PVC VCM Manufacture

Introduction
Polyvinyl chloride (PVC) is a major worldwide commodity used for the manufacture of a vast array of commercial and consumer goods including pipe, siding, wire, cable, film and sheet stock. PVC plants typically produce from 100 to 2,000 million pounds per year of polymer with most producing in the 300-600 million pounds per year range. Vinyl chloride monomer (VCM), the base component for production of PVC polymers, is the foundation on which final product quality is built. VCM plants typically have the capacity to produce 800 to 1,400 million pounds per year.

Achieving premium grade PVC production, consistent with its quality standard, requires an an effective filtration system to reduce contaminants that compromise the final product. This Customer Application Brief presents the benefits of using a 3M Purification filtration system to enable the manufacture of premium PVC grades.

The Process
Figure 1 shows a typical PVC process flow chart. VCM from storage is filtered and delivered to the PVC reactor along with a recycled VCM stream. Vinyl acetate (VAc) is sometimes added as a co-monomer to reduce crystallinity and to allow a lower processing temperature of the final PVC product. When used in a formulation, VAc typically comprises 9 to 15 weight percent of monomers. Downstream of the reactor, further treatment of the PVC polymer (incorporation of plasticiser, etc.) is determined by its end-use. Un-reacted VCM from the reactor is filtered, condensed and stored as recycle VCM. Filtration takes place on the VCM feed stream, the un-reacted VCM prior to the condenser and on the recycle VCM stream ahead of the reactor.
PVC producing facilities do not always manufacture VCM on site. VCM, manufactured at other plants, is transported and stored under pressure as a liquid. As shown in Figure 2, VCM is made by thermal cracking of ethylene dichloride. The ethylene dichloride feed is cracked and then condensed prior to flowing to the distillation column which will increase its purity. Following distillation, the purified VCM is filtered and then either stored or transported to the PVC production plant.

Figure 2. - Catalyst Bed Fouling

The Problem
The quality of PVC and therefore its price, is determined by its end use. High quality PVC polymers that are used in films, in the topmost layer of vinyl floor tiles, and in electrical wire coating command greater than ten percent price premium over PVC used for drain pipe, toys and garden furniture. When producing VCM for high quality PVC polymer production, critical issues include:

- **Contaminant reduction** – VCM contamination including visible gels from un-reacted monomer, and particles from tanks, piping or other environmental sources cause surface defects called “fish-eyes” in PVC film and other PVC products where appearance is critical. They can also cause failure sites in electrical wire insulation. Off-specification PVC polymer is used in applications where the higher quality is not required, resulting in the loss of premium pricing.

- **Recovery condenser fouling** – un-reacted monomers from foam generated in the reactor head space, principally VCM, are recovered by means of a condenser. The foam carries PVC product beads that foul the condenser and result in a process shutdown.

- **Poor Recycle VC Quality** – the quality of the recycle stream must equal to that of the virgin VCM to ensure process control. Solids from the condenser, from storage, or from the recycle VCM piping system must be recovered prior to the PVC reactor to ensure PVC product quality.

- **Contaminated VAc co-monomer streams** – Co-monomers must not introduce contaminants, from un-reacted monomer and particles from tanks and other sources, into the process that will compromise the quality of the PVC polymer.

The Solution
3M Purification absolute-rated Betapure™ BK series depth filter cartridges are very effective in the reduction of contaminant and protection of the recovery condenser. The combination of high efficiency and rigid media construction ensures effective particle reduction and high dirt holding capacity without the danger of particle unloading during operation. Betapure BK series filter cartridges are manufactured using a proprietary process that achieves a true graded pore structure with a clean and smooth inside diameter eliminating the need for a center core. The openings between the fibers become progressively smaller as the fluid flows from the outer surface to the inner core of the graded porosity structure. Each fiber is locked in this arrangement by a thermosetting binder resin to create a rigid structure. The overall effect is to sort, classify and stop particles by size as they progress through the cartridge. Larger particles are trapped in the upstream region of the filter and finer particles are trapped towards the inner core of the filter. Contaminants at or near the filter’s absolute rating are reduced in the inner section of the filter cartridge. Betapure BK series cartridges also feature an optimized groove pattern that increases the surface area by over 65% when compared to smooth cylindrical cartridges. The grooved surface prevents premature blinding of the outer surface by large particles and allows full utilization of the depth structure. Maximum surface area combined with a true graded pore structure means that Betapure™ BK series filters provide more reliable filtration and
greater service life (up to three times more than competitive filter cartridges of comparable efficiency). For more information see product brochure LITCBK001. Use of Betapure BK series filters in the VCM/PVC manufacturing process include:

- **After thermal cracking, condensing, and distillation, filtration of the VCM monomer to reduce visible gels or other particles before storage and prior to introduction into the PVC reactor (see Location “A”, Figures 1 and 2)** Betapure BK series 5-micron absolute filters provide the quality necessary to minimize or eliminate PVC quality problems, particularly when it is being produced for film.

- **Monomer recovery condenser protection downstream of the PVC reactor, at Location “B” in Figure 2, reduction of PVC polymer beads carried over by foam generated within the reactor when the reactor is depressurized at the end of a batch.** A typical filter housing used for degassing a large 18,000 gallon reactor would contain the equivalent of about 18 cartridges of 30” length. Betapure BK series 70 micron filters in this location provide the required separation and high flow rates needed at this stage.

- **On the recycle VCM stream must equal that of the virgin VCM fed to the reactor. Solids from the condenser, from storage, or from the recycle VCM piping system must not be introduced into the PVC reactor in order to maintain product quality (see filter location “C” in figure 2).** An absolute-rated Betapure BK series 5 micron filter is ideal for this application. Betapure BK series filter cartridges ensure that particles in the VCM stream are reduced and do not contaminate the produced PVC polymer.

- **Vinyl acetate (VAc) co-monomer that is sometimes used in making PVC to reduce crystallinity and allow a lower processing temperature of the end product (other co-monomers can be used to improve film barrier properties, to raise heat deflection temperature, or to improve thermal stability and melt flow).** While pumping VAc into the reactor, a 5-micron absolute Betapure BK series filter is recommended to ensure uniform quality of all monomers fed into the reaction. Betapure BK series filters will ensure that quality compromising particles are not introduced with the co-monomers entering the process.

**Case Study**

A large mid-western manufacturer of PVC resins needed to up-grade the quality of its filtration, because it planned to manufacture a higher quality PVC product. The filtration system upgrade consisted of new filter housings to replace defective old housings and high performance cartridge filters to replace the string-wound cartridges previously used. The manufacturer installed 3M Purification housings and changed from string-wound elements to 5 micron absolute 3M Purification Betapure BK series filter cartridges to process the VCM monomer as it is pumped into the PVC reactor. The resulting improved quality PVC resin enabled the manufacturer to upgrade its products and command a higher price for higher quality PVC resins.

**Betapure™ BK Series Advantages:**

- Absolute rated, minimum Beta 1000 (99.9% removal efficiency), for consistent particle retention performance throughout the filter’s life
- Betapure BK series rigid resin bonded structure, for no by-pass or unloading at high differential pressure
- Grooved surface with true graded porosity structure helps significantly extend service life compared to un-grooved, uniform porosity filters.

**Benefits**

The benefits of using a high quality 3M Purification filtration system are twofold:

- First, the cost of ruined batches is reduced. Failure to meet PVC quality specifications can ruin PVC batches. The ruined product must be sold as off-grade material and the process must be shut down to clean the system. For example, a typical PVC manufacturer produces 125,000 pounds per day. If the PVC does not meet higher quality specifications and requires that the PVC be sold at a price reduced by five cents a pound, the daily revenue loss amounts to $6250.00. Annual cost of quality failures in PVC production can be considerable, because of the high volumes of polymer produced at PVC plants.

- Second, the commitment to upgrading a PVC process to making higher quality PVC grades represents investments in more costly, more effective filters, together with more frequent cleaning of the reaction system. These investments can be profitably recovered, because of the higher price commanded by the improved quality PVC product made at the plant.

**Conclusion**

Use of a high quality 3M Purification filtration system, including 5-micron absolute Betapure BK series filter cartridges will assure uninterrupted manufacture of high quality PVC products providing increased revenues, maximized yields and minimization of downtime.
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