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Generic Scenario: Dry-Blend Processing of Powder Coatings

Introduction

The manufacture of powder coatings by dry blending is a very limited market as it is used only for high-priced and specialized thermoplastic base resins. The appliance industry is the major user of dry-blend thermoplastic powder coats. Dishwasher racks typically are coated using polyvinyl chloride (PVC) or nylon dry-blend powder coats via fluidized-bed application. Thermoplastic powders produced by dry blending represent 81% of the nearly 12 million pounds of thermoplastic powder coatings produced in the United States. No thermoset powder coatings are produced by dry blending.

In the dry-blending process, dry, powdered raw materials are mixed mechanically with only a minimum of liquid stabilizers added. These liquid additives are dispersed and absorbed by the powder materials so that the final product is a dry powder coating of the desired color. The particle size and distribution of the final powder product is a direct function of the quality of the raw materials.

Market Share

Powder coating manufacture in the United States has grown at a rate exceeding 10% for the past 10 years, and growth is expected to continue at this rate at least through 1995 [1,2]. The total powder coating market in the USA in 1991 was estimated to be 133.5 million pounds, at a market value of $13.5 million [2,3,4].

Powder coatings are divided into two classes according to the type of resin material used in the manufacture of the powder coat. Thermoset powder coatings are applied in relatively thin layers mainly for decorative and protective applications. Thermoset powder coats account for more than 90% of the powder coating market, having a total market volume of 122 million pounds in 1991 [3]. Thermoplastic powder coatings are applied as thicker coatings for extreme performance properties. Thermoplastic powder coatings account for the remaining 11.5 million pounds [4,5]. Based on these figures, 91% of the powder coating market is assumed to be based on thermoset resin systems, and the remaining 9% of the market is thermoplastic powder coatings. In recent years, significant gains have been made in the thermoset powder coating chemistry. As a result the thermoplastic market has been dwindling as replacement thermoset powder coatings have been introduced. Currently, the thermoplastic market is fairly stable, holding a very specialized niche in the powder coating market, and is expected to maintain its current industrial market.

The majority of powder coatings, 90 to 95% of the total powder manufactured, are manufactured by melt-blend processing. Most industry representatives quote the high end of this range, so it will assumed that 93% of the total powder market is manufactured by melt-blending techniques, and the remaining 7% is manufactured by dry-blending processes. 100% of the thermoset powder coats are manufactured by melt-blending techniques. Based on the assumption of 7% (9.3 million pounds) market share for dry blending, and the breakdown of market shares according to resin chemistry, this would imply that 19% (2.2 million pounds) of the thermoplastic powder market is manufactured by melt-blending processes and 81% (9.3 million pounds) of the thermoplastic powder market is manufactured by dry-blending processes.

Most, if not all, PVC-based thermoplastic powder coatings are manufactured by dry-blending processes [7]. PVC resin-based systems dominate the 11.5 million pound per year thermoplastic market, holding a 73% market share with in 1991 production of 8.5 million lb. Based on assumptions made thus far, 91% of all powders manufactured by dry-blending are based on PVC resin systems. Approximately 35% of the nylon powder coating market share and 2% of the polyethylene and propylene powder coating market shares are dry-blended. The remaining thermoplastic powders are manufactured by the melt-blend process.

Composition

A typical dry-blended PVC (highly plasticized) powder formulation consists of

- 51% PVC resin
- 33% fillers and pigments
- 15% plasticizer
- 1% liquid stabilizers [7].

With the exception of the 1% stabilizers, all raw materials are dry powders. No grinding is used after blending, so the characteristics of the raw materials dictate the size and distribution of the final blended powder coating product.

Process Description

The manufacture of powder coatings by dry blending is a fairly simple process, as shown in the flow diagram in Figure 1 [7]. The powdered raw materials are weighed and then transported to the dry-blending area. The components are then loaded into the mechanical mixer for blending. For PVC systems, high-intensity mixers generally are employed. Pigmentation occurs during dry blending as the raw components are mixed into a uniform powder dispersion. Small amounts of liquid stabilizers or plasticizers may be introduced during blending (used approximately 80% of the time). These liquids are dispersed and absorbed by the powder materials; hence the final product is in the dry powder form. Dry-blending vessels typically have a capacity of 200 to 1,000 pounds. Mixing usually takes 2 to 20 minutes, depending on the intensity of the mixing. Smaller batch sizes can be mixed more intensely as heat buildup is not a problem. Cooling jackets sometimes are used to control the temperature of the mix [7].

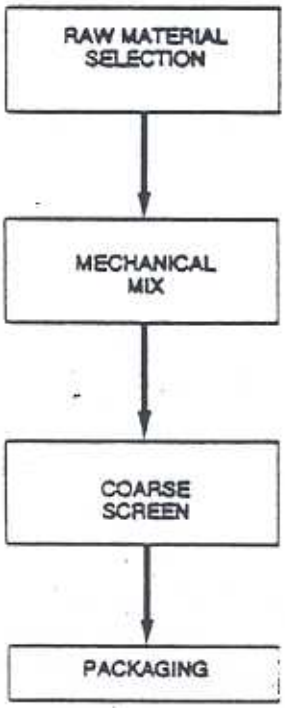

Figure 1. Flow diagram of manufacturing process for dry blending of powder coatings.

Once the materials are thoroughly blended, the final product is passed through a coarse screen to remove any impurities or agglomerations and fed into containers for shipping. No further grinding or sieving processes are performed. Although product size distribution may vary, dry-blended thermoplastic powder coatings typically are 40 and 200 microns, with a nominal particle size of 150 microns [10]. The percentage of fines (particles less than 10 microns) in fluidized bed-grade powders is less than those on powders manufactured for electrostatic spray application, and typically of the order of 1 to 2% [10,11]. The average density of dry-blended thermoplastic powders is approximately 1.3 g/cm^3 [11]. Pigment dispersion may not be uniform enough to produce consistent film color and opacity.

Waste Generation, Environmental Releases, and Exposure-Level Calculations

Manufacture of thermoplastic powder coatings in the United States is dominated by four manufacturers [6]. One company, having two manufacturing facilities, is responsible for almost all of the dry-blend production of PVC powder (91% of the material produced by the dry-blend process) [9]. Because there is only one major producer of thermoplastic powder coatings using dry-blending processes, industry averages for production capacities and rates must be estimated from the available numbers on the dry-blend thermoplastic market. As the thermoplastic market is fairly stable, it is assumed that the dry-blend powder market can be assessed on the basis of the 8.5 million pounds of PVC powder produced in 1991. The following model is used to calculate waste generation and exposure:

- 2 facilities are assumed to be operating 250 days a year
- 15 to 20 people working one shift of 8 hours
- average daily production of 17,000 pounds, or an average production rate of 2,150 pounds per hour
- 4 lines (mixers) per plant will be assumed
- thus, for a worst-case calculation, worker exposure and waste generation will be based on a production rate of 550 pounds per hour.

Unless otherwise given, the following is assumed:

- NS: 2 sites, each producing 4.25 MMlb/year (9.35 MMkg/yr)
- M: 4 mixers per plant site
- PR: average production rate of 550 lb/hour
- H: 8-hour shift, SH: 1 shift per day, DOP: 250 days of production per year
- W: 20 workers per plant site
- PMN: weight fraction of PMN material is given
- CR: concentration of respirable dust (5 mg/m^3)
- IR: inhalation rate (1.25 mg/hr) [12]
- TR: number of times/day powder materials handled
- T_t: time of exposure per transfer/handling operation

Waste Generation

Material waste generated in dry-blend manufacture of powder coatings typically is between 1 to 4% by weight, depending on batch types and sizes [6]. An industry mean of 2% weight loss typically is applicable [6]. Dry-blend powder waste is classified as nuisance dust and must be disposed of accordingly. The threshold limit value (TLV) of the respirable portion of these dusts (particles 5 microns in diameter or less) is 5 mg/m^3, with an overall TLV of 15 mg/m^3 [8]. Generally, waste is stored in containers on site until the waste containment area is full. At this time, the company contracted to perform the disposal is called to collect the containers. A trench is dug at the disposal site; the containers are collected, transferred to the site, placed in the trench, and

covered. Containers may be bags or boxes, metal or plastic. As such, 100% isolation from the environment should not be assumed.

Environmental Releases (kg/year):

Solids for Disposal: Assumed 98% (by weight) conversion of raw materials to product; 2% total waste during processing based on industry standards.

$$PR \times H \times SH \times M \times DOP \times NS \times 0.02 \times PMN \times 0.454 \text{ kg/lb} = \underline{?\text{ kg/year}}$$

Air Emissions: All materials are in powdered form. Assume 50% of solid waste occurs as dust, which is transported in the airstream and passed through a baghouse/filter with an efficiency of 99%; 1% loss of particulates (<1 micron) to air. Assume no incineration methods are used to dispose of waste. Waste is collected and disposed of as solid waste.

$$PR \times H \times SH \times M \times 0.02 \times 0.5 \times 0.01 \times PMN \times 0.454 \text{ kg/lb} = \underline{?\text{ kg/site/day}}$$

Water: None assumed.

Worker Exposure (1 worker; 8-hour shift; 1 day)

Powders are classified as nuisance dust, with an overall permissible exposure limit (PEL) of 15 mg/m^3. The PEL for the respirable portion of powder coatings is assumed to be 5 mg/m^3. It is assumed that all facilities manufacturing powder coatings are in compliance with the Occupational Health and Safety Act (OSHA) standards, so worst-case exposure will be a concentration equal to the PEL [12]. Exposure levels will be determined for 1 worker, working one 8-hour shift. It can be assumed that 1 worker operates each step of the dry-blend manufacturing process. Worker exposure will be limited to tasks involving handling of the powder materials during the manufacturing process. Exposure levels will vary according to specific tasks and the frequency at which these tasks are performed.

1.25 m^3/hr × 8 hr/day = 10 m^3/day

Inhalation Exposure: An inhalation rate of 1.25 m^3/hr will be assumed, or 10 m^3/day [12]. Powders are classified a Nuisance Dust, with an overall PEL of 15 mg/m^3.

$$CR\ (15 \text{ mg/m}^3) \times PMN \times 10 \text{ m}^3\text{/day} = \underline{?(\text{mg/day})}$$

Dermal Exposure: Dermal exposure is limited to incidental exposure during materials handling of raw components, dry-blended materials, liquid additives, and finished product. Equations approximating exposure levels are based on data compiled from contact operations as given in CEB (1991, Table 4-13) [12].

$$(6{,}500 - 18{,}200) \text{ mg/m}^3 \times PMN \times TR \times T_t = \underline{?(\text{mg/day})}$$

Disposal Concerns

All powdered waste generated is placed in secondary containers and covered in a landfill. As 100% containment of materials cannot be assumed, behavior of the waste in the landfill may be of concern. All of the materials are unbound and in their raw form. Solubility of the PMN material may be important. Solubility data on the PMN material must be provided by the manufacturer submitting the PMN. Refer to item 1 for the pertinent calculation.

References

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