PERP Program – New Report Alert

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Nexant's *ChemSystems* Process Evaluation/Research Planning program has published a new report, ***Vinyl Chloride/Ethylene Dichloride (VCM/EDC) (03/04-6)***.

Background

Ethylene dichloride (EDC), produced from ethylene or acetylene and a chlorine source, is used primarily as a feedstock for vinyl chloride monomer (VCM), which, in turn, is the monomer for the widely-used plastic polyvinyl chloride (PVC). Lesser EDC uses are as feedstock for certain chlorinated solvents and the plastic polyvinylidene chloride.

Polyvinyl chloride has numerous uses in the building and construction, transportation, electrical/electronic, medical, packaging, and home and leisure arenas. The most important PVC markets worldwide are for building and construction applications, such as pipe/conduit/fittings, siding, gutters/downspouts, window profiles, etc. Construction applications accounted for about 67 percent of U.S. demand for PVC in 2003, with West European construction applications accounting for about 59 percent of its PVC demand.

The rigid pipe market represents almost one half of global PVC demand, so PVC has vigorously defended its competitive position against traditional construction materials such as cast iron, clay, and asbestos cement on the one hand, and against other plastics such as high density polyethylene (HDPE), polypropylene, and acrylonitrile/butadiene/styrene (ABS) on the other.

PVC has proved successful as a siding (i.e., cladding) material in preference to wood because of PVC's low maintenance requirement. PVC is less energy intense and quieter in use (no noise from expansion and contraction) than aluminum. Vinyl siding will not dent, warp, crack, or support rot or mildew. Resistance to termites, salt water, and air pollutants provides durability.

Rigid profiles such as window frames are not subject to much interpolymer competition since PVC possesses a favorable price/performance balance. PVC offers maintenance advantages over soft woods and purchase cost advantages over hard woods and aluminum.

In flooring, PVC competes with linoleum (fragile and antiquated); carpeting made from synthetic fibers such as nylon, polyester, and polypropylene and natural fibers such as wool (all vulnerable to staining); and costly wood and ceramics. PVC has a good market share compared to these materials in the home kitchen/bathroom sector and in institutions where low cost and wearability are of paramount importance.

Technology

Acetylene-Based

Vinyl chloride monomer (VCM) was first produced by reacting acetylene with hydrogen chloride. Until the early 1950s, acetylene-based technology predominated. Due to the energy input necessary to produce acetylene and the hazards of handling it thereafter, ethylene-based routes have since become predominant.

Nonetheless, there are specific circumstances where the acetylene route has advantages. In China for example, almost 60 percent of the VCM capacity is based on acetylene. This is because many of the gas reserves in China are methane rich, rather than ethane rich, and at the same time China has large reserves of easily accessible coal.

Ethylene-Based

The majority of commercial VCM technology utilizes direct chlorination of ethylene to produce ethylene dichloride, followed by pyrolysis to VCM and HCl. In the oxychlorination step, the hydrogen chloride released by the subsequent pyrolysis of EDC is reacted with ethylene and oxygen to yield ethylene dichloride and water. The commercialization of oxychlorination technology paved the way for the "balanced process", combining direct chlorination, oxychlorination, and EDC pyrolysis reactions to produce only vinyl chloride and water.

A high proportion of VCM production capacity is based on the balanced process. However, a number of producers operate unbalanced schemes drawing HCl from other chlorination operations in an adjacent plant. A further variation runs in part on EDC brought in from other sources. Nevertheless, the balanced process is representative of the majority of the industry.

The principal features of the balanced process are:

- A direct chlorination section where ethylene dichloride (EDC) is produced from ethylene and chlorine.

- An oxychlorination section in which EDC is produced from ethylene, hydrogen chloride and oxygen.

- A purification section in which the crude EDC from both the direct and oxychlorination sections is purified to a pyrolysis grade specification.

- A pyrolysis section in which the purified EDC is thermally cracked to yield VCM, HCl, and unreacted EDC.

- A fractionation section in which pure VCM is separated from the other pyrolysis products, which are recycled.

The technology may be described as mature, but some differences do exist between the various designs for balanced processes. The main processing blocks are similar for the dominant processes.

Direct chlorination can be operated either at low temperatures or at high temperatures. The low temperature (or subcooled) chlorination process has the advantage of substantially lower by-product formation. The high temperature process requires alloy materials for all equipment in contact with the liquid, especially the reactor vessel where vigorous agitation causes erosion and corrosion. Iron is usually added to such reactors as anhydrous ferric chloride powder dissolved in EDC acts as a catalyst.

However, the high temperature process has an advantage over the low temperature process in that the EDC product does not usually have to be washed to remove iron and subsequently dried azeotropically. Furthermore, because EDC's formation heat is six times its vaporization heat, the boiling reactor lends itself to a process whereby the vapor generated from the reaction exotherm may be used together with a fractionating column to purify the direct chlorination product itself, the dried oxychlorination EDC, and possibly the unconverted EDC stream recycled from the pyrolysis section.

The EDC must be at least 99.5 percent pure to ensure trouble-free operation of the EDC pyrolysis unit. The purified EDC is cracked in the pyrolysis reactor to produce vinyl chloride and hydrogen chloride. By-products include acetylene, benzene, methyl chloride, and tars.

The pyrolysis reactor product is quenched with cold EDC to minimize heavy ends formation and sent to a fractionation system for the separation and recovery of hydrogen chloride, unconverted EDC, vinyl chloride product, and light and heavy byproducts such as 1,1,1-trichloroethane, chloroform, and carbon tetrachloride. The EDC is recycled to the EDC treating system for ultimate conversion to VCM, and the hydrogen chloride is sent to the oxychlorination reactor.

Oxychlorination of ethylene to balance the HCl flows in the plant is achieved by reacting ethylene with dry HCl and either air or pure oxygen to produce EDC and water. In general, the reaction is carried out in the vapor phase in either a fixed or fluidized bed reactor containing a catalyst.

Extensive facilities for the treatment of plant offgas (e.g. incineration), handling of lights and heavies, and wastewater treatment are also required to satisfy environmental regulations.

Both ethylene dichloride and vinyl chloride are hazardous chemicals, with flammable vapors that can explode when mixed with air, and both are potentially damaging to health. EDC can cause pulmonary edema on inhalation, and is carcinogenic, mutagenic and teratogenic. VCM is carcinogenic and has been linked to angiosarcoma.

OSHA (Occupational Safety and Health Administration) workplace standards are 1 and 5 ppm time weighted exposure for VCM and ethylene dichloride (EDC), respectively. The U.S. EPA has declared VCM to be a hazardous air pollutant. Water discharges are regulated, and solid waste containing 200 ppb or more of VCM is considered hazardous waste.

Additional discussion on environmental aspects of the production of VCM, its polymerization to PVC, use of PVC in various applications, and disposal of PVC is included in the body of the report.

Ethane-Based

The development of ethane-based technology for the production of vinyl chloride has been a long identified, albeit difficult to realize, target of VCM process research. A number of companies have been involved in the attempted development of an ethane-based process, several processes have been patented, but as yet none have been commercialized. However, EVC has operated a 1,000 ton per year pilot plant at Wilhelmshaven, Germany for several years and initially planned to build a commercial scale plant by 2003 on the U.S. Gulf Coast with Bechtel Engineering as the nominated contractor. The advantage of the EVC process over previous reaction schemes was the catalyst's ability to promote the reaction at a temperature below 400^{o}C. This reduced the reliance upon special materials of construction that had characterized other patented processes. The incentives for an ethane-based process are lower cost feedstock and a simpler process scheme, but high capital cost could be a significant disadvantage.

Economics

The commercial balanced oxychlorination process is compared with alternative/developing processes in the report.

EVC's ethane oxychlorination process looks quite competitive, based on low raw materials cost outweighing somewhat higher investment – though further definition of process requirements may lead to increased investment. In price sensitivity studies, the upper range of anticipated ethane prices gives VCM costs similar to the lower range of anticipated ethylene prices.

The acetylene-based process suffers from a capacity limited by feedstock availability and the high cost of that feedstock. Significant commercial use of this process - as in China - relies on special situations where the feedstock for ethylene is not abundant and there are specific factors that provide abundant low cost energy (coal in this case) for this energy intensive process route.

Supply/Demand

Supply and demand data and discussion are provided in the report for the United States, Western Europe, and Asia Pacific, covering history from 1995 and projections to 2015.

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