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THE UNIVERSITY OF LOUISVILLE

ETHYL CELLULOSE MODIFIED
EXTERIOR HOUSE PAINTS

A Thesis
Submitted to the Faculty
of the Graduate School
in Partial Fulfillment of the
Requirements for the Degree of

MASTER OF
CHEMICAL ENGINEERING

Department of Chemical Engineering

By
Hugo Louis Schaefer Jr.

1939

ETHYL CELLULOSE MODIFIED
EXTERIOR HOUSE PAINTS

Approved by Examining Committee:

Director
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Approved for English:

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June 6, 1939

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INTRODUCTION

The purpose of this investigation was to show the effects of the introduction of ethyl cellulose in exterior two-coat house paints.

The paints were prepared using as vehicles soyabean, linseed, and perilla oils into which were cooked different percentages of ethyl cellulose. The pigment formulations were the same for primers and topcoats respectively.

Various tests were made to show the effects of ethyl cellulose on those properties of house paints which are important from the standpoint of both the manufacturer and the consumer. The effects produced were obtained by:

1. The determination of the hiding power and gloss of the prepared samples.
2. The determination of the penetration of the exterior wood primers.
3. The determination of the brushing, sagging, and leveling properties.
4. The determination of the hardness and freedom from tack of the various paints.
5. The determination of the toughness of the paints when thoroughly dry.
6. The determination of the weatherability of the samples when exposed under ordinary conditions of temperature and humidity.

The experimental results obtained from these tests were given to show the beneficial or detrimental effects produced when ethyl cellulose was incorporated in the vehicle.

HISTORICAL

The history of art and pigmentation seems to have originated in Egypt. Excavations in Chaldaea by Americans in 1896 revealed monuments that carried dates back to 4000 B.C. Traces of color were present in all the mounds, with red, blue, and yellow predominating (16).

By the time of the Roman Supremacy there were several so-called white pigments known. However, all these were white earths of some sort and not pigments as we know them today. These earths were applied by mixing with glue, white of egg, or gums.

In the eighth century Gebir, an Arabian alchemist, was said to have been well acquainted with white lead.

The use of linseed oil as a vehicle dates back as far as the tenth or eleventh century when instructions were given in the writings of Theophilus for the preparation of varnish from linseed oil and gum. Directions for refining oil occur as early as 1350 and the use of driers has been known since the fifteenth or sixteenth century.

At the time of the colonization of America the use of paint as a preservative was not common. The oldest wooden buildings in American cities and towns are still unpainted.

It was not until after the Revolution that paint as a preservative came into general use. It was

usually a coarse red mixture and the manner still remains in the fashion of painting barns and outhouses red.

The first white lead factory was established at Philadelphia late in the eighteenth century and the manufacture of zinc white was begun as early as 1850.

The manufacture of mixed paints has been accredited to some New Englanders who observed that when a linseed oil paint was mixed with a solution of silicate of soda an emulsion was formed, and the paint so made showed very little tendency to settle in the package. The first mixed paint was marketed in small packages for home consumption and appeared about 1865 (10).

The general use of zinc oxide has had much to do with the progress of mixed paint, for it is well known that white lead and linseed oil settle quickly in the package while zinc oxide keeps the heavier lead in suspension longer.

Until the recent introduction of specially designed primers and topcoats, house painting practice has changed very little since the first use of "ready mixed" paints.

THEORETICAL

An exterior house paint may be defined as a protective coating for the preservation of surfaces exposed to the weather. It consists, briefly, of a pigment, an oil or vehicle, a thinner or diluent, and a drier. A paint therefore contains both volatile and non-volatile constituents.

Practically all commercial paints contain more than a single oil and a single pigment, because any one oil or pigment does not possess all the properties required for the production of a coating that will prove satisfactory to the ultimate consumer.

The most common of all exterior painting systems has been the type in which two or three coats of the same paint were applied over the surface to be painted. There were many rather obvious disadvantages to this system.

Within recent years there have been introduced specially designed primers and topcoats. These paints are two quite different types of coatings, both the pigments and vehicles varying as to type and formulation. This system has since become known as the "Two-Coat System" and is rapidly gaining popularity.

Briefly, the "Two-Coat System" is built upon the fact that the coating placed next to the wood has a very definite function to perform and is quite different

from that performed by the coating exposed to the atmosphere. Since the functions performed by the upper and lower coatings are different, then it is evident that the compositions of these coatings will also differ.

The function of a "Two-Coat System" is for it to combine ease of brushing, leveling, rapid drying, adhesion, and elasticity with film failure of a type that will give the most satisfactory surface for repainting.

All white paints prepared were made according to the "Two-Coat System", with the exception that a single vehicle was used for both primer and topcoat. This was necessary for comparison purposes.

Of the non-volatile or permanent film-forming materials in the paint, the oil or vehicle actually gives the resultant film the properties characteristic of the finish. The presence of pigments or resins has an effect but does not change, fundamentally, the mechanism that takes place (3).

Essentially a drying oil is a mixture of mixed triglycerides of fatty acids such as stearic, oleic, linoleic, linolenic, and so forth. When a drying oil is exposed to the air, it undergoes several changes which, according to Long (4), may be divided into four separate stages. These stages are not distinct but overlap and to some extent take place simultaneously. They

are as follows:

1. Induction Period -- This is a formative period in which oxidation plays an important role although the chemical changes used to characterize it are not yet in evidence.

2. Formation of Colloidal Nuclei Sols(micelles)
In this stage the molecules of the oil are gradually arranged and joined to each other in a definite fashion thus building the primary structure called the nucleus or micelle. The most important change is the decrease in the number of free double bonds left in the oil. The change is thought to take place somewhat as follows:

3. Coagulation and Solvation with consequent "set" to a solid gel -- The ability of the oil to dry or set is dependent on the presence of double bonds (ethylene linkages). Those containing four double bonds dry faster than those with three and so forth.

4. Subsequent changes in the solid gel film -- The changes in this stage are associated with the transition of liquid phase to solid and the weakening of the double-bonded structure as it adsorbs relatively inactive constituents such as water and

non-oxidizing materials. Over a long period of time this results in loss of elasticity and finally in cracking and failure.

Soyabean oil is not ideal for use in paint because of its poor drying qualities, but it possesses the excellent characteristics of permanent elasticity and freedom from discoloration. The relatively slow-drying of soyabean oil limits its use as the sole vehicle for air-drying exterior paints where the temperature conditions are variable and never ideal (11).

The popularity and utility of linseed oil have been assured by years of successful performance, and complete substitution by any other oil is questionable, except as the substitute oil approaches linseed in properties (11).

The high degree of unsaturation of perilla oil causes it to dry quickly and hard, and its film possesses good gloss and weather resistance, but its performance is peculiar, especially in air-drying finishes.

Although the film produced by a drying oil is considered as a protective coating for exposed surfaces, it is far from being perfect. Recently a cellulose derivative - ethyl cellulose - has been incorporated in drying oils and varnishes with the idea of producing properties not obtainable in the original oil or mix-

tures of it with other oils. It shortens the drying time, decreases surface tackiness, and provides harder, more elastic, and tougher finishes (15). This has caused a consideration of its use in exterior house paints.

According to Sherk and Peterson (9),

.....When ethyl cellulose is properly incorporated in a drying oil or varnish, the molecules of ethyl cellulose are considered to form a network which acts as a support for the wet film and as a binder for the dry film. Such a composition should provide quicker set-up and faster drying of an oil or varnish film, and should increase the toughness of the film after drying. This has been found to be true if the ethyl cellulose is not degraded excessively by the method of incorporation.

When ethyl cellulose is properly incorporated in the oil or varnish, a colloidal dispersion results, which has a viscosity much greater than that of the oil alone under the same conditions. Thus it is possible to produce an oil of high viscosity without cooking it to the extent that cross linkage of the oil molecules occurs.

Next to the oil in importance in an exterior coating are the pigments. It has been shown (3) that both the appearance and durability of a paint are affected by the type, particle size, and shape of the pigments used.

Since a "two-coat" system was involved, the primer was studied first. According to Robertson (6) a successful primer should meet the following requirements:

1. Good adhesion and ability to maintain it.
2. The retention of a sufficient degree of

elasticity after application, to respond to dimensional surface changes caused by moisture and temperature variations.

3. A degree of hardness sufficient to be compatible with the average topcoat.

4. Ability to form a uniform and non-absorbent film over all surfaces generally encountered in painting houses.

5. A degree of hiding power sufficient to give good appearance with a single topcoat.

6. Freedom from checking, cracking, flaking, or scaling even when exposed as a single film.

If the amount of reactive pigments such as lead, zinc, and barium compounds are reduced, and the percentages of inert pigments such as the titanium compounds are increased, a combination can be selected to give best adhesion (7).

Elasticity and its retention is in general promoted by reducing the reactivity between pigment and vehicle, which promotes hardening and embrittlement of the film (7).

Sufficient hardness may be obtained in the film by having present in the primer a suitable quantity of reactive pigments such as lead and zinc.

The hiding power may be controlled easily by varying the percentage of high hiding pigments such as

the titanium compounds.

Because the formation of zinc soaps, from the reaction between the basic zinc oxide and vehicle, results in loss of adhesion and peeling because of their high solubility in water, all zinc compounds should be omitted from the undercoat. This leaves as pigments, compounds of lead and titanium. Extenders or fillers, such as asbestine, whose purpose it is to prevent settling of the paint and to dissipate strains in the film, are usually added to the pigments.

The last point in connection with a primer designed with the above points in mind is the pigment volume concentration. The usual concentration for a primer of this type is a pigment volume of 40%. This concentration aids in producing a uniform coating over surfaces of varying porosity, such as yellow pine, and has a direct bearing on the film hardness (6).

Satisfactory results may be obtained with a great variety of topcoats if a primer of this type is used. The main function of the topcoat is to resist the rays of ultra-violet which cause deterioration of the film. It so happens that of all the white pigments in common use, the titanium compounds afford the greatest protection to the vehicle, at the same time increasing the hiding power. A topcoat having a high hiding power is almost a necessity if a "two-coat"

system is being used.

In general, a certain degree of chalking is desirable and aids in giving a clean bright surface. This property may be obtained by the inclusion of zinc compounds in the topcoat. The zinc soaps that are formed gradually dissolve in the rain and are washed away exposing a fresh surface.

A small quantity of lead compounds, such as the basic carbonate and sulphate, are included in order to retain a certain amount of plasticity in the finish.

As in the case of the primer, the proper pigment volume concentration is necessary for a successful topcoat. A pigment concentration of 27% to 30% by volume has been found satisfactory for topcoat formulations.

All exterior paints contain driers of some type. A drier may be defined as a highly concentrated solution of a metallic compound which acts as a catalyst in the drying reaction. The solid portion of a drier is a chemical compound of a metal such as lead, manganese, cobalt, or zinc with a class of substances known as naphthenic acids. The liquid portion is a petroleum diluent known to the trade as mineral spirits. The most popularly used driers are those containing lead, manganese, and cobalt.

In paints containing lead driers there is not

much tendency for the vehicle to skin over because it dries from the bottom up. However, when lead alone is used, the films retain a persistent tackiness and considerable amounts of drier must be used with resultant darkening. Accordingly, a certain amount of manganese or cobalt drier is used along with the lead. Manganese hardens the film to a greater extent than either cobalt or lead, and if used by itself will cause the film to become brittle and crack (5).

The remaining constituent of an exterior paint is the thinner or diluent. The purpose of the thinner is to reduce the viscosity of the coating to the proper brushing consistency. Factors (8) to be taken into account for the proper selection of a thinner are the rate of evaporation, solvent strength, effect on viscosity, wetting of pigments, and effects on skinning and gelling.

The use of mineral spirits as a diluent for exterior house paint is rapidly replacing turpentine and other thinners because of its superior qualities.

Repeated comparisons of the durability of white paints on wood, when applied over aluminum primers and when used in the customary manner over white primers, have consistently shown distinct superiority in service for the paints applied over the aluminum primers (2). The improvement in durability is usually shown by a

retardation in the rate at which coatings become embrittled with age and flake from the bands of dense summer wood present in many types of softwood lumber. The benefit obtained is greatest in the case of woods such as Southern Yellow Pine and Douglas Fir.

It was with this thought in mind that several aluminum paints were prepared for the purpose of comparison.

RAW MATERIALS

The raw materials used were ethyl cellulose, soyabean, linseed, and perilla oils with suitable pigments, driers, and thinner.

The pigments selected were titanox B-30, basic carbonate of white lead, basic sulphate of white lead, zinc oxide, aluminum powder, and asbestine. The latter compound was not a pigment but an extender or filler. These materials were representative of the types used in industry,

The driers selected for use were a 24% metallic lead drier and a 6% metallic manganese drier. They were of the liquid type and are common to industry.

The only thinner used was mineral spirits. This liquid is used more or less universally as a diluent for exterior house paints.

The properties of the raw materials are listed as follows:

Titanox B-30 -- This pigment was manufactured by the Titanium Pigment Corp. (19). It is a true composite pigment consisting of 30% titanium dioxide precipitated upon and coalesced with 70% barium sulphate. It had a specific gravity of 4.24 and a bulking value of 35.2 pounds per gallon or 0.0283 gallons per pound. The residue on a 325 mesh screen was 0.2%. Its oil absorption was 22.0.

Basic Carbonate of White Lead -- This pigment was manufactured by the National Lead Co. It is a double compound having the formula: $\text{Pb}(\text{OH})_2 \cdot 2\text{PbCO}_3$. It had a specific gravity of 6.8 and a bulking value of 56.7 pounds per gallon or 0.0176 gallons per pound. The residue on a 325 mesh screen was 0.2%. Its oil absorption was 9.0.

Basic Sulphate of White Lead -- This pigment was manufactured by the Eagle-Picher Lead Co. This compound is also known as sublimed white lead and has a composition corresponding to approximately 7% ZnO , 16% PbO , and 77% PbSO_4 . It had a specific gravity of 6.41 and a bulking value of 53.4 pounds per gallon or 0.0187 gallons per pound. The residue on a 325 mesh screen was 0.5%. Its oil absorption was 12.1.

Zinc Oxide -- This pigment was manufactured by the New Jersey Zinc Co. (17). It is the standard "Lead Free" zinc oxide used for general paint manufacture. It had a specific gravity of 5.66 and a bulking value of 47.1 pounds per gallon or 0.0212 gallons per pound. The residue on a 325 mesh screen was 0.5%. Its oil absorption was 18.6.

Aluminum Powder -- This powder was manufactured by the Aluminum Co. of America (13). It was specified as their standard varnish powder No. 321. It had a specific gravity of 2.55 and a bulking value of

21.3 pounds per gallon or 0.0470 gallons per pound. Its mesh or screen rating was 140.

Asbestine -- This extender was manufactured by the International Pulp Co. It had a composition approximately as follows: 92.0% magnesium silicate, 4.0% lime (as silicate) and 4.0% water of crystallization. It had a specific gravity of 2.85 and a bulking value of 23.7 pounds per gallon or 0.0421 gallons per pound. The residue on a 325 mesh screen was 1.0%. Its oil absorption was 20.4.

Ethyl Cellulose -- This cellulose derivative was obtained from the Dow Chemical Co. (14) under the trade name of "Ethocel". It had a standard ethoxy content of 47.5% to 49.0% and a specific gravity of 1.14. It was furnished as a white granular solid in a 20 centipoise viscosity grade.

Soyabean Oil -- This oil was alkali refined by the Bisbee Co. It was pale yellow in color, had a specific gravity of 0.925, an index of refraction of 1.473, an iodine number of 123 to 132 and a saponification value of 190 to 195. Its acid value was 1 to 3.

Linseed Oil -- This oil was alkali refined by Spencer Kellogg & Sons Inc. It was pale yellow in color, had a specific gravity of 0.931 to 0.935, an index of refraction of 1.478, an iodine number of 175 to 190 and a saponification value of 188 to 196. Its acid value

was 1 to 4.

Perilla Oil -- This oil was alkali refined by the Bisbee Co. It was pale yellow in color, had a specific gravity of 0.933, an index of refraction of 1.482, an iodine number of 200 to 206 and a saponification value of 190 to 192. Its acid value was 0.5 (Max.).

Mineral Spirits -- This thinner was a product of the Standard Oil Co. of Ky. It was a petroleum distillate derived from those fractions of petroleum between motor gasoline and kerosene. It was water-white in color and had a specific gravity of 0.780. The distillation range was from 312°F to 412°F and its flash point was 102°F. Its weight per gallon was 6.50 pounds.

Lead Drier -- This compound was manufactured by the Nuodex Products Inc. (18). It was a clear yellow solution and had a specific gravity of 1.150. The solid portion of the drier was a chemical compound of lead with cyclopentane carboxylic acid. The liquid portion was mineral spirits. The metal content was 24% lead.

Manganese Drier -- This compound was also manufactured by the Nuodex Products Inc. (18). It was a clear brown viscous solution and had a specific gravity of 0.980. This drier was composed similarly to the lead drier, but the metal content was 6% manganese.

GENERAL PROCEDURE

The incorporation of the various percentages of ethyl cellulose in the refined oils (soyabean, linseed, and perilla) was first undertaken. The method of incorporation consisted briefly in heating a suitable quantity of the oil to 450°F in a stainless steel cooker (Fig. 1), at which temperature the required amount of ethyl cellulose was added. The heating was then continued until the cook reached a temperature of 570°F. This temperature was maintained until any gel formation was broken down, as was evidenced by the inspection of samples taken at frequent intervals. The cook was allowed to cool to room temperature and a sufficient quantity of the oil stored for use as vehicle. A sample of the refined oil was also heat bodied for 2 hours at 625°F.

All the cooks were prepared under an atmosphere of carbon dioxide in order to prevent darkening of the oil by oxidation. A summary of the cooks prepared is given in Table I.

Several oils were also prepared by mixing various percentages of either refined or heat bodied soyabean oil with the 15% ethyl cellulose - soyabean oil cook to give oils containing 2, 4, 6, and 8 percent ethyl cellulose respectively. Another 6% ethyl cellulose - soyabean oil cook was prepared and sufficient

Figure 1

Stainless Steel Cooker

TABLE I
SUMMARY OF OIL COOKS PREPARED

Oil	Percent Ethocel	Ethocel Added Temp. °F	Cook Held Temp. °F Min.		Sp. Gr. of Cook #/Gal.
Soyabean	0	---	625	120	7.92
Soyabean	0	---	570	35	7.68
Soyabean	2	450	570	20	7.73
Soyabean	4	450	570	25	7.77
Soyabean	6	450	570	30	7.79
Soyabean	6	450	570	30	7.79
Soyabean	8	450	570	35	7.81
Soyabean	10	450	570	35	7.83
Soyabean	15	450	570	50	7.92
Soyabean	20	400	570	50	8.02
Linseed	0	---	570	35	7.80
Linseed	2	450	570	20	7.82
Linseed	4	450	570	25	7.86
Linseed	6	450	570	30	7.87
Perilla	0	---	570	35	7.86
Perilla	2	450	570	25	7.86
Perilla	4	450	570	30	7.88
Perilla	6	450	570	35	7.94

quantities removed at intervals to obtain samples of the solid gel stage, the liquid gel stage, the liquid stage, and the final cook.

Suitable pigments and formulations were then selected to be used in the preparation of the exterior paints. In Table II are given the pigment formulations selected as being typical of those used in modern "two-coat" painting systems.

The specific gravities of all oils and driers and the diluent were then determined by means of a paint pycnometer of the type developed by the Krebs Pigment Co.

The preparation of the samples was then undertaken. The required amounts of oil and pigment were weighed out and thoroughly mixed to form a stiff paste. This paste was then passed through a roller-type paint mill (Fig. 2). The milled paste was reground until complete wetting of the pigment was obtained, after which it was placed in pint cans and the proper amounts of thinner and drier added. In the preparation of the aluminum paints the pigment was weighed out and stirred into a small portion of the vehicle, the remainder being added when the powder was thoroughly wetted.

The proper amount of thinner to add was determined by a method developed by the Krebs Pigment Co.

TABLE II
SUMMARY OF PIGMENT FORMULATIONS

Primer Formulation (White) Pigment Volume 40%

Titanox B-30.....	37.5%	By Wt.
Basic Carbonate of White Lead.....	37.5%	By Wt.
Asbestine.....	25.0%	By Wt.
	<u>100.0%</u>	

Topcoat Formulation (White) Pigment Volume 28%

Titanox B-30.....	40.0%	By Wt.
Basic Carbonate of White Lead.....	29.0%	By Wt.
Basic Sulphate of White Lead.....	11.0%	By Wt.
Zinc Oxide.....	20.0%	By Wt.
	<u>100.0%</u>	

Primer Formulation (Aluminum) Pigment Volume 6.6%

Standard Aluminum Varnish Powder...	100.0%	By Wt.
-------------------------------------	--------	--------

and used at present by several of the larger paint concerns. It consisted briefly of measuring the viscosity or consistency of a given sample by means of a Stormer Viscoosimeter (Fig. 3) equipped with a special paddle agitator in place of the regulation cylinder and cup. The apparatus was previously standardized by immersing the agitator to a depth sufficient to require a definite time for 100 revolutions of the paddle in a paint of known or standard viscosity.

Mineral spirits was added to the prepared samples in an amount sufficient to reduce the viscosity to a limited range (26.0 to 34.0 seconds with 250 grams for the primers and 30.0 to 40.0 seconds with 200 grams for the topcoats).

The proper amounts of lead and manganese driers were then added to the thinned samples by means of a burette. The percent of driers added (0.5% metallic lead and 0.05% metallic manganese) was the same for each sample and was based upon the weight of the oil minus the ethyl cellulose, in order that any drying effect caused by the ethyl cellulose could be readily noticed.

In Table III is given a summary of the oils as used in this investigation. Tables IV and V present a summary of the primers and topcoats prepared for

Figure 2
Roller-Type Paint Mill

Figure 3
Stormer Viscosimeter

testing. Besides the test samples, three commercial "two-coat systems" were used for comparison purposes.

TABLE III
SUMMARY OF OILS USED IN EXTERIOR PAINTS

Series 1 -- Alkali refined soyabean oil cooked with 0,2,4,6,8,10,15, and 20% ethyl cellulose.

Series 2 -- 15% ethyl cellulose bodied soyabean oil added to heat bodied soyabean oil to give samples containing 2,4,6, and 8% ethyl cellulose.

Series 3 -- 15% ethyl cellulose bodied soyabean oil added to alkali refined soyabean oil to give samples containing 2,4,6, and 8% ethyl cellulose.

Series 4 -- Alkali refined linseed oil cooked with 0,2,4, and 6% ethyl cellulose.

Series 5 -- Alkali refined perilla oil cooked with 0,2,4, and 6% ethyl cellulose.

Series 6 -- Alkali refined soyabean oil cooked with 6% ethyl cellulose. At intervals the following samples were removed: One from the cloudy gel stage. One from the solid gel stage. One from the liquid gel stage. Two from the liquid stage.

TABLE IV

SUMMARY OF PRIMER FORMULATIONS PREPARED FOR TESTING

No.	Oil	Series No.	Percent Ethocel	Oil/Thinner Ratio	Type
1	Soyabean	1	0	1.63	White
2	Soyabean	1	2	1.55	White
3	Soyabean	1	4	1.65	White
4	Soyabean	1	6	1.03	White
5	Soyabean	1	8	0.99	White
6	Soyabean	1	10	0.97	White
7	Soyabean	1	15	1.04	White
8	Soyabean	1	20	0.77	White
9	Soyabean	2	2	1.37	White
10	Soyabean	2	4	1.31	White
11	Soyabean	2	6	1.37	White
12	Soyabean	2	8	1.31	White
13	Soyabean	3	2	3.67	White
14	Soyabean	3	4	2.96	White
15	Soyabean	3	6	2.28	White
16	Soyabean	3	8	1.99	White
17	Linseed	4	0	2.12	White
18	Linseed	4	2	2.71	White
19	Linseed	4	4	2.00	White
20	Linseed	4	6	1.88	White
21	Perilla	5	0	3.00	White
22	Perilla	5	2	2.50	White
23	Perilla	5	4	2.00	White
24	Perilla	5	6	1.78	White
25	Soyabean	6	6	1.49	White
26	Soyabean	6	6	1.15	White
27	Soyabean	6	6	0.93	White
28	Soyabean	6	6	1.24	White
29	Soyabean	6	6	1.24	White
30	Soyabean	1	2	4.46	Aluminum
31	Soyabean	1	6	2.25	Aluminum
32	Soyabean	1	10	1.72	Aluminum
33	Linseed	4	6	5.00	Aluminum
34	Perilla	5	6	3.60	Aluminum
35	Commercial Sample A				White
36	Commercial Sample B				White
37	Commercial Sample C				White

TABLE V
SUMMARY OF TOPCOAT FORMULATIONS PREPARED FOR TESTING

No.	Oil	Series [*] No.	Percent Ethocel	Oil/Thinner Ratio	Type
38	Soyabean	1	0	4.40	White
39	Soyabean	1	2	2.53	White
40	Soyabean	1	4	2.09	White
41	Soyabean	1	6	1.70	White
42	Soyabean	1	8	1.33	White
43	Soyabean	1	10	1.24	White
44	Soyabean	1	15	1.46	White
45	Soyabean	1	20	0.94	White
46	Soyabean	2	2	0.95	White
47	Soyabean	2	4	0.98	White
48	Soyabean	2	6	1.29	White
49	Soyabean	2	8	1.13	White
50	Soyabean	3	2	5.87	White
51	Soyabean	3	4	3.93	White
52	Soyabean	3	6	3.95	White
53	Soyabean	3	8	3.25	White
54	Linseed	4	0	3.98	White
55	Linseed	4	2	3.98	White
56	Linseed	4	4	3.27	White
57	Linseed	4	6	3.27	White
58	Perilla	5	0	6.00	White
59	Perilla	5	2	3.60	White
60	Perilla	5	4	3.02	White
61	Perilla	5	6	2.60	White
62	Soyabean	6	6	2.39	White
63	Soyabean	6	6	1.38	White
64	Soyabean	6	6	1.63	White
65	Soyabean	6	6	1.63	White
66	Soyabean	6	6	1.56	White
67	Commercial Sample A				White
68	Commercial Sample B				White
69	Commercial Sample C				White

* Refer to Table III

PART I
HIDING POWER

THEORETICAL

Hiding power may be defined as that property of a paint or coating which enables it to obliterate completely any surface over which it is spread.

When light falls upon an object, part of it is reflected at the surface, part of it is absorbed, and the remainder transmitted. When light falls upon a painted surface a part is reflected, both by the film surface and the individual pigment particles within the film. The remainder is either absorbed by the film or is transmitted to the background. Any light reaching the background is again either reflected or absorbed depending upon the lightness or darkness of the surface. An alternate light and dark background will reflect as contrasts through the paint film to show up as incomplete hiding (3).

The hiding power of a paint coating therefore depends upon the quantity of light that is reflected or absorbed before it reaches the background. The amount of light reflected depends in turn upon the particle size of the pigment and the difference in the refractive indices of the vehicle and pigment (3).

An instrument used to determine the absolute hiding power of paints is the Pfund Cryptometer, developed by A.H. Pfund and introduced in 1930.

The cryptometer consists primarily of two plates of glass whose optically flat surfaces are separated by a fixed angle in which a wedge-shaped film of paint is formed. The bottom plate of glass is opaque and is fitted with a convenient arrangement for determining and measuring the thickness of the film of paint necessary to hide an underlying surface completely. The top plate is transparent and fitted with metal pegs for maintaining a constant angle between the plates. The hiding power in square feet per gallon is given by the equation:

$$\text{H.P.} = 4.07/KxL \quad \text{where,}$$

H.P. = Hiding power in square feet/gallon.

K = Top plate constant in cm. = 0.0007

L = Scale reading on lower plate in mm.

EXPERIMENTAL WORK

A wedge-shaped sample of the paint was first formed by placing 1 to 2 cc of the sample on the bottom plate, over which was placed the transparent plate containing the metal pegs. By sliding the top plate backward and forward, a sharp line of demarcation (showing the line of complete hiding) alternately appeared and disappeared. At this point the thickness of the film was just sufficient to obliterate the background, and a reading was taken on the engraved scale on the bottom plate. This procedure was repeated several times in order to obtain an average value, which was then converted into square feet per gallon by means of the equation given previously.

The results of the tests were reported in Tables VI and VII as the hiding power in square feet of surface covered per gallon of paint.

TABLE VI
HIDING POWER OF EXTERIOR HOUSE PRIMERS

No.	Oil	Series [*] No.	Percent Ethocel	Cryptometer Reading M.M.	Hiding Power Sq. Ft./Gal.
1	Soyabean	1	0	12	484
2	Soyabean	1	2	13	447
3	Soyabean	1	4	13	447
4	Soyabean	1	6	14	415
5	Soyabean	1	8	14	415
6	Soyabean	1	10	15	387
7	Soyabean	1	15	14	415
8	Soyabean	1	20	15	387
9	Soyabean	2	2	14	415
10	Soyabean	2	4	13	447
11	Soyabean	2	6	14	415
12	Soyabean	2	8	13	447
13	Soyabean	3	2	13	447
14	Soyabean	3	4	13	447
15	Soyabean	3	6	13	447
16	Soyabean	3	8	14	415
17	Linseed	4	0	14	415
18	Linseed	4	2	14	415
19	Linseed	4	4	15	387
20	Linseed	4	6	15	387
21	Perilla	5	0	13	447
22	Perilla	5	2	13	447
23	Perilla	5	4	14	415
24	Perilla	5	6	14	415
25	Soyabean	6	6	14	415
26	Soyabean	6	6	14	415
27	Soyabean	6	6	14	415
28	Soyabean	6	6	14	415
29	Soyabean	6	6	13	447
35	Commercial Sample A			13	447
36	Commercial Sample B			13	447
37	Commercial Sample C			12	484

* Refer to Table III

TABLE VII
HIDING POWER OF EXTERIOR HOUSE TOPCOATS

No.	Oil	Series [*] No.	Percent Ethocel	Cryptometer Reading M.M.	Hiding Power Sq. Ft./Gal.
38	Soyabean	1	0	12	484
39	Soyabean	1	2	13	447
40	Soyabean	1	4	13	447
41	Soyabean	1	6	13	447
42	Soyabean	1	8	13	447
43	Soyabean	1	10	14	415
44	Soyabean	1	15	14	415
45	Soyabean	1	20	14	415
46	Soyabean	2	2	14	415
47	Soyabean	2	4	13	447
48	Soyabean	2	6	14	415
49	Soyabean	2	8	13	447
50	Soyabean	3	2	13	447
51	Soyabean	3	4	12	484
52	Soyabean	3	6	13	447
53	Soyabean	3	8	13	447
54	Linseed	4	0	15	387
55	Linseed	4	2	13	447
56	Linseed	4	4	13	447
57	Linseed	4	6	13	447
58	Perilla	5	0	14	415
59	Perilla	5	2	12	484
60	Perilla	5	4	12	484
61	Perilla	5	6	13	447
62	Soyabean	6	6	14	415
63	Soyabean	6	6	14	415
64	Soyabean	6	6	13	447
65	Soyabean	6	6	13	447
66	Soyabean	6	6	13	447
67	Commercial Sample A			13	447
68	Commercial Sample B			12	484
69	Commercial Sample C			12	484

* Refer to Table III

CONCLUSIONS

When the results obtained in each series were compared according to the ethyl cellulose content, it was readily seen that, in general, the hiding power decreased with increasing cellulose content.

This may be explained upon the basis that when the oils were cooked with varying amounts of ethyl cellulose, those containing higher percentages were also higher in viscosity. Since all samples were "cut" to approximately the same viscosity with mineral spirits the higher bodied oils required larger amounts of diluent. Thus the hiding power would naturally decrease as more non-hiding material was added to the sample. A point in favor of those paints containing high ethyl cellulose contents is the increase in total volume per unit volume of oil.

The primers were about equal in hiding power to the topcoats showing that the latter had a superior pigment formulation since the pigment volume ratio was lower. It may also be seen that the test paints were equal in hiding power to the commercial samples.

PART II

GLOSS

THEORETICAL

Gloss may be defined as the ability of a surface to reflect light regularly (3). A common method of measurement is the observation of how good a mirror the particular surface may be.

The type of gloss encountered in painted surfaces is that which has to do with the degree of perfection of the surface of the material. In general, the glossy appearance of coated surfaces is the result of the qualities of surface reflection which are characteristic of the surface as a whole.

As in several other tests of this nature, the results depend to a large degree upon the human factor involved. Types and conditions of surfaces usually have an effect.

EXPERIMENTAL WORK

The qualitative estimation of the gloss of the samples prepared was determined by coating surfaces of both brick and cardboard. The samples were thoroughly dried and compared with one another for the "mirror" effect produced by their coated surfaces. The paints were applied by means of a brush, two coats being necessary before suitable variations or differences were obtained.

The results of the tests were reported in Tables VIII and IX on the basis of ratings from A through F - A representing those surfaces which were very glossy, and F representing those which were very flat or dull.

TABLE VIII
GLOSS OF EXTERIOR HOUSE PRIMERS

No.	Oil	Series No.	Percent Ethocel	Rating	
				Cardboard	Brick
1	Soyabean	1	0	F	F
2	Soyabean	1	2	E	B
3	Soyabean	1	4	D	B
4	Soyabean	1	6	F	E
5	Soyabean	1	8	E	F
6	Soyabean	1	10	E	D
7	Soyabean	1	15	E	C
8	Soyabean	1	20	E	F
9	Soyabean	2	2	E	E
10	Soyabean	2	4	E	F
11	Soyabean	2	6	E	F
12	Soyabean	2	8	D	F
13	Soyabean	3	2	E	E
14	Soyabean	3	4	E	F
15	Soyabean	3	6	E	B
16	Soyabean	3	8	E	B
17	Linseed	4	0	B	B
18	Linseed	4	2	C	B
19	Linseed	4	4	C	B
20	Linseed	4	6	C	B
21	Perilla	5	0	B	A
22	Perilla	5	2	B	A
23	Perilla	5	4	B	A
24	Perilla	5	6	B	A
25	Soyabean	6	6	F	F
26	Soyabean	6	6	E	D
27	Soyabean	6	6	E	F
28	Soyabean	6	6	E	D
29	Soyabean	6	6	C	D
35	Commercial Sample A			B	B
36	Commercial Sample B			B	B
37	Commercial Sample C			B	C

* Refer to Table III

TABLE IX
GLOSS OF EXTERIOR HOUSE TOPCOATS

No.	Oil	Series No.	Percent Ethocel	Rating	
				Cardboard	Brick
38	Soyabean	1	0	D	E
39	Soyabean	1	2	B	E
40	Soyabean	1	4	D	D
41	Soyabean	1	6	B	D
42	Soyabean	1	8	E	E
43	Soyabean	1	10	E	E
44	Soyabean	1	15	D	F
45	Soyabean	1	20	C	F
46	Soyabean	2	2	D	E
47	Soyabean	2	4	C	C
48	Soyabean	2	6	D	C
49	Soyabean	2	8	C	E
50	Soyabean	3	2	C	C
51	Soyabean	3	4	A	C
52	Soyabean	3	6	A	D
53	Soyabean	3	8	A	B
54	Linseed	4	0	A	B
55	Linseed	4	2	A	A
56	Linseed	4	4	A	A
57	Linseed	4	6	A	A
58	Perilla	5	0	B	A
59	Perilla	5	2	B	B
60	Perilla	5	4	A	A
61	Perilla	5	6	B	A
62	Soyabean	6	6	B	E
63	Soyabean	6	6	C	E
64	Soyabean	6	6	C	E
65	Soyabean	6	6	B	C
66	Soyabean	6	6	B	E
67	Commercial Sample A			A	A
68	Commercial Sample B			A	A
69	Commercial Sample C			A	A

* Refer to Table III

CONCLUSIONS

It was at once evident that the presence of ethyl cellulose was neither beneficial or detrimental to the gloss of exterior house paints. It was also evident from a comparison of the first three series that it made very little difference whether the oil was a light or heavy bodied one.

However, upon comparing the three oils (soybean, linseed, and perilla) against one another it was noted that there was a decided difference among them, the perilla oil being superior to the linseed and the linseed superior to the soybean. This was evidently the result of the individual characteristics of the oils themselves.

It was also noted that the topcoats were superior in gloss to the primers. This was expected because of the lower pigment volume ratio.

The gloss of the test paints compared favorably with the commercial samples considering the fact that there was probably no soyabean oil in the latter.

PART III
PENETRATION

THEORETICAL

The penetration of a house primer may be defined as the degree of absorption of the vehicle by the surface upon which it is spread.

This property may be conveniently determined by examining a thin cross section of the primed wood under a microscope. The wood consists of a large number of cells surrounded by tiny cavities or canals all interconnected with one another. As the coating is applied to the surface, the oil portion of the vehicle is absorbed by the wood and penetrates to a depth depending upon its body or viscosity. A certain depth of penetration (2 to 3 wood cells) is necessary for good adhesion of the film to the surface. Excess penetration is not desirable because of the depletion of the oil from the film remaining on the surface.

The primers should have the same pigment vehicle ratio and should not contain excess quantities of thinner. The wood should be of the same type and should be as uniform and free from defects as possible. The moisture content is also important.

EXPERIMENTAL WORK

A rather soft wood such as white pine was used in determining the depth of penetration, in order to obtain a desirable section for examination. After wood of uniform quality and appearance was selected, the primers were applied with a brush and allowed to dry. A thin section was cut from the wood and examined under a microscope by means of transmitted light. The depth of penetration into the wood showed up as a yellow encircling net of oil around the cells.

The results of the tests were reported in Table X as the penetration in number of wood cells from the surface.

TABLE X
PENETRATION OF EXTERIOR HOUSE PRIMERS

No.	Oil	Series [*] No.	Percent Ethocel	Penetration in White Pine No. of Wood Cells
1	Soyabean	1	0	5
2	Soyabean	1	2	3-4
3	Soyabean	1	4	2
4	Soyabean	1	6	1-2
5	Soyabean	1	8	1
6	Soyabean	1	10	1
7	Soyabean	1	15	1
8	Soyabean	1	20	1
9	Soyabean	2	2	3
10	Soyabean	2	4	3
11	Soyabean	2	6	2
12	Soyabean	2	8	2
13	Soyabean	3	2	6-8
14	Soyabean	3	4	6-8
15	Soyabean	3	6	6-8
16	Soyabean	3	8	6-8
17	Linseed	4	0	3-4
18	Linseed	4	2	2-3
19	Linseed	4	4	2-3
20	Linseed	4	6	2-3
21	Perilla	5	0	3-4
22	Perilla	5	2	2-3
23	Perilla	5	4	2-3
24	Perilla	5	6	2-3
25	Soyabean	6	6	1-2
26	Soyabean	6	6	1
27	Soyabean	6	6	1
28	Soyabean	6	6	1
29	Soyabean	6	6	1
30	Soyabean	1	2	3
31	Soyabean	1	6	2
32	Soyabean	1	10	1
33	Linseed	4	6	2-3
34	Perilla	5	6	2-3
35	Commercial Sample A			3
36	Commercial Sample B			2-3
37	Commercial Sample C			2-3

* Refer to Table III

CONCLUSIONS

The ethyl cellulose content has a definite effect upon the penetration of wood primers. In practically all cases the penetration decreased as the cellulose content increased. As in other cases, this was probably caused by the bodying effect upon the oil, the heavier bodied oils penetrating to a lesser degree.

The high penetration of the third series was probably caused by the unbodied oil used in the preparation of the samples in this series. The percent of ethyl cellulose present had little or no effect as was evidenced by the equivalent penetration of the four samples.

There was very little difference shown by a change in oil composition, but the ethyl cellulose seemed to have a greater retarding effect upon the soyabean than on either the linseed or perilla oils.

The stage of cooking the ethyl cellulose in the oil had little effect upon the penetration as shown by the samples of series six.

The penetration of the test paints compared favorably with the commercial samples.

PART IV
BRUSHABILITY

THEORETICAL

Brushability may be defined as the ease of application of a protective coating upon a surface by means of a brush.

Up to the present time no simple and accurate means has been devised for determining the degree of brushability of an exterior paint. The common method in use today is a practical test which consists of brushing a sample on a test surface and noting such properties as the drag of the brush, the ability of the paint to flow from the brush and wet the surface and so forth.

This property is very difficult to judge even when carried out by an experienced operator. The determination exhibits the disadvantage of being dependent upon the mental vigor, or state of tiredness of the painter. With paints containing large percentages of easily volatile solvents, the difficulty of effecting suitable comparisons of various paints is particularly pronounced (12). Types and conditions of both brushes and surfaces are important factors.

EXPERIMENTAL WORK

The degree of brushability was noted in the preparation of the panels for exposure data. For further information reference should be made to the section on Weatherability.

The results of the tests were reported in Tables XI and XII as having ratings of excellent, very good, good, fair, or poor depending upon such properties as those previously listed.

TABLE XI
BRUSHABILITY OF EXTERIOR HOUSE PRIMERS

No.	Oil	Series [*] No.	Percent Ethocel	Rating
1	Soyabean	1	0	Poor
2	Soyabean	1	2	Fair
3	Soyabean	1	4	Good
4	Soyabean	1	6	Good
5	Soyabean	1	8	Good
6	Soyabean	1	10	Good
7	Soyabean	1	15	Good
8	Soyabean	1	20	Good
9	Soyabean	2	2	Very Good
10	Soyabean	2	4	Very Good
11	Soyabean	2	6	Very Good
12	Soyabean	2	8	Very Good
13	Soyabean	3	2	Fair
14	Soyabean	3	4	Fair
15	Soyabean	3	6	Fair
16	Soyabean	3	8	Fair
17	Linseed	4	0	Fair
18	Linseed	4	2	Good
19	Linseed	4	4	Good
20	Linseed	4	6	Fair
21	Perilla	5	0	Fair
22	Perilla	5	2	Good
23	Perilla	5	4	Good
24	Perilla	5	6	Good
25	Soyabean	6	6	Poor
26	Soyabean	6	6	Poor
27	Soyabean	6	6	Fair
28	Soyabean	6	6	Fair
29	Soyabean	6	6	Fair
30	Soyabean	1	2	Excellent
31	Soyabean	1	6	Excellent
32	Soyabean	1	10	Excellent
33	Linseed	4	6	Excellent
34	Perilla	5	6	Excellent
35	Commercial Sample A			Very Good
36	Commercial Sample B			Very Good
37	Commercial Sample C			Good

* Refer to Table III

TABLE XII
BRUSHABILITY OF EXTERIOR HOUSE TOPCOATS

No.	Oil	Series [*] No.	Percent Ethocel	Rating
38	Soyabean	1	0	Poor
39	Soyabean	1	2	Fair
40	Soyabean	1	4	Good
41	Soyabean	1	6	Good
42	Soyabean	1	8	Good
43	Soyabean	1	10	Good
44	Soyabean	1	15	Good
45	Soyabean	1	20	Fair
46	Soyabean	2	2	Very Good
47	Soyabean	2	4	Very Good
48	Soyabean	2	6	Very Good
49	Soyabean	2	8	Very Good
50	Soyabean	3	2	Fair
51	Soyabean	3	4	Fair
52	Soyabean	3	6	Fair
53	Soyabean	3	8	Fair
54	Linseed	4	0	Fair
55	Linseed	4	2	Good
56	Linseed	4	4	Good
57	Linseed	4	6	Good
58	Perilla	5	0	Fair
59	Perilla	5	2	Good
60	Perilla	5	4	Good
61	Perilla	5	6	Good
62	Soyabean	6	6	Poor
63	Soyabean	6	6	Poor
64	Soyabean	6	6	Poor
65	Soyabean	6	6	Fair
66	Soyabean	6	6	Fair
67	Commercial Sample A			Good
68	Commercial Sample B			Very Good
69	Commercial Sample C			Very Good

* Refer to Table III

CONCLUSIONS

The brushability of the samples after thinning increased with an increase in ethyl cellulose content. However, before thinning it may be said that the brushability decreased with an increase in the percentage of the cellulose derivative because of the increased body of the oil. A possible exception were those paints containing no ethyl cellulose. As a certain amount of body is necessary for good brushing properties, a small percent of ethyl cellulose is beneficial. This explains the fact that the paints in series two had the same brushability and were better than those in series three.

The aluminum paints were superior to all the others in brushability because of the leafing effect of the pigment involved.

In general the brushabilities of the commercial paints were better than the test samples because of proper vehicle formulations.

PART V
LEVELING

THEORETICAL

Leveling may be defined as the ability of a freshly applied coating to produce a smooth, level surface from an irregular one.

The simplest method in use is by the observation of the smoothness of the film when dry.

The results obtained depend upon the degree of brushing and the stiffness of the brush as well as the type and condition of the surface. In the case of sprayed coatings, the results depend upon pressure, type of nozzle, and other factors (3).

EXPERIMENTAL WORK

The amount of leveling produced by the various paints was obtained by observing the smoothness of the films applied for the determination of the degree of brushability.

The results of the tests were reported in Tables XIII and XIV as having ratings of very good, good, fair, poor, or very poor depending upon the apparent smoothness.

TABLE XIII
LEVELING OF EXTERIOR HOUSE PRIMERS

No.	Oil	Series* No.	Percent Ethocel	Rating
1	Soyabean	1	0	Very Poor
2	Soyabean	1	2	Poor
3	Soyabean	1	4	Poor
4	Soyabean	1	6	Fair
5	Soyabean	1	8	Fair
6	Soyabean	1	10	Good
7	Soyabean	1	15	Good
8	Soyabean	1	20	Good
9	Soyabean	2	2	Good
10	Soyabean	2	4	Good
11	Soyabean	2	6	Good
12	Soyabean	2	8	Good
13	Soyabean	3	2	Fair
14	Soyabean	3	4	Fair
15	Soyabean	3	6	Fair
16	Soyabean	3	8	Fair
17	Linseed	4	0	Poor
18	Linseed	4	2	Fair
19	Linseed	4	4	Fair
20	Linseed	4	6	Fair
21	Perilla	5	0	Fair
22	Perilla	5	2	Fair
23	Perilla	5	4	Good
24	Perilla	5	6	Good
25	Soyabean	6	6	Poor
26	Soyabean	6	6	Fair
27	Soyabean	6	6	Fair
28	Soyabean	6	6	Fair
29	Soyabean	6	6	Fair
35	Commercial Sample A			Good
36	Commercial Sample B			Very Good
37	Commercial Sample C			Fair

* Refer to Table III

TABLE XIV
LEVELING OF EXTERIOR HOUSE TOPCOATS

No.	Oil	Series [*] No.	Percent Kthocel	Rating
38	Soyabean	1	0	Poor
39	Soyabean	1	2	Fair
40	Soyabean	1	4	Fair
41	Soyabean	1	6	Fair
42	Soyabean	1	8	Good
43	Soyabean	1	10	Good
44	Soyabean	1	15	Good
45	Soyabean	1	20	Good
46	Soyabean	2	2	Good
47	Soyabean	2	4	Good
48	Soyabean	2	6	Good
49	Soyabean	2	8	Good
50	Soyabean	3	2	Fair
51	Soyabean	3	4	Fair
52	Soyabean	3	6	Good
53	Soyabean	3	8	Good
54	Linseed	4	0	Fair
55	Linseed	4	2	Good
56	Linseed	4	4	Good
57	Linseed	4	6	Good
58	Perilla	5	0	Fair
59	Perilla	5	2	Good
60	Perilla	5	4	Good
61	Perilla	5	6	Good
62	Soyabean	6	6	Fair
63	Soyabean	6	6	Fair
64	Soyabean	6	6	Fair
65	Soyabean	6	6	Good
66	Soyabean	6	6	Good
67	Commercial Sample A			Good
68	Commercial Sample B			Very Good
69	Commercial Sample C			Very Good

* Refer to Table III

CONCLUSIONS

From a comparison of the results obtained, an increase in ethyl cellulose content definitely produced better leveling. This was undoubtedly caused by the bodying effect of the cellulose upon the oil, since a bodied oil will usually produce a smoother surface when combined with a pigment than an unbodied one. This effect was shown again upon comparing series two with series three.

In general, the oils increased in their leveling properties from soyabean through linseed to perilla. The topcoats leveled somewhat better than the primers but not to any great extent. This was traced to the lower pigment volume ratio of the former.

As a whole the commercial paints were much better, as regards leveling, than the test samples. This may be attributed to the proper vehicle formulations of the former.

PART VI
SAGGING

THEORETICAL

The purpose of the sagging test is to determine the ability of the paint film to remain evenly spread over a vertical surface without "running" or "streaking".

A simple method of testing consists of brushing the paint on a metal panel which is stood in a vertical position until dry.

The results of this test depend in a large degree upon the consistency or viscosity of the paint as well as the quantity applied to the surface and the method of application. Types and conditions of surfaces also have a noticeable effect.

EXPERIMENTAL WORK

It was decided to use metal panels in conducting this test, for the tendency of the paint to sag was much greater than on wood because of the difference in the type of surface. The panels were of "soft" steel, 5 inches long and 3 inches wide. They were thoroughly cleaned with toluol before coating.

The paint was brushed along the length, the upper half of the panel then being brushed along the width so that the brush marks were horizontal when the panel was stood on the short end. The panel was allowed to remain vertical until the film had dried.

The results of the tests were reported in Tables XV and XVI as passing or failing.

TABLE XV
SAGGING OF EXTERIOR HOUSE PRIMERS

No.	Oil	Series [*] No.	Percent Ethocel	Rating
1	Soyabean	1	0	Passed
2	Soyabean	1	2	Passed
3	Soyabean	1	4	Passed
4	Soyabean	1	6	Passed
5	Soyabean	1	8	Passed
6	Soyabean	1	10	Passed
7	Soyabean	1	15	Passed
8	Soyabean	1	20	Passed
9	Soyabean	2	2	Passed
10	Soyabean	2	4	Passed
11	Soyabean	2	6	Passed
12	Soyabean	2	8	Passed
13	Soyabean	3	2	Passed
14	Soyabean	3	4	Passed
15	Soyabean	3	6	Passed
16	Soyabean	3	8	Passed
17	Linseed	4	0	Passed
18	Linseed	4	2	Passed
19	Linseed	4	4	Passed
20	Linseed	4	6	Passed
21	Perilla	5	0	Passed
22	Perilla	5	2	Passed
23	Perilla	5	4	Passed
24	Perilla	5	6	Passed
25	Soyabean	6	6	Passed
26	Soyabean	6	6	Passed
27	Soyabean	6	6	Passed
28	Soyabean	6	6	Passed
29	Soyabean	6	6	Passed
35	Commercial Sample A			Passed
36	Commercial Sample B			Passed
37	Commercial Sample C			Passed

* Refer to Table III

TABLE XVI
SAGGING OF EXTERIOR HOUSE TOPCOATS

No.	Oil	Series [*] No.	Percent Ethocel	Rating
38	Soyabean	1	0	Passed
39	Soyabean	1	2	Passed
40	Soyabean	1	4	Passed
41	Soyabean	1	6	Passed
42	Soyabean	1	8	Failed
43	Soyabean	1	10	Passed
44	Soyabean	1	15	Passed
45	Soyabean	1	20	Passed
46	Soyabean	2	2	Failed
47	Soyabean	2	4	Failed
48	Soyabean	2	6	Failed
49	Soyabean	2	8	Passed
50	Soyabean	3	2	Passed
51	Soyabean	3	4	Passed
52	Soyabean	3	6	Passed
53	Soyabean	3	8	Passed
54	Linseed	4	0	Passed
55	Linseed	4	2	Passed
56	Linseed	4	4	Passed
57	Linseed	4	6	Passed
58	Perilla	5	0	Passed
59	Perilla	5	2	Passed
60	Perilla	5	4	Passed
61	Perilla	5	6	Passed
62	Soyabean	6	6	Passed
63	Soyabean	6	6	Passed
64	Soyabean	6	6	Passed
65	Soyabean	6	6	Passed
66	Soyabean	6	6	Passed
67	Commercial Sample A			Passed
68	Commercial Sample B			Passed
69	Commercial Sample C			Passed

* Refer to Table III

CONCLUSIONS

It will be noted that of all the samples tested, only four showed signs of sagging and these were not extreme. Checks were run to determine whether the results would be inconsistent, but this was not found to be the case. There was an apparent reason for the three samples of series two to sag. This was traced to the body of the original oils and the very large amounts of thinner required to bring these samples within the required viscosity range - the ratio of oil to thinner being 0.95, 0.98, and 1.29 respectively for the 2%, 4%, and 6% samples. Also since these samples were top-coats, the lower pigment volume ratio would help to explain the failure.

It was evident that the ethyl cellulose content had little effect upon the sagging characteristics.

PART VII
HARDNESS OR TACK

THEORETICAL

The tack or hardness of a paint film from the time of application to the time of complete dryness may be taken as a measure of the oxidation that has taken place while the film has been exposed to the air.

A convenient instrument for measuring this property is the Sward Hardness Rocker (Fig. 4). This instrument measures the relative hardness of a film, considering the hardness of polished plate glass as 100%.

The rocker consists essentially of a pair of circular bronze rings four inches in diameter and spaced one inch apart. The peripheries of the rockers are turned down on a radius of 0.5 mm. Contained between the rockers are two small spirit levels which are arbitrarily set at the point where the rocker completes its fiftieth complete oscillation on polished plate glass. Glass as the standard becomes 100% by multiplying the 50 oscillations by 2. Values for other materials are expressed in percent hardness by multiplying the number of oscillations on their surfaces by 2.

The films must be equal in thickness, must be free of dirt and irregularities, and the tests should be conducted at a constant temperature and humidity.

Figure 4
Sward Hardness Rocker

EXPERIMENTAL WORK

It was first necessary to prepare films of the paints whose hardness it was desired to determine. This was accomplished by casting films of the same thickness with a Dow Filmograph on plate glass panels previously cleaned with toluol. By actual measurement the films cast were 0.003 ± 0.0005 inches thick.

The Sward Rocker was adjusted to 50 oscillations on polished plate glass, after which a hardness or tack reading was taken on the prepared films. It was necessary to wait 24 hours before taking the first reading, in order that the film could dry sufficiently to permit placing the rocker upon it. Readings were taken every 24 hours until the film was completely dry, as shown by identical readings.

The results of the tests were reported in Tables XVII and XVIII as the relative hardness of the film every 24 hours, expressed as a percentage of the hardness of polished plate glass.

TABLE XVII
HARDNESS OR TACK OF EXTERIOR HOUSE PRIMERS

No.	Oil	Series [†] No.	Percent Ethocel	Rocker Hard. in % every 24 Hrs.					
				24	48	72	96	120	144
1	Soyabean	1	0	-	1	1	2	2	3
2	Soyabean	1	2	-	1	2	3	3	3
3	Soyabean	1	4	1	1	2	3	3	3
4	Soyabean	1	6	1	1	2	3	3	3
5	Soyabean	1	8	1	1	3	3	3	3
6	Soyabean	1	10	1	2	3	3	3	3
7	Soyabean	1	15	1	2	3	3	3	3
8	Soyabean	1	20	1	2	3	3	3	3
9	Soyabean	2	2	-	-	-	-	-	-
10	Soyabean	2	4	-	-	-	-	-	1
11	Soyabean	2	6	-	-	-	-	1	1
12	Soyabean	2	8	-	-	-	-	1	1
13	Soyabean	3	2	1	1	1	2	2	2
14	Soyabean	3	4	1	1	2	2	2	2
15	Soyabean	3	6	1	1	1	2	3	3
16	Soyabean	3	8	1	2	2	3	3	3
17	Linseed	4	0	1	3	4	5	5	5
18	Linseed	4	2	2	3	4	5	5	5
19	Linseed	4	4	2	4	5	5	5	5
20	Linseed	4	6	2	4	5	5	5	5
21	Perilla	5	0	1	4	7	7	7	7
22	Perilla	5	2	3	5	7	8	9	9
23	Perilla	5	4	3	5	7	8	8	8
24	Perilla	5	6	3	5	7	9	9	9
25	Soyabean	6	6	1	2	3	3	3	3
26	Soyabean	6	6	1	2	3	3	3	3
27	Soyabean	6	6	1	2	3	3	3	3
28	Soyabean	6	6	1	2	3	3	3	3
29	Soyabean	6	6	1	2	3	3	3	3
30	Soyabean	1	2	1	2	3	3	3	3
31	Soyabean	1	6	2	2	3	3	3	3
32	Soyabean	1	10	1	2	2	2	3	3
33	Linseed	4	6	1	2	2	2	3	3
34	Perilla	5	6	2	2	3	3	4	4
35	Commercial Sample A			1	2	3	3	3	3
36	Commercial Sample B			1	1	2	3	3	3
37	Commercial Sample C			1	2	3	3	3	3

* Refer to Table III

TABLE XVIII
HARDNESS OR TACK OF EXTERIOR HOUSE TOPCOATS

No.	Oil	Series*		Percent Rocker Hard. in % every 24 Hrs.					
		No.	Ethocel	24	48	72	96	120	144
38	Soyabean	1	0	1	1	2	3	3	3
39	Soyabean	1	2	4	5	5	5	5	5
40	Soyabean	1	4	5	6	6	6	6	6
41	Soyabean	1	6	3	5	5	5	5	5
42	Soyabean	1	8	5	6	7	7	7	7
43	Soyabean	1	10	5	6	7	7	7	7
44	Soyabean	1	15	3	5	5	5	5	6
45	Soyabean	1	20	5	6	7	7	7	7
46	Soyabean	2	2	3	5	7	7	7	7
47	Soyabean	2	4	3	3	5	5	5	5
48	Soyabean	2	6	3	3	3	4	4	4
49	Soyabean	2	8	3	5	5	5	5	5
50	Soyabean	3	2	3	4	5	5	5	5
51	Soyabean	3	4	1	3	3	3	3	3
52	Soyabean	3	6	1	3	3	3	3	3
53	Soyabean	3	8	2	4	4	4	4	4
54	Linseed	4	0	1	3	3	4	4	4
55	Linseed	4	2	3	5	5	5	5	5
56	Linseed	4	4	4	4	5	5	5	5
57	Linseed	4	6	3	5	6	6	6	6
58	Perilla	5	0	1	2	3	3	3	3
59	Perilla	5	2	4	6	7	7	7	7
60	Perilla	5	4	5	7	8	9	9	9
61	Perilla	5	6	5	7	8	8	8	8
62	Soyabean	6	6	3	4	4	4	4	4
63	Soyabean	6	6	5	6	6	6	6	6
64	Soyabean	6	6	5	7	7	7	7	7
65	Soyabean	6	6	5	7	7	7	7	7
66	Soyabean	6	6	5	7	7	7	7	7
67	Commercial Sample A			1	2	2	2	3	3
68	Commercial Sample B			1	1	2	3	3	3
69	Commercial Sample C			1	1	1	1	2	2

* Refer to Table III

CONCLUSIONS

A comparison of the data obtained showed a greater initial set for the paints containing higher percentages of ethyl cellulose. The soyabean oil paints dried at a much slower rate than either the linseed or perilla oils. This was expected, however, since soyabean oil has poorer drying qualities because of the large percentage of oleic acid contained. The soyabean oil paints also produced much softer films when thoroughly dry than did the other samples.

The behavior of the primers in series two was very peculiar. These samples showed practically no amount of drying other than the loss of volatile matter. After 144 hours the films were still too tacky for use of the hardness rocker.

When the primers were compared with the topcoats, it was seen that the latter dried much faster. Although the hardness of the linseed and perilla oil topcoats, when dry, were about equal in hardness to their respective primers, the soyabean oil topcoats became much harder than their corresponding primers.

In general the test samples took about the same length of time to dry but were much harder than the commercial paints.

PART VIII
ABRASION RESISTANCE

THEORETICAL

The abrasion resistance of a paint film may be defined as its ability to resist wear.

This property may be measured relatively by means of a gravity sand blast. The quantity of sand required to wear through films of equal thickness is a relative measure of their ability to resist wear.

The apparatus consists essentially of a glass tube 5 feet long having an internal bore of one inch. The tube is supported in an upright position over the panel to be tested.

The films must be thoroughly dry and the test should be conducted at a constant temperature and humidity. Also the type of abrasive material selected should be such that it will not wear or change its shape readily. Such a material is Ottawa sand. It is round, will not wear readily, and has no sharp protruding surfaces.

EXPERIMENTAL WORK

Instead of preparing fresh films for use in this test, the films cast previously for the hardness determination were used. As stated before, these films had a thickness of 0.003 ± 0.0005 inches by actual measurement.

The abrasive material consisted of Ottawa sand ranging in size from 20 to 30 mesh or approximately 1 mm in diameter.

The test panel was set at an angle of 45° to the horizontal and the sand allowed to drop through a funnel having a bore of 0.125 inches. When the sand reached the bottom of the tube, it scattered to strike a surface on the panel about one inch in diameter. The sand was continually poured in until the coating had worn away, just disclosing the glass surface beneath.

The results of the tests were reported in Tables XIX and XX as the pounds of sand required to wear through a known thickness of film. These values were taken as a measure of the abrasion resistance of the paints.

TABLE XIX

ABRASION RESISTANCE OF EXTERIOR HOUSE PRIMERS

No.	Oil	Series [*] No.	Percent Ethocel	Abrasion Resistance Pounds of Sand
1	Soyabean	1	0	54
2	Soyabean	1	2	67
3	Soyabean	1	4	73
4	Soyabean	1	6	48
17	Linseed	4	0	86
18	Linseed	4	2	89
19	Linseed	4	4	100
20	Linseed	4	6	95
21	Perilla	5	0	40
22	Perilla	5	2	48
23	Perilla	5	4	36
24	Perilla	5	6	31
35	Commercial Sample A			12
36	Commercial Sample B			22
37	Commercial Sample C			38

* Refer to Table III

TABLE XX

ABRASION RESISTANCE OF EXTERIOR HOUSE TOPCOATS

No.	Oil	Series No.	Percent Ethocel	Abrasion Resistance Pounds of Sand
38	Soyabean	1	0	34
39	Soyabean	1	2	45
40	Soyabean	1	4	72
41	Soyabean	1	6	38
54	Linseed	4	0	27
55	Linseed	4	2	31
56	Linseed	4	4	35
57	Linseed	4	6	30
58	Perilla	5	0	34
59	Perilla	5	2	39
60	Perilla	5	4	29
61	Perilla	5	6	26
67	Commercial Sample A			79
68	Commercial Sample B			81
69	Commercial Sample C			90

* Refer to Table III

CONCLUSIONS

The results of the abrasion tests showed a remarkable degree of toughness on the part of those films containing higher percentages of ethyl cellulose, although in practically all cases this toughness apparently decreased when the percent of the cellulose derivative reached approximately 4% to 6%. The only explanation for this behavior is that the ethyl cellulose may have been excessively degraded because of the longer time required to cook the higher percentages. Also the drying effect may have increased in proportion to the increase in toughness. It is to be noted that as the films became tougher they became more flexible and less hard, thus yielding higher values. This was substantiated in part by the rocker hardness of these films.

It was also evident that the linseed and perilla oils formed harder films than the soyabean oil because of the high percentage of oleic acid in the latter.

In general the test samples showed that the primers were softer and more flexible than the topcoats while in the case of the commercial paints this relation was reversed. A possible explanation was the variation in the vehicle formulations.

PART IX
WEATHERABILITY

THEORETICAL

The purpose of weathering or exposure tests is to obtain information on the durability of paint products intended for protective coatings.

There are a large number of variables which enter into the testing of paints on a small scale, and it is doubtful whether the results thus obtained can be applied directly to the durability of the same coatings on large structures.

Factors (1) which have an effect upon the durability of coatings in relation to exposure tests are listed below:

1. Method of preparation.
2. Aging paint.
3. Drying period between coats.
4. Indoor preparation.
5. Aging of fresh film before exposure.
6. Type of wood.
7. Repainting.
8. Painting of panel back.
9. Paint application.
10. Color
11. Time of exposure.
12. Weather immediately after exposure.
13. Climate.

14. Atmospheric conditions.
15. Angle of exposure.
16. Moisture.
17. Size of panel limitation.
18. Acceleration.
19. Personal equation.

These factors are more or less dependent upon one another and may either be detrimental or beneficial to the coating as far as results are concerned.

EXPERIMENTAL WORK

Southern Yellow Pine was selected as a test surface because of the known effect of protective coatings to deteriorate more rapidly on it than on other types of wood.

The panels used were of first grade stock and had a test surface of 6 by 14 inches or 84 square inches. The backs and edges of the test panels were sealed with two coats of aluminum paint. The test surface was sanded with two grades of paper in preparation for coating.

The primers were applied with a 2 inch brush and allowed to dry for a period of one week. In applying the paint to the surface, the panels were painted first along the length from top to bottom and from left to right. This was followed by an application at right angles to the first from bottom to top and from right to left. In this way a uniform coating was obtained on the test surface. The topcoats were applied similarly.

A summation of the panels prepared for exposure data is given in Table XXI. The panels were exposed (Fig. 5) at 45° to the South on March 6, 1939.

Because of the short time the panels have been exposed no definite failure has taken place, the test surfaces being in perfect condition.

TABLE XXI
SUMMARY OF PANELS PREPARED FOR WEATHERING

Panel No.	Primer No.	Oil Series No.	Percent Ethocel	Topcoat No.	Oil Series No.	Percent Ethocel		
1	1	Soy.	1	0	38	Soy.	1	0
2	1	Soy.	1	0	54	Lin.	4	0
3	2	Soy.	1	2	39	Soy.	1	2
4	2	Soy.	1	2	54	Lin.	4	0
5	3	Soy.	1	4	40	Soy.	1	4
6	3	Soy.	1	4	54	Lin.	4	0
7	4	Soy.	1	6	41	Soy.	1	6
8	4	Soy.	1	6	54	Lin.	4	0
9	5	Soy.	1	8	42	Soy.	1	8
10	5	Soy.	1	8	54	Lin.	4	0
11	6	Soy.	1	10	43	Soy.	1	10
12	6	Soy.	1	10	54	Lin.	4	0
13	7	Soy.	1	15	44	Soy.	1	15
14	29	Soy.	6	6	65	Soy.	6	6
15	8	Soy.	1	20	45	Soy.	1	20
16	-	---	-	-	-	---	-	-
17	1	Soy.	1	0	39	Soy.	1	2
18	1	Soy.	1	0	40	Soy.	1	4
19	1	Soy.	1	0	41	Soy.	1	6
20	1	Soy.	1	0	42	Soy.	1	8
21	1	Soy.	1	0	57	Lin.	4	6
22	2	Soy.	1	2	57	Lin.	4	6
23	3	Soy.	1	4	57	Lin.	4	6
24	4	Soy.	1	6	57	Lin.	4	6
25	5	Soy.	1	8	57	Lin.	4	6
26	6	Soy.	1	10	57	Lin.	4	6
27	1	Soy.	1	0	58	Per.	5	0
28	2	Soy.	1	2	58	Per.	5	0
29	3	Soy.	1	4	58	Per.	5	0
30	4	Soy.	1	6	58	Per.	5	0
31	5	Soy.	1	8	58	Per.	5	0
32	6	Soy.	1	10	58	Per.	5	0
33	1	Soy.	1	0	61	Per.	5	6
34	2	Soy.	1	2	61	Per.	5	6
35	3	Soy.	1	4	61	Per.	5	6
36	4	Soy.	1	6	61	Per,	5	6
37	5	Soy.	1	8	61	Per.	5	6
38	6	Soy.	1	10	61	Per.	5	6
39	9	Soy.	2	2	46	Soy.	2	2
40	10	Soy.	2	4	47	Soy.	2	4

* Refer to Table III

TABLE XXI

CONTINUED

SUMMARY OF PANELS PREPARED FOR WEATHERING

Panel No.	Primer No.	Oil	Series* No.	Percent Ethocel	Topcoat No.	Oil	Series* No.	Percent Ethocel
41	11	Soy.	2	6	48	Soy.	2	6
42	12	Soy.	2	8	49	Soy.	2	8
43	13	Soy.	3	2	50	Soy.	3	2
44	14	Soy.	3	4	51	Soy.	3	4
45	15	Soy.	3	6	52	Soy.	3	6
46	16	Soy.	3	8	53	Soy.	3	8
47	30	Soy.	1	2	30	Soy.	1	2
48	31	Soy.	1	6	31	Soy.	1	6
49	32	Soy.	1	10	32	Soy.	1	10
50	33	Lin.	4	6	33	Lin.	4	6
51	34	Per.	5	6	34	Per.	5	6
52	30	Soy.	1	2	38	Soy.	1	0
53	31	Soy.	1	6	41	Soy.	1	6
54	32	Soy.	1	10	43	Soy.	1	10
55	33	Lin.	4	6	54	Lin.	4	0
56	34	Per.	5	6	58	Per.	5	0
57	30	Soy.	1	2	39	Soy.	1	2
58	31	Soy.	1	6	40	Soy.	1	4
59	32	Soy.	1	10	42	Soy.	1	8
60	33	Lin.	4	6	57	Lin.	4	6
61	34	Per.	5	6	61	Per.	5	6
62	28	Soy.	6	6	65	Soy.	6	6
63	27	Soy.	6	6	64	Soy.	6	6
64	26	Soy.	6	6	63	Soy.	6	6
65	25	Soy.	6	6	62	Soy.	6	6
66	21	Per.	5	0	43	Soy.	1	10
67	21	Per.	5	0	42	Soy.	1	8
68	24	Per.	5	6	41	Soy.	1	6
69	23	Per.	5	4	40	Soy.	1	4
70	22	Per.	5	2	39	Soy.	1	2
71	21	Per.	5	0	38	Soy.	1	0
72	21	Per.	5	0	61	Per.	5	6
73	21	Per.	5	0	60	Per.	5	4
74	21	Per.	5	0	59	Per.	5	2
75	24	Per.	5	6	61	Per.	5	6
76	23	Per.	5	4	60	Per.	5	4
77	22	Per.	5	2	59	Per.	5	2
78	21	Per.	5	0	58	Per.	5	0
79	17	Lin.	4	0	43	Soy.	1	10
80	17	Lin.	4	0	42	Soy.	1	8

* Refer to Table III

TABLE XXI

CONTINUED

SUMMARY OF PANELS PREPARED FOR WEATHERING

Panel Primer Oil Series* Percent					Topcoat Oil Series* Percent				
No.	No.	No.	Ethocel		No.	No.	Ethocel		
81	20	Lin.	4	6	41	Soy.	1	6	
82	19	Lin.	4	4	40	Soy.	1	4	
83	18	Lin.	4	2	39	Soy.	1	2	
84	17	Lin.	4	0	38	Soy.	1	0	
85	17	Lin.	4	0	57	Lin.	4	6	
86	17	Lin.	4	0	56	Lin.	4	4	
87	17	Lin.	4	0	55	Lin.	4	2	
88	20	Lin.	4	6	57	Lin.	4	6	
89	19	Lin.	4	4	56	Lin.	4	4	
90	18	Lin.	4	2	55	Lin.	4	2	
91	17	Lin.	4	0	54	Lin.	4	0	

* Refer to Table III

Figure 5
Paint Fence

SUMMARY

A summary of the results obtained in this investigation is stated as follows:

1. The introduction of ethyl cellulose in drying oils for use in exterior house paints produced a greater initial set or faster drying time but not in proportion to its increase in concentration.
2. Ethyl cellulose imparted an increasing degree of toughness or flexibility up to a certain concentration where it seemed to loose effect.
3. Ethyl cellulose definitely decreased the penetration of wood primers, although high percentages of the derivative did not produce a proportional decrease in penetration.
4. The hiding power was decreased as the concentration of the ethyl cellulose was increased.
5. The leveling as well as the brushability was increased to some extent by raising the ethyl cellulose content.
6. Ethyl cellulose had little effect upon the gloss or sagging properties of exterior paints.
7. The method of incorporation of the derivative in a drying oil is important from the standpoint of the results produced by the oil when used as a vehicle in paints.

8. The effects produced on different oils were found to be practically the same.

A small amount of the derivative seemed to have as much effect as larger quantities. Although ethyl cellulose did not produce any detrimental effects, the magnitude of the beneficial effects produced in the exterior paints were not considerable. However, the incorporation of this derivative in a drying oil is a most convenient and useful method for bodying the oil. Before proceeding further an economic consideration of this problem should be undertaken.

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