

CHEMSYSTEMS PERP PROGRAM

Polyvinyl Chloride (PVC)

Process Technology (Chisso, Ineos Vinyls, Vinnolit), Production Costs (COP) (for PVC via Suspension, Emulsion, Mass, and Microsuspension Processes), Regional Supply/Demand Forecasts.

PERP07/08-7

Report Abstract

November 2008

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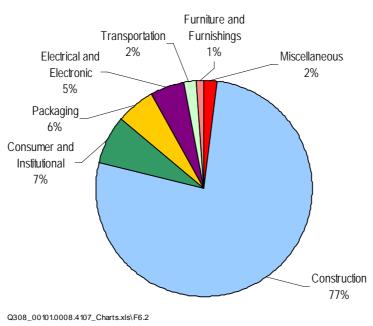
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INTRODUCTION

Polyvinyl chloride (PVC) has proven to be one of the most versatile commercial thermoplastics with a broad range of applications from rigid pipe for construction to thin crystal clear film for consumer packaging depending on formulation. The first preparation of PVC was made in 1872 by Baumann. Difficulties in processing rigid PVC resulted in a delay in commercial development until the early 1930s, when Semon and Goodrich developed a method to produce PVC with a rubber like functionality by heating PVC with plasticizers.

The product of the polymerization process is unmodified PVC. Before PVC can be made into finished products, it almost always requires conversion into a compound by the incorporation of additives such as heat stabilizers, UV stabilizers, lubricants, plasticizers, processing aids, impact modifiers, thermal modifiers, fillers, flame retardants, biocides, blowing agents and smoke suppressors, and, optionally pigments. Compounding of PVC, along with other aspects involved in preparing PVC resins for commercial use are discussed in detail in this ChemSystems PERP report.

Most of the market products are durable goods with long life spans. Its use in short-term, onetime-use products is limited. PVC consumption is mostly influenced by the construction industry. PVC has been increasingly used as a replacement for traditional construction materials such as wood and metals owing mainly to the inherent flame retardant property. The PVC applications in each market segment are shown in the figure below.



PVC Demand by Market Sector



Essentially all major PVC end-uses can be considered as mature, though some, such as rigid PVC applications in the construction market, are still exhibiting good growth particularly in the developing world. The decline in the North American housing market is causing a slowdown in demand for PVC in the housing and construction sector. Major markets for PVC and areas/applications gaining market share or where there may be potential are discussed in the report.

CHEMISTRY & TECHNOLOGY

There are four principal steps in PVC process chemistry:

- Initiation
- Reactive monomer radical propagation
- Chain transfer
- Chain termination

The polymerization reaction begins when the initiator thermally decomposes to form two free radicals for each molecule of initiator. An initiator fragment then reacts with the olefin double bond of the vinyl chloride monomer (VCM). The electrovalent imbalance results in the formation of a reactive monomer radical.

The reactive monomer radicals are then free to combine with other vinyl chloride monomers resulting in a series of sequential additions of monomer units in the following manner:

$$RCH_{2}\dot{C}HCI + CH_{2} = CHCI \longrightarrow RCH_{2}CHCICH_{2}\dot{C}HCI$$

$$R(CH_{2}CHCI)_{x}CH_{2}\dot{C}HCI + CH_{2} = CHCI \longrightarrow R(CH_{2}CHCI)_{y}CH_{2}\dot{C}HCI$$
where y=x+1

These and subsequent process steps are explained and expanded upon in the report.

The raw material used in the PVC polymerization process is VCM which is produced industrially by two main reactions:

- hydrochlorination of acetylene
- thermal cracking of ethylene dichloride (EDC) produced by direct chlorination or oxychlorination of ethylene or both paths.

The following PVC resin manufacturing processes – suspension, emulsion, bulk/mass, solution, microsuspension, and gas phase polymerization are each discussed in the report, along with process descriptions of the commercially licensed technologies by Chisso, INEOS and Vinnolit.

Ever since PVC was first synthesized over 100 years ago, there have been many technological advancements on PVC production. Today, PVC production technology is considered quite mature, but with the highly competitive market, and tightening consumer and industrial restrictions, licensors and leading PVC producers have been constantly developing and

improving the process to increase production yield, lower cost, reduce VCM emission as well as improve quality and properties of PVC resin. Developments in PVC production including new process technology, improvements in process design and new performance additives are detailed in the report.

SAFETY & ENVIRONMENTAL ASPECTS OF PVC PRODUCTION

PVC resin is manufactured primarily by batch polymerization of VCM in water suspension. The process uses various highly efficient control measures to assure that process emissions of VCM are extremely small. Exposure to VCM has been shown to lead to two distinct problems.

Both direct and oxychlorination routes to EDC production have chlorinated by-products that must be destroyed. It is feasible that a certain amount of dioxins could be produced in the process. Dioxins are believed by some to be among the most genetically disruptive compounds known.

The report expands upon these matters, along with a discussion on environmental aspects, including issues raised by the European Commission's Green Paper and REACH, and other matters pertinent to the rest of the world.

ECONOMIC & MARKET ANALYSIS

Cost of production estimates for Suspension, Emulsion, Mass and Microsuspension polymerization processes are analyzed and compared in this report. Production costs based on a range of inputs, including raw materials priced at Nexant's estimated market prices and capital cost estimates for complete turnkey systems (not including compounding facilities) have been developed.

In the chemical industry, feedstock integration is typically an important consideration in assessing the competitive position of participants in a given value chain. This is true in the case of PVC, where most participants are integrated into VCM. To test the effect of alternative VCM prices on PVC production costs, the VCM price was varied. This analysis was performed for suspension and emulsion PVC, the two most common PVC production processes.

The production cost estimates calculated are based on PVC plants having world scale facilities. However, in the PVC industry, smaller plants are presently in existence. To test the impact of varying suspension and emulsion PVC plant sizes on the economics, a plant scale sensitivity analysis was performed.

Extensive supply, demand and trade data for the USA, Western Europe and Asia Pacific are tabulated and discussed in the report.





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