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High performance gas/liquid ejector Technology for safe oxidation processes written by Dr. J.E. Juvet

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Conventionally, air is the source of oxygen gas for a number of liquid-phase oxidation reactions. The air is usually delivered into the reactors via axial flow impellers, gas spargers, or, better, ejectors which break up the gas into tiny bubbles providing a high interfacial area for mass transfer between the gas (oxygen) and the liquid reactants in the reaction vessel.
However, since air also contains the inert nitrogen gas, the reactor vent gas contains significant amounts of solvent and reactants entrained in the gas as vapours. The recovery of such organic chemicals from the gas requires an extensive chemical treatment. In general, solvent loss is higher than it would be when using an oxygen-enriched gas. Additionally, the lower concentration of oxygen in air depresses the oxidation rate necessitating higher reaction times and larger reactors. As most of the liquid-phase oxidation reactions are mass transfer limited, increased dispersion of oxygen also results in an enhanced absorption rate of the gas in the liquid phase, which in turn accelerates the rate of reaction.
Nevertheless, the use of oxygen in the liquid-phase oxidation of organic chemicals has not enjoyed widespread commercial use to date because of the safety and flammability concerns associated with the use of pure oxygen particularly with hydrocarbons.

Gas-Liquid ejectors have been used successfully in combination with Loop Reactors, in most cases for hydrogenation. The most versatile design of such a commercial Loop Reactor is claimed to that developed by the former Buss AG (now Davy Process Technology) in Switzerland.
In this type of reactor, the ejector is mounted on the top of the reaction autoclave and the batch volume is circulated by a circulation pump over a heat exchanger through the ejector.
Recent research work has now resulted to the use of the gas-liquid ejector "mixer" for oxidation reactions with pure oxygen. The operating principle of the gas-liquid ejector is shown in Fig.1. The high velocity jet, discharging from the nozzle, creates a slight under pressure in the gas suction chamber and entrains considerable amounts of gas. At the moment when the high velocity jet discharges in the two-phase mixture, there is a sudden increase in pressure (mixing shock). After this mixing shock area, the dispersion is created with very small bubbles with sizes in the range between 20-40 µm. Dependent on the ejector configuration and operating conditions, the gas-liquid flow ratios can be varied between 0.5 and 3.

Recent research work has shown that very local high energy dissipation rates are obtained within the mixing shock area and the ejector section: Typical ranges are (500 - 5000 W/kg). The gas-liquid mass transfer coefficient, interfacial area and the liquid-solid mass transfer coefficient are influenced by the local energy dissipation rate and are thus improved compared to the traditional reactors used. In general it can be said that the local mass transfer rates, both gas-liquid and liquid-solid within ejectors are at least an order of magnitude higher in comparison to the conventionally gas-liquid-solid reactors used and can be especially utilised for fast chemical reactions. When using a fast reaction, the selectivity can also depend on the mixing time of the liquid feed stream. When micro-mixing plays an important role, the feed stream injection should be in the mixing zone of the ejector. The micro mixing time is approximately 10^{-4} s. This shows that the mixing zone within the ejector mixes the injected liquid very fast and hence all the required reaction species, intensively and homogeneously.

Thus the reaction rate can be sufficiently boosted that the unreacted oxygen emerging at the headspace of reactor is reduced below the explosive limits.

Extensive safety analyses have performed for laboratory-, pilot-, and commercial-scale systems. There are essentially three areas of concern from the point of view of potential development of flammable oxygen-hydrocarbon mixtures: the gas suction chamber, the bubbly gas-expanded liquid volume, and the headspace of the reactor. Engineered systems have been developed and tested to prevent backflow of the organic into gas suction chamber and to mitigate flammable mixtures by nitrogen-inserting in order to minimize the possibility of fires. It has been experimentally investigated and tested the possibilities of detonation in bubbled fluids and determined that "chain" detonation of bubbles is not a practical issue. From the perspective of the headspace, the absence of moving parts like agitators or mechanical seals is contributing to the safety of the reactor. Nevertheless the oxygen concentration in the head space is monitored and the rate of injection of the pure oxygen is limited in order to avoid any problematic situations.

All the above-mentioned factors are influenced by the Reactor Technology chosen and hence will affect initial investment cost and operational cost of the process as a whole. Davy's newly developed Advanced Loop Reactor Technology is made up of a reaction vessel with a high performance gas/liquid ejector to achieve high mass transfer rates and has been around for a number of years. It provides a significant improvement of intensification for heat- and mass transfer. This gives a net saving in terms of capital expenditure and operating costs.