# Baseline document for Suspension PVC powder manufacturing

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# Summary:

This proposal documents the baseline of a PVC[1] powders manufacturing process and its recommendations on how to improve process cycle time and the quality of the products produced. Baselining the PVC manufacturing process requires the monitoring of key process parameters measured (ex. purity of raw materials, heat exchanger efficiency, VCM recovery rate etc.) over time in developing a understanding on how to improve manufacturing process and final PVC product quality. The process baseline can be established by defining 1) the process and its needed measurements 2) the process inputs of raw materials and outputs of final PVC products 3) the process flow of manufacturing PVC powders. With these necessary sequences defined, data can be gathered and analyzed based on process control metrics. The Cause-and-Effect (fishbone) diagram will be used to identify the defects and help reduce cycle time. The plan for quality improvement, cycle time reduction as well as budgeting will also be established in this proposal.

# Introduction:

There are three main processes can be used for the commercial production of PVC powders 1) Suspension 2) Emulsion 3) Bulk methods. The PVC produced by suspension process provides 80% of worldwide support. So, the process of PVC polymerization will be focused on the suspension method. In this proposal , the Chisso Process (reference) is used to produce PVC from vinyl chloride monomer (VCM) using suspension polymerization. The Chisso[2] process sequences are illustrated in Figure 1.

PVC Suspension Process:

This process can be divided into 6 different steps from input of raw materials to the end products:

a) Input Fresh VCM, additives and water into a stirring reactor (1), and maintaining temperature during the polymerization to control the grade of the PVC

b) Discharge PVC powder after 85-90% VCM/PVC conversion to a blowdown tank (2) to flush off VCM gas and recover VCM gas to VCM gas holder (6)

c) PCV slurry containing VCM is fed into the stripping column (3) continuously, most of the residual VCM will be recovered from this column

d) The slurry will be de-watered with a centrifuge device (4)

e) The slurry will be dried by the proprietary dryer (5). It is then passed to storage silos.

PVC Process Inputs and Outputs:

Block diagram and process sequences can be seen from figure 1. This figure also identifies several needed raw materials and equipment for PVC polymerization. Many more inputs are needed to produce PVC powders.

Inputs:

Capacity of the Reactor: 130 m3

Mixing speed with rotator : 120 r/s

Water Temperature in Jacket : 60 $^{o}C$

Reaction time (with 85% conversion) : 6 hours

Raw Materials:
- 1) VCM
- 2) Purified Water
- 3) Additives
  - a) PVC additives
  - b) Initiators
  - c) Inhibitors

Centrifuge Time: 10 minutes

Drying Time: 2 Hours

Outputs:

PVC powders with different grading.

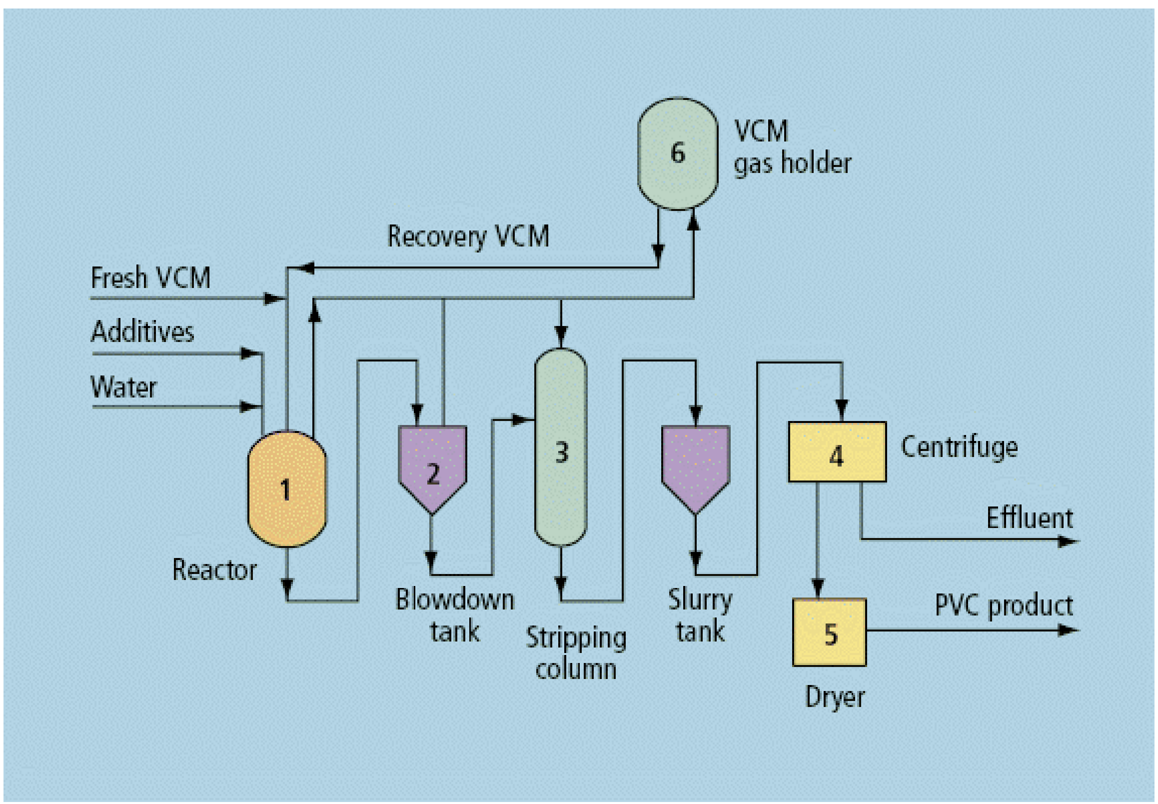


Figure 1 The Chisso Process for PVC suspension polymerization.

Process quality[3]/defect metrics:

For each grade of PVC resin, the plant applies a defined control plan which checks all necessary properties of the PVC resin in order to be able to guarantee the quality of the delivered resin.

The main properties which are regularly controlled for all types of resins are:
• The molecular weight of the polymer (Kvalue)
• The absence of foreign particles
• The bulk density
• The particle size distribution of the powder
• The moisture content of PVC powders
• the porosity of the PVC resin.

## Process cycle time metrics:

For each batch of PVC polymerization, the reaction time of the VCM/PVC[4] conversion is almost the total time of the process cycle time. To be more efficient for the batch processing, the VCM/PVC conversion rate is set at 85-90%. The optimized conversion rate is shown in figure 2.

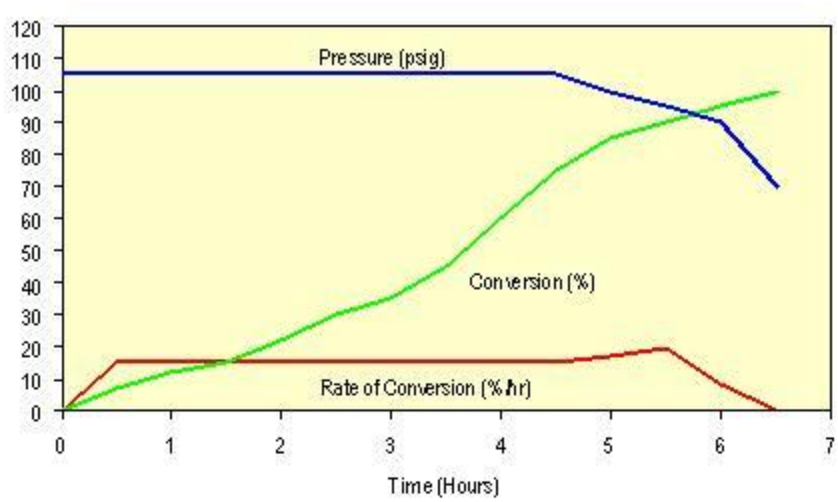

Figure 2 Relevant information on conversion rate of VCM/PVC versus VCM pressure

The main factors that impact the PVC batch process time are:
• The VCM pressure measured
• The water temperature in the reactor's jacket.
• The RPM of stirrer
• The amount/type of initiators and inhibitors used

With the metrics defined for both PVC quality and its cycle time, the fishbone diagram can be used to identify the cause of defects and effect of the potential solutions to this problem in quality and cycle time.

## PVC powder quality control:

Root Cause analysis of potential defects as shown in figure 3 is the fishbone diagram that provides a cause-effect diagram for quality control of PVC products.

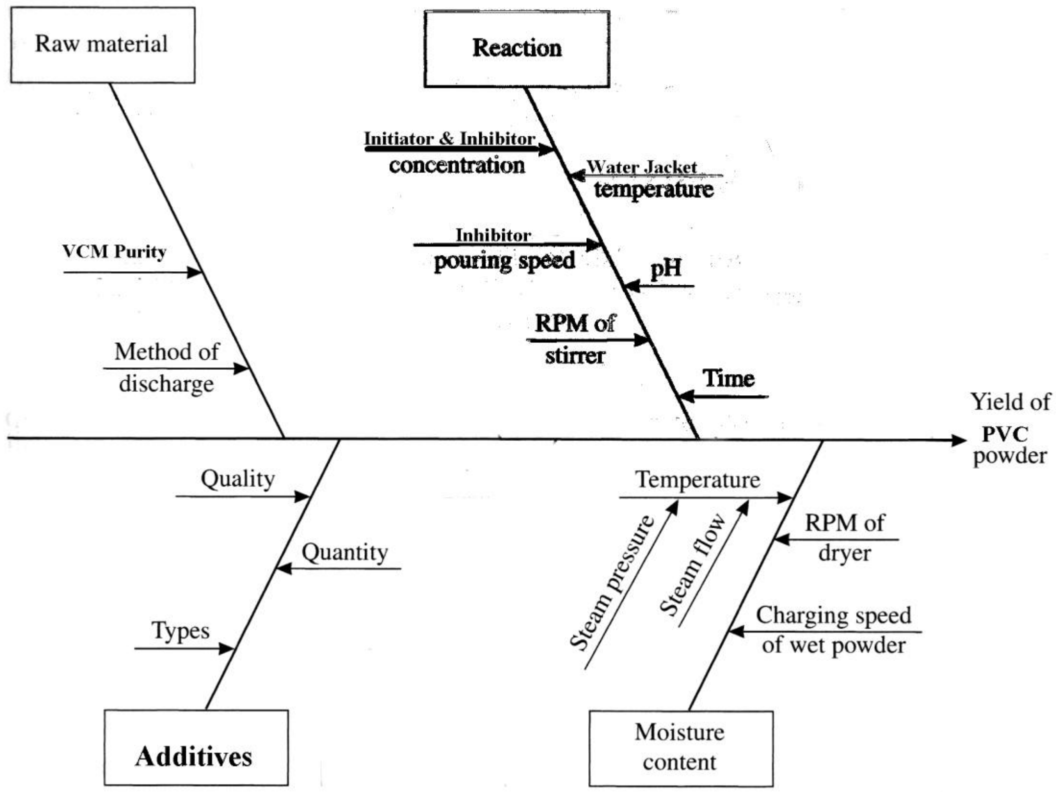


Figure 3 Fishbone diagram for PVC powder quality control cause-effect factors.

## PVC process cycle time reduction:

Root Causes analysis of cycle time factors are shown in figure 3 is the fishbone diagram that provides a cause-effect diagram for batch process cycle time of a PVC polymerization process.

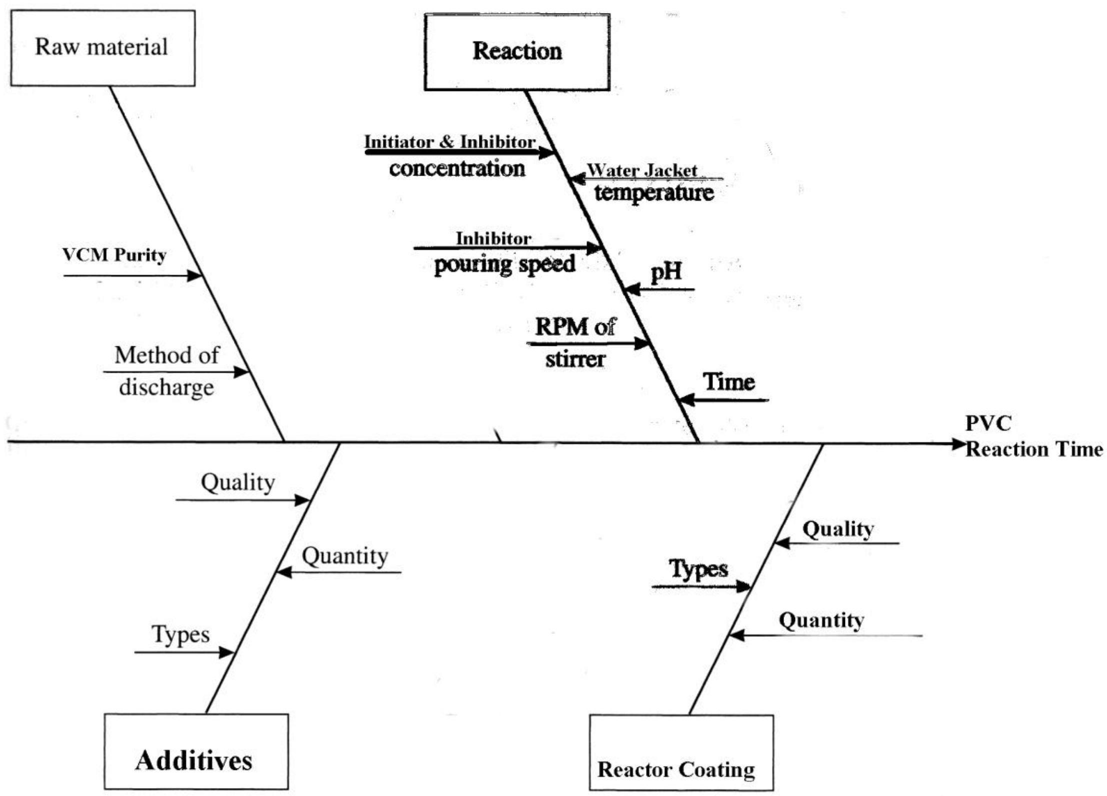


Figure 4 Fishbone diagram for PVC polymerization cycle time cause-effect factors.

## Plan for quality improvement/cycle time reduction

Quality Improvement:

The grade of PVC powders is defined for its usage and the quality baseline set by these factors: 1) the molecular weight of PVC powder 2) ratio of foreign particles 3) bulk density 4) the particle size distribution of the PVC powders 5) moisture content 6) the porosity of the PVC powders. The fishbone diagram from figure 3 identified the cause of the possible defects that could lower the quality of the PVC produced by reducing these problems, the quality of the PVC powder should be able to improve. These causes allow us to identify what measurements needed for data collection and what model/tool needed for proper analysis to find the correlation among these causes and quality of the PVC powders. The process control plan then can be drawn with these changes that being benchmarking for better quality then the baseline defined. The plan for PVC quality control is listed in table 1.

| | Score(1-10) | Measurement Device | Data Collection | Improvement Plan | Budget | Timeline |
|---|---|---|---|---|---|---|
| ***Raw Material | | | | | | |
| VCM purity | 8 | GC | laboratory | on-line | 50,000 | 6 months |
| Method of Discharge | 3 | N/A | reactor control unit | | | |
| ***Reaction | | | | | | |
| Initiator Concentration | 10 | HPLC | laboratory | Certified by Supplier | | ASAP |
| Inhibitor Concentration | 10 | HPLC | laboratroy | Certified by Supplier | 0 | ASAP |
| Inhibitor pouring timing | 10 | N/A | reactor control unit | Operator Recording | 0 | ASAP |
| RPM of Stirrer | 5 | N/A | reactor control unit | | | |
| Water Jacket Temperature | 10 | N/A | reactor control unit | Feed-back controller | 30,000 | 3 months |
| pH of Water | 3 | pH meter | laboratory | on-line | 10,000 | 1 year |
| Time of reaction | 10 | N/A | reactor control unit | Feed-back controller | 50,000 | 3 months |
| ***Additives | | | | | | |
| Quality | 10 | HPLC | laboratory | Certified by Supplier | 0 | ASAP |
| Quantity | 10 | HPLC | laboratory | Certified by Supplier | 0 | ASAP |
| Types | 10 | HPLC | laboratory | Certified by Supplier | 0 | ASAP |
| ***Moisture Content | | | | | | |
| Steam Pressure | 3 | N/A | dryer control unit | | | |
| Steam flow | 3 | N/A | dryer control unit | | | |
| RPM of Dryer | 3 | N/A | dryer control unit | | | |
| Charging Speed of Wet PVC | 3 | N/A | dryer control unit | | | |

Table 1 plan for quality improvement, timeline and budget

Cycle Time Reduction:

The main factors that impact the PVC batch process time are:

- The VCM pressure measured
- The water temperature in the reactor’s jacket.
- The RPM of stirrer
- The amount/type of initiators and inhibitors used

The plan for PVC polymerization process cycle time improvement is listed in table 2.

| | Score (1-10) | Measurement Device | Data Collection | Improvement Plan | Budget | Timeline |
|---|---|---|---|---|---|---|
| ***Raw Material | | | | | | |
| VCM purity | 8 | GC | laboratory | on-line | 50,000 | 6 months |
| Method of Discharge | 1 | N/A | reactor control unit | | | |
| ***Reaction | | | | | | |
| Initiator Concentration | 10 | HPLC | laboratory | Certified by Supplier | | |
| Inhibitor Concentration | 10 | HPLC | laboratroy | Certified by Supplier | | |
| Inhibitor pouring timing | 10 | N/A | reactor control unit | Operator Recording | | |
| RPM of Stirrer | 8 | N/A | reactor control unit | on-line | | |
| Water Jacket Temperature | 10 | N/A | reactor control unit | Feed-back controller | 30,000 | 3 months |
| pH of Water | 1 | pH meter | laboratory | on-line | 10,000 | 1 year |
| Time of reaction | 10 | N/A | reactor control unit | Feed-back controller | 50,000 | 3 months |
| ***Additives | | | | | | |
| Quality | 10 | HPLC | laboratory | Certified by Supplier | 0 | ASAP |
| Quantity | 10 | HPLC | laboratory | Certified by Supplier | 0 | ASAP |
| Types | 10 | HPLC | laboratory | Certified by Supplier | 0 | ASAP |
| ***Reactor Anti-Scale Coating | | | | | | |
| Quality | 10 | N/A | N/A | Certified by Supplier | 0 | ASAP |
| Quantity | 10 | N/A | N/A | Certified by Supplier | 0 | ASAP |
| Types | 10 | N/A | N/A | Certified by Supplier | 0 | ASAP |

Table 2 plan for PVC cycle time reduction timeline and budget

## Conclusion:

PVC production technology is now quite mature and seems little left to improve. But with baseline established for both the PVC quality (grade) and process cycle time, the cause-effect diagram can be used to identify potential problems and to propose the proper solutions. The metrics of both quality and cycle time for PVC were defined that allows the plan for both to be set with both the timeline and budget as listed in table 1 and 2.

## References:


1. “Polyvinly Chloride” by Michael W. Allsopp and Giovanni Vianello, retreated at http://www.mindfully.org/Plastic/Polyvinylchloride/Polyvinyl-Chloride-PVC-Vinyl.htm on July 31, 2008
2. “Polymerization VCM to PVC”, retreated from http://www.vinythai.co.th/aboutvinythai/ourplant/polymerisationofvcmtopvc/0,,1827-2-0,00.htm on July 31, 2008.
3. “Manufacturing of PVC resin”, retreated from http://www.solvinpvc.com/faq/pvcresin/1,,55304-2-1,00.html on July 31, 2008.
4. “polyvinyl Chloride-PVC”, retreated from http://nexant.ecnext.com/coms2/gi_0255-3041/Polyvinyl-Chloride-PVC.html on July 30, 2008.