1972

Electrostatic Fluidized Bed Plastic Powder Coating Process

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Abstract

The plastics industry is the most rapidly expanding industry in the United Stated today. By 1983, the total weight of plastics produced in one year will exceed that of steel/ Since Industrial Arts is a general education curriculum which supposedly include the study of all significant industrial tools, materials, and processes, they study of the plastics industry should definitely be included.

One of the fastest growing segments of the plastics industry is the application of dry plastic powder coatings, such as vinyl, for protection and beautification of metallic objects. This change is prompted in part by the limitations and/or disadvantages of solvent-suspension coatings, which are listed in Table 1.

Most of the solvent-suspension coating disadvantages can be overcome by employing a suitable dry plastic powder coating. The advantages of dry plastic powder coatings are listed in Table 2.

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June 22, 1972

Date

ELECTROSTATIC FLUIDIZED BED DRY PLASTIC POWDER COATING PROCESS

RESEARCH PAPER

Presented to the

DEPARTMENT OF INDUSTRIAL ARTS AND TECHNOLOGY

UNIVERSITY OF NORTHERN IOWA

In Partial Fulfillment

of the Requirements for the Degree

MASTER OF ARTS

by

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June 1972

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION

The plastics industry is the most rapidly expanding industry in the United States today. By 1983, the total weight of plastics produced in one year will exceed that of steel. Since Industrial Arts is a general education curriculum which supposedly includes the study of all signifigant industrial tools, materials, and processes, the study of the plastics industry should definitely be included.

One of the fastest growing segments of the plastics industry is the application of dry plastic powder coatings, such as vinyl , for protection and beautification of metallic objects. This change is prompted in part by the limitations and/or disadvantages of solvent-suspension coatings, which are listed in Table 1.

Most of the solvent-suspension coating disadvantages can be overcome by employing a suitable dry plastic powder coating. The advantages of dry plastic powder coatings are listed in Table 2.

The plastics industry currently employs three processes for applying dry plastic powders: fluidized bed, electrostatic spray, and electrostatic fluidized bed. The fluidized bed and the electrostatic spray processes are well established in the industry today. The electrostatic fluidized bed process was first successfully utilized within the

Table 1

The Disadvantages of Solvent-Suspension Coatings

1. The solvents (carriers) increase cost.
2. The solvents do not contribute to the final product in terms of film thickness, strength, or substrate protection.
3. Solvents dilute coatings--several coats are needed for thick application.
4. Solvents create a great fire hazard, and vapors can be toxic--an air pollution problem.
5. Not all good coating materials can be carried by a useable solvent.
6. Most solvent-suspension coating materials exhibit only medium corrosion resistance.

Table 2

The Advantages of Dry Plastic Powder Coatings

1. They exhibit high corrosion resistance.
2. If desired, heavy one coat applications are possible.
3. Plastic coatings have high impact and abrasion resistance.
4. Proper application techniques result in virtually no waste nor air pollution.
5. Coating thickness can be closely controlled over irregular shaped parts.
6. They exhibit excellent edge coating characteristics.
7. Different textures and gloss options are available--soft, tough, rigid, flexible, permanent, or strippable coatings.

United States in 1971. As such, no information in the form of library or text books exists at this time. But it appears that the electrostatic fluidized bed process will take a prominent position in the dry plastic powder coating industry in the immediate future. It thus behoves the Industrial Arts discipline to incorporate this process into its curriculum.

<u>Statement of the Problem</u>

The overall objective is the fabrication of a functional electrostatic fluidized bed dry plastic powder coating apparatus which can be utilized in an Industrial Arts laboratory.

<u>Limitations</u>

1. The constructed apparatus must utilize existing laboratory equipment as found in most moderately equipped Industrial Arts shops.
2. The construction cost must be under $10.00.
3. The operating cost must be comparable to that of enamel coating methods.
4. The process must be safe enough to operate inside the typical Industrial Arts shop.
5. The apparatus must require minimal shop space, both while in operation and during storage.
6. The cured plastic coating should be at least equal to a cured enamel coating when subjected to abuse and weathering tests.

Definitions of Terms

A complete definition of terms is located in Appendix B.

Chapter 2

BACKGROUND INFORMATION

HISTORY

The Material

The first synthetic plastic was developed in 1846 by Dr. Friedrick Schonbein, a German professor of chemistry working at Bosle University. He converted plant cellulose and nitric acid into nitrocellulose (cellulose nitrate), commonly called guncotton. (Cook, 1964, p. 12). This was the beginning of the development of the cellulosic family of thermoplastics. In 1854, J. Cutting of Boston obtained patents to cover his use of gum camphor in collodion for the improvement of photography (film), and this appears to be the first mention of camphor with cellulose nitrate. (Du Bois, 1967, p. 13). It was John W. Hyatt, a New York printer, who realized the unique and all important action of camphor on cellulose nitrate. Mr. Hyatt patented his camphorated cellulose nitrate in 1870 under the name of Celluloid. (Du Bois, 1967, p. 14). The first commercial application of Celluloid was in 1870 by Mr. Hyatt who established the Hyatt's Albany Dental Plate Co. Thus, Hyatt's invention was the start of synthetic plastics product manufacturing in the United States. (Du Bois, 1967, p. 14).

In 1894, Cross and Bevan produced an industrial process for the manufacture of cellulose acetate. (Du Bois, 1967, p. 14). It was first used for artificial fibers, and somewhat later, for aircraft dope. (Brydson, 1966, p. 6). "The discovery of suitable plasticisers in 1927 led to the introduction of this material (cellulose acetate) as a non-inflammable counterpart of Celluloid." (Brydson, 1966, p. 6). In 1938, cellulose acetate was first modified through esterization with acetic acid, and this resulted in the development of cellulose acetate butyrate.

The Process

The history of dry plastic powder coating processes begins with the development of the fluidized bed process by Erwin Gemmer of the Knapsack-Grie-Shiem division of Farbwerke Hoescht in Germany in 1953. (Modern Plastics Encyclopedia, 1963, p. 672).

> The system was introduced in the United States late in 1955 by Polymer Processes, Inc., which now controls patents covering this process in the United States and Canada. (Modern Plastics Encyclopedia, 1963, p. 672).

The original application of the fluidized bed process utilized melt compounded polyvinyl chloride resin, which was converted to a powder by first freezing, and then grinding. (Sarvetnich, 1963, p. 208). The fluidized bed process was quickly adopted to other plastics compounds, including cellulose acetate butyrate.

In 1962, the Societe Anonyme De Machines Electro-Statiques of Grenoble, France developed the electrostatic spray method of dry powder coating. (Savage, 1971, p. 18).

The patent rights were acquired by Sames U.S.A., in 1965, for the United States and Canada.

For industrial applications of dry plastics powder, it was either fluidized bed or electrostatic spray until 1970 when the Societe Anonyme De Machines Electrostatiques of Grenoble, France developed the electrostatic fluidized bed method. (Savage, 1971, p. 24). This process combined some of the advantages of both of its predecessors, while eliminating some of their disadvantages. Although this process is still somewhat developmental and is not yet widely used, it shows promise of becoming the most widely used method, particularly in high production, continuous coating complexes. (Savage, 1971, p. 24).

PROCESS

The electrostatic fluidized bed coating process is a natural outgrowth of two earlier processes: fluidized bed and electrostatic spray. Thus, a logical starting point for developing an understanding of the electrostatic fluidized bed process is with these two processes.

The Fluidized Bed Process

In this method of dry powder coating, plastic powder is placed in the bed or tank. Compressed gas is passed through the tank's bottom porous plate and keeps the plastic powder in a fluidized state. Objects to be coated are heated above the plastic powder's melting temperature and then dipped into the fluidized powder.

As the powder particles contact the heated parts, they fuse and adhere to the object. The longer the object is kept in the material, the thicker the coating will become. After the object is removed from the fluidized bed, it is again heated above the melting temperature of the plastic to complete the fusing of the powder, or to cure the resin if it is a thermosetting compound. Figure 1 depicts the fluidized bed coating technique. The advantages of the fluidized bed method of dry powder coating are listed in Table 3, while Table 4 lists the disadvantages of this process.

The Electrostatic Spray Process

In this method of dry powder coating, the fluidized material from an enclosed bed is pumped through a hose to a spray gun from which it is discharged through an electrostatic field toward the object to be coated. The electrostatic field, which varies in intensity from thirty thousand to one hundred thousand volts, imparts to each plastic particle an excess of electrons. These negatively charged particles are attracted to the object which is connected to a positive ground. As the plastic particles coat the object, which does not have to be preheated, a negatively charged coating forms on the object. This charged coating repells the rest of the charged material coming from the spray gun. As a result, it is possible to obtain an even coating over the entire object. It is also possible to coat both sides of an object with the spray gun held at a stationary position.

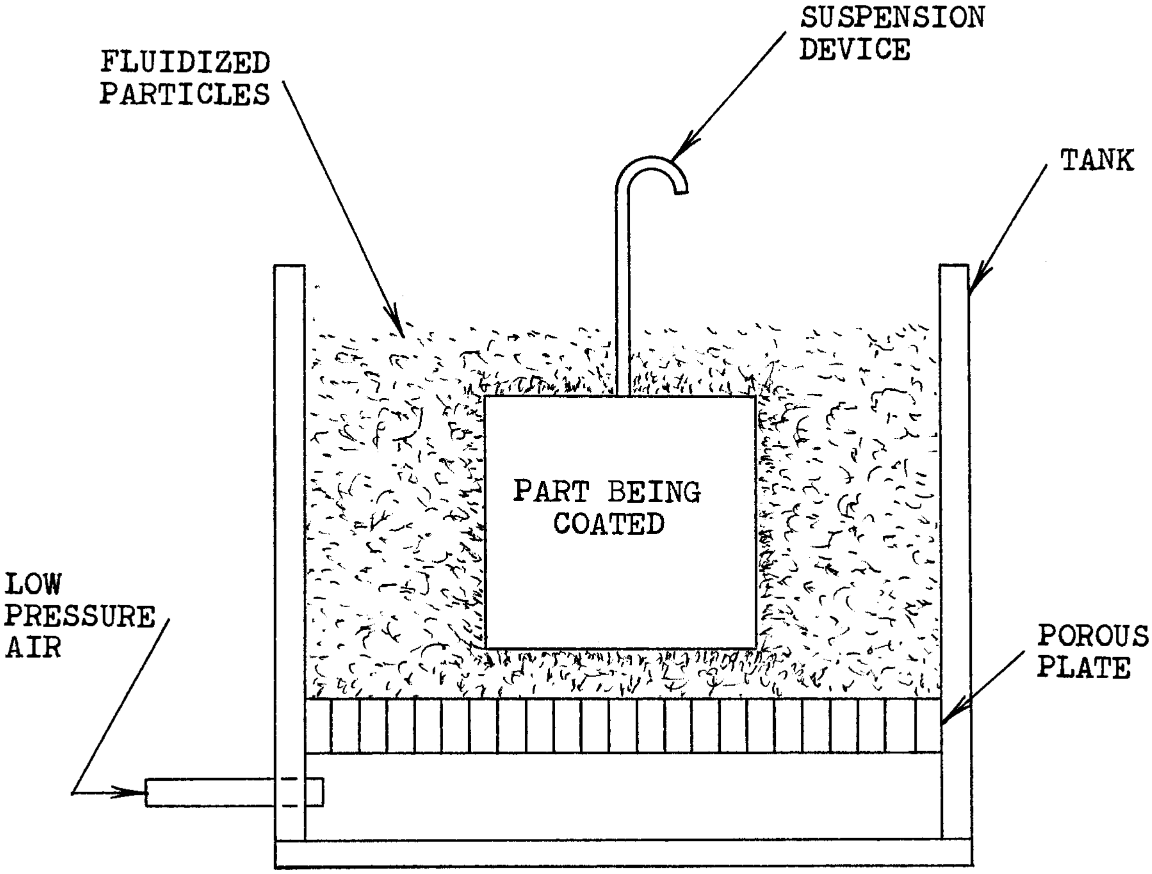

Figure 1

Fluidized Bed Coating Technique

Table 3

Advantages of the Fluidized Bed Process

1.	Low initial cost of equipment.
2.	Low operating cost.
3.	Low operator skill required.
4.	No elaborate air control equipment is needed.
5.	Smooth finishes can be applied over rough surfaces.

Table 4

Disadvantages of the Fluidized Bed Process

1.	Excess powder must be removed from object before curing.
2.	Thick and thin sections on same object receive different coating thicknesses.
3.	Thin coatings result in porous coats.
4.	It is hard to mask off selected areas.
5.	Powder quantity must be sufficient to cover entire object.
6.	Large objects require large tanks.
7.	Pre and post heating requires large heating facilities.

After the object is coated, it is heated above the plastic's melting point to cure the coating material.

Figure 2 shows the electrostatic spray technique. Table 5 lists the advantages of the electrostatic spray method of dry powder coating, and Table 6 lists the disadvantages of this process.

The Electrostatic Fluidized Bed Process

In this method of dry powder coating, an electric grid is placed just below the porous plate of a regular fluidized bed tank. The grid is charged with a high voltage electrostatic charge which imparts a negative polarity to the plastic particles in the fluidized bed. The object to be coated is positively grounded and suspended over the fluidized material; close to, but not within the fluidized powder. The charged particles in the bed are attracted to the object and travel to its surface. This process is expected to gain wide use by industry since it allows even coating of continuously moving objects at high speed, and at low cost.

Figure 3 presents the electrostatic fluidized bed technique. Table 7 lists the advantages of the fluidized bed, electrostatically charged method of plastic powder coating, while Table 8 lists the disadvantages of this process.

MATERIAL

Currently, there are nine basic dry plastic powders being used in American industry. These powders, along with

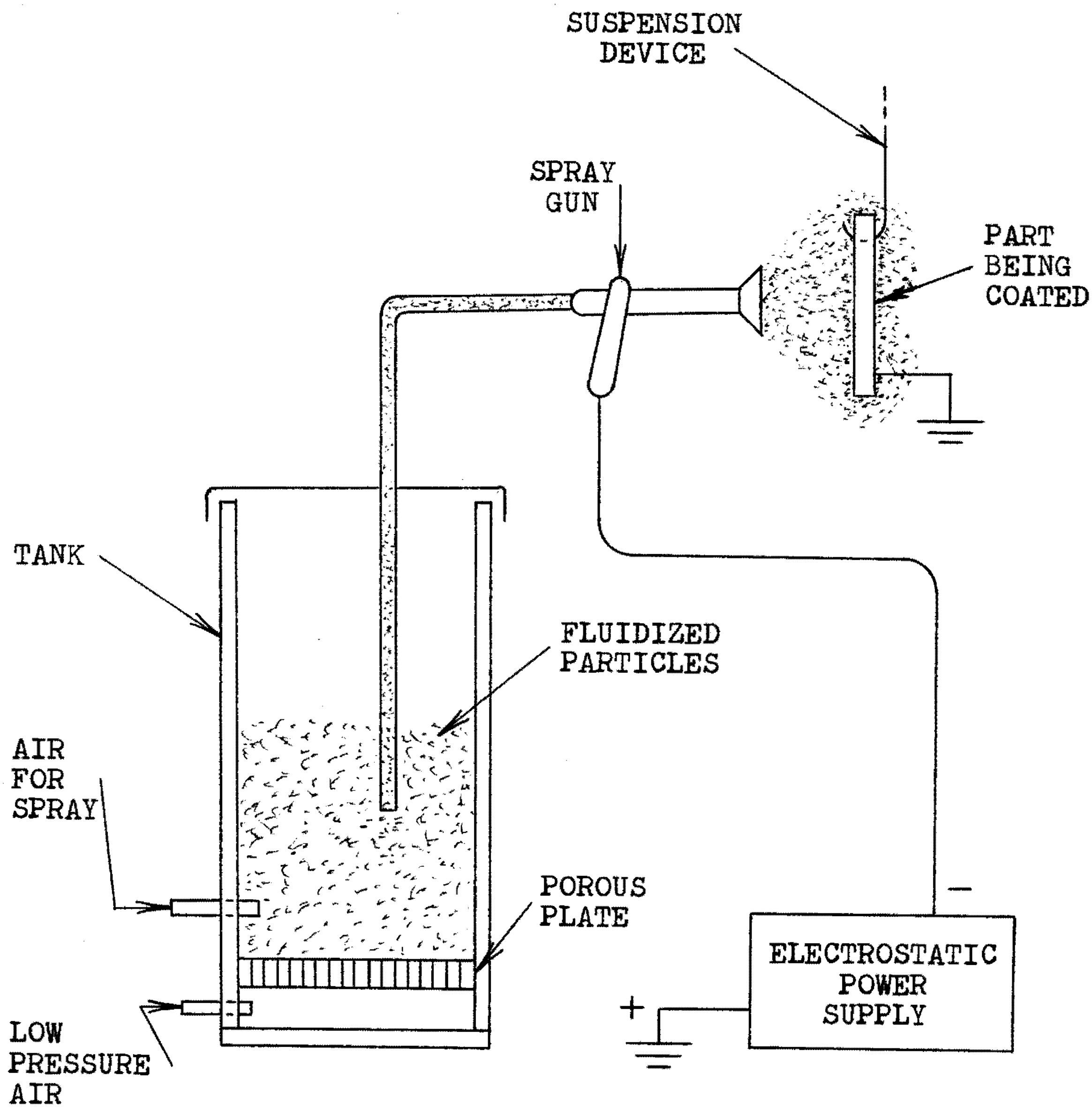

Figure 2

Electrostatic Spray Coating Technique

Table 5

Advantages of the Electrostatic Spray Process

1. High quality thin coatings are possible.
2. No preheating is required.
3. Coating thickness can be precisely controlled.
4. Thick and thin object sections receive the same coating thickness.
5. Simple, inexpensive masking is possible.
6. Large objects can be readily coated.
7. Intricate parts are easily coated.

Table 6

Disadvantages of the Electrostatic Spray Process

1. High initial equipment cost.
2. High operator skill needed.
3. Costly air control and reclaim equipment are required.
4. Fire and personnel hazards are moderately high.

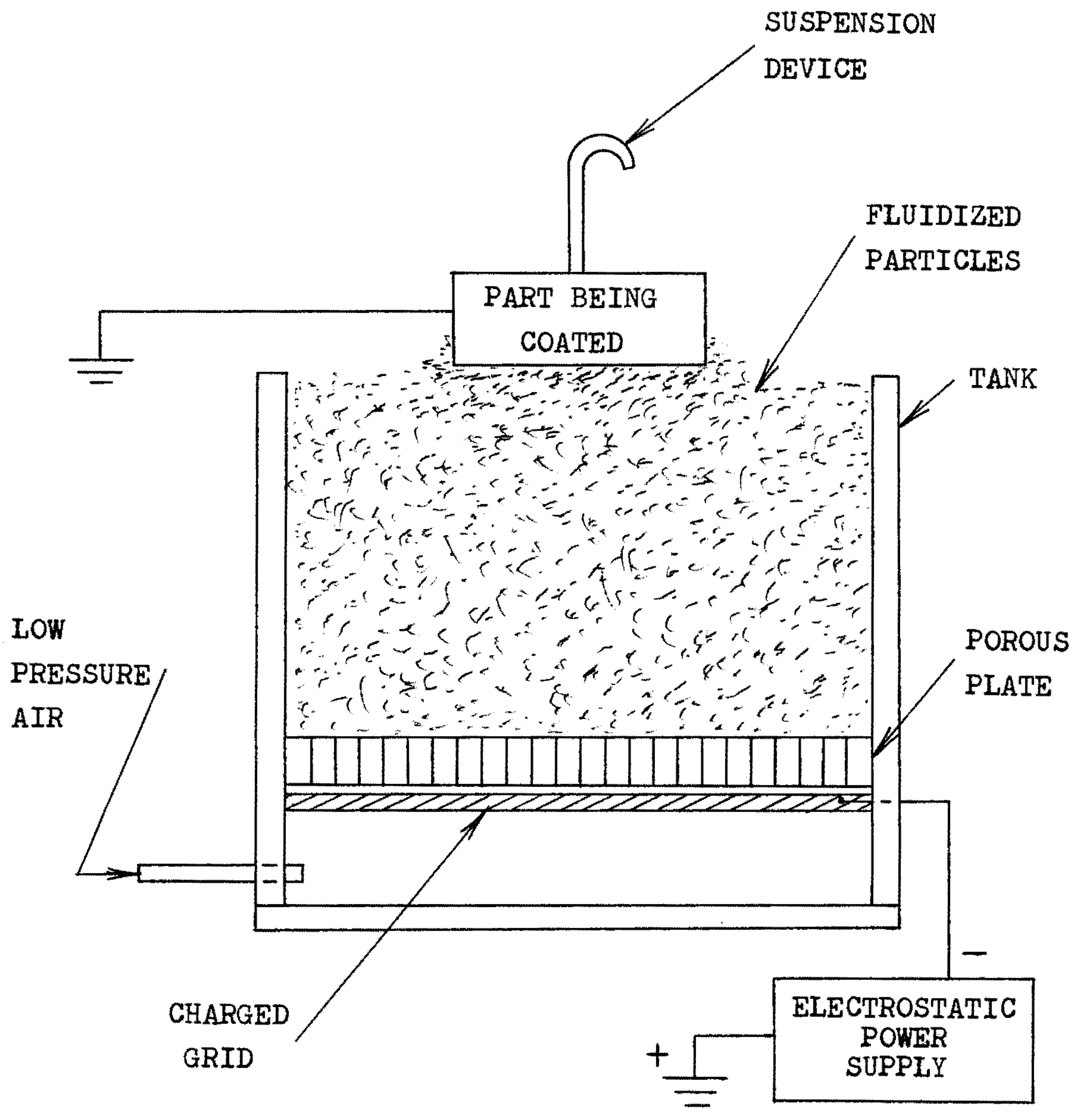

Figure 3

Electrostatic Fluidized Bed
Coating Technique

Table 7

Advantages of the Electrostatic Fluidized Bed Process

1. Precise thickness control is possible.
2. Thick and thin object sections receive the same coating thickness.
3. No preheating is required.
4. Simple, inexpensive masking is possible.
5. Intricate parts are easily coated.
6. Very thin, high quality coatings are easily applied.
7. No elaborate air control system is required.
8. Moderately low fire hazard.
9. Easily adapted to high speed coating operations.

Table 8

Disadvantages of the Electrostatic Fluidized Bed Process

1. It is difficult to coat inside corners.
2. Large objects require large beds.
3. Large, three dimensional objects cannot be coated in one operation.
4. Equipment cost is moderately high.

their mechanical and chemical properties are listed in Appendix A. It must be kept in mind by the material selector that there are hundreds of different chemical formulations which can be purchased from these nine basic groups. These formulations can meet the functional requirements of applications ranging from simple decorative coatings to some of the more severe aerospace and interspace requirements. Basically, the selector must choose the one powder which envelops the most valuable attributes at the least expense.

The material selected for demonstrating the electrostatic fluidized bed process was Tenite Butyrate; Eastman Chemical Products, Inc. brand of cellulose acetate butyrate.

Cellulose Acetate Butyrate

Cellulose acetate butyrate is a member of the cellulosic family of thermoplastics. All cellulosics are based upon cellulose, a naturally occuring thermosetting polymer which is highly concentrated in cotton fibers (linters). During manufacture, the cellulose is pretreated with forty to fifty percent sulfuric acid for twelve hours. After drying, it is treated with acetate acid. (Brydson, 1966, p. 171). It is then retreated with a mixture of acetic acid and butyrate acid. The resultant product is cellulose acetate butyrate.

Chemically, cellulose is a polysaccaride of glucose anhydride with a molecular weight as high as three hundred thirty thousand. (Modern Plastics Encyclopedia, 1969, p. 117). Its molecular configuration is that of a chain of recurring hydrocarbon rings or mers. Each mer contains three hydroxyl groups and one anhydride group. Any one or all of these hydroxyl groups can be reacted with either butyric or acetic acid to form new cellulosic, thermoplastic compounds.

The basic building block of the large cellulose molecule is shown in Figure 4, with a hydroxyl group, OH, attached to two side carbon atoms, while the third hydroxyl group is combined in the anhydride group attached to the other side carbon atom. Table 9 shows the reaction of acetic acid with a hydroxyl group and the reaction of butyric acid with a hydroxyl group. In the formation of cellulose acetate butyrate, not all of the hydroxyl groups are reacted; a typical commercial cellulose acetate butyrate composition is formed from nineteen percent acetic acid and forty-four percent butyrate acid. (Brydson, 1966, p. 372). Figure 5 shows the result of such a reaction on part of a cellulose acetate butyrate molecular chain. Such an ester yields the desired combination of strength, flexibility, and stability that is characteristic of cellulose acetate butyrate.

Cellulose acetate butyrate has been used as a molding powder for more than twenty-five years. Common articles made from it through the molding process include: telephone housings, plastic piping, typewriter keys, tool handles, (Brydson, 1966, p. 372), toothbrush handles, pens, combs, bobbins, (Redfarn, 1958, p. 32), knife handles, and spectacle frames. (Kaufman, 1968, p. 106). Only since the development of the fluidized bed process has cellulose acetate butyrate been extensively utilized as a coating material. Some of the

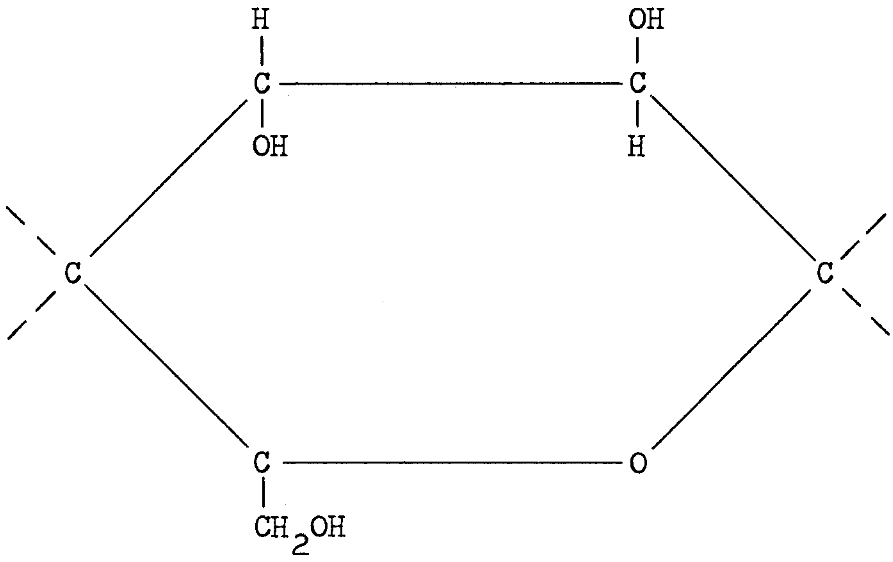

Figure 4

Cellulose Building Block
(Kaufman, 1968, p. 107)

Table 9

Acetic and Butyric Acid Reactions
with Cellulose

Acetic acid	$CH_3COOH + OH \longrightarrow CH_3CO_2 + H_2O$
Butyric acid	$CH_3(CH_2)_2COOH + OH \longrightarrow CH_3(CH_2)_2CO_2 + H_2O$

Attributes of cellulose acetate butyrate include: glossy surface, unlimited range of colors, clarity when pigments are absent, pleasant feel, toughness, good hardness, corrosion resistance, anti-outdoor weathering, and high electrical insulation.

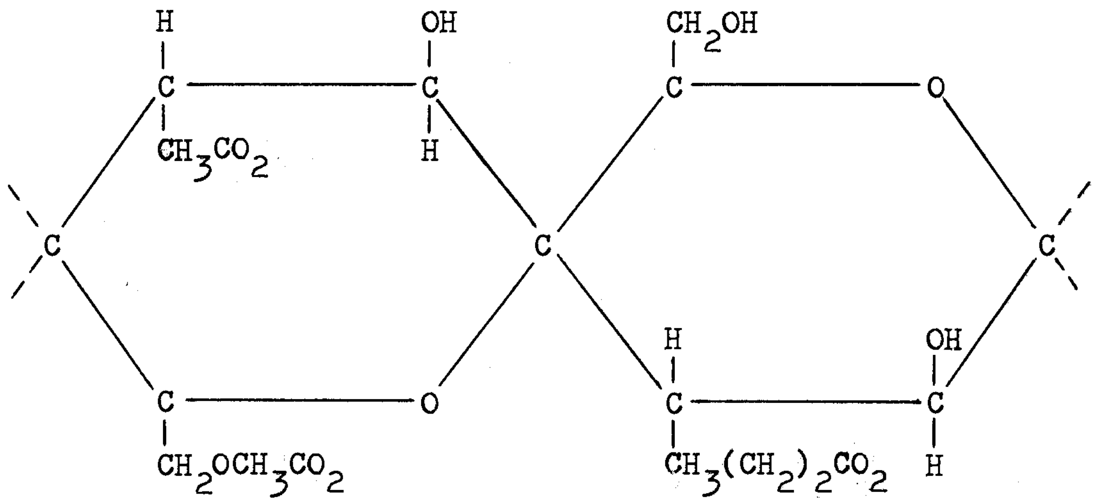

Figure 5

Cellulose Acetate Butyrate
Building Block

Chapter 3

THE INVESTIGATION

APPARATUS

Design Considerations

Specific design considerations are listed in Table 10 for the construction of an electrostatic fluidized bed coating apparatus.

Table 10

Design Considerations for an Electrostatic Fluidized Bed Coating Apparatus

1. The constructed apparatus must accept a metal plate of at least ten inches square.
2. The apparatus must be capable of being quickly placed into, and taken out of, operation.
3. The apparatus must present no undue safety risks to the operator or other personnel.
4. The apparatus must be easily stored in a comparatively small space.
5. The apparatus should be made of common materials which are low in cost.

The Tank

The tank actually utilized was constructed by Dave Bruns during the Fall, 1971 semester while he was a student in the Industrial Arts and Technology Department. It consists of an enclosed box constructed of three-quarter inch plywood, open at the top, and assembled with a weatherboarding partition dividing it into one enclosed and one open chamber. (See Figure 1, p. 9). Its outside measurements are approximately twelve inches wide by twelve inches deep by eighteen inches high. A quick-couple air hose connection links the enclosed chamber with the outside. The weather-boarding serves the function of a porous plate almost as well as the much more expensive ceramic plate used by industry. Air pressure entering the closed chamber must be regulated externally; best operation is with an air pressure of about one to three pounds per square inch. The air must be absolutely dry to prevent packing of the powder.

The charged grid was built by the writer, and consists of another weatherboarding partition, five-eights of an inch thick. A grid of one and one half inch squares was laid out on one side of the partition, and a three-eights of an inch brass tack was driven its full length into each grid intersection. A tinned, copper wire was soldered to each brass tack, forming a series circuit. The wire was passed out through a hole in the side of the tank when the partition was installed by gluing it into position with the wiring and tack heads against the original partition.

<u>Electrostatic Power Supply</u>

Variable output commercial power supplies are capable of delivering a direct current voltage of thirty thousand to one hundred fifty thousand volts at a current not exceeding two hundred microamps. These power sources have variable outputs to help control coating thicknesses. Such power supplies are far too expensive for use in school industrial art laboratories. The writer's problem was to obtain a direct current voltage source high enough to produce a usable electrostatic field (one in excess of thirty thousand volts), without exceeding the average school equipment budget.

The writer's solution to providing a suitable direct current power supply was to utilize a common automobile battery ignition system, consisting of a distributor (with points, condenser, rotor, and cap), coil, battery, and a regular ignition wiring harness. Any electric motor could be used to turn a distributor to obtain a direct current voltage up to forty thousand volts, but the writer utilized a distributor test bench since one was on hand. The eight spark plug wires coming from the distributor cap were hooked in series to a common copper wire which was connected to the grid within the tank. Such a supply is not variable in output, so high quality thin coatings were not to be expected. The coating thickness can be varied somewhat by the time the object to be coated is held near the charged bed.

The Material

The material used was a coating powder grade of Tenite Butyrate, Eastman Chemical's trade name for cellulose acetate butyrate. About ten pounds was obtained free of charge from Standard Manufacturing Inc., Cedar Falls, Iowa, by Dave Bruns.

OPERATION PROCEDURE

Safety

It is important that the operator of an electrostatic plastic coating apparatus be cognizant of the potential fire and respitory hazards. The first industrial applications of the electrostatic fluidized bed utilized a charged grid located above the porous plate. Most plastics have an organic base, and during fluidization, a plentiful supply of air is continuously mixed with a plastic powder. If a spark occurs at a charged grid which is surrounded by a plastic-powder-air mixture, a sudden conflagration may result. In fact, Mr. Adcocks, a representative of the De Villbiss Co. which manufactures electrostatic fluidized beds, told the writer during a telephone interview on April 5, 1972, that his company has had so many explosions while experimenting with this process, that the De Villbiss Co. now advises the charged grid should always be separated from the powdered plastic by the porous plate.

Another important safety consideration concerns the control of air-born plastic particles. These particles can create serious lung damage if inhaled over a long period of time. They also can produce eye and skin irritations. With these problems in mind, the writer suggests that an adequate ventilation hood be utilized over any operating fluidized bed; and that the operator wear good eye protection. A hospital type face mask and coveralls are also recommended for extended periods of operation by any one person.

Object Material Selection and Preparation

Obviously, the material to be coated should be electrically conductive. It also must be completely clean and/or degreased if good adhesion of the coating is desired. Most thermoplastic coatings require the use of a primer for permanent adhesion of the material after curing takes place. It is best to check with the manufacture of the particular coating powder being used for determination of the proper primer and its method of application. Use of a thermoplastic powder on a cleaned, but unprimed surface results in a coating which adheres adequately enough for most objects which are not to be subjected to extensive physical abuse. The object to be coated must also be able to withstand the cure temperature of the coating being applied.

Operation

The apparatus should be assembled as shown in Figure 3, p. 14. The writer utilized an automobile exhaust pipe air evacuation system for air quality control. The air pickup tube opening was positioned two feet above and one foot to the side of the fluidized bed. Its operation was both adequate and flawless.

Best fluidization of the butyrate powder was obtained with an air pressure of about one and one half pounds per square inch.

An oscilloscope check of the distributor-electrostatic power supply showed the output to average thirty-seven thousand volts before the spark jumped to ground inside the distributor.

The metal object to be coated was cleaned with alcohol, and dried. Then it was connected to positive ground with a wire and brought into close proximity to the fluidized bed. The particles readily adhered to the object, but it was quite possible to wipe off the particles and start over if desired.

After the desired coating thickness was obtained, the object was heated to melt and cure the Tenite Butyrate powder. Eastman Chemical Co., Inc., recommends a postheating temperature of five hundred to five hundred seventy-five degrees Farenheit for Tenite Butyrate. (Eastman, 1968, p. 9). The heated object should be removed as soon as the coating has smoothed out; excessive heating may cause discoloration. (Eastman, 1968, p. 9). Any ordinary kitchen-type oven will work for the curing operation, assuming it will accept the coated object. The cured object can be either air or water cooled.

TESTING

Most tests of plastics powder and enamel coatings as specified by the American Society for Testing and Materials require specialized equipment and/or extended periods of time. As such, it was necessary for the writer to turn to published test data for performance comparisons of enamels and Tenite Butyrate. The writer discovered that comparison was virtually impossible since both enamels and Tenite Butyrate are supplied in dozens of different formulations, each possessing its own specialized characteristics. In addition, the test techniques and equipment developed to measure plastics characteristics differ from the test equipment developed to measure enamel characteristics. To establish comparative testing techniques and apparatus for the comparison of enamels and plastic coatings would be beyond the scope of this study. Therefore, no formal comparisons between enamel and plastic coatings were attempted by the author.

Informal testing techniques reveiled that it was impossible to scratch the cured Tenite Butyrate with a thumbnail. Also, a section of the cured butyrate was forceably removed from a zinc-plated metal object, and the zinc separated from the object and remained with the butyrate section. All evidence would indicate that Tenite Butyrate, when used as a coating material, exhibits a hardness and adhesion factor which surpasses most, if not all, enamels and/or other solvent-suspension coatings.

Chapter 4

SUMMARY

The use of the electrostatic fluidized bed method of plastic powder coating allows utilization of the many advantages of different plastics when used as a protective coating on metal objects. Although this process is new to the industry, it is expected to gain wide application since it allows rapid and economical coating of objects on a continuously moving assembly line.

There are hundreds of different plastic powder formulations which can be used with the electrostatic fluidized bed process. The selection of the best powder to meet a particular need involves careful evaluation of the advantages and limitations of each formulation, along with the cost.

The fabrication of a functional electrostatic fluidized bed dry plastic powder coating apparatus which can be utilized in an Industrial Arts laboratory is both possible and practical. Such an apparatus can be developed using existing laboratory equipment. It can be operated in a safe manner, and utilize only a small amount of shop space. The construction cost will be less than ten dollars if used and/or available parts are employed. And the cured coatings will be equal to or better than comparable solvent-suspension coatings.

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APPENDIXES