be used very effectively in conventional columns and towers because the packed beds must be made too deep.

What is HIGEE?

References to rotational equipment used for (centrifugal) separation of fluids, evaporation, and use of membranes go back several decades before the 1983 patents issued to Wem (US 4,382,045), and Ramshaw and Mallinson (US 4,400,275), both assigned to Imperial Chemical Industries. Although neither patent uses the term HIGEE (High Gravitational field) the device soon became known by that term as part of commercialization attempts.



A simple form of Hige device is shown in the preceding figure (from Y. Tamhankar, MS Thesis, Oklahoma State University, Dec., 2010). Liquid is fed to the “eye” of the rotor and flows radially outward as a film driven by the centrifugal force generated by rotation. Gas enters between the outer casing and the outer edge of the rotor and is forced by pressure to flow radially inwards counter-current to the solvent flow.

A semi-commercial scale demonstration unit was developed through a joint project between the Gas Research Institute (GRI) and what was then Fluor Daniel in the early 1990s. The rotor was packed with an open-structure, cellular, metal foam having a pore size of roughly one millimeter. (Incidentally, this was the same material used for crushable padding in automobile dashboards to prevent passenger injury in a crash.) The study was concerned with using HIGEE as a way to increase selectivity for H₂S in absorption using MDEA. As part of the study, mass transfer rate based simulation software was developed to try to understand the effect of the important parameters on H₂S and CO₂ absorption rates, and selectivity.

The computer model was concerned with acid gas absorption (and stripping) into the liquid film flowing on the surface of the packing pores as well as into the liquid droplets that were spun from the rotor and went flying across the space onto the wall of the casing. Typical rotor speeds were 1,000–2,000 rpm and the rotor itself was 3–4 feet diameter. At these rates of rotation, a centrifugal force near the periphery of the rotor of 1,500 g's was not unusual.

Selectivity is affected by chemical reaction kinetics (on entering the aqueous amine phase, H₂S reacts or dissociates infinitely fast; CO₂ doesn't react with a tertiary amine such as MDEA at all. This fact makes MDEA highly selective for H₂S). Liquid flowing at low velocity as a film over packing

has a fairly high resistance in the liquid phase to being absorbed or stripped, improving selectivity even further. But when the liquid is centrifugally driven to flow at high speed over a packing surface such as the walls of a small cavity in an open foam, it mixes at the very frequent junctions between cells, becoming so frequently mixed it's essentially turbulent. Its resistance to CO₂ absorption becomes lower, and selectivity is for the most part lost. The mass transfer rate based modelling study suggested that HIGEE would not be an effective way to improve selectivity—in fact selectivity would be reduced, if not destroyed altogether.

This conclusion runs completely counter to the expectation one might have from residence time thinking. The residence-time approach holds that the CO₂ reaction with MDEA is the rate limiting step in absorption, so greatly lowering residence time should force less absorption to occur. This mantra has been debunked in an earlier Contactor (http://www.protreat.com/files/contactors/Contactor_Vol_4_No_3.pdf). In fact, CO₂ really doesn't react with MDEA because MDEA lacks a mobile hydrogen atom on the amino group to enable reaction with CO₂. Instead, MDEA's role is to act as a sink for the hydrogen ions released by CO₂ hydrolysis. The rate limiting step is the resistance to mass transfer in the liquid phase. The industry's continued fixation with residence time is an example of the tyranny of precedent.

Replacing Gravity

Rocking motion causes towers to go through periodic tilt of up to 10° or more, resulting in liquid flowing down one side of the tower, then the other, with vapor flowing up the opposite side, in other words, periodic bypassing. The problem is that the liquid flow is gravity driven so the resistance of the bed to liquid flow has to be kept relatively low. However, this means the resistance of the packed bed to lateral flow is also weak, too weak to prevent significant cross-column flow should any flow unevenness arise. In fact, once gas has found an easier route through a packed bed (a rat hole), it will grow the width of the rat hole by pushing liquid aside to minimize flow resistance. With fine cellular foam, flow resistance for both phases is too high to allow rat holes to form very easily.

In a centrifugal force field of many hundreds of g's the bed resistance to flow can be made so high that tilt of the rotating bed is immaterial. The gravitational acceleration is a very small fraction of one percent of the centrifugal acceleration. The

centrifugal effect completely dominates so the device operates well in any orientation at all, overcoming the effect of rocking motion of an FLNG barge, for example.

In many respects, fine, open-celled, metal foam is an excellent material for the packing. It has extremely high surface area which means the gas-liquid interfacial area per unit volume of bed is enormous. The high centrifugal force drives liquid at relatively high velocity through the bed (holdup times of roughly one second) in thin films with greatly reduced mass transfer resistance. An enormous amount of absorption can be achieved in a very small device. And mechanically, this particular configuration of high area packing is very crush resistant, important in a centrifugal field of 100s of times normal gravity.

One inherent disadvantage of a HIGEE device is its restriction to clean service—small pores clog easily. Others include, high gas-phase pressure drop (there are ways divulged in the patent literature to mitigate this), the seals and leaks that plague rotating equipment, the need for careful balancing (an issue that seems to have been overcome by centrifuge manufacturers), and the power required to rotate the device and spin up both gas and liquid to high tangential velocities, to mention a few. However, the device is extraordinarily light and compact compared to conventional towers and is completely resistant to platform motion.

First patented by Ramshaw and Mallinson 33 years ago as a device specifically for mass transfer separations (e.g., distillation and absorption), the basic patent has long since expired and apart from one or two small installations, HIGEE has yet to be truly commercialized (a not uncommon state of affairs in the patenting of technology). Because of new economic drivers, however, the next few years may bring a change.

To learn more about this and other aspects of gas treating, plan to attend one of our training seminars. Visit www.protreat.com/seminars for details.

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