

now (which perhaps might be done) which one of them is, on good scientific grounds, the most appropriate for index purposes in view of present knowledge, and further (which of course could not be done), could one be assured that such name would remain the approved name for all future time, such title could, without hesitation, be now adopted as the indexing title, under which all references to literature or patents could be entered, and all other titles and names cross-referenced into it; but while this might be done now in certain cases, which and how many of these names now used and approved will remain in use in years to come is something that no one can at present determine. Evidently the dictionary plan, unmodified, was not the best, and some better system had to be devised not open to these objections.

The system adopted was based on the chemical formula. In establishing for the Patent Office a card index to chemical literature, it was therefore decided to use, as an indexing basis, the kind and number of the component atoms of a chemical compound, these being its most unvarying characteristics, being subject only to errors of chemical analysis, and being, therefore, the most stable and unchanging basis for any scheme for the indexing and digesting of chemical literature: a conclusion reached at about the same time independently by Richter, as illustrated in his since published *Lexicon der Kohlenstoff-Verbindungen*, and by other later workers in this field, the Patent Office system differing from that of Richter in being simpler and of more general application.

It was found that the simplest, most certain, and most direct system, was to rewrite the so-called empirical chemical formula in a particular manner, that is to say, to write the atoms in the alphabetical order of their chemical symbols, upon library catalogue cards of standard size, and place these cards, arranged in alphabetical order, in standard library cases. For example, take the following chemical compounds:

$(\text{CH}_3)_2\text{C}_2\text{H}_2(\text{NO}_2)_2$ .....	Dinitrobutane
$(\text{CH}_3)_2\text{CHNO}_2$ .....	Isopropylic nitrite
$\text{KH}_3\text{C}_2\text{O}_4$ .....	Potassium acetate
$\text{CH}_3\text{Cl}$ .....	Methyl chloride
$\text{Cu}(\text{AsO}_2)_2$ .....	Copper arsenite

Rewriting them and arranging them alphabetically by formulas instead of titles, they are:

$\text{As}_2\text{CuO}_4$ .....	Copper arsenite
$\text{CH}_3\text{Cl}$ .....	Methyl chloride
$\text{C}_2\text{H}_3\text{KO}_4$ .....	Potassium acetate
$\text{C}_8\text{H}_7\text{NO}_2$ .....	Isopropylic nitrite
$\text{C}_4\text{H}_8\text{N}_2\text{O}_4$ .....	Dinitrobutane

It should be noted, however, that the compounds containing carbon and hydrogen, and broadly included in the domain of organic chemistry, constitute so large and important a class that it is fully justifiable to depart slightly from the strictly alphabetical arrangement of chemical symbols, and write C always first and H accompanying C always second, in order to bring more closely together in the index bodies more or less closely related in chemical and physical properties.

In practice, therefore, the following general rule has been followed in compiling the chemical card index of the Patent Office: Reject water of crystallization and rewrite the empirical formula in the alphabetical order of the chemical symbols, except that in carbon compounds, C is to be written first and H second. Follow this rewritten formula with the constitutional formula, when given, adding the water of crystallization, if any, but arrange the cards alphabetically by the rewritten formula.

The reason for disregarding water of crystallization may be illustrated as follows: The three bodies,  $\text{Na}_2\text{SO}_4$  or anhydrous sodium sulfate,  $\text{Na}_2\text{SO}_4 + 10\text{H}_2\text{O}$  or Glauber's salt, and the heptahydrated salt,  $\text{Na}_2\text{SO}_4 + 7\text{H}_2\text{O}$ , are in this way indexed under the same indexing formula,  $\text{Na}_2\text{O}_4\text{S}$ , and are thereby brought together, as they should be, for in solution they are chemically identical. If, on the other hand, water of crystallization were taken into account for indexing purposes, the corresponding indexing formulas would become  $\text{Na}_2\text{O}_4\text{S}$ ,  $\text{H}_{20}\text{Na}_2\text{O}_{14}\text{S}$ , and  $\text{H}_{14}\text{Na}_2\text{O}_{11}\text{S}$ , respectively, and these three practically identical bodies would, in consequence, be widely separated in the index, which result would evidently be a very undesirable one.

The index was commenced and has been continued on the library-card catalogue plan, using the regular standard card, size  $7\frac{1}{2}$  by  $12\frac{1}{2}$  centimeters, or approximately 3 by 5 inches, without rulings except a single colored horizontal line  $\frac{3}{8}$  of an inch below the top of the card—this for typewritten cards and cards upon which printed matter cut from books and periodicals is pasted. A limited use has also been made of cards having ruled lines, where for certain reasons the cards are written by hand.

I believe it would be very desirable to have an exchange of opinions on this subject in the correspondence column of this journal. It is our duty to assist by any helpful suggestions possible, the good work which is now being performed by the Washington Patent Office.

L. H. BAEKELAND

## ORIGINAL PAPERS

### PRELIMINARY REPORT UPON A PRACTICAL ACCELERATED TEST FOR PAINTS AND VARNISHES<sup>1</sup>

By A. M. MUCKENFUSS

There being comparatively few constants in nature,

<sup>1</sup> Author's abstract of paper presented at the Milwaukee meeting of the American Chemical Society, March 25-28, 1913.

it follows that most materials are continually changing their properties with use, though at widely varying rates. In the case of paints, varnishes and some other materials affected by exposure to atmospheric agencies of destruction, this change of properties is quite rapid at first and continues generally at a di-

minishing speed. The coating when fresh is liquid, but soon becomes "tacky," and later firm but elastic, finally descending into a condition of brittleness, chalkiness, and other manifestations of old age. Among the properties of the paint and varnish film might be enumerated: permeability to various liquids and gases, electrical conductivity, elasticity, and hardness. All such characteristics are changing from the moment the coating is applied until it is finally destroyed. What is the internal cause of the alterations and to what extent are they independent of each other? It seems to be generally agreed that there are four classes of changes going on within a protective coating: A—*Chemical*: (1) Reactions between constituents of the air and the vehicle, gum, and in some cases the pigment. (2) Reactions between the coating and the surface covered. (3) Reactions upon each other of the various constituents of the coating. B—*Physical*: (4) Alterations in crystalline form, size of particles, and the like, in the pigment, and physical changes in the vehicle produced by the above chemical actions. The line of demarcation between the physical and the chemical is steadily growing more obscure and nowhere is its haziness more manifest than in such a complex mixture as that of the organic, inorganic, colloidal, crystalline materials of a paint film.

It being self-evident that reactions like the above are the causes of the aforesaid changes in properties, it seems to follow that, with the exception perhaps of the first physical alterations referred to, it is impossible for any one property of the film to gain or lose in value without also a difference becoming manifested in all the other properties. In other words, the variable properties of the paint and varnish coating are dependent and not independent functions. Here we have the foundation for the research outlined below. If the film becomes "flat," there will be an alteration of the density, permeability, hardness, and of all other properties. Theoretically, therefore, it is only necessary to measure one of these characteristics at various periods during the life of the coating in order to obtain an index of the alteration at all other points. Since the coefficient of change with time will be different for each property, the greater the number of these measured, the better; though from a practical view point, it may not be worth while to measure more than one accurately. These variables differ considerably in importance and ease of measurement. Some cannot be measured without injury to the film, as hardness, and some not without unfair treatment, as resistance to chemicals.

Of all these characteristics, permeability is second to none in importance and stands first in ease of measurement. It seems generally agreed among experts that differences in the permeability of the membranes lie at the base of the explanation of the wide contrasts between the durability of protective materials. Many methods, more or less accurate, have been devised for rating the perviousness of the paint film, in recognition of its importance as a distinct property, entirely aside from its periodic measurement as an

index to durability. As to the latter, the panel test is the standard and by its results, slowly obtained though they be, all other processes with similar purpose should be gauged. In the course of the numerous accelerated paint tests described in the literature, little attention has been paid to the age of film, thickness of coat, temperature and humidity of air, amount of sunshine, etc., after coats were applied. As will be shown later, no inferences can be drawn from measurements for the durability of membranes, unless all factors entering into the process of drying and decay are carefully standardized or unless all panels of a set of comparative tests are subjected to practically identical conditions as regards both intensity and duration.

The attempt was made at the outset of this investigation to devise for measuring permeability an apparatus that could be operated as accurately as needed, without in any way subjecting the membrane of the material to unfair treatment. Further

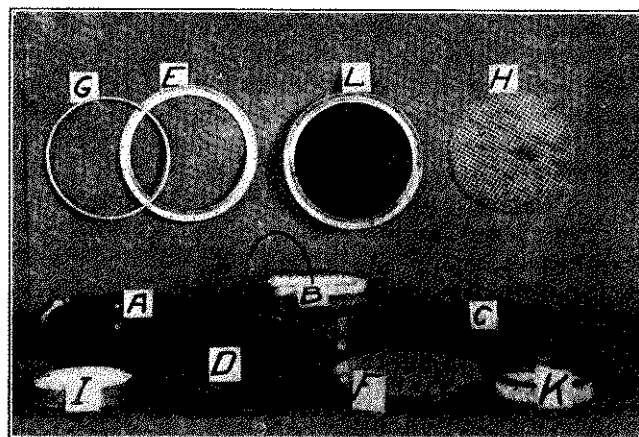


FIG. 1

objects were simplicity, ease of manipulation, a wide range of conditions for measurement, and the possibility of construction in various forms and from various materials. Fig. 1 exhibits several parts of the third and present form of the apparatus and Fig. 2 shows the parts assembled in several units arranged side by side on a shelf. In Fig. 1, A is the base; B, the general cover; D, the convex ring; C, the concave ring; E,



FIG. 2

the clamping ring; L, the two latter clamped together with a steel porous surface stretched tightly between them; F, the pan; G, the wire ring; H, the wire screen

disc; *K*, the weighed dish containing the water absorbent; and *I*, the corresponding unweighed dish. The cover to the weighed dish is sealed with a composite wax of proper viscosity. The materials used are cast iron, glass, and painted tin, but there is yet room for many improvements in this regard. When setting up this apparatus, the base is leveled and sufficient mercury is placed in each groove. Sufficient water is also poured into the central trough. Just beyond the water is a tube opening through a plug of cotton to the outside air and across from this is a similar space for placing another tube, if permeability to another gas besides water vapor is to be measured. The general cover of glass permits observation during the interval of a measurement and has a tube which serves both as a handle and as a means of communication with atmospheric pressure, the end of this tube being plugged with water absorbent and cotton to prevent ingress of moisture. The painted surface is prepared by first clamping or otherwise sealing the two rings together or the concave ring to the clamping ring by means of springs or wire through the small holes placed around at equal distances. A porous surface of strength and uniformity is placed between the rings before clamping and is automatically stretched because of the "dovetailing" of the parts into each other. This also minimizes danger of later leakage through points of contact. The porous surface is always of the same material that the paint is intended to cover, steel wire cloth for steel, hardened paper for wood, or cement and sand for concrete. This search for a satisfactory and fair imitation of the actual surface will continue to be the subject of study, commensurate with its importance.

The ring completed forms a "panel," the area of whose surface for painting is 341 sq. cm. The paint or varnish is applied uniformly with a brush just as to any other kind of panel or surface and by weighing before and after, the weight of coating may be obtained as accurately as desired, depending on whether the parts fit well and allow very little "dead" material to creep under the areas of clamping contact and whether or not the weighing is recorded immediately after each coat is spread.

The blank is run as follows: Invert the pan on the base and place on it the wire ring. Upon this place the wire screen disc and then the unweighed dish. Finally put the cover in position. After some hours, when a uniform condition has been reached, note the time, remove cover, replace the unweighed with the weighed dish, remove dish cover, and replace general cover. The next day, at the same time, raise general cover, replace cover of weighed dish and weigh the dish. The increase of weight in milligrams is the "blank" (generally about 50 milligrams) to be subtracted from the number of milligrams obtained in the next step. The pan is now removed and the panel whose permeability is sought is placed in position. After this, the steps are exactly as in the case of the blank. The final result gives the net milligrams for twenty-four hours. If the period is not twenty-four hours, the figure is calcu-

lated to that interval, which gives the "actual" permeability of the panel.

An inspection of the construction of the apparatus will demonstrate that, during the measurement, it is impossible for moisture to escape from the trough, except through the paint film of the panel. It is further impossible for it to enter or escape from the apparatus, disregarding any slight leakage, which is canceled by the blank. Both sides of the film are nevertheless open to atmospheric pressure; hence there is no excess in total pressure in any one direction. The area under the film has a humidity of 100 per cent, while that above has a humidity approaching as near to zero as the activity and quantity of the absorbent and the permeability of the film will permit. Under these conditions, the vapor is absorbed by the film on its under side and evolved on its upper side in a steady stream.

The mechanism by which the water or other substance passes through the film will be discussed in a later paragraph, when results bearing upon the point have been presented. Theoretically the standard value for permeability would be that obtained under standard conditions as regards each component that effects the result, or at standard temperature with unit area of film, unit weight or volume of coating, etc. At present, there is no need of attempting to establish such a standard. Practically, however, there is need of adopting a method of comparison by which successive results on the same and on different coatings may be compared with each other. The data to be presented later will indicate that, allowing for errors in spreading the paint already explained, the permeability decreases as the weight of the film increases. Whether the actual results times the weight of film equal a constant for the same coating will be determined by later measurements, but it seems to be true where the divergence in weight of film is not too large. The following proportion is then applicable: Weight of film in grams : 10 :: "weight permeability" : "actual permeability." In other words, the weight permeability represents the result that would be obtained if the film of area given had weighed exactly 10 grams. The major portion of the data presented in this paper is plotted on this basis, largely because the extra calculation involved slight additional labor and afforded the best ready means of comparison. It is true that a film weighing 5 grams would probably not have exactly twice the permeability of one of the same material weighing the standard 10 grams but if 5 grams is the weight of the regulation number of coats for that material, the results on 5 grams should be the basis of calculation. If the densities of the liquids are very divergent some other means of comparison must be adopted before it can be stated that one substance is "high" and another "low" in perviousness. While the "actual" permeability makes comparison on the basis of equal number of coats, yet a "coat" may vary greatly according to the thickness and spreading qualities of the material applied. Of course both the weight and volume of a coating change with time,

but it would appear unnecessary to make more than one determination of these under uniform conditions in order to secure a comparison sufficient for all practical purposes.

One of the first points noticed during this investigation was that successive measurements on the

were reversed, and finally the panel brought to its original position. Thus the moisture passed first from the inside out, and this direction was reversed twice for the white and once for the varnish. This order was changed in the case of corroded lead, with also two reversals.

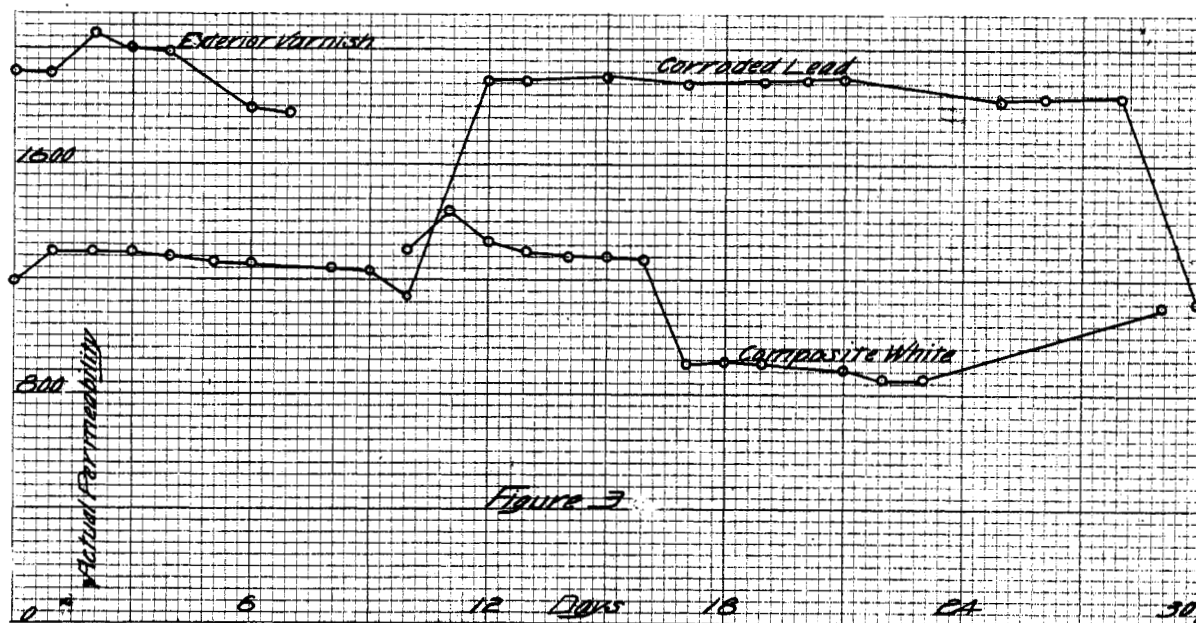


Figure 3

same panels without intervening exposure did not check with each other. This was not surprising since an appreciable temperature coefficient was to be expected. Unless otherwise stated, the results presented in this paper were under conditions of sufficiently uniform temperature, on the average  $32.9^{\circ}$  C. The exact coefficient under all conditions will be a matter for later determination. The effect of temperature is marked. Thus, it was found that the panel of white (Fig. 3) which gave a permeability of 854 and 853, successively, at  $32.9^{\circ}$  C., gave two days later, with no intervening exposure, 137 and 139 at  $10.9^{\circ}$  C., or a drop of 32.52 milligrams for each degree. In this case, the coefficient is 0.0381 per degree C., based on the result at the higher temperature.

Measurements have been made on panels with no water in the trough underneath, with results of about 100 less the blank, representing the moisture actually in the film at the beginning. This is mentioned merely as proof that during the measurements the source of the water is ultimately in the trough of the base.

Fig. 3 is presented as a test of the accuracy of the apparatus under the degree of uniformity considered sufficient for practical purposes. Three panels were prepared at different times from concave and convex rings. Each was placed in a unit of the apparatus and kept there day after day with a dish of absorbent continually drawing water through the film. Generally it was a weighed dish and measurements were made daily, though this was not always convenient. For the varnish and composite white, the uncoated side was at first down; later the sides

RESULTS ON FIG. 3  
CORRODED LEAD

Wt. of coat	Meas. Days		Actual permeability		Meas. Days		Actual permeability		Days inter-val	Actual permeability
	No.	interval	No.	interval	No.	interval	No.	interval		
14.38	1	0	1197	2	1	1298	3	1	1296	
	4	1	1292	5	1	1273	6	1	1251	
	7	1	1253	8	2	1241	9	1	1223	
	10	1	1156	11	2	1894	12	1	1889	
	13	2	1896	14	2	1839	15	2	1847	
	16	1	1869	17	1	1868	18	4	1812	
	19	1	1821	20	2	1830	21	2	1110	
OUTSIDE WHITE										
	1	0	1302	2	1	1445	3	1	1339	
	4	1	1298	5	1	1285	6	1	1285	
	7	1	1261	8	1	910	9	1	918	
	10	1	903	11	2	884	12	1	854	
	13	1	853	14	6	1106	..	..	..	
EXTERIOR VARNISH										
	1	0	1915	2	1	1911	3	1	2049	
	4	1	2001	5	1	1995	6	2	1799	
	7	1	1775	..	..	..	..	..	..	

It is easily apparent that the lead shows the greatest contrast and the exterior varnish the least, when comparing permeability on either side. Whether this expressed any particular advantage cannot yet be stated. The position of the panel on the base is important, but the length of time elapsing before a measurement is made after the panel is in position is unimportant for a small number of days. The steady decrease in permeability noticed is due doubtless to a slight drying action in progress even while the panel is on the base and in the absence of light. The fluctuations apparent enable one to gauge the degree of error probable for all other measurements to be submitted, which were made with the coated side up.

The most interesting point about Fig. 3 is the apparent fact, suspected by experts, that a paint film is more pervious in one direction than the other. Paint thus may have the advantage of "valve action," offering a greater resistance to water which tends to

same paint on the same surface will not last two years with a succession of bad seasons in a severe climate. In certain areas of the tropics situated on the southern slopes of mountains, we may actually see in nature practically all the extremes of temperature, light, and humidity regularly every twenty-four hours for

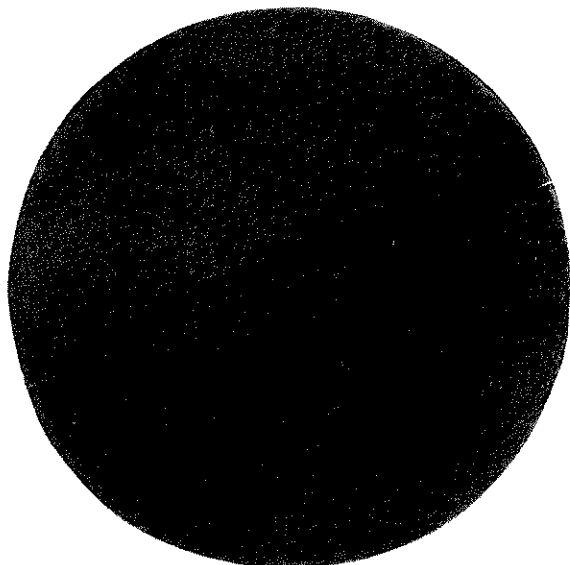


FIG. 4

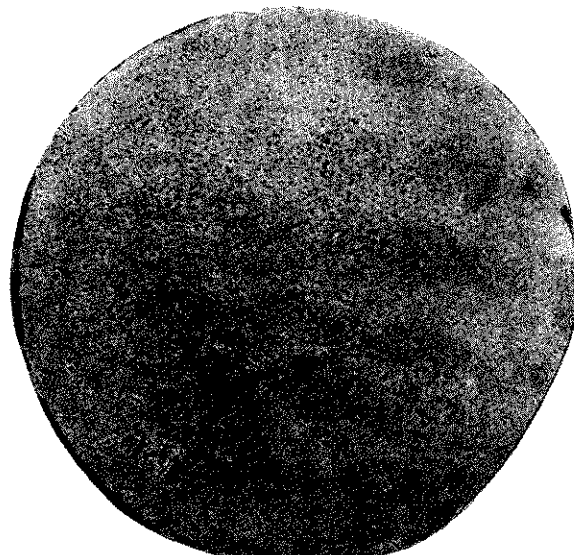


FIG. 5

reach the protected surface than to moisture which at other times and on wooden surfaces must be allowed to escape freely. This point will later receive further experimental trial, too many other phases of the research being more important at present. It may be concluded that the surface covered is probably the chief cause of the contrasts observed. A paint coating is in more intimate contact with the moisture of the under surface than with the moisture of the air (except during a rain). The under surface of wood during a measurement absorbs moisture more rapidly than the paint coating itself; hence, the permeability is higher from this direction.

#### PRACTICAL RESULTS ON PAINTS AND VARNISHES

It has been shown so far that each of the various components of what is termed "the weather" has its own peculiar effect upon permeability. The next step in this investigation would naturally be to expose panels of various compositions until each is evidently "broken down," measuring permeability from time to time. This has been done, and the results are presented on ten charts below. All of the panels involved were not exposed at the same time nor to exactly the same conditions but those reported together were coated at the same time, measured at the same time, and given the same kind and length of exposure as far as practicable. In order to obtain results more quickly the exposure used was severe. Whether the same comparative results would be produced from a milder treatment, only future experiments can tell. The rate of decay of paint and varnish is well known to differ considerably with the kind and degree of exposure. A good paint under favorable conditions will last perhaps six years, while the

part of the year. Such was the exposure by which the results to be tabulated were obtained. No element in it was more intense than that found in actual service. The panels were not subjected to acid fumes, soaking in water, or any other unnatural condition that could be a source of criticism.

To describe this part of the work properly would double the length of this paper. Suffice it now to state that air-tight cylindrical boxes, sufficiently large (7 ft. in diameter, 4 ft. in height), were used, the weathering force emanating from the axes. The exposure used was indeed artificial, but of the same kind as that acting naturally. Rain was imitated with a whirling garden spray; sunlight, by the use of the mercury vapor and tungsten lamps in combination; and cold weather, by admitting the outside air at night. Plenty of ventilation was afforded by use of a fan while the lamps were in operation. The panels were arranged around the sides of the boxes so as to be easily removed or replaced, care being taken to have those of any one comparative set at the same level in the box. Since the lamps could not be located exactly along the axes of the box and in any event mercury lamps do not radiate equally in all horizontal directions, the lamps and panels were rotated along the above axes for different positions with reference to each other from day to day, so that each panel would receive practically its share of exposure. This illustrates one of the many precautions observed in order to secure valid results. From 7 A.M. to 6 P.M., the panels were subjected to a good imitation of a hot, breezy, summer day, the temperature going up to 60° C. for part of the time. From 6 P.M. to 11 P.M. there was rain, and from 11 P.M. to 7 A.M. cold weather.

Permeability, of course, is simply one of many indications of paint and varnish decay. Nothing more is claimed for the process being outlined in this article than recognition as an additional method of rating protective coverings. The work is at present

be reported within the proper limits of this paper. Among these should be mentioned the effects of the exposure on several lines of paints for structural iron,

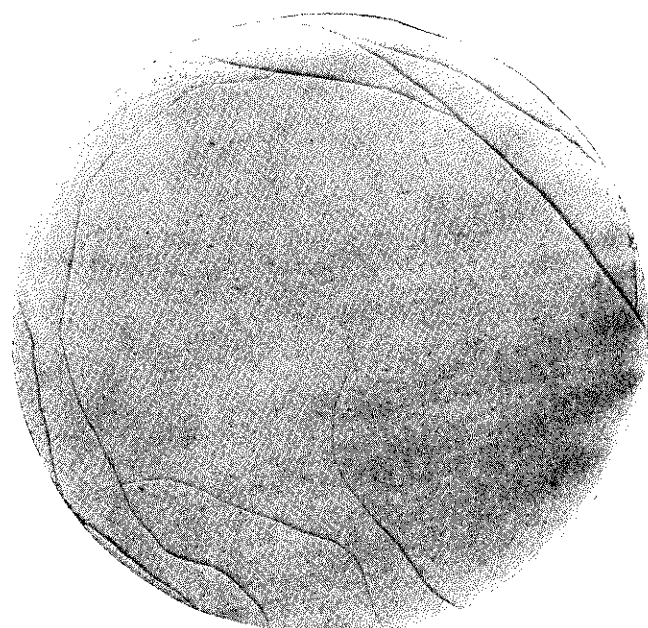


FIG. 6

merely in a preliminary stage and only later studies, which will be prosecuted as rapidly as possible, will demonstrate the real meaning and value of the practical results now to be submitted. The finished

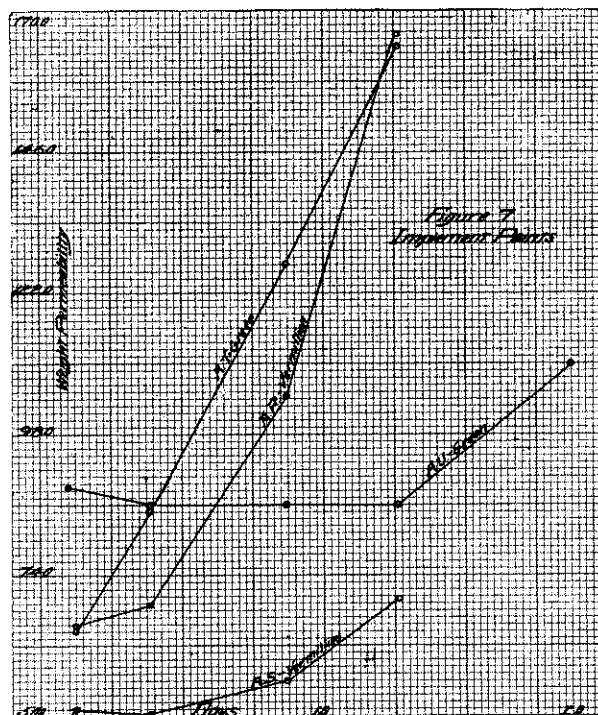


Figure 7  
Implement Paints

spread over steel panels, and on specially prepared mixtures of lead and zinc with various oils and driers.

RESULTS ON FIG. 7—IMPLEMENT PAINTS

	Weight of coat	Meas. No.	Days interval	Permeability		Meas. No.	Days interval	Permeability		Meas. No.	Days interval	Permeability	
				Actual	By weight			Actual	By weight			Actual	By weight
A R <sub>1</sub> .....	3.41	1	0	2044	697	2	3	2227	759	3	5 1/2	3074	1048
A R <sub>2</sub> .....	3.27	1	0	1871	612	2	3	1878	614	3	5 1/2	3265	1042
Average.....	..	1	0	..	654	2	3	..	686	3	5 1/2	..	1045
A S <sub>1</sub> .....	2.13	1	0	2374	506	2	3	2323	495	3	5 1/2	2596	553
A S <sub>2</sub> .....	2.14	1	0	2428	520	2	3	2357	516	3	5 1/2	2632	563
Average.....	..	1	0	..	513	2	3	..	505	3	5 1/2	..	558
A T <sub>1</sub> .....	3.29	1	0	2119	697	2	3	2428	799	3	5 1/2	3239	1066
A T <sub>2</sub> .....	3.08	1	0	1929	594	2	3	2922	900	3	5 1/2	4609	1419
Average.....	..	1	0	..	645	2	3	..	849	3	5 1/2	..	1242
A U <sub>1</sub> .....	3.78	1	0	2408	910	2	3	2440	922	3	5 1/2	2408	910
A U <sub>2</sub> .....	3.73	1	0	2350	877	2	3	2143	799	3	5 1/2	2155	804
Average.....	..	1	0	..	893	2	3	..	860	3	5 1/2	..	857
A R <sub>1</sub> .....	..	4	4 1/2	4515	1540	..	..	..	..	..	..	..	..
A R <sub>2</sub> .....	..	4	4 1/2	5574	1823	..	..	..	..	..	..	..	..
Average.....	..	4	4 1/2	..	1681	..	..	..	..	..	..	..	..
A S <sub>1</sub> .....	..	4	4 1/2	3360	716	..	..	..	..	..	..	..	..
A S <sub>2</sub> .....	..	4	4 1/2	3216	688	..	..	..	..	..	..	..	..
Average.....	..	4	4 1/2	..	702	..	..	..	..	..	..	..	..
A T <sub>1</sub> .....	..	4	4 1/2	4365	1436	..	..	..	..	..	..	..	..
A T <sub>2</sub> .....	..	4	4 1/2	5967	1838	..	..	..	..	..	..	..	..
Average.....	..	4	4 1/2	..	1637	..	..	..	..	..	..	..	..
A U <sub>1</sub> .....	..	4	4 1/2	2553	965	5	7	3121	1180	..	..	..	..
A U <sub>2</sub> .....	..	4	4 1/2	2010	750	5	7	2746	1024	..	..	..	..
Average.....	..	4	4 1/2	..	857	5	7	..	1102	..	..	..	..

products of these tests were either purchased in the open market or mixed under the direction of the writer in the laboratory. The composition is based either on published analyses or determinations in the laboratory. The raw materials were of the best grade and had received the "O. K." of the factory chemist, unless otherwise stated.

Many interesting results were obtained that cannot

One of the first pieces of work completed was on a line of agricultural paints. The samples were from materials in actual use by manufacturers for the coating of their products. The panels were prepared in exactly the same way with the same material as in the painting of a plow or wagon, all coats being applied at dipping consistency. There was first spread on each as nearly as possible to the same thickness

the ordinary "pink primer" consisting of lithopone and some iron and zinc oxides ground to a paste in linseed oil. All panels were given as a final coat as nearly as possible the same thickness of the same short oil (linseed) No. 1 kauri varnish, so the only difference between the panels, disregarding the above sources of error, consisted in the intermediate coat of vermilion or green. Fig. 7 illustrates the great difference noted, and the numerical results are appended

of actual pores evidenced in the appearance or of a decreased thickness of film. This is borne out by the condition of these panels at the end of the testing period; for it is easy to separate them by their marked difference in appearance. Thus a remarkable contrast is shown between these implement coatings. It would be difficult to believe that A S and A U are not more durable than A R and A T.

The next set of tests to be presented is a group of

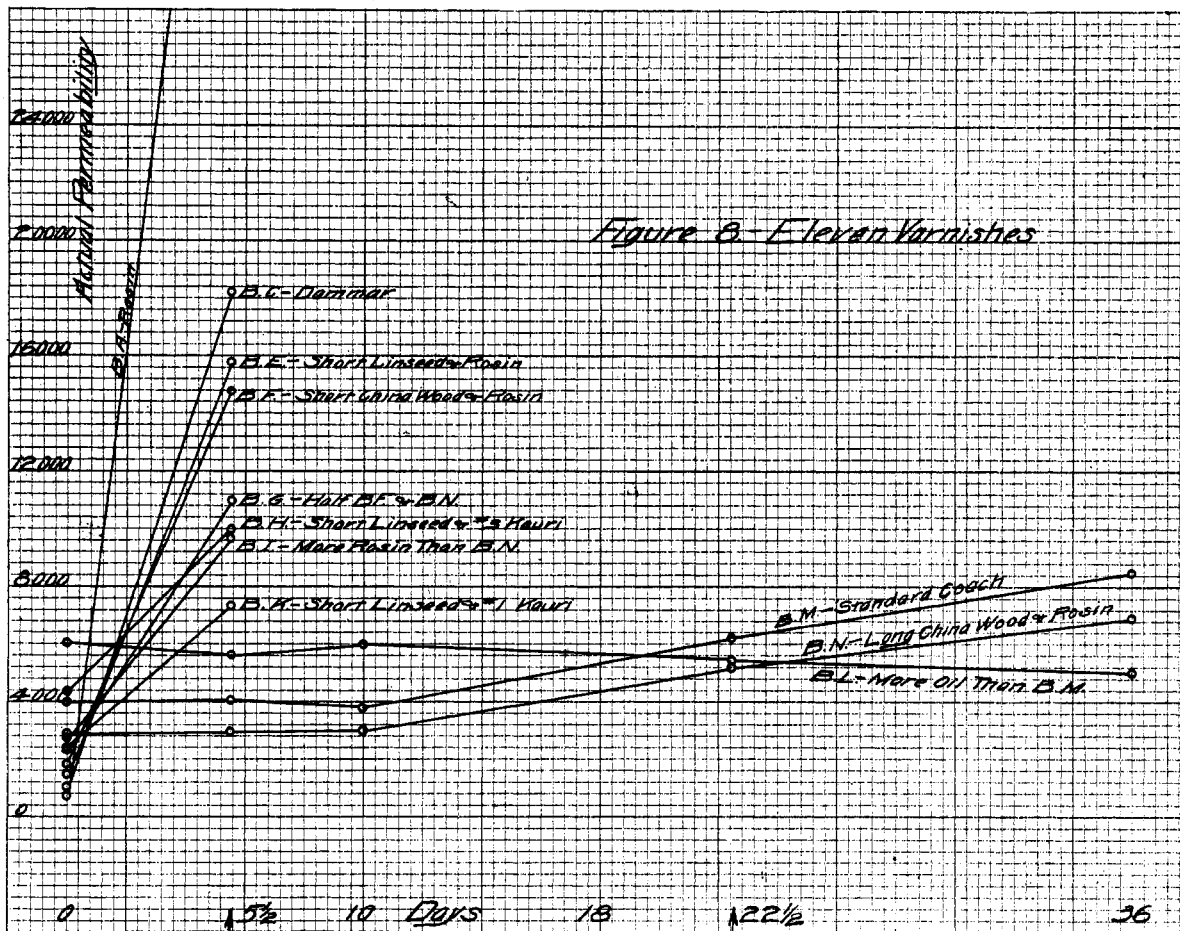


Figure 8—Eleven Varnishes

below. As in all later diagrams presented where duplicate determinations were made, only average results are plotted.

It will be noticed that where a material has slight durability, as A R and A T, the duplicate with the thinner coating shows the greater change in permeability, as might be expected. In the light of later data, it is justifiable to conclude that all of these panels would have decreased in permeability if the second measurement had been made after a sufficiently short period of exposure, 1 1/2 days being too long. Reasoning now once for all, we conclude that as long as permeability is going down, the rate of oxidation is greater than that of dissolving action, hydrolysis, and decreasing elasticity. But when the latter changes have produced a larger effect than the former, the curve of permeability turns up and the film itself soon goes flat, chalks, checks, or cracks. The rise in permeability would thus seem to be finally the result

of eleven varnishes, embodied in Fig. 8. The actual data are presented herewith:

RESULTS ON FIG. 8—ELEVEN VARNISHES									
	Meas. No.	Days interval	Actual per-meability	Meas. No.	Days interval	Actual per-meability	Meas. No.	Days interval	Actual per-meability
B F <sub>1</sub>	1	0	1782	2	5 1/2	15215	..	..	..
B F <sub>2</sub>	1	0	1898	2	5 1/2	14365	..	..	..
Ave.	1	0	1790	2	5 1/2	14790	..	..	..
B E <sub>1</sub>	1	0	1507	2	5 1/2	16064	..	..	..
B E <sub>2</sub>	1	0	1418	2	5 1/2	15574	..	..	..
Ave.	1	0	1462	2	5 1/2	15819	..	..	..
B N <sub>1</sub>	1	0	2978	2	5 1/2	3090	3	4 1/2	3008
B N <sub>2</sub>	1	0	2900	2	5 1/2	2922	3	4 1/2	2916
Ave.	1	0	2939	2	5 1/2	3006	3	4 1/2	2962
B N <sub>1</sub>	4	12 1/2	5816	5	13	..	..	..	..
B N <sub>2</sub>	4	12 1/2	4696	5	13	..	..	..	..
Ave.	4	12 1/2	5256	5	13	..	..	..	..
B G <sub>1</sub>	1	0	2590	2	5 1/2	12612	..	..	..
B G <sub>2</sub>	1	0	2123	2	5 1/2	9335	..	..	..
Ave.	1	0	2356	2	5 1/2	10975	..	..	..
B K <sub>1</sub>	1	0	2465	2	5 1/2	8119	..	..	..
B K <sub>2</sub>	1	0	2273	2	5 1/2	6578	..	..	..
Ave.	1	0	2369	2	5 1/2	7348	..	..	..

## RESULTS ON FIG. 8—(Continued)

	Meas. No.	Days interval	Actual		Meas. No.	Days interval	Actual		Meas. No.	Days interval	Actual	
			per-meas. bility	per-meas. bility			per-meas. bility	per-meas. bility				
B H <sub>1</sub> ..	1	0	4346	2	5 1/2	9157	..	..	..	..	..	..
B H <sub>2</sub> ..	1	0	4363	2	5 1/2	10844	..	..	..	..	..	..
Ave.	1	0	4354	2	5 1/2	10000	..	..	..	..	..	..
B M <sub>1</sub> ..	1	0	4170	2	5 1/2	4042	3	4 1/2	4044	..	..	..
B M <sub>2</sub> ..	1	0	3804	2	5 1/2	4173	3	4 1/2	3620	..	..	..
Ave.	1	0	3987	2	5 1/2	4107	3	4 1/2	3820	..	..	..
B M <sub>1</sub> ..	4	12 1/2	7056	5	13	..	..	..	..	..	..	..
B M <sub>2</sub> ..	4	12 1/2	5456	5	13	..	..	..	..	..	..	..
Ave.	4	12 1/2	6256	5	13	..	..	..	..	..	..	..
B L <sub>1</sub> ..	1	0	6037	2	5 1/2	5667	3	4 1/2	5802	..	..	..
B L <sub>2</sub> ..	1	0	6050	2	5 1/2	5652	3	4 1/2	6300	..	..	..
Ave.	1	0	6043	2	5 1/2	5659	3	4 1/2	6051	..	..	..
B L <sub>1</sub> ..	4	12 1/2	5253	5	13	..	..	..	..	..	..	..
B L <sub>2</sub> ..	4	12 1/2	5688	5	13	..	..	..	..	..	..	..
Ave.	4	12 1/2	5470	5	13	..	..	..	..	..	..	..
B A <sub>1</sub> ..	1	0	826	2	5 1/2	45246	..	..	..	..	..	..
B A <sub>2</sub> ..	1	0	688	2	5 1/2	46184	..	..	..	..	..	..
Ave.	1	0	757	2	5 1/2	45715	..	..	..	..	..	..
B C <sub>1</sub> ..	1	0	989	2	5 1/2	18295	..	..	..	..	..	..
B C <sub>2</sub> ..	1	0	968	2	5 1/2	18100	..	..	..	..	..	..
Ave.	1	0	978	2	5 1/2	18200	..	..	..	..	..	..
B I <sub>1</sub> ..	1	0	2974	2	5 1/2	10037	..	..	..	..	..	..
B I <sub>2</sub> ..	1	0	2401	2	5 1/2	9412	..	..	..	..	..	..
Ave.	1	0	2687	2	5 1/2	9724	..	..	..	..	..	..

These were the first varnishes tested and evidently the first period of exposure (5 1/2 days) was far too long; for by that time all but three had "gone to pieces," so much so that in the measurements much absorbent was practically exhausted. Measurements on rosin mixtures to be presented later indicate that these varnishes also at first decreased in permeability and that during the 5 1/2 days interval much interesting history was lost. Nevertheless, it is remarkable how closely the slopes of the curves agree with experience.

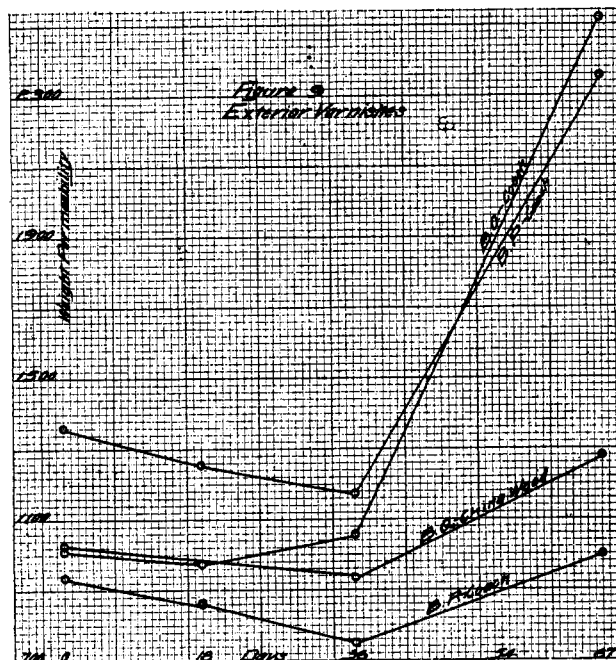
## FIRST CHECKING

B A	7 days, or at the first rain
B C	7 days, or at the first rain
B F	13 days
B E	13 days
B K	17 days

## FINAL CONDITION

Practically no coating left
Mostly scaled off
No worse than on 13th day
Badly checked
Very slightly checked

None of the others has as yet begun to check, but experiences teaches that they will also act very much in agreement with their permeability changes.



Comparing B K, B H, B F, and B E, we see that No. 3 kauri is less durable than No. 1 but both far

## RESULTS ON FIG. 9—EXTERIOR VARNISHES

	Weight of coat	Meas. No.	Days interval	Permeability		Meas. No.	Days interval	Permeability		Meas. No.	Days interval	Permeability	
				Actual	By weight			Actual	By weight			Actual	By weight
B O.....	3.71	1	0	2727	1012	2	17	2620	972	3	19	2836	1052
B P.....	4.13	1	0	3308	1366	2	17	3033	1253	3	19	2832	1170
B Q.....	4.23	1	0	2421	1024	2	36	2212	936	3	31	3025	1280
B R.....	4.46	1	0	2097	935	2	17	1929	860	3	19	1642	749
B O.....	..	4	31	6782	2516	..	..	..	..	..	..	..	..
B P.....	..	4	31	5644	2353	..	..	..	..	..	..	..	..
B R.....	..	4	31	2246	1002	..	..	..	..	..	..	..	..

The composition of the materials is sufficiently described thus:

B A-Gloss oil, consisting of about 45 per cent of rosin and 55 per cent benzine

B C-Dammar in turpentine

B E-Short oil varnish (linseed and rosin)

B F-Short oil varnish (China wood and rosin)

B H-Short oil varnish (linseed and No. 3 kauri)

B I-Same as B N below, but containing more rosin

B L-Contains about twice as much oil as the standard coach varnishes

B N-Long oil varnish (China wood and rosin)

B G-Consists of half B F and B N by volume

B K-Short oil varnish (linseed and No. 1 kauri)

B M-A standard turpentine coach varnish

That these permeability tests agree with well established methods is shown by the results of exposure of these materials placed on regulation wooden panels and exposed on the roof during the winter. The number of days after beginning of exposure when checking first became noticeable is first given; then the condition at the close, after 38 days.

more durable than rosin compositions; also that in short oil rosin varnishes, china wood oil is better than linseed. Comparing B N, B M, and B L, it would appear that on long oil varnishes, if the effect of rosin is considered, china wood is more durable than linseed oil and that an increase in linseed oil adds to the permanency, since B L, though it starts higher in perviousness and loses its gloss more quickly, yet outwears B M. Another set of varnishes (exterior) was given a long exposure mainly as a means of testing out the process, for it was impracticable at the outset to expose duplicate panels. The results are worth reporting, as is seen in Fig. 9 and the table appended, because they illustrate well the steadily changing character of permeability. The appearance of these panels corresponds with the weight permeabilities, and as a fact they have been assorted by eye in the same order as is shown in Fig. 9.

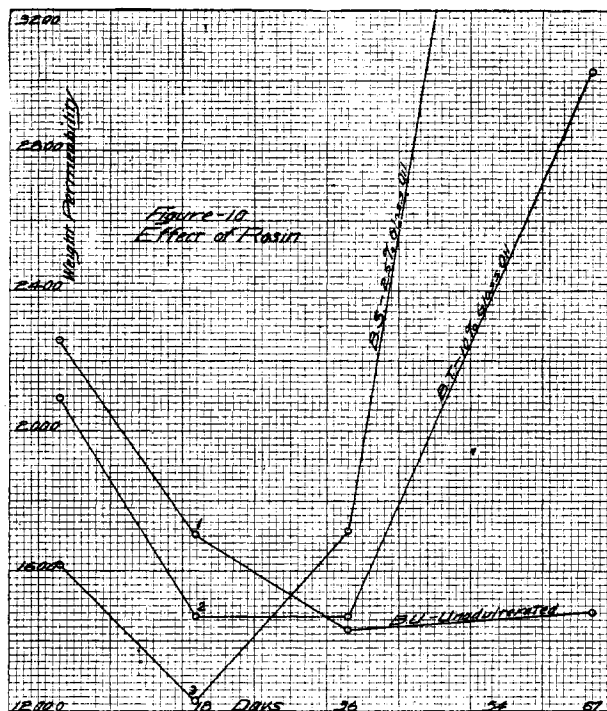


Fig. 4 shows a portion of the panel of B R at the end of the test, having a permeability of 2246. While checked up slightly, the major portion of the coating is still left to view. Fig. 5 is a corresponding portion of B P. This panel has a permeability of 5644 and it is evident that little of the original varnish film has withstood the exposure. The differences between these two photographs show that the numerical data upon which these charts are based have real meaning in expressing the condition of the panels.

All of these are standard coach varnishes, except B Q, which is a china wood oil mixture. B O and B P are seen to be running "neck and neck," if we allow for the lack of check panels and for the thinner coating of B O. B R gains its greater durability from its greater oil content. China wood oil makes its best showing in B Q, this being manifestly a fine varnish.

The evil effect of rosin in an exterior paint is well known, though the word "japan" often covers a multitude of such sins in the paint formula. In order to obtain a graphic representation of this evil, a sample of a standard outside white, B U, was divided into three portions. One part was left unadulterated. Ten per cent. of the vehicle by weight was removed from the second portion and an equal weight of gloss oil substituted. In the third portion, twenty-five per cent of gloss oil was similarly replaced. Panels were then constructed and tested. The records of these measurements are now submitted, accompanied by the striking contrast of the curves shown in Fig. 10.

1, 2, 3. In the cases of more durable coatings, it is sometimes possible to arrange the panels in the order of durability long before the measurements are com-



pleted or before any of the films show signs of age. Fig. 6 gives the appearance of B S, containing 25

RESULTS ON FIG. 10—EFFECT OF ROSIN

	Weight of coat	Meas. No.	Days interval	Permeability		Meas. No.	Days interval	Permeability		Meas. No.	Days interval	Permeability	
				Actual	By weight			Actual	By weight			Actual	By weight
B U <sub>1</sub> .....	14.22	1	0	1623	2308	2	17	1155	1642	3	19	980	1394
B U <sub>2</sub> .....	14.80	1	0	1491	2207	2	17	1196	1770	3	19	990	1465
Average.....		1	0	..	2258	2	17	..	1706	3	19	..	1429
B U <sub>1</sub> .....		4	31	1004	1427	..	..	..	..	..	..	..	..
B U <sub>2</sub> .....		4	31	1039	1537	..	..	..	..	..	..	..	..
Average.....		4	31	..	1482	..	..	..	..	..	..	..	..
B T <sub>1</sub> .....	18.73	1	0	1212	2270	2	17	792	1483	3	19	890	1671
B T <sub>2</sub> .....	17.62	1	0	1088	1917	2	17	826	1455	3	19	722	1272
Average.....		1	0	..	2094	2	17	..	1469	3	19	..	1471
B T <sub>1</sub> .....		4	31	1667	3122	..	..	..	..	..	..	..	..
B T <sub>2</sub> .....		4	31	1660	2926	..	..	..	..	..	..	..	..
Average.....		4	31	..	3024	..	..	..	..	..	..	..	..
B S.....	13.91	1	0	1163	1618	2	17	883	1228	3	19	1232	1714
B S.....		4	31	4559	6341	..	..	..	..	..	..	..	..

The composition of the gloss oil has been already stated. B T, therefore, contains only about 4½ per cent of rosin, while B S contains about 11 per cent. Doubtless the reader will observe that B S appears to fall in permeability more slowly than either of the other materials at first. If a measurement had been made at the end of 5 days, instead of 17, it is believed that B S would have shown the most rapid decrease. It would appear also to be frequently true, if one reasons from all the data presented in this paper, that the smaller the angle of bend plotted at the points of measurement, not beyond the line where the curve first points upward, the sooner will the curve take an upward trend and the coating break down. This is indicated on Fig. 10 by angles

per cent of gloss oil. The film is quite flat and the cracks shown are large. These cracks began after the second measurement. Probably in no line of protective coverings is there so much waste of money as in the so-called barn paints, in spite of their cheapness. In order to develop this point, three liquid paints belonging to this class were made up on different lines, C A, C B, and C D, and each divided into two portions. One portion, marked x, remained untreated, while in the other portion, marked y, rosin in decreasing quantities was incorporated for the several formulas. Thus, C A<sub>y</sub> has more rosin than C D<sub>y</sub>, but not more than that found in many commercial barn paints. Duplicate panels were made up for each of the six liquids and the results of their



even the first three days showed a considerable rise in perviousness. C B<sub>y</sub> broke down before the fifth day, while C D<sub>y</sub> held up until the 6th measurement, and then only is just beginning to pass C D<sub>x</sub>, having only a trace of rosin. Attention may be called to the first slopes of these curves as another prediction of the fate of a coating, for C D<sub>y</sub> points downward farther than C D<sub>x</sub> and bends upward sooner. The

with checks at the end of the test. It must, however, be remembered that the exposure was severe, though there was no rain for the first two days. That in milder weather there would be a great contrast between these two coatings should not be asserted at present.

From the very first it was realized that the severest and indeed final gauge of the value of permeability

RESULTS ON FIG. 20—EXTERIOR ENAMELS

	Weight of coat	Meas. No.	Days interval	Permeability		Meas. No.	Days interval	Permeability		Meas. No.	Days interval	Permeability	
				Actual	By weight			Actual	By weight			Actual	By weight
E C <sub>1</sub> .....	5.74	1	0	2168	1246	2	2	2047	1177	3	1	2045	1174
E C <sub>2</sub> .....	5.75	1	0	2287	1313	2	2	2186	1252	3	1	2125	1218
Average.....		1	0	..	1279	2	2	..	1214	3	1	..	1196
E C <sub>1</sub> .....	..	4	1 3/4	2130	1246	5	8	5017	2880	..	..	..	..
E C <sub>2</sub> .....	..	4	1 3/4	2229	1255	5	8	5910	3386	..	..	..	..
Average.....	..	4	1 3/4	..	1250	5	8	..	3133	..	..	..	..
E D <sub>1</sub> .....	8.53	1	0	2536	2162	2	2	2462	2101	3	1	2276	1940
E D <sub>2</sub> .....	8.65	1	0	2794	2419	2	2	2734	2366	3	1	2539	2195
Average.....	..	1	0	..	2290	2	2	..	2233	3	1	..	2067
E D <sub>1</sub> .....	..	4	1 3/4	2262	1930	5	8	2161	1627	..	..	..	..
E D <sub>2</sub> .....	..	4	1 3/4	2508	2170	5	8	2447	1872	..	..	..	..
Average.....	..	4	1 3/4	..	2050	5	8	..	1749	..	..	..	..

same is true notably for C B<sub>y</sub> and x. The two curves of C A<sub>x</sub> and C B<sub>x</sub> are nearly parallel. Investigation showed that the two coatings represented by these have almost the same composition. While in the process being outlined, coatings are judged by what they "do" rather than by what they contain, yet it is apparent that their conduct under the test is a function of their composition.

as a measure of durability would be upon the best exterior paints. Five representative outside whites were among the first exposed (in duplicate panels) and tested at convenient periods. Fig. 13 is an embodiment of the facts developed in the tabulated permeabilities on page 546:

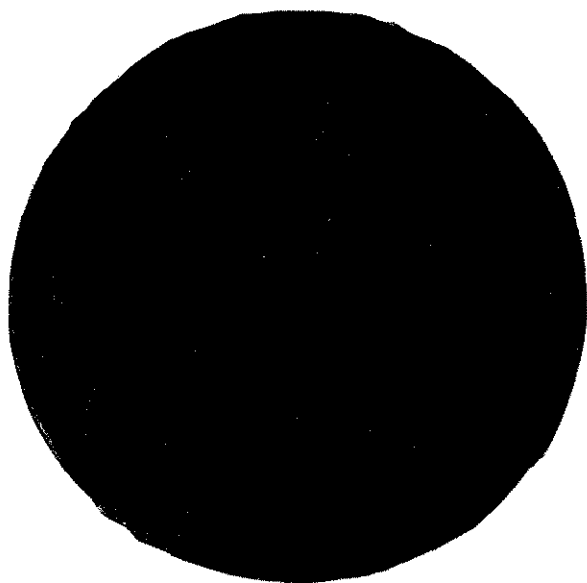
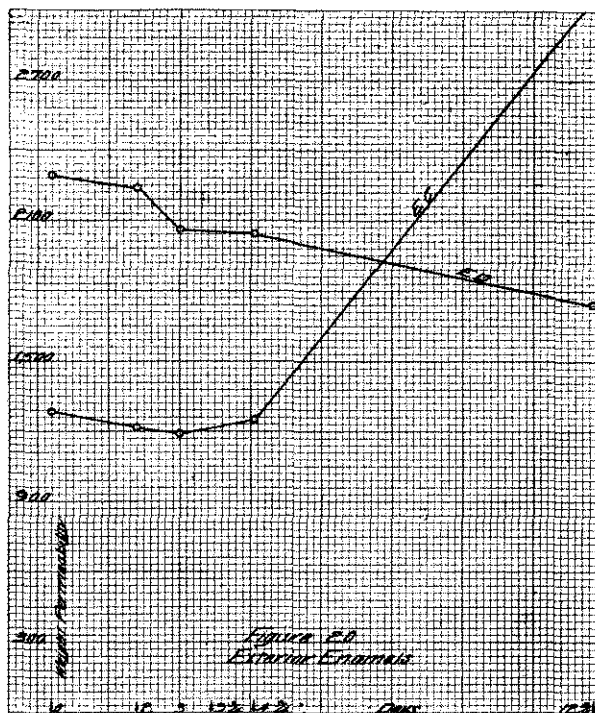


FIG. 14

Fig. 14 is a photograph of panel No. 1 for paint C A<sub>y</sub>, which went to pieces so rapidly. The illustration is of its condition after three days exposure. It is checked up even worse than the view indicates.

Two exterior enamels were spread on panels in duplicate and tested at frequent intervals for nearly two weeks, at the end of which time they had begun to break down. Fig. 20 and the accompanying table explain the effect of exposure upon them.

The values on duplicates agree very well. E D shows up far better than E C, the latter being covered



The composition of these whites corresponds somewhat to their conduct. C K has the highest per cent of lead and of pigment of the five and its curve exhibits next to the greatest bends. One of the panels of C K has a small crack, so that this covering will probably be the second to break down. Generally cracks and checks appear simultaneously on duplicates, and the resulting increased permeabilities agree well. C L contains the highest percentage of



conditions to secure incontrovertible conclusions. The results, however, check up nicely in rate of change of permeability. The panels have all gone more or less flat. It is gratifying that in eighty-one days one first-class exterior oil paint has been broken down and another has started on the downward grade. Just how far we may speculate as to the relation of these changes to durability is difficult to state. The tale is hardly half told. Practical experience is the

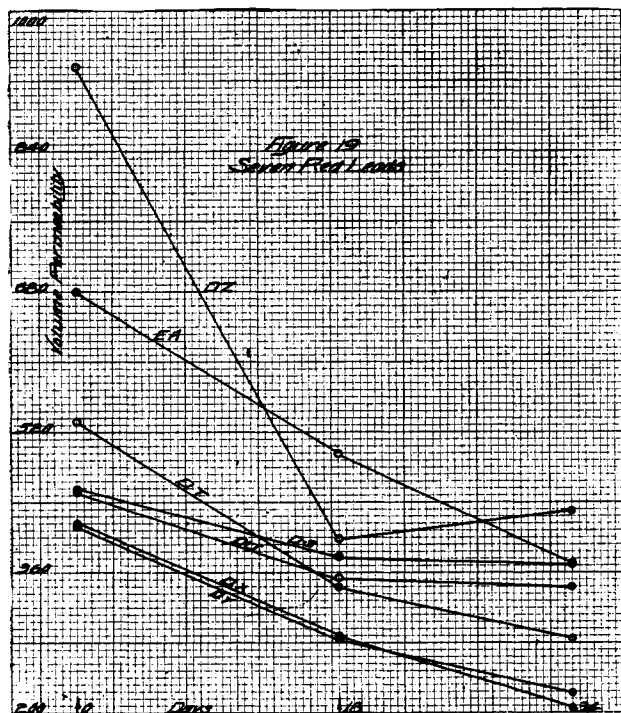
official climate that will break down even the best coatings in three months, imitating nature with valid results, but using a greater intensity and variety of weather. Herein lies the "trick" of securing quick results.

We come now to the evaluation of metallic coverings. A great many attempts have been made to improve the time-honored red lead and oil. Seven of such modifications were selected as typical of the trend of improvement, and the mixtures were brushed on steel wire-cloth panels, one being run in duplicate. These paints contained five pigments, which show the variety of coverings placed in comparison. The data below correspond to the curves in Fig. 19.

The results are reported on a basis of volume (weight permeability divided by the specific gravity of the paint) and therefore show within the limits of experimental error the true differences in permeability of these protective coverings. For example, E A is much more pervious than D X and differs from it simply in containing a better grade of red lead. D X and D Y are almost identical in conduct, yet D Y has the greater percentage of pigment. D T carries the least pigment of all and is next to the worst, yet is not highest in permeability, as might be expected. D Z contains a water absorbent, and its curve indicates that it is set apart from all the others. D S and D U differ merely in inert constituents and their changes in permeability are similar. A continuation of the measurements would prove instructive.

The kind of exposure given the panels so far considered was that of a severe tropical climate, ill adapted to interior coatings, though results obtained even on the interior varnishes of Fig. 8 agreed remarkably with experience. In order to secure the intermediate history of such coatings, eight were spread on panels, mostly in duplicate, and given an exposure corresponding to the mountainous regions of our arid southwest. The humidity was high for about an hour each day, but no rain ever reached the coatings. In other respects the exposure was the same as that heretofore described. Fig. 21 explains their conduct under these conditions.

E F is a medium combination oil (linseed, china wood) and manila varnish. E G is short oil (linseed) and No. 1 kauri. E H is short linseed and manila. E K is medium china wood and rosin. E L is dammar,



final arbiter, and the process should be compared with the consensus of expert opinion. Should a protective covering, for example, be high or low in permeability in order to afford the highest degree of protection consistent with all the other useful qualities of the paint film? Assertions are easily made, but there are so many variables in a general problem of this kind that a theoretical point of view appears inadvisable. The accomplishment of a practical solution would seem possible by the process being outlined, given a sufficiency of the right kind of exposure. It is a disappointment that eighty-four days of severe

RESULTS ON FIG. 19—SEVEN RED LEADS

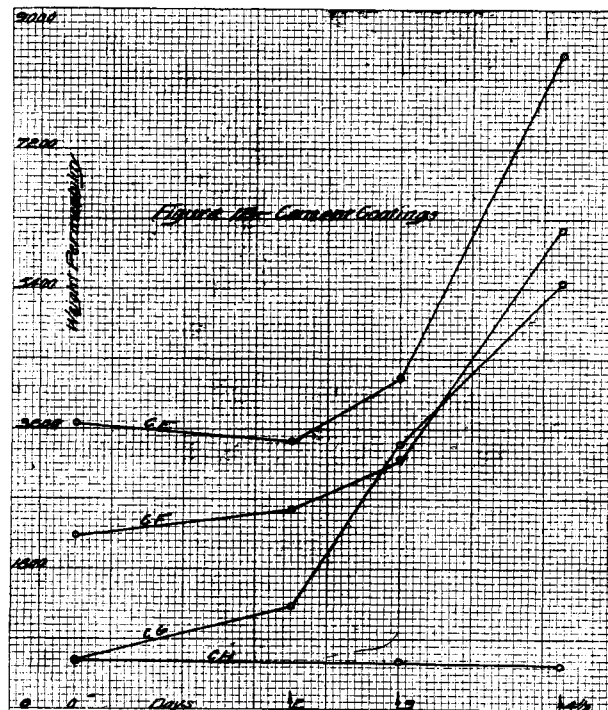
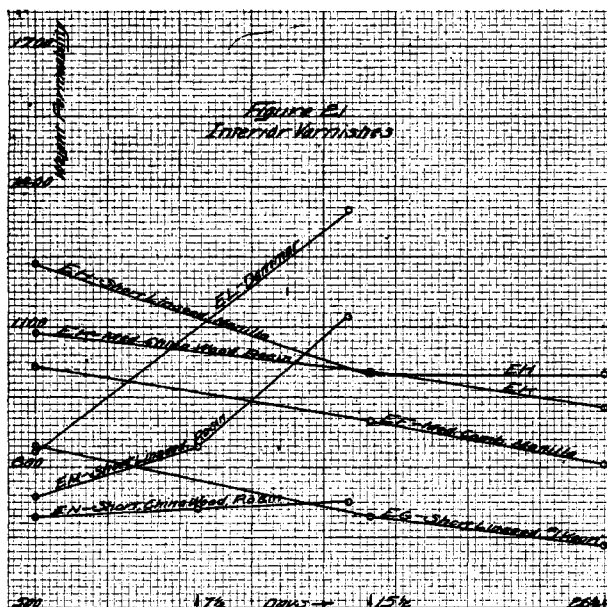
	Weight of coat	Meas. No.	Days interval	Permeability		Meas. No.	Days interval	Permeability		Meas. No.	Days interval	Permeability	
				Actual	Volume			Actual	Volume			Actual	Volume
D S <sub>1</sub> .....	18.18	1	0	478	422	2	18	317	306	3	15 1/2	250	220
D S <sub>2</sub> .....	15.33	1	0	685	507	2	18	640	450	3	15 1/2	703	522
Average.....		1	0	...	464	2	18	...	378	3	15 1/2	...	371
D T.....	10.16	1	0	866	532	2	18	558	343	3	15 1/2	463	285
D U.....	12.20	1	0	626	462	2	18	479	355	3	15 1/2	467	345
D X.....	11.85	1	0	652	417	2	18	452	289	3	15 1/2	323	207
D Y.....	14.72	1	0	696	412	2	18	481	283	3	15 1/2	378	223
D Z.....	14.63	1	0	1307	937	2	18	557	399	3	15 1/2	599	430
E A.....	10.50	1	0	1076	680	2	18	861	497	3	15 1/2	645	373

exposure should not give greater contrasts, but from another point of view, this is a fine testimony to straight oil mixtures. The writer believes that it is merely a matter of patient search to find the arti-

while E M is short linseed and rosin. E N is the same as E M with china wood substituted for linseed oil. Of course, the term "short oil" does not refer in each case to the same low percentage of oil.

Comparing now Fig. 21 with Fig. 8 and remembering that the former concerns interior and the latter exterior exposure, we see that in general the results are not divergent. The dammar holds up better on the interior, as we should expect. The short linseed

It has already been observed that among the many possibilities in imitating actual service conditions by the process of testing here presented is the use of



rosin coating in both cases is not so good as that containing china wood oil (E M and E N; B E and B F). E K, the medium combination manila, was not tested with those shown on Fig. 8, but in Fig. 21 it holds its own quite satisfactorily. The No. 1 kauri coating

the same surface for painting as the liquid is designed to cover. In the following results (Fig. 12) obtained on cement coatings, the porous surface used was  $\frac{3}{8}$

RESULTS ON FIG. 21—INTERIOR VARNISHES

	Weight of coat	Meas. Days		Permeability		Meas. No.	Days interval	Permeability		Meas. No.	Days interval	Permeability	
		No.	interval	Actual	By weight			Actual	By weight			Actual	By weight
E F <sub>1</sub> .....	3.45	1	0	2716	937	2	15 1/2	2247	775	3	11	2150	741
E F <sub>2</sub> .....	4.02	1	0	2738	1106	2	15 1/2	2550	1025	3	11	2188	879
Average.....	..	1	0	..	1018	2	15 1/2	..	900	3	11	..	810
E G.....	3.30	1	0	2566	847	2	15 1/2	2102	694	3	11	1911	631
E H <sub>1</sub> .....	3.46	1	0	3227	1117	2	15 1/2	2620	907	3	11	2554	884
E H <sub>2</sub> .....	3.33	1	0	4058	1352	2	15 1/2	3320	1105	3	11	3358	1118
Average.....	..	1	0	..	1234	2	15 1/2	..	1006	3	11	..	1001
E K.....	3.79	1	0	2876	1089	2	15 1/2	2659	1008	3	11	2437	924
E L.....	4.24	1	0	1568	837	2	14 1/2	2676	1135	..	..	..	..
E M.....	4.75	1	0	1553	738	2	7 1/2	1772	842	3	7	2368	1125
E N.....	4.46	1	0	1558	695	2	7 1/2	1615	720	3	7	1634	728

which was broken down in five and a half days on the exterior shows little sign of rising in permeability during twenty-six and a half days on the interior. Thus, some of the history lost in Fig. 8 is now recovered but even here more frequent measurements at shorter intervals would be necessary in order to establish a complete record of the behavior of these varnishes.

inch thick and was composed of 1 part of Portland cement to two parts of sand. The liquids were purchased in the open market, the cans being labeled "damp-proof," "water-proof," "steam-proof," and other like claims. Evidently C E, C F, and C G afford little, if any protection, though C F is the best of the three. C H stands apart from the others, being low in permeability throughout, and justifying

RESULTS ON FIG. 12—CEMENT COATINGS

	Weight of coat	Meas. Days		Permeability		Meas. No.	Days interval	Permeability		Meas. No.	Days interval	Permeability	
		No.	interval	Actual	By weight			Actual	By weight			Actual	By weight
C F.....	15.49	1	0	1457	2255	2	2	1663	2578	3	1	2073	3209
C F.....	..	4	1 1/2	3980	6165	..	..	..	..	..	..	..	..
C G.....	7.51	1	0	914	686	2	2	1778	1335	3	1	4523	3398
C G.....	..	4	1 1/2	7286	5472	..	..	..	..	..	..	..	..
C E.....	8.58	1	0	4293	3682	2	2	4007	3438	3	1	4980	4280
C E.....	..	4	1 1/2	9781	8392	..	..	..	..	..	..	..	..
C H.....	9.12	1	0	740	680	2	3	697	635	3	1 1/2	640	58

its water-proofing claims. The data are published simply to indicate the possibilities in some such method for evaluating these coverings.

By the results, C F and C G afford tolerable protection in keeping the water out at first, and through the beneficial valve action previously demonstrated, they will let out all excessive moisture in the concrete beneath. C E, however, is nothing else than a sieve, though it retails at \$1.75 per gallon.

The basal difficulty in the presentation of this paper is a proper selection from the wealth of experimental and speculative material at hand. The question of the mechanism by which water passes upwards through a panel during a measurement of permeability is important, since the same movement occurs in actual exposure, but space does not permit a complete discussion. Certainly on the apparatus, it is in part at least a phenomenon of gaseous diffusion, for the water is in the form of vapor where it touches the film. The far larger portion of work published on diffusion and osmosis has dealt with the gas or liquid, and very little emphasis has been placed upon any view from the standpoint of the membrane. As far as the paint film itself is concerned, it would seem unwise to presuppose a fundamentally different process for the passage of water through it according to whether this happens to be in contact with it in the liquid or gaseous state. Kahlenberg<sup>1</sup> and others have indicated that "semi-permeability" depends on a chemical similarity between the membrane and the solvent, by which the latter dissolves on one side and escapes on the other through a difference in solution or osmotic pressure, the solute, being far less soluble, passing through much less rapidly. It appears to be thus a question of solution, *little though we understand the term*. A variety of experiments are projected to test this point as regards paint films. If such a coating becomes less soluble in water as it dries, the fact would account for the decrease in permeability due to heating or drying, the latter being true.

The writer has further found that continuous contact of a thoroughly dried linseed oil skin with water causes a steadily increasing absorption up to at least fourteen per cent, as shown by increase in weight of the skin. In other words, a condition of equilibrium between liquid water and linoxyn demand a high percentage of water dissolved in the paint film, but as between aqueous vapor and linoxyn, equilibrium would be reached at a lower percentage, varying with the nature of the substance in contact with the vapor and with the vapor pressure. We have in the latter, one of the components of the marked effect of changing temperature on the results obtained by use of the permeability apparatus. During a measurement on the same, we may imagine the coating to be divided up into a large number of layers. The lower layer contains the highest percentage of water, being in contact with the vapor saturated air. The upper layer holds the lowest percentage of water because of contact with air kept at very low humidity.

The actual percentage in both cases will depend on a number of factors, among which is the dissolving power of the coating. Between these two layers there will be a uniform decrease in water content from the lower to the upper, if the affinity for water is the same throughout all layers. These differences in concentration cause corresponding differences in solution tension, resulting in an upward movement of dissolved water through the surface covered and the coating. With gases other than aqueous vapor and membranes other than paint and varnish coatings, the same explanation for permeability as outlined should be postulated, and the apparatus is adapted to such a line of inquiry.

It does not seem necessary to postulate the existence of microscopic or even ultramicroscopic pores in the fresh paint or varnish film, though this theory seems to be generally believed by experts. As the coating becomes thinner through saponification and the resultant formation of more soluble products leaving a chalky upper surface or when it has lost its elasticity and has begun to check or crack, then indeed pores are evidenced by the rise in permeability; the panel has begun to break down.

The foregoing work is believed to be a good start towards an accurate rating of protective coverings. The investigations will be continued by the writer along all lines as rapidly as is practicable with the cooperation of his students and of manufacturers. He desires to express here his thanks to the Patton Paint Company, the Pitcairn Varnish Company, and the Corona Chemical Company for the space in their joint laboratories which has been courteously afforded during this research, and for the stimulating interest and at times assistance of their officials and experts.

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## THE DETERIORATION OF FIREBRICKS DURING SERVICE

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The duration of life of a firebrick during service depends upon a multiplicity of factors, physical and chemical, not all of which are by any means understood. These factors may be grouped under three heads, namely:

- (1) The manufacture of the brick.
- (2) The laying of the brick.
- (3) The application of the brick.

Each of these groups of factors has a profound effect upon the value of the other two in determining the life of a brick during service. The third group is to a large extent out of control (but not altogether; for example, carelessness in drying out and starting up a furnace will in many cases shorten the life of the lining). Taking the third group as fixed, then, the problem becomes: How can the other two groups be varied so as to minimize as far as possible the destructive influences in the furnace?

The problem is complicated by the fact that the three groups of factors are controlled by three different sets of men, and to a large extent each of these sets of men understands only the group of factors which he

<sup>1</sup> *Jour. Phys. Chem.*, **10**, 141.