

THE CONTROL OF QUALITY IN
THE MANUFACTURE OF PAINT

by

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SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
BACHELOR OF SCIENCE

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
(1950)

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TABLE OF CONTENTS

	<i>Page</i>
LETTER OF TRANSMITTAL	
SUMMARY	1
CHAPTER I - INTRODUCTION	
A. Purpose	4
B. Method	4
C. Scope	5
D. Description of Paint	5
E. Manufacturing Process	7
CHAPTER II - QUALITY IN PAINT	
A. Definition	11
B. Creation of Quality	12
C. Measurement of Quality	13
CHAPTER III - QUALITY CONTROL	
A. Definition	18
B. Control in Formulation	18
C. Controlling Factors in Manufacture	21
D. Analysis	24
CHAPTER IV - ORGANIZATION FOR QUALITY CONTROL	26
CHAPTER V - EVALUATION	
A. General Situation	29
B. Areas of Possible Improvement	32
C. Obstacles	35
D. What Might Be Done	36
APPENDIX	
SAMPLE FACTORY ORDER	39
SOURCES OF INFORMATION	
A. Bibliography	40
B. Persons Interviewed	40

May 15, 1950

*Professor Joseph S. Newell
Secretary of the Faculty
Massachusetts Institute of Technology
Cambridge 39, Massachusetts*

Dear Professor Newell:

In accordance with the requirements for graduation I herewith submit a thesis entitled "The Control of Quality in the Manufacture of Paint".

To several persons who have given valuable assistance in the preparation of this thesis I owe sincere thanks. I am particularly grateful to Professor William V. A. Clark, Gordon Colton, William Holmes and Alfred Janes for their advice and assistance. To Miss Dorothy Ellsworth go my thanks for typing and aiding in the presentation of the material.

Sincerely yours,

"

SUMMARY

Paint is a liquid suspension of solid pigments in a combination of liquids called the vehicle. The vehicle consists of a drying oil, a drier, and a volatile thinner. The purposes of paint are protection and decoration.

The manufacture of paint involves mixing, grinding, thinning, tinting, straining, and canning operations.

Paint quality is measured on two principle bases -- first, the paint characteristics and secondly, its performance. The key characteristics used as a basis for determining paint quality are consistency, fineness of grind, color, hiding power, brushability, durability, drying time, leveling and gloss.

The quality of the materials used and the conditions of manufacture create quality in paint. The selection of the materials and establishment of the manufacturing conditions is called the "formulation".

Quality control is the exercise of measures for the purpose of maintaining a given level of quality in the paint product. Control is exercised during the formulation and during the manufacturing operations. The control in manufacturing results from raw materials inspection, conformance to instructions, in-process

testing, and maintenance of batch records.

Batch-type processes entail quality control methods vastly different from those involved in unit production processes because of the cost conditions, the interrelation of the successive operations, the need for quality consciousness, and the possibility of making adjustments.

The effectiveness of a quality control program is measured by the number of batch rejects and reworks. The annual losses are surprisingly small considering the high dependence on human judgment involved in paint manufacture.

The quality control organization is headed by a Technical Director and a staff of laboratory chemists and technicians. The Purchasing Agent is important in the quality control organization because much of the final paint quality is purchased in the raw materials. Of equal importance with the other members of the organization are plant employees because they are responsible for the quality that arises from the conditions of manufacture.

In evaluating the present status of quality in paint manufacture several areas for improvement are apparent. Improvement along the line of the subjective

methods of control, the allowable width of variation, and increased mechanization are worthy of investigation. Hindering any proposals for change will be such obstacles as resistance to change, the required research, the required capital investment, and finally, overcoming of the deep-rooted craft tradition. At the very least a study of quality levels consistent with the conditions of use and an analysis of the cost of the present control system should be made.

CHAPTER I
INTRODUCTION

A. Purpose

The purpose of this thesis is to examine what constitutes control of quality in the manufacture of paint. The intent is to note the means and methods of control and to evaluate their effectiveness in producing high quality paint.

B. Method

The information used in the preparation of this paper was obtained from three types of sources, (a) the literature in the field of paint technology, (b) interviews with men associated with paint manufacture, and (c) observation of the manufacturing process.

Very little obtainable printed material on the specific subject of this thesis was available. Because of this handicap it was felt that the necessary information could be best obtained first hand. Consequently, aside from a general introduction to the field of paint and its manufacture obtained from the writings of Heaton and Mattiello, the bulk of the information was taken from personal interviews with men associated with paint manufacture, and actual observation of the

manufacturing process.¹

C. Scope

This analysis is based primarily upon the general line of oil paint used for homes. It does not include special consideration for such special types of paint as anti-fouling, luminescent, printing, etc.

The chief limitation results from the use of four firms as a basis that are all of approximately equal size. In order of relative size these firms would be classed between the fifteenth and twenty-fifth largest in the United States. The prime reason for using this basis was that their proximity permitted personal visit.

D. Description of Paint

A paint may be defined as a liquid suspension of a solid colored material called the pigment, which is applied to surfaces for protective and decorative purposes. The solid pigment (or mixture of pigments) and a liquid medium (called the vehicle) are the prime components of any paint. The vehicle consists of a drying oil (usually linseed oil), a drier (called terebines) and a volatile thinner, (most often turpentine). When

¹See Sources of Information

the paint is applied the thinner evaporates rapidly, leaving behind a wet coating of pigment and oil; this mixture gradually dries into an elastic solid skin by evaporation of the oil or by direct oxidation of the oil by the air. When the oil solidifies it acts as a binder to hold the particles of pigment together and in place; a tough paint film is thus formed which adheres firmly to the surface. It is this tough film which protects and decorates the surface.

Paint pigments are finely divided insoluble white or colored powders. They exist in two classes -- natural occurring earths and chemical pigments. Most colored pigments are the result of chemical manufacturing processes. Common white pigments are the oxides of basic sulfates and carbonates of lead, zinc and titanium. Basic carbonate of lead (white lead) has been and is the most important white pigment but the others, particularly titanium oxide, have experienced wider acceptance in recent years. The number of colored pigments is too great to discuss here.¹

It is often found necessary to add certain inert pigments as extenders to the active coloring or white

¹For an extensive list of colored pigments see Noel Heaton, Outlines of Paint Technology, (Glasgow, 1940), p. 33.

pigments. While the principle reason for their use is to extend the active pigments they also serve to reduce the high opacity of expensive pigments such as titanium oxide. Some are helpful in preventing hard settling of the pigment in storage, while others improve the durability of the paint. Most commonly used as extenders are barium sulphate (called barytes when naturally occurring and blanc fixe when chemically prepared), calcium sulphate and calcium carbonate.

The drying oils of the vehicle have the property of being oxidized by the air to form a smooth, hard solid surface. Linseed oil is the most common drying oil but tung and soybean oil are also of importance. The driers are used to reduce the drying time of the drying oil. Generally these terebines are soluble lead, manganese or cobalt compounds. To make the thick mixture of pigment and oils suitable for convenient and easy application to a surface volatile liquid thinner is added. The paint consistency is a function of the thinner. Principle thinners are turpentine, petroleum spirits, and solvent naphtha.

E. Manufacturing Process

The essential steps in the preparation of paints

are mixing, grinding, thinning, tinting. Straining and canning operations take place after the paint batch has been tested and accepted as meeting the prescribed standards.

1. Mixing

The prime purpose of the mixing operation is to combine the ingredients into a uniform paste and to wet the pigments with the vehicle as thoroughly as possible. The mixing operation must be continued until the paste is smooth, uniform and free of unwetted agglomerates. In the mixing operation the pigment is gradually added to the vehicle keeping the paste relatively stiff. This is done in order to maximize the shearing action as an aid to breaking up large lumps of unwetted pigment.

2. Grinding

The grinding operation is actually a means of dispursing rather than reducing the size of the individual particles of the pigment. Some naturally occurring pigments are reduced in particle size by grinding but most chemical pigments are already fine enough. Frequently these fine particles agglomerate during shipping and storage and it is necessary to dispurse them by a grinding operation. The grinding

operation also serves to extend the wetting action begun in the mixer. The grinding operation is performed by passing the paint through a series of rollers under great pressure.

In some cases the mixing and grinding operations are performed in one operation in what is called a "pebble mill". This consists of a revolving cylinder containing hundreds of steel or porcelain balls which bounce about. The materials are subjected to a mixing and grinding action caused by the falling balls. The higher the ratio of balls to paste weight the finer the grind. Pebble mills are used in preference to roller mills for pastes containing highly abrasive materials (e.g., silicates, iron oxides) or when the batches are relatively large.

3. Thinning and Tinting

The thinning operation consists of adding the remaining quantities of oils, driers, thinners, and any other liquids called for in the formula but no dry pigments. The consistency of the paste is reduced by gradual addition of the liquids while stirring and mixing the batch.

When tinting is required the colors previously ground in oil are added to small portions of the batch,

then added to the complete batch and stirred until the color distribution is uniform.

At this point samples are sent to the lab for testing. Any adjustments found necessary by the testing procedure are made. The batch is retested and adjusted until final approval is given by the laboratory.

4. Straining and Canning

The batch is passed through a series of wire gauze drums where any remaining particles or extraneous material is removed. Another method in widespread use is to strain the batch by means of a centrifuge.

The strained batch is loaded into an automatic machine which fills cans carried on a continuous conveyor. This same machine fits the covers to the cans and delivers the filled sealed cans to a point of packaging.

CHAPTER II
QUALITY IN PAINT

A. Definition

Any examination of the means of quality control must first define what is meant by quality with regard to the product under consideration. It is difficult to spell out in so many words what constitutes quality in paint, but a definition that might serve would be:

Those characteristics that contribute to or improve upon the performance desired of the paint.

From this definition it follows that quality in paint results from its characteristics and its performance. These factors are closely interrelated; that is, one is the cause (characteristics) and the other the effect (performance).

A paint's performance refers to the relative success in realizing the purposes of the paint. The two primary purposes of paint are protection and decoration.¹ The protective function of paint is that of preserving material against weather, light, moisture, chemical forces and wear. The decorative function is

¹Secondary purposes of paint include illumination, printing and sanitation.

that of coloring and beautifying material. Related to the decorative function is hiding and concealing.

A general rule relating the functions of paint with the components is

"...the decorative value of paint depends upon the pigment used, whilst the preservative value is mainly a function of the vehicle."¹

The characteristics that relate to the quality of a paint are many. Certain of the characteristics are the result of the properties and quality of the basic components used in the manufacturing process. Others arise directly from the conditions and methods of manufacture. Most of the properties affecting quality arise from a combination of both these factors.

The most common properties that are used as the basis for determining paint quality are consistency, fineness of grind, color, hiding power, brushability, durability, drying time, leveling, and gloss.

B. Creation of Quality

The paint quality derives from two main sources. First, the quality of the materials used in producing

¹Heaton, Outlines of Paint Technology, p. 320.

the paint. There exist wide gradations in the quality of the materials available for use in paint, and the selection of materials to be used must take into account this factor. The quality of materials used therefore is a direct source of the final paint quality.

The conditions of manufacture are the second source of paint quality. Variations in the types of equipment used, the time of processing, and the machine settings are all factors in the development of paint quality. It follows that changes in conditions of manufacture will be responsible for changes in the quality of the paint product.

C. Measurement of Quality

Paint quality is measured by a series of tests. The characteristics mentioned under Section A are tested by using certain objective and subjective procedures.

1. Objective testing procedures

a. Fineness of Grind

To measure the fineness of grind a grind guage is used which consists of a hard steel block with a wedge shaped channel $\frac{1}{8}$ inch wide and ranging from zero to 0.005 inches deep. A linear

scale is imprinted along the side of the channel ranging from 0 at a point 0.004 inches deep to 8 at zero. The length of the channel is 5 inches. A sample of paint is placed at the deep end of the channel and drawn down the block with a scraper. Holding the block horizontal in the plane of the eye, the point where coarse particles appear on the surface of the paint indicates the fineness of grind.

b. Consistency

This property of paint is measured by an apparatus consisting of a paddle connected by a pulley system to a falling weight. The consistency is measured by the time required for 200 revolutions of the standard paddle immersed a given distance in the paint at a constant temperature of 25°C. The time is a direct measure of the consistency of the paint, and can be subjected to a conversion factor to give the consistency in standard units (Stormer Units).

c. Durability

The durability of a paint is assessed by preparing painted panels. These are exposed to the weather for extended periods of time. Procedures have been developed whereby the resistance of the

vehicle to alteration and disintegration can be evaluated.

Since test panels give varying results depending upon location, season, etc. and require considerable time, devices have been constructed that speed up the process by artificial weathering. These machines attempt to reproduce as closely as possible actual weather conditions. One such device intermittently subjects panels to a powerful arc lamp and sprays of water as the rack carrying the panels revolves.

The durability of the paint is then evaluated by its resistance to fading, cracking, peeling, erosion, mildew and moisture failure.

d. Drying Time

The time required for a paint to dry is determined by spreading a sample on a glass plate placed vertically in a well ventilated room and making a qualitative measurement of time required to dry as determined by a finger touch of the surface.

For a precise determination of the drying time many devices have been constructed. One of recent significance consists of a round plate covered with the paint upon which a fine stream of sand trickles in a spiral pattern. The plate is calibrated to read

the elapsed time from the first point where the sand does not stick to the surface.

e. Weight per Gallon

The weight per gallon is readily obtained by determining the weight of paint required to fill a cup which is designed to contain exactly 83.3 grams of water. The weight in pounds per gallon is obtained by dividing this weight in grams by 10.

"Contrary to much advertising on the subject, weight per gallon does not determine the quality or durability of a paint."¹

The importance of this measurement is that it serves as a basis for comparing certain other properties (e.g., consistency, durability).

2. Subjective testing methods²

a. Brushability

The procedure for judging the brushability of paint consists of making brushouts on a relatively large area usually with a three inch brush. The relative ease of application is then compared with the results of a similar brushout made with a standard

¹Wesley G. Vannoy, "Exterior Finishes" in Protective and Decorative Coatings, (New York, 1943), vol. III, p. 288.

²Methods have been devised for objectively measuring these properties, but their use in the industry is very limited. For this reason the subjective tests used will be described.

sample.

b. Leveling¹ and Gloss

These characteristics are judged from brushouts and compared with a similiar brushout of the accepted standard sample.

c. Color

The comparison of the batch with the accepted sample is made by the experienced eye of a technician. The colors are compared when wet and when dry. The human eye is capable of perceiving very minute differences in color and shades, and a trained technician can distinguish color and shade differences that would escape most observers.

d. Hiding Power

A brushout on a panel composed of a checkerboard of white and black spaces is used to judge the relative hiding power of a paint. As with color the testing involves a comparison with a standard sample by eye.

¹*Leveling refers to the freedom from brush marks in the surface.*

CHAPTER III

QUALITY CONTROL

A. Definition

Quality control is the exercise of measures for the purpose of maintaining a given level of quality in the paint product. Certain standards have been established and the measures are taken to insure conformity of the product with these standards.

Certain paint characteristics are subject to variation and must be controlled. The controlling measures are taken during the formulation procedure and during the manufacturing process.

B. Control in Formulation

1. Hiding power

Since the hiding power of a paint depends primarily upon the difference in refractive index of the pigment and the medium in which it is ground, control of this property is exercised by careful selection of the pigments and vehicles. The greater the difference in refractive power the greater the opacity. The hiding power of a pigment is inversely proportional to the particle size until sizes of the order of wave lengths of light are reached. The suppliers of pigments and vehicles provide detailed

information on the refractive indices and particle size of their products. With this information the paint chemist can select those materials that will give the desired hiding power.

2. Durability

Because so many factors incapable of accurate measurement and definition affect the durability of a paint, the selection and proportions used in formulating paints must be made on the basis of previous trial and error methods. The results of test fences and artificial weathering devices have been used to classify pigments into three groups¹ according to durability:

Group I Pigments which are stable under all conditions of exposure.

Group II Pigments which are stable under average conditions, but are liable to fade in strong light and other trying conditions, or to be affected by other pigments.

Group III Pigments which are more or less unstable, and can only be relied upon for a limited period or when special precautions are taken to protect them from light and air.

With a knowledge of the eventual conditions of use as a guide, the chemist can select those pigments and vehicles that are best suited for those conditions.

¹Heaton, Outlines of Paint Technology, p. 29.

3. Weight

The resulting weight per gallon is most easily controlled because extensive knowledge is available to the chemist in formulating the paint concerning the weight of the components. In fact, the weight per gallon is capable of being predicted within one ounce. The variation from predicted weight is a direct indication of excesses or shortages of materials during the manufacturing process.

4. Drying

As with the gallon weight the drying time can be predicted within a quarter of an hour. Since the time required for drying is usually not a critical factor there is no need for elaborate control measures.

5. Gloss

Gloss in paint is due to the smoothness of the surface formed and the reflective properties of the drying oil. Adjustments in gloss are made by varying the ratio of drying oil to thinner. High gloss paints have about a 4 to 1 ratio of the drying oil to thinner in the vehicle while flat paints reverse the proportions using only sufficient oil to bind the pigment. In formulating the paint the gloss properties will be controlled by the selected ratio of oil to

thinner.

6. Color

The paint color is probably the property most difficult to control in formulation. Deep colored paints are made by grinding colored pigments with the vehicle. Most other shades of paint are made by tinting white pigment pastes to the desired color by the use of colored pigments ground in oil. A very important consideration in the development of paint color is that pigment colors change under the influence of combination with other pigments and vehicles. The key point of control for the color properties is the tinting operation in the manufacturing process.

C. Controlling Factors in Manufacture

In the manufacturing process there are several conditions and procedures that promote the control of the paint quality. Of prime importance at every point in the process is "quality mindedness" on the part of each person concerned with the processing.

1. Raw Material Inspection

Raw materials are inspected to verify conformance with purchase specification.

The past experience of the company usually determines the extent of raw material inspection necessary.

Most firms have some program for sample inspection of their purchased materials. These inspections are usually simple procedures to check the key physical properties of the paint component. In the case of pigments the particle size and oil absorption are typical of the properties checked. The vehicles usually are tested for such characteristics as viscosity, acid value, and color.

2. Conformance to Instructions

Quality arising as a result of the conditions of manufacture is dependent upon the conformance to the processing instructions issued by the laboratory in formulating the paint. It is particularly important that the quantities of materials specified be used. Small errors in weight or liquid measure frequently cause characteristics that make the paint unacceptable. Metered delivery pipes that record the quantities of liquid drawn off are one means of control in use.

The care in setting the mixing and grinding machines as prescribed by the lab instructions is another factor in process quality control.

The in-process testing permits identification of the source of deviation from prescribed instructions. Since each man involved in the processing initials the

Factory Order¹ that accompanies each batch, he can be held responsible for rejections that arise at his operation.

3. In-Processing Testing

At two points in the manufacturing process samples are taken and tested in the laboratory for specific properties. Approval must be received from the lab before the continuance of the operation.

The first lab sample is taken from the first portion of the batch through the grinding operation. Using a grind guage, the fineness of the grind is measured. Should this measurement indicate too coarse a grind the machine is adjusted and the whole batch ground.

The second sample is taken after the thinning and tinting operation. This sample is tested for gloss, hiding power, color, consistency, brushability, weight per gallon, drying time, leveling using the procedures outlined in Chapter II-C. Some adjustment is possible in the color and consistency, but important deviations² from standard of the other

¹A sample of Factory Order form will be found in the Appendix.

²Discussion of allowable deviations is difficult because acceptance is primarily a matter of judgment.

properties usually result in scrapping of the batch.

4. Batch Records

In order to compare similar batches and as a means of analyzing customer complaints a sample of each is maintained. Each batch is assigned a unique factory order number that identifies this batch during manufacture. Each can of paint filled from this batch carries the factory order number. The number is generally perforated in the label or stamped into the can.

D. Analysis

1. Batch Process Control Characteristics

Controlling the quality of products manufactured in batch-type processes entails methods quite different from those involved in unit production processes. Several conditions are responsible for these differences in method.

First, the cost of a batch is usually vastly greater than the cost of a single unit. This requires a totally different approach because whereas a few pieces can be scrapped in a lot with little effect on profit, the scrapping of a paint batch can be disastrous to a small firm.

Secondly, since the batch as a whole is subjected to successive operations, errors at any point mean

inferior quality regardless of the caliber of the operations that follow. This situation requires close inspection throughout the process.

"Quality Mindedness" on the part of the manufacturing organization is a necessity because of the high value of the product and the direct relation that each man's work bears to the final product. Many paint firms undertake incentive programs to promote quality consciousness in their employees.

Finally, batch processes often permit adjustments that do not impair the final quality of the product. It is this factor that permits the fine control of color in paint manufacture.

2. Effectiveness

The real test of a quality control program is its effectiveness. The number of rejects and reworks directly indicate the effectiveness of the program. In the firms visited the number of total scrapped batches per year was very small in comparison with the annual volume. Most total losses resulted not from weaknesses of the process control program, but rather from small lots of sub-standard raw material.

CHAPTER IV

ORGANIZATION FOR QUALITY CONTROL

The control of the quality during the process of paint manufacture is exercised by many persons. A wide generalization of who controls the quality is "every person whose work involves direct association with the paint or any of its components." By this rule of thumb, the man who loads the mixer controls the ultimate paint quality in the same sense as the Chief Chemist who develops the paint formula. Though their work is totally different each makes his contribution to the paint quality and each by the caliber of his work could cause the production of an inferior product.

There exists an organizational arrangement for the program of quality control in order to

- (1) establish responsibility for quality at the various stages of manufacture,
- (2) promote the maintainence of high quality,
- (3) to facilitate operation of quality improvement programs.

The Chief Chemist, who with the aid of the laboratory staff, develops the exacting formulation of the paint product. The laboratory staff is generally composed of a Technical Director and/or Head Chemist, one or more graduate chemists and several technicians.

The technicians often are delegated responsibility for certain of the properties of the paint.¹ The staff may be organized on the basis of a Development group and an In-process testing group. The former develop the formulas while the latter are engaged in testing the paint during its manufacture.

The Quality lab usually functions in a staff relationship to the Plant Manager on the same level as the Plant Superintendent.

Those workers directly related to the manufacturing operations also contribute to the control of quality. Though all the operations involved in combining the components into a fine paint are carried out in various types of electro-mechanical equipment, the performance of the employee in loading, setting and caring for these machines directly effects the quality of the product.

The Director of Purchases plays a key role in the quality control program by obtaining materials of a quality consistent with the quality desired in the finished product. The weak link-chain adage is part-

¹For example, the paint drying properties may be the responsibility of a technician who will check the quality of the paint on this basis.

icularly applicable to an effective program of quality control in the manufacture of paint. Certainly since part of the final paint quality must be bought, the purchasing agent partially controls the quality.

In summary, controlling the final paint quality involves many people. The lab and purchasing personnel control the quality to the extent that they set the level of quality, while the workers contribute by attaining and maintaining that required level.

EVALUATION

In the preceding chapters the present status of quality control in paint manufacture has been reported. An attempt will now be made to evaluate the present methods pointing out those areas where improvements might be possible. Some suggestions are offered which may serve as a guide to further investigation.

A. General Situation

1. Evolutionary Development

The use of paint for protective and decorative purposes dates back to the earliest of times. Genesis records Noah's use of pitch to seal the ark. As the centuries have passed the manufacture of paint has developed from a crude mixing of natural substances into an involved process with several intricate steps. The refinements in manufacturing methods have been largely responsible for the gradually improved quality of the paint product.

For the most part the changes in manufacturing technique have been of an evolutionary nature. The methods of today are basically refinements of the manufacturing methods of 150 years ago.

Consideration of a few of the essential factors in the manufacture will serve to illustrate the

evolutionary development.

a. *Particle Size*

Pigments were first ground by hand between two stones. The naturally occurring earths were placed upon a flat stone and crushed by repeated rolling with another stone. In time the stones were placed upon shafts to become the origin of the Stone Mill which is used today. The prime modification has been the development of new grinding stones in order to obtain smaller particle sizes.

b. *Mixing*

The method of mixing the vehicle and pigment by beating them together with rocks is the operating principle of the "pebble mill".

The grinding and mixing operations are combined today in some paint batches by "beating" the components together with rollers under pressure.

c. *Batch Size*

The requirements for paint have multiplied necessitating changes in the size of the paint batch. Once paint was mixed in a small pot or bucket; today the buckets have been replaced by vats mounted on wheels. The method of in-process handling is essentially the same but the size of the equipment has been increased.

d. Components

The naturally occurring pigments and vehicles are still in widespread use, but the increased quantities required have been the important factor in the use of materials produced by chemical synthesis. The need for greater uniformity in the raw materials accentuated the development of chemical materials as opposed to those naturally occurring.

2. Adequacy of the Present Situation

It seems unlikely that the paint of tomorrow will be at a level of quality much above that of today. The quality level in most paints today is adequate and in many cases higher than the use requires.

Competition within this industry is not based upon paint quality primarily. In a given price range the difference in quality between several brands of paint are small and difficult for a consumer to measure. For this reason the consumer buys paint by color and type first, price second, and brand third. The brand is usually that which the consumer's paint dealer carries.

The annual loss for paint batches because of inferior quality is small in comparison with the total production. Most losses are the result of inadequate specifications. Of course, the loss from inferior quality has to be minimized because of the high value

of the batch. Few firms can afford the scrapping of a large batch of paint so the quality must be maintained in order to remain in business.

In summary, the present situation certainly seems adequate from the standpoint of the level of paint quality.

3. Prospects for the Future

Granting that the level of paint quality is high enough, there appears need for improvement along the line of manufacturing practice. There exists a broad gap between science and actual practice. Application of many of the techniques already developed to the manufacturing process may permit greater batch to batch uniformity and at the same time lower the production cost.

B. Areas of Possible Improvement

1. Subjective Elements of Control

The reliance upon human judgment as a means of control of quality is a feature of the present practice. The mixing operation is illustrative of one stage where the operator's judgment determines the completeness of the operation. This determination is largely an "educated guess". The trial and error color matching is another in-process measure of control that relies

upon subjective methods.

With the advanced objective testing methods that have been developed it would seem wise to investigate the feasibility of replacing these subjective control techniques with more objective procedures. In the case of color matching the use of a colorimeter would permit greater accuracy because the testing is reduced to a comparison of meter readings. By replacing the subjective control practices by devices incorporating readings or setting the process would make batch to batch uniformity easier and probably cheaper.

2. Width of Variation

An outstanding feature of the present quality control program is the emphasis on high quality. The measures of control purpose to maintain a level of quality above some standard. Very little consideration is given to controlling the quality variation between upper as well as lower limits. This situation is the chief reason why so many paints are of a higher quality than the conditions of use require. Since high quality is expensive to attain it would seem wise to consider establishing levels of quality consistent with use.

The adoption of more objective methods of control would facilitate the control of the width of quality

variation. This control would be one means of reducing the manufacturing cost.

Related to controlling the width of variation is a study aimed at establishing quality levels more in line with the conditions of use.

3. Mechanization

The logical step from better control of variation is an investigation of the possibilities of increased mechanization of the process. The process of paint manufacture is certainly not so complex that it could not be made fully mechanized. Complete mechanization would necessitate more exact raw material specification. The raw materials used would have to be of very consistent quality in order for different batches of the same type of paint to be completely uniform. Slight variations in raw materials usually show up in the final paint product. In order to insure consistent quality exact specifications would have to be developed for the raw materials.

Some progress has been made toward the development of equipment which performs more than one of the operations of the process. The "pebble mill" is one example.¹

¹Heaton's text gives illustrations of machinery that performs the mixing and grinding operations successively.

C. Obstacles

The areas for improvement mentioned in the preceding section must have been apparent to other investigators. One reason why extensive progress has not been made in these areas is that several obstacles hinder such progress. These four considerations are among the obstacles to be overcome.

1. Resistance to Change

There is always reluctance to experiment with new methods or techniques, particularly when there is no great pressure for change. Profitable operation with the methods of control now in use acts as a deterrent to change.

2. Required Research

Incorporation of new manufacturing methods would have to be preceded by a costly program of research and testing to try the merits of the new techniques. There is hesitancy toward research in the direction of extensive changes in methods of manufacture because, historically, research has been primarily devoted to new and better paint products.

3. Required Capital Investment

Undertaking the installation of the equipment that would be required for a mechanized process would call for new capital investment. The nature of

competition in this industry would require that no one firm gain any large advantage. For this reason mechanization by one firm means necessary mechanization for many. It is dubious that companies want to undertake the risk of seeking new capital investment.

4. Craft Tradition

In many segments of the industry there exists the attitude that the quality is a direct result of the operators' skill. In those firms where human judgment is a large element in the control procedure the attitude is probably justified. Mechanization would minimize this reliance on human judgment and thereby do away with much of the basis for the deep-rooted craft tradition. Naturally, any program of mechanization must first overcome the opposition of the craftsmen.

D. What Might Be Done

In the light of these obstacles to improvement it is difficult to state what might be done practicably. At the very minimum investigation along two lines should be undertaken.

First, a thorough study of quality levels consistent with use should be made. This study could best be undertaken as a project of the American Paint, Varnish and Lacquer Association.

Secondly, an analysis of the cost of the control measures should be made as a basis for evaluating any changes in the system. This study will permit determination of which subjective techniques could be replaced by objective procedures.

APPENDIX

FACTORY ORDER

CODE No. _____ DATE ISSUED _____ BATCH No. _____

PRODUCTS _____ COLOR _____

MADE FOR _____ WHEN REQUIRED _____

O. K. BY _____ DATE COMPLETED _____

STRAIN _____

KIND OF CANS

	BBL.	1-2 BBL.	5	1	4	8	16	32
No. WANTED								
No. FILLED								
THEO. YIELD			TANK MEASURE			ACT. YIELD		
THEO. WT. PER GAL.								

NO. BATCHES	WHITE BASE			NO. GRINDS	
LBS.				GALS.	

NO. BATCHES	COLOR BASE			NO. GRINDS	
LBS.				GALS.	

TINTING COLOR	REDUCER	
LBS.	GALS.	

DATE OF LAST BATCH _____

SOURCES OF INFORMATION

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Mattiello, Joseph J., (editor). *Protective and Decorative Coatings*. 5 vols. New York: John Wiley, 1944.

B. Persons Interviewed

Boston Paint and Varnish Company, Everett, Mass.
Alfred Janes, Purchasing Agent

Frank G. Bownes Company, Chelsea, Mass.
J. F. Berstein, Technical Director
D. W. Dean, Director of Public Relations

Carpenter-Morton Paint Company, Everett, Mass.
Gordon Colton, Production Manager
William Holmes, Plant Superintendent

West Paint and Varnish Company, Everett, Mass.
Arthur Anderson, Chief Chemist