1923

FOREST SERVICE PAINT PROBLEMS - II

PAINT PURCHASES

Summary

A thorough discussion is given of the reasons why a rigid paint specification based principally on chemical composition does not insure a good paint and is not an economical basis of purchase. These reasons are in brief: (1) such a specification does not define all the factors which are necessary for the production of a good paint, (2) the buyer is not primarily interested in the composition of the paint, but in its durability, and at the present time the influence of composition on durability is not accurately measurable and is not agreed upon by paint experts, (3) such a specification excludes some very good products and by limiting the field of possible purchase operates to the buyer's economic disadvantage.

A detailed summary is given of the status of our present knowledge of the influence of variations in the different ingredients of paint on its behavior when exposed to the weather. The writer expresses the opinion that the most suitable white paint for Forest Service purposes has a pigment composition of approximately 80 per cent white lead and 20 per cent zinc oxide.

An alternate method of making paint purchases is suggested which has the following advantages: (1) definite standards are established before a purchase is made so that the buyer may know exactly what he is purchasing and check up after delivery to insure compliance with the contract, (2) the entire field of high class paints is open to purchase so that full advantage can be taken of the prevailing market, (3) purchases can be made from the regular stock of the manufacturers instead of on special order, insuring a more carefully standardized product, promptness of delivery, and ease of obtaining further supplies of the same material, (4) the Forest Service business is made more attractive to the better class of paint manufacturers, making it easier to purchase from reliable sources.

The method consists in calling for bids for the quantity of paints in question to be accompanied by statements of their composition and by sample cans of the products. The samples can then be tested for such properties as caking in the can, drying time, drying to satisfactory color and gloss, satisfactory working under the brush, hiding power, absence of flocculation, etc. In addition test panels can be put out with these sample paints which after a few years will give a more definite foundation for the selection of the best paints for Forest Service purposes than we now have. Purchase can then be guided by price, the examination of the samples, and the statement of composition interpreted as best we may in the light of present knowledge of the influence of composition on durability. When shipment is received, the material must equal in every way the sample submitted and show the stated composition when analyzed.

To illustrate the influence that composition should have on the price of paint, the raw materials cost of various paint compositions are computed, as well as a comparison in the cost of a ready mixed lead-zinc paint with the cost of the same paint mixed from white lead in oil, zinc oxide in oil, linseed oil, drier and thinner.

In an appendix a table of "bulking values" of common paint ingredients is given and the method of using them in computing the raw materials cost (to which the retail cost should be proportional) of paints of any given composition is explained. The chemical names and formulas of some of the most common paint pigments are also given as an aid to those not familiar with them in understanding paint formulas which are sometimes expressed in terms of the chemical names instead of the commercial names.

Need for Standards for Forest Service Paint Purchases

District 1 requires 750 gallons of paint annually. Assuming that the remaining western districts have about the same requirements and that Districts 7 and 8 each take about half as much, the total for the Forest Service would amount to over 5000 gallons and cost somewhere around $15,000. Much of this paint is used in places where it is particularly desirable to have the maximum durability possible because their inaccessibility makes it undesirable to paint them more often than absolutely necessary. When allowance is made for the value of the time consumed in applying this paint, the annual paint bill would amount to $30,000 to $45,000. The necessity for adopting some kind of standards to insure the purchase of satisfactory material is at once apparent.

Some of the Districts have felt that the U. S. Interdepartmental Specifications are too broad to be of value for this purpose. The specification for white and tinted paints (Bureau of Standards Circular 89) for example calls for:

	Maximum	Minimum
Pigment	66	62
Liquid (at least 90% pure raw or refined linseed oil)	38	34
Water	0.5	---
Retained by 200 mesh screen	0.5	---

the pigment to consist of:	Maximum	Minimum
White lead (basic carbonate or basic sulfate or mixture)	70	45
Zinc oxide	55	30
Silica, barytes, asbestine, tinting color or mixture	15	0

These specifications have seemed unreasonably broad to some of the Districts with the result that this laboratory has been asked on several occasions to supply more rigid ones. One District has adopted the 50-50 white lead and zinc oxide paint in their specifications. This is unquestionably a mistake.

Difficulties with Arbitrary Specifications Based Chiefly on Chemical Composition

Three fundamental principles in purchasing on specification are that (1) the specification shall define unambiguously the important properties of the material in question, (2) these properties shall be measurable by methods which shall yield the same results when applied by different observers, and (3) unless economy is of no importance, the specification must not exclude products that would be suitable for the purpose in view in order that the buyer may have as wide a field to select from as possible so that he can take full advantage of the market. Now the paint maker sells a can of paint, but what the buyer is interested in is the length of time a dried film of that paint will retain its color and hiding power on a certain surface. This final result is influenced by a number of other factors than the characteristics of the can of paint received from the maker, such as the nature of the surface to which it is applied, the skill with which it is applied, the conditions under which it dries, and the conditions to which it is exposed. These factors are usually more important than the composition of the paint. Since the maker of the paint has no control over these factors a difficulty is immediately introduced in finding suitable means of measuring the value of the paint in a definite and reproducible way.

In the absence of direct methods of specifying and measuring the things in which the buyer is interested and also to get around the obstacle of the length of time required for practical exposure tests, resort is made to the indirect method of specifying the chemical nature and amounts of the substances used in making the paint. These can be measured by acceptable laboratory means and therefore satisfy the second fundamental condition above. It remains to be seen whether they satisfy the first. To do this it is necessary to show that (a) all materials having the same composition are identical in service value, (b) the relation between the composition and the service value is definitely known. Neither of these is the case.

(a) Merely specifying the chemical nature and the proportions of the different components of a paint does not insure its being of good quality. In the first place the quality and suitability for paint manufacture of such materials as zinc oxide, white lead, silica, and barytes may vary very widely according to the control of certain factors in the processes of manufacture. To take a specific case, in the manufacture of zinc oxide the fume is conducted through a long flue and over a series of huge bags where the particles of pigment settle out, the coarsest ones being collected in the first bag and the finest in the last. Now neither the coarsest nor the finest particles are most suitable for paint pigments because the hiding power of the resultant paint is less than is produced by particles of an intermediate size. The size of particles affects another most important property of a paint pigment, namely, the amount of oil necessary to reduce a given amount of pigment to a paint of a given consistency. Again, the "whiteness" of all white pigments varies considerably with variations in minute amounts of impurities present. Thus French process zinc oxide is usually whiter than American process zinc oxide.

In the second place the quality of the resultant paint varies considerably with the care with which the raw materials are worked up into the final paint. To take an extreme case to illustrate the point, no one would expect to be able to make a paint by mixing together in a paint pail with a paddle linseed oil, drier, thinner and dry pigments such as white lead, zinc oxide, and barytes even though these pigments are ground to the proper degree of fineness to begin with. To make good paint the pigments are first ground to a paste with the oil, using heavy paint mills, and the paste then thinned with the rest of the vehicle. This process of paint grinding is not under scientific control, but is an art.

Now these factors of variations in the raw materials and in the manufacturing process are not taken into consideration in the ordinary specification based on chemical composition. It would probably be possible to draw up a specification that would include them all, but it would be so complicated and so expensive to enforce that it would not be practicable. Consequently these important matters of selecting proper raw materials and working them up satisfactorily into paint have to be left to the judgment of the manufacturer. Whether or not the paint is purchased on specification, the reliability of the manufacturer is the only guarantee of quality at the present stage of our paint knowledge.

(b) Surprising as it may seem, the relation between paint composition and its service value is not yet known, although we do know a good deal about the behavior of paints of different composition under different conditions. The reason for this is that we have no accepted measure of the service value of any paint. When paint is applied to a surface it is in its best condition both from the standpoint of appearance and protection during the first few months. Its value in both these respects then begins to fall off slowly and continuously. There is no point at which we can say that it has ceased to function satisfactorily. It is entirely a matter of personal opinion as to when the surface should be repainted. But when it comes to comparing the service value of two paints of different composition, say for example a straight white lead paint with a 50-50 lead and zinc paint, we are confronted with the added difficulty that the two paints fail in altogether different ways and different paint experts will not agree as to which one has failed first.

The following quotations from the reports of different groups of inspectors who examined the 1906, 1907 and 1908 test fences at North Dakota Agricultural College during the fall of 1910 illustrates the divergence of opinion among experts in judging the behavior of different kinds of paint:

"It was clearly demonstrated that in climates of the North Dakota type white lead alone is not entirely satisfactory. The addition of zinc oxide to white lead forms paint that has proven much superior to white lead alone. It was conclusively demonstrated that mixtures of white lead and zinc oxide, properly blended with moderate percentages of reinforcing pigments such as asbestine, barytes, silica, and calcium carbonate, have proved most satisfactory from every standpoint, and are superior to mixtures of prime white pigments not reinforced with inert pigments" - Paint Bulletin No. 1, page 9.

"On the 1906 fence, white lead (basic carbonate) only is giving satisfactory results. On the 1907 fence, the pure white lead (basic carbonate) paints are generally holding up well and are better in general condition and general appearance than any of the other paints. On the 1908 fence, some of the pure white lead paints are chalking noticeably. In the light of the information furnished by the 1906 and 1907 fences, it would appear probable that this chalking of the pure white lead paints on the 1908 fence in comparison with the other paints will be found relatively less in another year" - Paint Bulletin No. 2, page 4.

"Under the conditions of the above tests all white lead pigments require addition of other pigments. Zinc oxide is available for use in moderate proportions. The various inert mineral pigments are capable of advantageous employment in moderate proportions. Equivalent percentages of sublimed and corroded white leads show a greater preservation of elasticity by the former" - Paint Bulletin No. 3, page 12.

The men who have conducted these North Dakota tests from Senator Ladd who started them to Professor Pearce who now has them in charge have always been of the opinion that no paints showed up better than straight white lead from the standpoint of durability. On the other hand Dr. Gardner, who conducted the test fences for the Paint Manufacturers Association believes that the most durable paint contains zinc oxide and inerts in addition to white lead.

Such differences of opinion among paint men have characterized the inspections of all the test fences the results of which have been made public. They are due to the entire absence of any means of measuring the service value of a paint film and to the decidedly different ways in which paint films of different composition behave on weathering.

In view of this situation it is at once apparent why the committee which prepared the U. S. Interdepartmental Specifications was compelled to adopt the broad specification quoted above. The only just criticism that can be made of this specification is that it excludes a number of good paints and therefore violates the third fundamental principle of specification writing given above. The specification does not permit the use of straight white lead paint or paint containing less than 30 per cent zinc oxide. (It should be noted that the New Jersey Zinc Company in their "Mapaz Handbook No. 1" designed to aid the sale of zinc oxide says on page 9, "paint should contain from 20 to 40 per cent zinc oxide.") Moreover the specification does not permit the use of the newer pigments titanox and timonox at all, although there is good evidence that both of these can be used to make a very satisfactory mixed paint.

Influence of Composition on Weathering of Paint Films

While the several paint test fences that have been put out in the past have not settled the question of the best paint composition beyond dispute they have afforded a wealth of information on how paints of different kinds behave under different conditions of exposure. Some of this information will be reviewed very briefly.

White lead

The only white pigment that is ever recommended in this country for use in exterior paints without admixture of other pigments is white lead, principally basic carbonate white lead. Straight white lead paint is usually bought as a heavy paste containing 92 per cent white lead and 8 per cent linseed oil and then is reduced with oil, drier, and thinner by the painter just before application. About a third of the paint used each year in this country is paste white lead. This is consumed for the most part by the master painters, who greatly prefer to make their own paint from the paste because of the greater elasticity it gives them in adapting their paint to particular conditions.

The amount of zinc oxide paste paint sold is considerably less than a tenth of the white lead paste. Recently at least one concern has put a ready mixed paint on the market the pigment portion of which, aside from tinting pigments, consists entirely of basic carbonate white lead.

Straight white lead paints give what is often called a "soft" paint film. White lead paints are also generally considered to adhere strongly to wooden or metal surfaces, and for this reason white lead is a very popular priming coat for both wood and metal. When such paints are exposed to the weather they lose their gloss and begin to chalk after a year or so. They may chalk quite badly for some time and then practically stop chalking for the rest of their life. This chalking is not in itself a particularly serious matter, at least from the standpoint of protection of the surface. With tinted paints, however, it may cause some change in color, and in any case such a surface is more easily discolored by dirt and smoke than a harder paint film. Chalking seems to be increased by climates of high humidity. White lead paints after several years of exposure always show fine checking, but do not scale or peel. They form an excellent foundation for repainting. As shown above, experts do not agree as to their relative durability as compared with harder paints containing zinc oxide or zinc and inerts, but after considering the published records, inspecting the fences at Fargo, North Dakota and Sayville, Long Island, and talking with most of the paint experts who have been prominently associated with such tests, the writer feels that the situation is something like this: The straight white lead paint passes through a stage, after two or three years of service, when, judged by its general appearance (which is all we have to go by), it is in a less favorable state than the zinc containing paints, but on further exposure the difference becomes much less, and no paint will keep the surface covered with a film capable of hiding the surface and imparting color to it for a longer time than straight white lead. The writer is unable to give an opinion as to which kind of paint fails soonest from the standpoint of protection of the surface as he knows of no way of measuring it. He does not feel that the time required for the painted surface to lose its gloss is any measure of this property, as has been suggested.

Sublimed white lead does not differ very greatly from basic carbonate white lead as far as the behavior of the paint film is concerned. It probably chalks a little more readily and checks slightly less. The quick process leads also behave very similarly to basic carbonate made by the Dutch process.

Before leaving white lead it should be mentioned that besides good adhesion, white lead is usually said to impart "elasticity" to the paint film. It has been found that the moisture content of a dried paint film varies considerably with the humidity of the atmosphere to which it is exposed and that the tensile strength and elastic modulus are greatly affected by the moisture content of the film. In particular, a "hard" paint film containing much zinc is very brittle at low moisture contents, while a straight lead film is very much less brittle under these conditions. This gives a theoretical foundation to the observed fact that more zinc can be safely used in paint exposed continuously to atmospheres of high humidity than when the paint is used in dry climates.

Zinc oxide

Zinc oxide alone as a paint pigment is not used, in this country at least, for a number of reasons. Its high oil requirement gives a paint which brushes out to a very thin coating, leaving very little pigment per unit of area and consequently having too little hiding power. The dried paint film is very hard and brittle and fails relatively quickly by cracking and scaling, leaving a surface that is not in good condition for repainting. These objections can be overcome by the choice of suitable vehicles and it is said that such paints are used in France, but they have never been of any importance in the United States.

Addition of zinc oxide to white lead paint cuts down the chalking and gives a surface which retains its gloss longer, holds its tint better, and is not so easily soiled. For these reasons, after two or three years of service it may appear to be in better shape than straight white lead paints. As stated above, however, the writer does not think that there is any reason to believe that the addition of zinc prolongs the useful life of the paint. On the other hand, the use of more than a certain amount of zinc undoubtedly cuts down the durability. Opinions differ as to what the optimum zinc content is. The New Jersey Zinc Company, the largest producer of zinc oxide, places it between 20 and 40 per cent, recommending about 30 per cent. Dr. Pearce of North Dakota told the writer that he felt that for North Dakota climate, not more than 20 per cent should be used. John Dewar, a prominent master painter, told a recent meeting of master painters that it is good practice on the Atlantic seaboard to prime with straight white lead and use about 25 per cent zinc oxide in the finishing coat.

Inert pigments

A few years ago the theory of "minimum voids" proposed by R. S. Perry was rather widely heralded as a fundamental law on which a paint science could be based. The theory likened paint to concrete in which we have particles of various size, namely sand, gravel, and crushed rock suspended in a solid matrix of cement, and find the greatest strength when the proportions of the components of various sizes are so adjusted as to give a minimum of "voids" to be filled up by the cement. Applying this to paint, it was considered that best results would be obtained with a mixture of pigments consisting of very fine particles such as zinc oxide, coarser particles such as white lead, and still coarser particles such as the inerts. This theory was particularly popular because it seemed to justify the use of inert pigments on other grounds than economy. At the present time, however, the theory seems to have been very largely abandoned by paint experts.

The inert pigments, such as silica, barytes, blanc fixe, calcium carbonate and asbestine, are used in the manufacture of ready mixed paints for several purposes. They tend to keep the pigment in suspension more satisfactorily and to prevent "caking in the can." Their differences in oil requirements give the manufacturer certain valuable advantages in adjusting the consistency of the paint in relation to the pigment oil ratio. The chief advantage of the inert pigments, however, is their cheapness, This is a perfectly legitimate reason for employing them in paint manufacture, provided there is no misrepresentation involved in the sale of such paints. Some large paint manufacturers also find it advantageous to use the inerts because they can hold their manufacturing costs more nearly constant during fluctuations in the raw materials markets by adjusting the content of inerts.

The inert pigments impart practically no hiding power to the paint film, consequently the hiding power of a paint is reduced in proportion to the amount of inerts present. This at once places a limit on the amount that can be employed in a good paint. But in addition it is universally agreed that the durability of the paint film is cut down if the content of inerts is increased beyond a certain point. It is of course impossible to obtain any very substantial agreement among paint experts as to where this point lies, but some light is thrown upon this question by the writer's experience in consulting a meeting of paint chemists at Dr. Gardner's laboratory last spring on the question of the best formula to choose for the mixed paint in our "Study of the Painting Characteristics of Different Kinds of Wood." We proposed to use a pigment composition of 45 per cent white lead, 40 per cent zinc oxide, and 15 per cent inerts as being the paint that differs most widely in behavior from straight white lead and is still in accordance with the Interdepartmental Specification. All of the paint men consulted were of the opinion that a more durable paint would be obtained by keeping the inert content under 10 per cent.

A few years ago many paint experts believed that the addition of a limited amount of inert pigments added to the life of the paint. The writer feels that at the present time, however, this view has been largely abandoned and the question at issue has shifted to how much can be added without noticeably reducing the durability.

The above discussion of inerts in paint is not to be confused with the presence of barium sulfate in certain pigments such as lithopone, titanox and timonox paints in which the barium sulfate is an integral part of the pigment. In the case of lithopone the barium sulfate is formed simultaneously with the zinc sulfide by mixing solutions of zinc sulfate and barium sulfide. In the cases of titanox and timonox the titanium oxide or antimony oxide is precipitated in the presence of the barium sulfate. The amount of barium sulfate in these pigments is generally from 70 to 80 per cent, but the barium sulfate particles are believed to be coated with a film of adsorbed titanium oxide, zinc sulfide, or antimony oxide so that the latter substances control the behavior of the pigment.

The newer white pigments

Titanox and timonox have only recently become of importance in the paint industry. The former is being exploited by several American manufacturers and the latter is an English product. Titanium oxide and antimony oxide are far superior in hiding power to zinc oxide and white lead, but if used alone would be too expensive. When precipitated on a base of barium sulfate, which may form as much as 80 per cent of the total pigment, pigments of hiding power equal to the older pigments are obtained.

Titanox when used alone in paint gives a "soft" film that chalks badly. Addition of zinc oxide hardens the film and gives a very durable paint. It is said that titanox paints will permit the admixture of as much as 60 per cent inerts and still give a very satisfactory paint. Since this pigment has been introduced so recently it is not yet possible to say exactly how it can be best employed or how its durability compares with the older paints, but the present status of the numerous exposure tests indicates that it will prove very satisfactory.

Lithopone

Lithopone has been used practically exclusively for interior purposes because of its tendency to turn dark in sunlight and its lack of durability for exterior exposure. The first objection has been overcome by improved manufacturing methods and the New Jersey Zinc Company has been experimenting extensively on methods of improving its durability for exterior purposes. They report that the indications are that ways may be found of using it satisfactorily for such purposes.

Drying oils

Linseed oil is by far the most important drying oil used for paint manufacture, but it is not the only oil that is suitable for such purposes. Dr. Gardner has published information concerning a long list of such oils which would be suitable if available in sufficient quantities. It is not at all improbable that some of these may become important in the future, but at the present time only soya bean oil and to a much lesser extent perilla oil find any practical use. Menhaden oil is used for certain specialties, but not much for general house paints, although its slow drying and frequently its undesirable odor are the only objections to it as it gives an exceedingly durable paint film. Perilla oil is generally considered the equal of linseed oil as it has a higher iodine number, dries as rapidly, and has proved equally satisfactory in practical paint tests. If it ever becomes available in important amounts it should be recognized in a good paint specification. Soya bean oil does not have as high an iodine value as linseed oil and does not dry as rapidly. It should not be used alone as a paint oil, but when mixed with linseed oil in proportions as high as 50 per cent it behaves very satisfactorily and has given excellent results in practical exposure tests.

It should always be remembered that it is to the buyer's advantage to maintain as wide a source of supply as possible because this tends to give him the advantage of the market. A specification which limits the source of supply unnecessarily tends to give that advantage to the seller.

Linseed oil from North American seed is generally considered more desirable than that from South American seed. The Interdepartmental Specification (Bureau of Standards Circular 82) allows an iodine number as low as 170 for the South American oil but requires a minimum of 180 for North American. Oil with an iodine number under 178 is slower drying. At the present time, however, the paint industry has to rely very largely on South American linseed oil.

With paints containing a large amount of zinc oxide it is desirable to use oil having low acid number. The Interdepartmental Specification permits a maximum acid number of 6.0, but for a paint containing more than, say 30 per cent of zinc oxide in the pigment portion, an oil with an acid number less than 4.0 should be used. Alkali refined linseed oil is particularly suitable for this purpose. The reason for this is that zinc oxide is the most chemically active of the common paint pigments and combines readily with the free fatty acids of the oil to form zinc soaps, whose solubility in the paint vehicle is limited. The lead soaps are much more soluble.

Thinners

The function of the thinner in paint is to reduce the mixture of pigment and oil to a suitable consistency for application by means of the brush. Moreover it is commonly considered that a paint vehicle which has been reduced in viscosity by the addition of thinner is absorbed more readily by the wood and therefore serves to attach the paint film more firmly to the wood. In certain special cases where the wood contains large amounts of certain oils or resins it is said that a thinner having good solvent power for these materials, such as benzol or turpentine, helps to fix the paint more firmly to the surface. Having done its work the thinner evaporates completely from the paint film and therefore exerts no further influence on the durability of the paint.

The rate of evaporation of the thinner has a practical significance in paint making because a too highly volatile thinner leaves the film too quickly and results in brush marks and laps unless the painter is unusually skillful. It is also likely to have a low flash point, thereby increasing the fire risk.

Although turpentine used to be used practically exclusively as a paint thinner it has been largely replaced by certain special petroleum distillates cut to have approximately the same boiling point range and consequently volatility as turpentine. This substitution is due chiefly to the higher cost of the turpentine. It is a perfectly proper one because the "mineral spirits" serves the purposes of a paint thinner as well as turpentine.

For the special cases of certain oily or resinous woods mentioned above it may be desirable to thin the priming coat with either benzol or turpentine. Since the great majority of the thinner for the priming coat is added to the paint taken from the can anyway, this matter need not be taken into consideration in purchasing the paint.

The statement is sometimes made that turpentine acts as a drier in paint. While it is true that certain turpentines, particularly highly oxidized ones, do accelerate the oxidation of linseed oil slightly, this action is insignificant in comparison with that of the lead and manganese driers which are employed, and is therefore of no consequence. Such oxidized turpentines also leave a slight amount of a resinous material behind in the paint film, but there is no evidence to show that it plays any part in the durability of the paint.

Driers

The amount of driers used in paint should be limited to a quantity sufficient to bring about the drying of the oil in a reasonable length of time, say 18 hours. Excessive amounts seriously cut down the durability of the paint.

Recommended System for Forest Service Paint Purchases

The purchasing agent will invite bids for the required quantities of paints of specified colors. These bids are to be accompanied by complete statements of the composition of the paints including the nature and amounts of the different pigments, of the drying oils, and of the thinners, and the relative amounts of total pigments, oils, and thinners. A quart can of the paint which the bidder proposes to furnish is also to be submitted.

The sample cans of paint furnished can be tested for caking in the can, drying time, drying to satisfactory color and gloss, satisfactory working under the brush, hiding power, absence of flocculation, etc. In addition, for guidance in making future purchases, two or three wooden test panels, of the species most commonly painted in the District in question, could be painted with each sample of paint and exposed at some convenient location, preferably one that has climatic conditions similar to those commonly encountered in the District. After keeping records of such tests for four or five years the Districts would then have their own exposure records from which to form a judgment of the kind of paint they think most suitable for their own needs instead of having to rely upon the conflicting opinions of different paint experts based upon test fences in other parts of the country.

On the basis of the information furnished by the Bureau of Standards, this laboratory, or such other sources of information they may wish to consider, the Districts will decide what paint composition is most suitable for their purposes. The paint submitted which comes nearest to this standard will be accepted, provided that the sample has passed the tests mentioned above satisfactorily and provided further that none of the other paints are much cheaper in price. Where other paints offered are notably lower in price, however, it will be necessary to decide whether the more expensive paint is sufficiently superior to justify the difference in price.

In this connection the following considerations of the raw material cost of paint of various compositions will be of interest. The computations are based on the pigment-vehicle ratios given in Circular 142 of the Paint Manufacturers' Association and the Chicago market report for November 5, 1923, as published in the American Paint Journal. The liquid portion of the paint is assumed to consist of 90 per cent raw linseed oil and 10 per cent combined drier and petroleum thinner. In order to include a typical cheap paint, the Sears and Roebuck "outside white" paint has been included, the formula for which is given in their paint catalog. The bulking values of the various pigments are taken from Circular 148 of the Paint Manufacturers Association. It must be remembered that these are raw material costs only and do not include the cost of grinding and mixing the paint, manufacturer's and jobber's overhead, packing, transportation, and profits. The costs to the consumer would probably be at least double the raw material costs, but all these latter costs are independent of the composition of the paint. The raw material costs on which the figures are based are:

Raw linseed oil	$0.82 per gallon or 0.106 per pound.
Silica $16 a ton or	0.008 per pound
Zinc oxide, Green seal	0.110 per pound

Sublimed white lead	$0.0875 per pound
Basic carbonate white lead	$0.0925 per pound
Drier and thinner	0.30 per gallon (assumed)
Whiting $16 a ton or	0.008 per pound
Barytes $26 a ton or	0.013 per pound
Talc $16 a ton or	0.008 per pound

<u>All lead paint:</u>

100 lbs. white lead paste (8% oil)	2.65 gallons	
Pigment cost 92 x 0.0925 =		$8.50
Oil in paste 8 x 0.106 =		0.85
Requires 4 gallons of oil liquids	4.00	
Linseed oil 3.5 x 0.82 =		2.87
Thinner and drier 0.5 x 0.30 =		0.15
Total 131 pounds of material	6.65	)12.37
		1.86 per gallon

This paint contains approximately 70 per cent pigment and 30 per cent liquids and is correct for third coat work. It weighs 19.7 pounds per gallon.

<u>All zinc paint:</u>

100 lbs. zinc oxide paste (18% oil)	4.05 gallons	
Pigment cost 82 x 0.110 =		$9.02
Oil in paste 18 x 0.106 =		1.91
Requires 8 gallons of oil liquids	8.00	
Linseed oil 7 x 0.82 =		5.74
Thinner and drier 1 x 0.30 =		0.30
Total 162 pounds of material	12.05	)16.97
		1.41 per gallon

This paint contains approximately 50 per cent pigment and 50 per cent liquids and is correct for third coat work. It weighs 13.5 pounds per gallon.

50-50 lead and zinc paint:

100 lbs. composite paste (20% oil) 4.12 gallons

White lead cost	40 x 0.0925 =	$3.70
Zinc oxide cost	40 x 0.110 =	4.40
Oil in paste	20 x 0.106 =	2.12

Requires 4.25 gallons of oil liquids 4.25

Linseed oil	3.58 x 0.82 =		2.94
Thinner and drier	0.67 x 0.30 =		0.20
Total 133 pounds of material		8.37	)13.36
			1.60 per gal.

This paint contains approximately 60 per cent pigment and 40 per cent liquids and is correct for third coat work. It weighs 15.9 pounds per gallon.

Composite pigment containing 45% lead, 45% zinc, 10% silica:

100 lbs. composite paste (25% oil) 4.87 gallons

Silica cost	7.5 x 0.008 =	$0.06
Zinc oxide cost	33.8 x 0.110 =	3.72
White lead cost	33.8 x 0.0925=	3.13
Oil in paste	25 x 0.106 =	2.65

Requires 3.25 gallons of oil liquids 3.25

Linseed oil	2.6 x 0.82 =		2.13
Thinner and drier	0.65 x 0.30 =		0.20
Total 125 pounds of material		8.12	)11.89
			1.46 per gal.

This paint contains approximately 60 per cent pigment and 40 per cent liquids and is correct for third coat work. It weighs 15.4 pounds per gallon.

Sears, Roebuck Paint:

Composition in weight per cent		Bulk in gallons	Cost dollars
Sublimed white lead	25.0	0.468	2.188
Zinc oxide	8.3	0.176	0.913
Whiting (calcium carbonate)	23.3	1.033	0.186
Barytes (barium sulfate)	6.7	0.181	0.086
Talc (magnesium silicate)	5.0	0.211	0.040
Linseed oil	27.5	3.542	2.915
Naphtha drier	2.2	0.329)	
Naphtha	2.0	0.310)	0.192
	100.0	6.250	6.520
			1.04 per gal.

Weight per gallon 16.0 pounds.

Assuming now that the cost to the consumer is about twice the raw material cost, the prices that would have to be paid for these paints, other things being equal, are as follows:

Sears, Roebuck paint	$2.08 per gallon
Straight zinc paint	2.82 "
45 Lead - 45 Zinc - 10 inert paint	2.92 "
50 Lead - 50 Zinc paint	3.20 "
80 Lead - 20 Zinc paint	3.54 "
Straight lead paint	3.72 "

Inquiry at local paint stores on November 22, 1923, shows that the retail price of Devoe and Reynolds 50 lead - 50 zinc paint is $4.00 per gallon, and Patek Brothers paint composed of 65 lead-25 zinc- 10 silica is the same price. Buying in larger lots the prices would probably be more nearly as indicated above. The local price for white lead in oil on the same day was $14.75 per 100 pounds, for linseed oil $1.25 per gallon, and we recently paid $0.21 per pound for a 25 pound keg of Mapaz zinc oxide ground in oil. The cost of making a 50-lead-50-zinc paint containing 60 per cent pigment and 40 per cent oil on the basis of the above figures would be:

White lead in oil	47 lbs. or 1.25 gals.		$ 6.94
Zinc oxide in oil	53 lbs. or 2.15 gals.		11.13
Linseed oil (drier and thinner)		6.5 gals.	8.10
		9.90	)26.17
			2.64 per gal.

and for the 80 lead - 20 zinc paint containing 66 per cent pigment:

White lead in oil	78 lbs. or 2.07 gals.		$11.51
Zinc oxide in oil	22 lbs. or 0.89 gals.		4.62
Linseed oil (drier and thinner)		4.61 gals.	5.78
		7.57	)21.91
			2.90 per gal.

The mixed paint manufacturers insist that paints made in this way from the pigments ground in oil, linseed oil, drier, and thinner are inferior to the ready mixed paint having the same composition. The master painter and the white lead manufacturers of course hold the contrary opinion. The writer can see no reason for any difference between paint made in these two ways because the grinding of the pigment in the oil takes place in the manufacture of the paste. This paste is then thinned by adding more vehicle. It seems immaterial whether this last operation is performed by the paint manufacturer or by the painter. Hence it is apparent that we are paying about $4.00 less $2.64 or $1.36 per gallon for the convenience of getting our paint ready mixed in the can. When we consider that for proper painting we have to add oil and thinner to make the first and second coat paint anyway, this convenience is not a very great one.

It is generally customary to figure the cost of labor in applying paint as twice the cost of the paint. We shall take this as $6.00 per gallon. Hence, if we assume, rather arbitrarily it is true, that the straight zinc and the Sears Roebuck paint will last four years, the 50-50 lead-zinc and the lead-zinc-inert paints five years and the others six years, we find that the cost per gallon per year would be:

80 lead - 20 zinc paint	$1.59	per	gallon	per	year
Straight lead paint	1.62	"	"	"	"
Lead-zinc-inert paint	1.78	"	"	"	"
50 lead - 50 zinc paint	1.84	"	"	"	"
Sears Roebuck paint	2.02	"	"	"	"
Straight zinc paint	2.21	"	"	"	"

We may as well consider that the spreading rates of the different paints are the same because, while a given painter will spread one over more surface than another, a second painter may do just the opposite. The assumptions made in regard to the durability of the different paints are entirely arbitrary for reasons that have already been discussed and represent merely the rough estimate of the writer based upon his views of how paint should fail and how soon it should be repainted. For Forest Service purposes, however, much consideration should be given to the fact that paints containing much white lead tend to leave a better surface for repainting than those high in zinc and inerts.

It will be noticed that if the writer's estimates of the durability of the different paints are approximately correct and if the selling prices of paints were proportional to the manufacturing cost, the spread in the costs per gallon per year is not nearly as great as the spread in the original costs per gallon. The Sears Roebuck paint was selected for these calculations because it has the reputation of being a very good paint in its class. It will be noted that while 48.7 per cent by weight of the pigment portion of this paint consists of true pigments, a consideration of the bulk occupied shows that the true pigments occupy only 31.5 per cent of the total volume of pigments. The hiding power of this paint must necessarily be low and for this reason if for no other it will require repainting sooner. However, if it lasts five years against six for straight lead paint, its cost per gallon per year will be the same, $1.62. This is probably an overestimate of its durability. Where the labor charges can be neglected, as for example in the case of a householder or farmer repainting his house in his spare time, this paint will cost less than any of the others per gallon per year if it lasts only four years, the value being $0.52 against $0.58 for the lead-zinc-inert and $0.59 for the 80 lead-20 zinc paint. There is a wide field in which such paints are really economical, provided the selling price is in proportion to the raw material costs and that they are made by reliable manufacturers.

We may now consider further the question of how much more the purchaser is willing to pay for the paint of his choice than he would have to pay for other paints that are offered. If the above estimates of the durability of the different paints were accurate this would be a simple matter and could be expressed as follows:

Let C be the cost of the cheapest paint in the six year class in dollars per gallon

" X be the maximum price that could be paid for a paint in the five year class

" P be the cost of applying the paint

$$\text{Then} \quad \frac{X + P}{5} = \frac{C + P}{6}$$

$$\text{or} \quad X = \frac{5C - P}{6}$$

Obviously the result depends very largely on the estimated cost of applying the paint; the higher this is the greater must be the price differential against the more durable paint. These considerations, however, attribute an altogether unjustifiable accuracy to the above guesses concerning the durability of the different paints.

A more practical procedure is to establish two classes of paint based on the pigment composition with an arbitrary price differential between them. The following are suggested:

Class A	Maximum	Minimum
Pigment consisting of		
White lead (basic carbonate or basic sulfate or mixture) -	100	60
Zinc oxide -	30	--
Inert -	10	---
Liquid to consist of at least 90 per cent linseed oil (or suitable drying oil) and to be 30 to 36 per cent of the total paint by weight		

Class B		
Pigment consisting of		
White lead	70	45
Zinc oxide	55	30
Inert	15	--
Liquid to consist of at least 90 per cent linseed oil (or suitable drying oil) and to be 34 to 38 per cent of the total paint by weight.		

This class is to include also titanox or similar paints made by reputable manufacturers.

A price differential of about $1.00 per gallon between class A and class B paints is suggested. This would mean that the lowest priced paint in class A would be purchased unless the lowest one in class B were more than $1.00

cheaper, in which case the latter would be ordered. This price differential is slightly greater than the difference between the cheapest class B and the most expensive class A paint at present market prices and computed on the basis of the raw material costs as above.

It should be noted that this division into class A and class B paints is intended only for the guidance of the purchasing agent in selecting a paint from those offered and is not to be used as a specification to be submitted to the manufacturers as the basis for bids.

When the shipment of the paint purchased has been received it must match in every respect the sample previously submitted with the bid, and chemical analysis must show that it conforms to the manufacturer's statement of composition.

Testing of Paint Purchased

Any system of purchasing paint which involves an agreement as to composition between buyer and seller requires that the buyer test the material received to see that the contract has been carried out. The amount of such testing will probably be less under the system of purchase herein proposed than when arbitrary chemical specifications are used because in the former method the paints purchased will be usually the standardized product of the manufacturers while in the latter case they are likely to be specially made or "specification paints". But in either case, the Districts should make arrangements for the testing of their paint supplies.

APPENDIX

Method of Computing Raw Material Cost of Paint from the Composition

The raw materials cost of any paint can be quickly computed if the composition, the cost of the different ingredients, and their bulking values are known. The bulking values are the volumes in gallons occupied by one pound of the ingredients in the finished paint and are obtained by multiplying the true specific gravity by 8.33, the weight of a gallon of water. A table of the bulking values of some of the important paint materials taken from Circular 148 of the Educational Bureau of the Paint Manufacturers' Association of the United States is given below. The wholesale prices of the raw materials can be obtained from the weekly market reports of such trade journals as the "Oil Paint and Drug Reporter", (100 William Street, New York City, $5.00 a year) and the "American Paint Journal", (3713 Washington Boulevard, St. Louis, $2.00 a year).

To explain the method, let us take the practical example of the following paint:

Basic carbonate white lead	45 %	
Zinc oxide	40 %	
Silica	15 %	
Pigment portion	100 %	60 %

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Raw linseed oil	90%	
Mineral spirits	5%	
Liquid drier	5%	
Liquid portion	100%	40%

The compositions are first converted from percentages of pigment and liquid portions respectively to percentages of the total paint by multiplying the pigment ingredients by 0.60 and the liquid ingredients by 0.40, giving the number of pounds of the different ingredients in 100 pounds of paint as follows:

	Pounds in 100 lbs. of paint	Bulking value (per lb.)	Bulk in paint (Gals.)	Cost per pound or gallon	Cost in 100 lbs. of paint
White lead	27.0	0.01763	0.476	0.09255	2.50
Zinc oxide	24.0	0.02121	0.509	0.1100	2.64
Silica	9.0	0.04531	0.408	0.0080	0.07
Linseed oil	36.0	0.1288	4.638	0.82	3.80
Mineral spirits	2.0	0.1549	0.310	0.30	0.09
Drier	2.0	0.1497	0.299	0.30	0.09
	100.0		6.640		9.19
					1.38 per gallon

In the next column are given the bulking values per pound of these materials. Multiplying the pounds by the bulking values gives the bulk of each material in the paint and the sum of these, or 6.661 gallons, is the total volume of paint. The weight per gallon is therefore $\frac{100}{6.661}$ or 15.0 pounds. In the fifth column is given the cost per pound for the solids and per gallon for the liquids. Multiplying in the case of the solids by the weights (column 2) and in the case of the liquids by the volume (column 4) gives the cost of the materials in 100 pounds of paint, given in the last column. The sum of these is the cost for materials in 6.661 gallons, so that the cost per gallon is $1.38.

In the manufacture of paint there is a loss due to volatilization, wetting of stones and containers, etc. which is usually figured at 2 per cent but has been neglected throughout this report.

Table of Bulking Values

	Specific gravity	Weight per solid gallon pounds	One pound bulks, gallons
Raw linseed oil	0.932	7.764	0.1288
Boiled linseed oil	0.942	7.847	0.1274
Raw soya bean oil	0.929	7.739	0.1292
*Liquid paint drier	0.85	6.681	0.1497
Turpentine	0.867	7.222	0.1385
*Mineral spirits	0.775	6.456	0.1549
Benzol	0.882	7.347	0.1361
Benzine (62°)	0.745	6.206	0.1611
Solvent naphtha (160°)	0.902	7.514	0.1331
Basic carbonate white lead	6.81	56.73	0.01763
Basic sulfate white lead	6.41	53.40	0.01873
Zinc oxide	5.66	47.15	0.02121
Zinc oxide, leaded 35%	5.95	49.56	0.02018
Lithopone	4.30	35.82	0.02792
Titanox	4.30	35.82	0.02792
Asbestine	2.85	23.74	0.04212
Barytes	4.45	37.07	0.02698
China clay	2.62	21.82	0.04583
Silica	2.65	22.07	0.04531
Talc	2.84	23.66	0.04227
Whiting	2.71	22.57	0.04431
Ochre	2.80	23.32	0.04288
*Venetian red (20% Fe_2O_3)	3.05	25.41	0.03935
Indian red (90% Fe_2O_3)	4.92	40.98	0.02440
Sienna, raw	3.27	27.24	0.03671
Sienna, burnt	3.95	32.90	0.03040
Umber, raw	2.68	22.32	0.04480
Umber, burnt	3.80	31.65	0.03160
Red lead	8.80	73.30	0.01364
*Chrome green, C.P.	3.90-5.08	-	-
*Chrome yellow, C.P.	6.0	-	-
Lampblack	1.78	14.83	0.06743
Carbon black	1.81	15.08	0.06631
Drop black	2.64	21.99	0.04548

* These materials vary considerably in specific gravity.

CHEMICAL NAMES AND FORMULAS OF SOME COMMON PAINT PIGMENTS

Commercial Article	Chemical Name of Chief Component	Chemical Formula
Basic carbonate white lead	Basic lead carbonate	$2PbCO_3 \cdot Pb(OH)_2$
Basic sulfate white lead	Lead sulfate and lead oxide, usually contains some zinc oxide	($PbSO_4$, about 75% (PbO about 20% (ZnO about 5%
Zinc oxide	Zinc oxide	ZnO
Lithopone	Zinc sulfide and barium sulfate	(ZnS 29.5% ($BaSO_4$ 70.5%
Titanox	Titanium dioxide and barium sulfate	(TiO_2 15 to 30 % ($BaSO_4$ 85 to 70 %
Asbestine	Magnesium silicate	$MgSiO_3$
Talc	Magnesium silicate	$MgSiO_3$
Barytes	Barium sulfate	$BaSO_4$
Blanc fixe	Barium sulfate	$BaSO_4$
Clay	Aluminum silicate and Silicon dioxide	($Al_2(SiO_3)_3$ (SiO_2
Silica	Silicon dioxide	SiO_2
Whiting	Calcium carbonate	$CaCO_3$
Ochro	Iron oxide (ferric oxide) and clay	(Fe_2O_3 about 10 to 30%
Sienna	Iron oxide and clay	Fe_2O_3 about 25-60%
Umber	Clay containing iron oxide and manganese dioxide	(Fe_2O_3 about 25% (MnO_2 about 5%
Venetian red	Ferric oxide and calcium sulfate	(Fe_2O_3 20 to 40% ($CaSO_4$ 80 to 60%

Commercial Article	Chemical Name of Chief Component	Chemical Formula
ndian red	Ferric oxide	Fe_2O_3 about 90%
ed lead	Lead oxide	Pb_3O_4
hrome yellow, C.P.	Lead chromate	$PbCrO_4$
russian blue	Ferric Ferrocyanide	$Fe_4[Fe(CN)_6]_3$
hrome green, C.P.	Mixture of Prussian blue and chrome yellow	