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UNIVERSITY OF LOUISVILLE

I WATER AND WATER VAPOR BARRIERS FOR STRUCTURAL PLYWOOD

II CORE VOID FILLERS FOR STRUCTURAL PLYWOOD

A Thesis

**Submitted to the Faculty
of the Graduate School
of the University of Louisville
in Partial Fulfillment
of the Requirements
for the Degree of**

MASTER OF CHEMICAL ENGINEERING

Department of Chemical Engineering

By

James Van Dyck Fear

1947

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I WATER AND WATER VAPOR BARRIERS FOR STRUCTURAL PLYWOOD

II CORE VOID FILLERS FOR STRUCTURAL PLYWOOD

James Van Dyck Fear

Approved by the Examining Committee

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September, 1947

A C K N O W L E D G M E N T

The author wishes to acknowledge
the kind assistance and helpful guidance
of Dr. R. G. Ernst and Mr. W. R. Barnes
who directed this research

ABSTRACT

This thesis presents the results of an investigation conducted to improve the weather resistance of plywood assemblies used in prefabricated housing manufacture. Specifically, this work involved water sealers for edge joints (called edge sealers), the prevention of surface transfer of water vapor through plywood (called vapor barriers), and fillers for structural defects in the wood (called core void fillers).

Two edge sealers for plywood were developed that were considered successful in resisting water permeation. One was a quick drying paint formulated by the addition of 30 per cent leaded zinc oxide to 70 per cent Arco primer paint No. 156. However, a better but slower drying sealer was found in the use of two coats of 40 per cent leaded zinc oxide and 60 per cent glyceryl phthalate varnish.

Two vapor barriers were developed that were successful in combatting moisture condensation in the stud space of exterior wall assemblies. One of these was an aluminum-gilsonite paint. The other was an aluminum foil bonded to the plywood. Either would reduce the moisture diffusion through wood in excess of 95 per cent. A method is presented that would make the use of aluminum foil economically feasible.

A filler for core voids consisting of an asbestos extended resoreinol glue mixture was developed. The filler showed optimum resistance to weather conditions, heat and water bleeding, and had an excellent pot life.

TABLE OF CONTENTS

	Page
List of Tables	v
List of Figures	vi
Acknowledgement	vii
Abstract	ix
I. Moisture and Vapor Barriers for Structural Plywood	
Introduction	1
Historical	4
Theoretical	12
Experimental	24
A. Water Immersion Test of Water Barriers . .	26
B. Vapor Resistance Test of Enamel Water Barriers	41
C. Water Immersion Test of Water Barriers . .	51
D. Evaluation of Water Vapor Barriers	56
Summary and Conclusions	70
II. Core Void Fillers for Structural Plywood	
Introduction	73
Historical	75
Theoretical	77
Experimental	80
Summary and Conclusions	86
Literature Cited	88

TABLE OF CONTENTS - continued

	Page
Acknowledgment	92
Appendix	93
Sample Calculations	94
Experimental Data	96
Vita	111

LIST OF TABLES

Table	<u>Title</u>	<u>Page</u>
I.	Composition of Edge Sealers Used in a Water Immersion Test	29
II.	Moisture Pickup of Edge Sealed Wood	32
III.	Moisture Pickup Retained by Edge Sealed Wood During a Seven Day Drying Period	33
IV.	Per Cent Effectiveness of Edge Sealers Against Water	34
V.	Composition of Edge Sealers Used in a Water Vapor Test	43
VI.	Water Vapor Pickup of Edge Sealed Wood	45
VII.	Per Cent Effectiveness of Edge Sealers Against Water Vapor	46
VIII.	Composition and Results of Samples Tested to Investigate Vapor Resistance of Paraffin Seals . .	49
IX.	Composition of Water Immersed Edge Sealers	53
X.	Gain in Moisture Content of Edge Sealed Wood . . .	54
XI.	Per Cent Effectiveness of Sample Edge Sealers . .	54
XII.	Composition of Sample Vapor Barriers Tested . . .	64
XIII.	Moisture Diffused Through Vapor Barrier Samples. .	65
XIV.	Rate of Water Vapor Diffusing Through Vapor Barriers	68
XV.	Per Cent Effectiveness of Vapor Barriers	68
XVI.	Core Void Fillers Compositions and Test Results. .	82

LIST OF FIGURES

<u>Figure</u>	<u>Title</u>	<u>Page</u>
1.	Moisture Pickup of Edge Sealed Wood Samples (1)	35
2.	Moisture Pickup of Edge Sealed Wood Samples (2)	36
3.	Moisture Pickup of Edge Sealed Wood Samples (3)	37
4.	Water Vapor Pickup of Edge Sealed Wood Samples	47
5.	Gain in Moisture Content of Edge Sealed Wood Samples	55
6.	Picture of Weighing Bottles (Interior View) . . .	59
7.	Picture of Weighing Bottles (Exterior View) . . .	60
8.	Interior of Vapor Permeability Apparatus	61
9.	Vapor Permeability Apparatus Ready for Operation.	62
10.	Vapor Diffusion Curves (1).	66
11.	Vapor Diffusion Curves (2).	67

**I. WATER AND WATER VAPOR
BARRIERS FOR STRUCTURAL
PLYWOOD**

INTRODUCTION

Mass production of prefabricated homes is a relatively new industry in the United States, coming into prominence with World War II as a solution for the housing shortage. Many different constructional designs are used by manufacturers in producing these homes. One manufacturer uses a center pole to support a web of chains which form a lattice support for sheet metal sides. Another uses a large mold into which concrete is poured, and after the houses have set, the form is removed. Another makes several standard packaged unit panels of plywood which are sent to the housing site. It is with the last type that this thesis is concerned, as unforeseen problems were encountered in the successful construction of these panels.

One of these problems was the successful sealing of the unit wall sections against edgewise water penetration. In the mass production of the panels, sheets of plywood are bonded to both sides of a wooden framework. The panel received a coat of white primer paint and after drying, was ready for shipping. The finishing coats of paint were applied after the house had been erected, and consequently, the edges of the panel did not receive this further protection. The manufacturer felt that the edges of the plywood were not sufficiently protected from water by the application of one primer coat of paint. The addition of more than one spray coat of paint in the plant did not lend itself to the production schedule. Further, the company did not know how many additional coats would be necessary to provide adequate protection.

A second problem encountered was in combating moisture condensation in the stud space of the panels while in use. Various investigators have shown that vapor will condense inside tightly constructed wall sections unless an excellent vapor barrier is properly incorporated in the wall. In this case the phenomenon was observed particularly in the window panels.

An investigation and recommended solution of these two related problems is presented in this report and was a portion of contract research in the University of Louisville Institute of Industrial Research.

HISTORICAL

Wood is one of our most abundant natural resources. Despite the fact that wood has been used extensively as a constructional material for thousands of years, it is comparatively recently that man has begun to investigate its properties. One of the properties of wood that leads to its deterioration is the ability to absorb and hold water. A study of paints and organic films as moisture barriers for wood has been made.

To give a complete history of protective coatings for wood would be beyond the scope of this report. This section is limited to the history of the study of permeability of paint, varnish, and synthetic organic films.

A large variety of organic films has been investigated. The permeability of these films was found to vary over a wide range from the almost impermeable paraffin waxes to highly permeable raw linseed oil. Gardner (1), in 1920, followed by Dunlap (2), in 1926, the Forest Products Laboratory (3), in 1925, and Payne (4), in 1940, stated that the mere impregnation of wood with an oil was not sufficient moisture protection. This work destroyed an age old belief that oils, because of their small affinity for water, would make wood highly resistant to water. It is significant to note that almost all the authors since Muckenfus (5), in 1913, have used aluminum pigmented paints as their base material for permeability investigations. All these authors (1, 2, 3, 6, 7, 8, 9) used vapor resistance tests to study permeability, except Gardner (1), who used water immersion tests and vapor resistance tests.

Gardner (1), studying enamels, varnishes, shellacs, oils and dopes, reported the reduction in moisture pickup of wood (called effectiveness henceforth) by using three coats of enamel to be 95 per cent, but a mixture of oil and graphite had very poor effectiveness. Listed below is the per cent effectiveness of films tested by various authors :

Composition	No. of coats	Per cent effectiveness
Gardner (3), in 1920		
An enamel of spar varnish	3	95
Asphalt paint	3	96
Forest Products Laboratory (2), in 1925		
Graphite	3	61
Spar varnish	3	60
Linseed oil and wax	3	38
Aluminum and spar varnish	3	96
Dunlap (1), in 1926		
Aluminum in pitch	3	98
Asphalt enamels	3	90
Aluminum in spar varnish	3	94
Aluminum in spar varnish	3	92
Forest Products Laboratory (28) in 1935		
Furniture wax	3	8
Rubbing varnish	3	89
Shellac	3	92
Aluminum in asphalt	3	98
Aluminum in asphalt	3	96

In 1933, Browne (8) and Wray and Van Vorst (7) demonstrated the decrease in permeability of paint films with a decrease in pigment particle size. The increase in effectiveness of a paint film with increasing pigment concentration has been demonstrated

by Gardner (1) and Wray and Van Vorst (7). The addition of pigments to varnishes was shown to decrease the permeability of films by many authors (1, 5, 10, 11). However, in 1936, Wing (12) reported that certain pigments that retard the drying time of the film actually decrease the effectiveness of the varnish. Gardner (1), supported by other authors (15, 8), was the first to show the increasing effectiveness of a film with the number of coats applied. In 1926, Dunlap (2), working with various coatings, found that application of a second coat greatly increases the effectiveness of the coating, but that the addition of two more coats resulted in only 6-8 per cent increase.

Keinle (13), in 1936, gave a theoretical equation for permeability which showed that permeability is directly proportional to film thickness. This work was supported, in 1935, by Charch and Scroggie (14), in 1936, by Edward and Wray (15), by Wing (12), in 1936, and in 1943, by Gomar and Miller (16). Payne and Gardner (17), in 1936, found Keinle's equation to be partially true. In 1944, Dotty, Archer and Mark (18) presented an elaborate theory on permeability showing that permeability may be proportional to film thickness depending upon the material.

A study of varnish films (3, 10) indicated that coatings formulated using short-oil varnishes are better than those using long-oil varnishes. The effect, however, is not great.

Payne (19) recommended using bodied oils instead of blown oils.

Edwards and Wray (15) and Payne (4) recommended baking films instead of air-drying films. Within limits, the higher the temperature of baking the less permeable the film. Service temperature was shown to have little effect on permeability. Wray and Van Vorst (7) found that aging a film increases its effectiveness.

Gardner (1) demonstrated that many films are as effective against vapor as they are against water. Dunlap (2), in 1926, supported Gardner. While, in 1936, Taylor, Herman and Kemp (20) and, in 1937, Kline (11) found this rule invalid in certain cases. The simplest explanation postulated to explain the mechanism of diffusion through a film was the classical theory of water diffusion through a semi-permeable membrane. It was assumed that the permeating liquid or vapor dissolves in the film and evaporates from the solution formed. However, Henry's law indicated that permeation based on this theory would be inversely proportional to the temperature. Since it had been shown (15) that temperature had little effect on permeability, Payne and Gardner suggested that factors other than simple diffusion were involved in determining the permeation of a film. Payne and Gardner (17) explained permeation of varnish films as imbibition by the film which forces the closely packed fibrils apart forming capillaries. Then diffusion takes place normally. Later, in 1944, Payne (19) elaborated on his explanation by listing five properties of films involved in permeation of organic films :

(1) porosity; (2) adsorption and absorption; (3) imbibition; (4) relative polarity; and (5) solubility. By far the most important factors influencing the permeation of an apparently good film were polarity and imbibition. The characteristic of polarity was shown by Gardner (21) to be responsible for the high permeability of shellac. Gortner (22) has shown that great pressures can be built up inside a film as a result of imbibition pressures. In 1944, Dotty, Archer, and Mark (18) presented a theory explaining Payne and Gardner's (17) work. It was stated that essentially three diffusion mechanisms take place at once : (1) molecules enter the matrix of the film and by an effect similar to the Brownian movement, move through the film; (2) molecules enter the capillaries in the film and by rebounding from the walls, move through the film; and (3) a combination of the first two mechanisms.

Many methods of testing films have been reported with varying results. Gardner (1) tested paint films by coating wood samples and, after weighing, immersing the samples in water. The gain in weight of the sample noted after removal from the water was the rate of permeation of the films. Kline (13) stated that the permeation of a film was the same when it was exposed to water as when it was exposed to vapor. Wray and Van Vorst (7) found the permeability of three coats of a lacquer film to be higher in contrast with water than with air saturated with water but that the reverse was true for a

single-coated lacquer film. Taylor, Herman, and Kemp (20) found the permeability of some materials to be appreciably higher in water than in water saturated air. In a later investigation, Kline (11) found a reversal in permeability of alkyd and phenolic varnish films when the partial pressure gradients of water were varied across the films.

Payne (19) classified moisture resistance tests into four categories :

1. Water Immersion Tests: Gardner (1) was the pioneer in this type of test. His procedure has been previously described. Evidently, this type of test has never been modified.
2. Vapor Permeability Tests: The largest number of investigators have used this method for evaluation of films. Muskenfus (15) in 1913 pioneered this work by coating wood samples with films and sealing the wood to a water container. Browne (8), testing coatings on wood samples, stressed the difficulty in obtaining uniform wood samples. Payne (19) states, however, that the resistance of wood in testing films is negligible. Essentially, all these types of apparatus were similar, depending upon the measurement of the rate of movement of water vapor caused by a partial pressure gradient to measure the permeability of the film. The New York Paint and Varnish Club (10) described a procedure in 1937 that is representative of the group. Payne (19) discussed several of the typical types. In 1941, Burr and Stamm (23)

analysed the problems involved in accurately measuring the water vapor permeability of a film and described an apparatus which they felt gave precise values. This consisted essentially of removing the stagnant air film existing on both sides of the film being tested. A method of measuring the gas permeation of materials of low permeability was described by Shuman (24).

3. Electrical Resistant Tests: Obtaining film permeabilities by electrical breakdown was a method described as measuring the change in conductance before and after water vapor saturation.

4. Chemical Analysis Tests: Chemical methods of permeability measurements involved placing a salt solution on one side of a film and finding the change in salt concentration during a time interval.

T H E O R E T I C A L

This section of the report is subdivided into five sections : (1) Structural and Physical Properties of Wood ; (2) Permeation of Films; (3) Properties of Aluminum Powder and Lead Oxide; (4) The Factors Influencing the Use of Vapor Permeability Apparatus; and, (5) Theoretical Conclusions.

The discussion of these topics in succeeding sections is summarized below:

1. Since the investigation involved the sealing of wood, the first section is devoted to discussing, in general, the structure of wood and the physical properties inherent in Douglas fir. Thus, since the characteristics of wood are known the sealing problem involved may be visualized.

2. One method of sealing wood is to cast a film on its surface. This procedure was adopted. So that the reasons for the success and failure of various coatings may be understood, the nature and factors influencing film permeability are discussed in this section.

3. Many organic films alone cannot effectively seal wood against permeation. This is particularly true of varnishes and lacquers, but the addition of a pigment to these coatings greatly increases their effectiveness. The work of several investigators, using aluminum pigmented coatings, indicates, that this pigment is quite superior to others. The reasons for this phenomenon are presented in this section. However, an aluminum color was not always suitable as a sealer, and the

advantages of using a leaded zinc oxide pigment are discussed.

4. In evaluating vapor barriers an apparatus was needed that would establish water diffusion rates through plywood. Several types are known and these are discussed.

5. Several conclusions are listed that summarize the information presented in the theoretical and historical sections of this report.

1. Structural and Physical Properties of Wood

No attempt is made here to describe completely the complex structure of wood or the variations in species. A complete description of wood structure is presented by Tieman (25) and Wise (26) from which the following discussion was abstracted.

Looking, under a microscope, at a cross-section of wood, one sees many fine, hair-like cells running vertically and arranged in radial rows. These cells are called tracheids. Interspersed every few rows apart and running horizontally are flat plates of smaller and finer cells, called medullary or wood rays. Scattered among the vertical cells and to a lesser degree among the horizontal cells are resin ducts. These ducts, occurring in the pines only, are fine tube-like openings filled with resin. Examination reveals that the medullary cells are thin-walled, short, and blunt while the tracheid cells are rectangular in shape overlapping in long splices to form a continuous chain. Along the splices of the vertical cells are border pits appearing as a chain of small dots, serving as a method of communication between the cells.

The work presented in this report was done on Douglas fir. A description of Douglas fir was abstracted from the Forest Products Laboratory Handbook (27, 28).

The properties of Douglas fir are affected somewhat by the location of the stand (geographical location). Most structural Douglas fir comes from the West Coast. The outer layers and lower sections of the tree furnish the best cuts while the upper and inner cuts are relatively soft and less dense. The wood is strong, moderately hard, heavy, durable, has a tendency to check and split, and does not hold paint well.

The paint holding properties of the wood may be improved by the use of aluminum pigmented varnish primers or white lead and zinc paints. If white paints are used, the addition of zinc oxide increases the film durability. In humid climates, the use of zinc oxides up to 50 per cent of the total pigment content is advantageous in that it reduces mildew, chalking, and fading.

Water is held by wood in four ways (26, 29) :

1. Water of constitution
2. Surface-bound water
3. Capillary-condensed water
4. Free water

Water held by the first three methods is almost always present in wood, but it is with the fourth method that this report is concerned. Free water is present in wood only as long as it is being soaked or exposed to high humidities. The water, in this case, is absorbed in the capillaries formed by the tracheids. The imbibition pressure of the water forces the fibrils apart making room for more water. This process continues until the strength of the wood is sufficient to overcome the imbibition pressures.

Seborg and Stamm (30) have presented the Sigmoid curves for wood on a vapor-pressure-versus-moisture-content plot. They observed that the desorption curves were higher than the absorption curves. This hysteresis effect in cellulosic materials was first observed by Masson and Richards (31) in 1906. Urquhart (32) and Urquhart and Williams (33) present the most plausible

ible explanation of this phenomenon : As water is absorbed by wood, the free hydroxyl groups become satisfied. Upon desorption shrinkage occurs bringing the now freed hydroxyl groups close together so that some of them satisfy each other. Hence, upon absorption, again, there are less hydroxyl groups to be satisfied and less water is absorbed.

2. Permeation of Films

All organic films have a gel structure - this being a colloidal system. The gel structure is composed of units, called fibrils, varying in size and bound together in a haphazard manner by molecular forces. Four factors which govern the rate of gel formation are

- a. Molecular size distribution in the original liquid
- b. Rate of evaporation of the volatile constituent
- c. Process of liquid conversion to the gel stage
- d. Type and concentration of any solid dispersed phase

The characteristics of organic surface coatings which determine this degree of water permeability are

- a. Film porosity
- b. Adsorption and absorption
- c. Imbibition pressure
- d. Relative polarity
- e. Solubility

Payne (19) discussed these properties as follows:

- a. Film porosity: If a film were sufficiently porous, a liquid would pass through it at a constant rate. Organic films,

however, are not initially porous enough to exhibit a constant rate of permeation, but after sufficient swelling occurs, an increased tendency toward a constant rate is noted. Swelling tends to separate the fibrils of the film, thereby increasing the film's porosity. After sufficient swelling, a film tends to obey Poiseuille's law of capillary flow :

$$V = \frac{kPR^4}{\mu L} \text{ where,}$$

V Volume of water flowing

k A constant

P Pressure

R Capillary radius

T Time

μ Viscosity

L Capillary length

From this equation it was concluded that the addition of a pigment to a coating would reduce permeability in three ways :

- a. Increase viscosity
- b. Reduce the number of capillaries
- c. Reduce the capillary radius

b. Adsorption and Absorption: Adsorption is the phenomenon that occurs when one substance makes contact with the surface of another substance. There are three classifications of water adsorption :

- a. Mechanical - The adsorption resulting from molecular condensation on a film surface
- b. Chemical - The adsorption resulting from a water molecule striking a surface and forming a new compound
- c. Electrical - The adsorption resulting from water molecules held at the film surface by polar forces

All three mechanisms may occur simultaneously. However, the effect is small compared to the amount of water passing through a film by absorption.

Absorption is the passage of water through the inter-fibril spaces. In 1944, Doty, Acker and Mark (18) gave an excellent description of this mechanism. The flow of molecules through an organic polymer was visualized by three mechanisms :

- a. Flow through capillaries - By virtue of its kinetic energy, a molecule enters a capillary of the film. Being reflected from wall to wall in a manner similar to the Brownian movement, the molecule emerges from the other side of the film.
- b. Activated diffusion through the polymer matrix - Some of the molecules colliding with a homogenous, amorphous matrix of the film will rebound and others will penetrate the film a few atomic layers. By virtue of its energy, the molecule moves about creating a small hole into which it moves. The old vacant hole closes. By this method the molecule finally passes through the film.
- c. A combination of a. and b. - A third process occurs when water chemically combines with a film's free hydroxyl groups. Later thermal fluctuations due to molecular vibrations cause the water molecule to free itself and to continue diffusing through the film.

From this discussion it was concluded that a film could be improved by

- a. Reducing the free hydroxyl groups
- b. Reducing the relative polarity of the film
- c. Adding pigment to the film to reduce the number of capillaries
- d. Increasing the toughness and hardness of the film
- e. Imbibition Pressures: No completely satisfactory ex-

planation has been offered to account for the phenomenon of imbibition, but it has been recognized that it is related to relative polarity, absorption, and gel structure. When a gel, such as gelatine, is placed in water, a large amount of swelling occurs. The expansion of the gel is due to imbibition pressures developed by the water. Gortner (22) has shown that this pressure may become very large - large enough to rupture a steel enclosure. Glasstone (34) states that certain salts will inhibit imbibition while others increase the effect. The pressure developed will depend upon pH being a minimum at the isoelectric point.

A definite degree of absorption and relative polarity have been observed as necessary in a film before imbibition pressures can be developed. This is further indicated by the similarity of absorption and imbibition curves plotted versus time (35, 36, 20, 17) which are parabolic from the origin.

d. Relative Polarity: Relative polarity is defined as the electrical attraction exhibited by two molecules for each other. Polarity in a molecule is the result of unsymmetrical distribution of positive and negative charges as would be caused by an acid group, a hydroxyl group, or erratically scattered double bonds. Saturated hydrocarbons are non-polar while many resins and drying oils are relatively polar.

The effect of molecular linkages in combating polarity has been demonstrated by two phthalates, glycol and glycerol. Both resins are quiet polar. Glycol phthalates are straight chained

resins held together by cohesive forces of the secondary valance type. These glycol resins are quite permeable since the imbibition pressures developed overcome the strength of the straight chain linkages. However, the glycerol resins are three dimensional polymers. The strength of the cross linkages are sufficient to reduce the effects of polarity so that this resin is widely used in moisture barrier formulations such as spar varnish.

Evidently, then, as may be seen from the above discussion and the conflicting reports presented in the Historical section, only a guess can be made as to the actual mechanism of permeation. The author has formulated a theory both short and simple that will essentially explain permeability of most paint films.

Assume a theoretical film with a gel structure of closely packed fibrils. Allow the film to be subjected to a partial pressure water gradient. At first an infinitesimal amount of water will penetrate the film by adsorption and by kinetic energy absorption. Because of polarity a small imbibition pressure is built up within the film. This pressure separates the fibrils slightly so that more water can be absorbed and larger pressures built up. As this process continues, the film becomes more and more porous until the film strength overcomes the imbibition pressure. At this point, constant rate permeation occurs. If significant amounts of water are passing through the film at this time, it is almost all due to capillary flow. This explanation is not meant to be rigorous but merely a simple means of visual-

izing permeation.

3. Properties of Aluminum Powder and Leaded Zinc Oxide

Aluminum powder has the unique property of tending to leaf when added to various liquids such as oils, varnishes, and some solvents (37). When aluminum paints are applied to a surface, some of the pigment flakes float by means of convection currents, to the top of the film. Although a continuous leaf is not formed on the surface, the top layer and successive under layers are so arranged as to form a tortuous path for the passage of water through the coating. As a result, aluminum paints are almost impervious to water and water vapor.

Viscous vehicles retard the leafing properties of aluminum. Phenolic and alkyd long-oil varnishes of low acid value are excellent vehicles for aluminum. Coal tar thinners should be used avoiding lead driers.

Aluminum color was not considered suitable for edge sealers and the use of this pigment was limited to vapor barriers. Leaded zinc oxide, being recommended as an excellent pigment for paints being applied to Douglas fir, was selected as the second choice for edge sealer formulation. Leaded zinc oxide is composed of basic lead sulfate and zinc oxide (38). The pigment components may appear cofumed or as individual constituents.

4. The Factors Influencing the Use of Vapor Permeability

Apparatus

Many types of apparatus have been described in the literature for measuring film permeability. The good ones are essentially the same. Burr and Stamm (23), in 1941, described an apparatus both simple and apparently accurate. The salient features of a good permeability apparatus were described in the report and are listed below :

1. The sample should be sealed in a weighing bottle
2. Low vapor pressures should be maintained in the weighing bottles while the high humidities should exist on the exterior side.
3. The surface of the salt solution in the bottles must be continuously broken and the air above the solution circulated.
4. The bottles should be placed in a constant humidity room equipped for air circulation and thermostatic control.
5. Neglect of air circulation and breaking of the liquid surface in the bottles may result in permeability values 40 per cent below normal.

5. Theoretical Conclusions

The conclusions that have been made, based on the work of other experimenters, show that the effectiveness of various organic films against water and water vapor may be increased by

- a. adding a pigment to the film forming material up to point where the further addition of pigment would cause rapid deterioration of the film.
- b. decreasing the pigment particle size.
- c. adding more than one coat, but the increased effectiveness is not necessarily directly proportional to the number of coats applied.

- d. increasing the viscosity of the film forming material before it is applied except where "leafing" pigments are used.
- e. aging the film for a short time before testing for maximum effectiveness.
- f. baking the film instead of air drying.
- g. using a material that forms a glossy surface.
- h. using crossed linked and relatively non-polar vehicles.
- i. avoiding free hydroxyl groups.
- j. using short instead of long oil vehicles.
- k. using aluminum and zinc oxide pigments in coating to be used in connection with Douglas fir.
- l. using enamels.
- m. using spar varnish vehicles.

A change in effectiveness should not be expected with a change in the service temperature. Equal resistance to water and water vapor may be expected but need not occur.

EXPERIMENTAL

Coatings were desired to serve two functions: (1) as a water barrier; and, (2) as a vapor barrier. Two types of tests were selected which would show readily the per cent effectiveness of the various water barriers and water vapor barriers. One of these tests was a simple water immersion test. The other was a test designed to show the rate of water vapor diffusion through wood.

The work is presented in four sections:

A. Water Immersion Test of Water Barriers: In this test various types of samples were tested to confirm previously reported results, to clarify certain conflicting reported results, and to pick out the best material suitable for further investigation.

B. Vapor Resistance Test of Enamel Water Barriers: The better samples found in the first test were examined to see whether they had equal resistance to water vapor.

C. Water Immersion Test of Water Barriers: Attempting to quicken the drying rate of edge sealers, several barriers were formulated using the principles established by the first test.

D. Evaluation of Water Vapor Barriers: The diffusion rate of water through several paint coatings and aluminum foil was found in order to determine the effectiveness of the barriers.

A. Water Immersion Test of Water Barriers

For this phase of the work, a successful coating was arbitrarily selected as one that would reduce the amount of water absorbed by the protected wood sample by about 90 per cent after seven days water immersion. The per cent reduction is called, hereafter, per cent effectiveness.

In view of the theory presented and industrial limitations of color, the use of a white enamel was chosen as the primary barrier to be examined. Several other materials were chosen for a general examination. By this procedure, a type of material could be found for further investigation. However, the enamels were examined closely because it was felt that an enamel of leaded zinc oxide and an alkyd varnish would definitely show sufficient resistance to water immersion.

Procedure

In the initial test the procedure consisted of treating the edges of plywood squares, face sealing with paraffin, and soaking the samples in water.

Carefully selected samples of 1/4 inch, 3 ply, Douglas fir, plywood furnished by Gunnison Homes, Incorporated, were cut approximately 4.7 cm. square, and sanded. The samples were conditioned in a heating oven at 25°C and 45 per cent relative humidity for three days. The sealers were applied to the four edges of the wood test samples with one day drying time allowed between successive coatings. After all the samples were prepared, a thin coat of paraffin was applied, using a heated

glass rod, to the two faces of the wood squares.

Five test samples were prepared for each sample moisture barrier. These samples were designated as test groups A, B, C, D, and E, each group representing a different soaking period.

Test Group	Soaking Period
A	Three hours
B	Twelve hours
C	One day
D	Three days
E	Seven days

After weighing the samples on an analytical balance, they were bundled in their respective test groups in a manner such that the paraffin faces were together. An extra wood square was added to both ends of the bundles. The five groups were weighted and immersed in water at a depth that barely covered the samples; thus, any pressure effects were eliminated. After expiration of the various soaking periods, the samples were removed, wiped dry, and reweighed. Examination of the samples upon removal from the water showed that the technique of paraffining and bundling had prevented any water from reaching the plywood faces. This was necessary since edge-wise water penetration was the sole interest of the work at this point. After reweighing, the samples were placed in a heating oven and dried at 25⁰C and 45 per cent relative humidity. During the seven-day drying period the samples were weighed daily.

Materials tested

The composition of the materials tested appear in Table I. Samples one to ten were prepared to show that the cross linkage of a glyceryl phthalate resin was strong enough to overcome imbibition pressures and polarity effects, to show the effect of pigment in increasing the effectiveness of the barrier, and to show the effectiveness of successive coats of the enamels. Heat reactive varnish was applied to wood on the theory that it would impregnate the wood cells, and upon polymerization with heat, large molecules would be formed, sealing off the "doors of water entrance". Hence, the phenolic varnish samples, eleven through thirteen, were applied to wood until it would absorb no more. Chlorofin 42 is a chlorinated paraffin and was tested upon the request of the Gunnison Homes, Inc. Traffic paints are known to have little affinity for water and are weather resistant. A typical traffic paint was formulated as sample fifteen.

Sample sixteen was prepared to see if a thin varnish would penetrate wood and upon drying seal the cell opening. The formaldehyde that was added was supposed to aid in water proofing by reacting chemically with the free hydroxyl groups of the wood cellulose.

Sample seventeen, of untreated wood, was used for comparison with the moisture barriers.

TABLE I: COMPOSITION OF EDGE SEALERS USED IN A WATER IMMERSION TEST

Sample No.	Vehicle Content	Solid Content	Coat Cure	No. of Coats
1.	85 % spar varnish	15 % leaded zinc oxide	air drying	1
2.	85 % spar varnish	15 % leaded zinc oxide	air drying	2
3.	85 % spar varnish	15 % leaded zinc oxide	air drying	3
4.	70 % spar varnish	30 % leaded zinc oxide	air drying	1
5.	70 % spar varnish	30 % leaded zinc oxide	air drying	2
6.	70 % spar varnish	30 % leaded zinc oxide	air drying	3
7.	60 % spar varnish	40 % leaded zinc oxide	air drying	1
8.	60 % spar varnish	40 % leaded zinc oxide	air drying	2
9.	60 % spar varnish	40 % leaded zinc oxide	air drying	3
10.	100 % spar varnish		air drying	2
11.	100 % phenolic heat reactive varnish		1 hour at 40°C and 1 hour at 150°C	2
12.	100 % phenolic heat reactive varnish		1 hour at 100°C	2
13.	100 % phenolic heat reactive varnish		1 hour at 180°C	2
14.	50 % chlorofin 42 50 % acetone		air drying	2

TABLE I - continued

Sample No.	Vehicle Content	Solid Content	Coat Cure	No. of Coats
15.	4.0 % tung oil 4.6 % butanol 9.2 % acetone 9.1 % ethanol	15.1 % damar resin 14.5 % titanium dioxide 43.5 % barium sulfate	air drying	2
16.	80 % spar varnish 15 % ethanol 5 % formaldehyde		air drying	2
17.	Blank			

- * Spar Varnish - - glyceryl phthalate, No.19264, B.Chandler Co., Newark, N.J.
- Loaded Zinc Oxide - - loaded zinc oxide Lehigh 61, New Jersey Zinc Oxide Co. New York, N.Y.
- Phenolic Varnish - - Heat reactive phenolic clear varnish, VG 5293 E.I. du Pont de Nemours and Co., Wilmington, Del.
- Chlorofin 42 - - Hercules Powder Co., Wilmington, Del.

Results

The computed results are tabulated in Table II, Table III, and Table IV. Table II shows the amount of water pickup by the samples for each soaking period; Table III lists the amount of water pickup retained after seven days soaking by the samples of the seven-day soaking group; Table IV lists the per cent effectiveness of the coatings for each soaking period. The experimental data and the computed results of the drying of the other groups appears in Appendix B.

Water is absorbed parallel to the grain much faster than in other directions. Since three-ply plywood has the center ply cross bonded, two opposite edges have two plys parallel to the direction of water absorption while the adjacent edges have only one. Consequently, when the results were calculated to a foot of edge length, the value was based on the rate of water penetration per average foot of edge length.

Figures 1, 2, and 3 show a plot of Tables II and III. The lower half of the figures being Table II or the soaking curves, and the upper half, being Table III or the drying curves.

The soaking curves of Figure 1 are shown as dotted straight lines. The abscissa of Figure 1 represents less than one sixth of the abscissa of Figure 2. As a result, the points of Figure 1 were scattered sufficiently so that drawing true soaking curves was not justified. Had these points been plotted on Figure 2, curves could have been drawn.

TABLE II: MOISTURE PICKUP OF EDGE SEALED WOOD

MOISTURE PICKUP IN GRAMS PER FOOT OF AVERAGE EDGE LENGTH

Sample No.	Group A	Group B	Group C	Group D	Group E
1	.186	.244	.800	2.54	3.72
2	.039	.091	.072	.157	1.04
3	.060	.066	.109	.142	.485
4	.248	.509	1.06	1.55	3.45
5	.036	.069	.069	.141	.918
6	.032	.111	.089	.067	.134
7	.636	.371	.760	3.36	3.60
8	.029	.142	.795	.194	.582
9	.018	.086	.117	1.55	.104
10	.635	1.38	2.03	3.33	4.41
11	.144	.354	.955	2.66	3.68
12	.236	-	1.54	2.99	4.20
13	.476	.935	2.23	2.84	4.17
14	1.28	1.40	2.20	3.00	4.35
15	.114	.393	.422	.995	3.08
16	1.05	.282	1.53	3.36	5.00
17	2.11	2.48	3.42	4.38	6.50

TABLE III: MOISTURE PICKUP RETAINED DURING A SEVEN DAY DRYING PERIOD

WATER PICKUP RETAINED BY GROUP E IN GRAMS PER FOOT OF AVERAGE EDGE LENGTH

Sample No.	One Day	2 Days	3 Days	4 Days	5 Days	6 Days	7 Days
1	1.55	1.19	.856	.648	.566	.516	.481
2	.870	.790	.712	.649	.611	.577	.554
3	.444	.436	.421	.408	.397	.390	.382
4	2.00	1.64	1.30	1.04	.901	.791	.720
5	.864	.844	.823	.805	.794	.783	.774
6	.131	.131	.131	.127	.128	.140	.130
7	2.38	2.12	.179	1.51	1.34	1.21	1.11
8	.528	.519	.498	.485	.471	.461	.452
9	.091	.092	.091	.089	.089	.089	.089
10	1.68	1.10	.680	.462	.412	.390	.370
11	1.78	1.38	1.08	.865	.803	.768	.933
12	1.69	1.29	1.09	.639	.580	.536	.507
13	1.65	1.21	.793	.575	.516	.488	.464
14	1.68	1.06	.625	.431	.390	.388	.374
15	2.18	1.94	1.64	1.43	1.31	1.18	1.14
16	1.40	1.93	.579	.378	.346	.343	.326
17	2.29	1.44	.730	.467	.426	.403	.378

TABLE IV: PER CENT EFFECTIVENESS OF EDGE SEALERS AGAINST WATER

Sample No.	Group A	Group B	Group C	Group D	Group E
1	91.2	90.2	76.5	41.9	42.8
2	98.1	96.3	97.9	96.1	83.9
3	97.1	97.3	96.8	96.8	92.9
4	87.8	79.5	69.0	64.6	46.8
5	98.3	97.2	98.0	96.8	85.9
6	98.5	95.5	97.4	98.5	97.9
7	69.8	85.6	77.8	23.4	44.6
8	98.6	94.3	76.7	95.6	91.0
9	99.1	96.5	96.6	64.6	98.4
10	70.0	44.5	40.6	24.0	32.1
11	93.2	86.7	72.0	39.5	43.5
12	88.8	-	55.0	31.8	35.4
13	77.4	62.3	44.8	35.1	35.9
14	39.0	43.4	45.6	30.0	33.0
15	94.6	84.8	87.3	77.3	62.5
16	50.0	88.6	65.2	23.4	23.0
17	0.0	0.0	0.0	0.0	0.0

FIGURE 1: MOISTURE PICKUP OF EDGE SEALED WOOD SAMPLES (1)

Time in Days
Soaking Period
Drying Period

LEGEND

- Sample 1
- Sample 4
- Sample 7
- Sample 10
- Sample 15
- Sample 16

Grams of Water Per Foot of Average Edge Length

FIGURE 2: MOISTURE PICKUP OF EDGE SEALED WOOD SAMPLES (2)

Grams of Water Per Foot of Average Edge Length

FIGURE 3 : MOISTURE PICKUP OF EDGE SEALED WOOD SAMPLES (3)

Discussion

Examination of the results and curves just presented revealed many discrepancies in the soaking curves. There were two probable errors in the soaking curves.

1. A separate wood sample was used for each soaking period. It was considered impossible to obtain wood samples that were entirely uniform.
2. In coating each of the five samples for a given sample moisture barrier, it was almost impossible to maintain a uniform film thickness.

These conclusions were borne out by the fact that the drying curves show far greater precision than the soaking curves. It will be remembered that each of these curves was plotted from data taken on a single sample. However, the precision was sufficient to show the Qualitative results that were desired.

Examination of the enamel soaking curves reveals the following:

1. As the number of coats or film thickness was increased the amount of moisture absorbed decreased regardless of the pigment concentration. However, this decrease became smaller as the number of coats increased.
2. As the pigment concentration increased, the amount of moisture absorbed at any time decreased. It was realized, however, that this conclusion had limitations above a certain unknown pigment concentration.

3. The pigment in a moisture barrier of this type played an important part in the efficiency of the coating as was evidenced in the difference in efficiency of the pigmented spar varnish samples and the unpigmented spar varnish (sample ten).
4. The percent effectiveness of the enamels decreased with the increase in soaking time.

Of the other samples, the following conclusions were reached:

1. In no case was an unpigmented sample as good as a pigmented sample.
2. The method of curing the phenolic varnish had little effect on its effectiveness.
3. The attempt to effect a seal of the wood cells by impregnation and polymerisation of varnish was not successful.
4. In general all the samples showed a slight decrease in effectiveness with an increase in the immersion time.

Examination of the drying curves revealed the following:

1. The drying was rapid at first, and in some cases, such as in sample nine, equilibrium was essentially reached at the end of the drying period.
2. Certain enamel coated samples, such as sample five retained more moisture after drying than did untreated

wood. This was a hysteresis effect and will multiply itself somewhat on further soaking and drying. This condition, of course, was undesirable. As pointed out in the theory, certain barriers show this effect. In selecting the best sample this effect was kept in mind. If the barrier does not allow sufficient release of the moisture in the wood during drying, blisters may appear.

3. None of the samples dried to its original weight although in many cases equilibrium was definitely reached.

Since the best per cent effectiveness was shown by the 40 per cent pigment spar varnishes, in either the three-coated groups or the two-coated groups, the selection to be made was between using two or three coats of this enamel. Since the two-coated sample was almost as effective as the three-coated sample, sample eight was chosen because production time could be saved.

B. Vapor Resistance Test of Enamel Water Barriers

In certain sections of the country an edge sealer would be subjected to high humidity conditions. What effect the humid air would have on the barriers was not certain. Although, theoretically, the barriers should resist water vapor to the same degree that they resisted water immersion, the four best barriers were taken from the previous test groups and subjected to a vapor resistance test. Since the results were to be essentially qualitative with respect to untreated wood and to expedite the work, a quick and simple test was used.

Apparatus

A vacuum drying oven, with a volume of about 1/2 cubic foot having a thermostatic control, was selected for the test chamber because it was air tight. An analytical balance was used for weighing.

Procedure

Samples of 1/4 inch, 3 ply, Douglas fir plywood were cut and sanded to about 4.7 cm. square. The, as yet, untreated wood samples were placed in the oven over a saturated solution of lithium chloride. The samples were weighed each day until after eight days the loss in weight of the wood was negligible. The moisture content of the wood was, then, in equilibrium with air at 25°C at 15 per cent relative humidity.*

*The relative humidity maintained by a saturated salt solution at a given temperature was obtained from the International Critical Tables, Volume I, page 68.

The samples were coated on their edges with their respective moisture barriers, and paraffin was applied to the faces. After the samples were weighed, they were placed in the sealed humidity chamber which was now maintained at 25°C and 95 per cent relative humidity. The humidity was maintained by a saturated solution of potassium sulfate. The salt solution was placed in a tray to give as large a surface area as the chamber would permit.

The samples were weighed each day for eight days.

Materials Tested

The materials tested are listed in Table V. Samples one through eight were dual coatings of the best enamels found in the water immersion testing. Samples nine and ten were dual blanks.

In the water immersion test, no water penetrated the faces of the wood samples. However, in this test water vapor was involved, and it was deemed impossible to keep the vapor away from the paraffined faces. The changes in the weight of the samples were to be small so that any vapor penetrating the faces would cause serious errors. The effect of paraffin in preventing vapor penetration at the plywood face was investigated by the use of samples eleven through thirteen.

Results

Table VI lists the computed results showing the moisture pickup of the samples each day converted from the data to moisture pickup in grams per foot of average edge length.

TABLE V: COMPOSITION OF EDGE SEALERS USED IN A WATER VAPOR TEST

Sample No.	Vehicle Content	Solid Content	Coat Cure	No. of Coats
1.	60 % spar varnish	40 % leaded zinc oxide	air drying	2
2.	60 % spar varnish	40 % leaded zinc oxide	air drying	2
3.	60 % spar varnish	40 % leaded zinc oxide	air drying	3
4.	60 % spar varnish	40 % leaded zinc oxide	air drying	3
5.	70 % spar varnish	30 % leaded zinc oxide	air drying	2
6.	70 % spar varnish	30 % leaded zinc oxide	air drying	2
7.	70 % spar varnish	30 % leaded zinc oxide	air drying	3
8.	70 % spar varnish	30 % leaded zinc oxide	air drying	3
9.	Blank			
10.	Blank			

Table VII lists the results in terms of per cent effectiveness of the moisture vapor as compared to blank wood. Figure 4 is a plot of Table III showing the gain in weight of the samples versus time. Only one curve was plotted for the dual samples being an average of the two results. The experimental data are listed in Appendix B.

Discussion

The ability of the paraffin face seal to keep moisture from penetrating the wood faces was unknown. With the aid of the data taken for the purpose of determining the effect of the seal, calculations indicated that, essentially, the seal was satisfactory.

Although the samples eleven through thirteen were weighed each day during the test, the following calculations were made on the basis of the first day's weighing. This was done because the rate of moisture pickup was greatest at this time; i.e. the wood was at its farthest point from equilibrium and a true condition existed in that the vapor penetrating the edges was not interfering with that penetrating the faces. The experimental results for samples eleven through thirteen are listed in Table VIII.

The calculations were made using the original data because converting to a foot of edge length would double the edge length but make the face area eight times its original area. In following the calculations refer to the results in Table VIII by their respective sample numbers.

TABLE VI: WATER VAPOR PICKUP OF EDGE SEALED WOOD

GRAMS OF WATER PICKUP PER FOOT OF AVERAGE EDGE LENGTH

Sample No.	1 Day	2 Days	3 Days	4 Days	5 Days	6 Days	8 Days
1	.0300	.058	.080	.099	.116	.140	.185
2	.034	.061	.071	.100	.117	.135	.185
3	.020	.044	.067	.068	.069	.071	.075
4	.038	.079	.110	.133	.157	.191	.247
5	.065	.125	.157	.190	.227	.268	.342
6	.046	.093	.147	.161	.195	.243	.296
7	.037	.076	.100	.121	.143	.175	.224
8	.022	.043	.063	.078	.093	.117	.153
9	.466	.661	.773	.875	.951	1.01	1.11
10	.415	.622	.741	.832	.871	.954	1.01

TABLE VII: PER CENT EFFECTIVENESS OF EDGE SEALERS AGAINST WATER VAPOR

Sample No.	1 Day	2 Days	3 Days	4 Days	5 Days	6 Days	8 Days
1	93.2	91.0	89.4	88.4	87.3	85.7	82.6
2	92.2	90.5	90.6	88.3	87.2	86.3	82.6
3	95.5	93.2	91.0	92.1	92.4	92.9	92.4
4	91.3	87.7	85.4	84.4	82.8	80.5	76.3
5	85.3	80.5	79.1	77.7	75.1	72.7	67.8
6	89.5	95.6	80.5	81.1	78.6	75.2	72.1
7	91.6	88.2	86.7	85.9	84.4	82.2	78.9
8	95.1	95.7	91.7	90.8	89.8	88.1	85.6
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LEGEND

- Sample 1 and 2
- ▽ Sample 3
- △ Sample 5 and 6
- Sample 7 and 8
- ⬢ Sample 9 and 10

Grams of Water Per Foot of Average Edge Length

FIGURE 4: WATER VAPOR PICKUP OF EDGE SEALED WOOD

Calculation 1: Sample 12 minus Sample 11
 $0.0734 \text{ minus } 0.0101 \text{ equals } 0.0633$
 grams of water

Calculation 2: Sample 13 minus Sample 12
 $0.2680 \text{ minus } 0.0734 \text{ equals } .1846$
 grams of water

Calculation 1 represents the reduction in moisture pickup due to face sealing with paraffin. Calculation 2 represents the reduction in moisture pickup due to edge sealing. The assumption was made that the ratio of the moisture pickup through the edge to the pickup through the face of a completely sealed sample was directly proportional to the ratio of calculation 2 to calculation 1. Accordingly, this ratio was $0.1846/0.0633$ or, 3; that is, 25 per cent of the moisture which penetrated sample No. 11, penetrated through the paraffined face. This amount was 25 per cent of 0.0101 grams or 0.00252 grams. Referring to Appendix B and averaging the two blank samples (9 and 10) after one day's exposure, the amount of moisture pickup was 0.2278 grams. Of this amount, about 0.00252 grams should be due to vapor passing through the face seal. This value was 1.1 per cent of the total gain in weight and represents the error in Tables 6 and 7. For the purpose of this work the effect of moisture penetrating the faces of the samples was neglected.

The errors in the results were

1. Inability to control film thickness
2. Non uniformity of the wood samples
3. Vapor penetration of the wood faces.

The errors were assumed to be small because of the excellent

TABLE VIII: COMPOSITION AND RESULTS OF SAMPLES TESTED TO INVESTIGATE VAPOR
RESISTANCE PARAFFIN SEALS

Sample No.	Composition	Grams of water vapor pickup after one day exposure
11.	A wood sample completely sealed with paraffin	.0101
12.	A wood sample edge sealed with paraffin only	.0734
13.	A wood sample completely unsealed	.2681

results obtained. However, sample 4 was evidently a poor sample since it did not compare to its twin sample 3. The results obtained for sample 4 were rejected and not plotted in Figure 2. Examination of the sample revealed damage to the paraffin seal and a defective coating of enamel.

Examination of Table VII and Figure 4 revealed the following conclusions:

1. Enamel barriers behaved against water vapor as they did against water.
2. The enameled wood samples showed the same curve distribution in Figure 4 as they did in Figures 1, 2, and 3; i.e. as the pigment concentration and film thickness increases, the effectiveness of the coating increases.
3. As the time of exposure increased, the effectiveness decreased.
4. The data were sufficiently accurate to consider the test conclusive.

C. Water Immersion Test of Water Barriers

At this point, the sponsor specified that he desired the edge sealer to meet the production drying schedule of the Gunnison Plant. The production schedule allowed for an eleven minute air drying period and two twelve minute drying periods at 120°F. After attempting, without good results, to quicken the drying rate of 40 per cent leaded zinc oxide, 60 per cent spar varnish enamels, the use of a quick drying paint modified by increasing its pigment composition was investigated. Such a coating should be successful against water immersion since the basic composition would be similar to that of the previously tested enamels.

Apparatus

The apparatus used in this experiment was the same as that used in the first water immersion test.

Procedure

The wood samples were cut and prepared as in the previous immersion test. However, a special coating application was used. The test coatings were applied with a brush to a thickness of one coat followed by an eleven-minute drying period. An unadulterated coat of Arco primer paint was sprayed on followed by a ten minute drying period at 120°F. Then another unadulterated spray coat of Arco primer paint was applied followed by a twelve-minute drying period at 120°F. This procedure was easily adaptable to the Gunnison production schedule. As in the previous water immersion test, three groups of each sample

to be tested were prepared.

Group A	3 days soaking
Group B	5 days soaking
Group C	7 days soaking

The samples were paraffined, weighed, bundled together, and immersed in water. The materials tested are listed in Table IX.

Results

The experimental data were converted from grams of moisture pickup to grams of moisture pickup per foot of average edge length and were tabulated in Tables X and XI. Table X gives as the weight of moisture pickup by the samples per day while Table XI expresses Table X in per cent effectiveness. Figure 5 is a plot of Table X showing grams of water absorbed per day-foot of average edge length versus time. The experimental data are listed in Appendix B.

Discussion

It was evident from the results shown in Table X that the accuracy of this test was not as good as previous work. For instance, sample 4 showed an extremely low effectiveness, in general, and an increasing effectiveness with time of soaking. Since the sample was so similar to sample 1, it was expected that the results would be similar. However, sample 1 did show excellent results and was recommended as a fast drying moisture barrier for edge sealing. If time had permitted, a check of some of the results with another test would have been desirable. However, the results obtained for sample 1 would have varied little.

TABLE IX: COMPOSITION OF WATER IMMERSED EDGE SEALERS

Sample No.	Vehicle Content	Solid Content	Coat Cure	No. of Coats
1.	66 % Arco primer	34 % leaded zinc oxide	air drying	1
2.	66 % Arco primer	34 % zinc oxide	air drying	1
3.	60 % heat reactive phenolic varnish	40 % leaded zinc oxide	air drying	1
4.	75 % Arco primer	25 % leaded zinc oxide	air drying	1
5.	Blank			

* Arco primer — Arco Paint No. 156 Arco Paint Company, Cleveland, Ohio

**TABLE X: GAIN IN MOISTURE CONTENT OF EDGE
SEALED WOOD**

Grams of Water per Foot of Average Edge Length

Sample No.	Group A	Group B	Group C
1.	.414	.580	.847
2.	1.66	—	2.50
3.	1.06	.748	2.36
4.	1.35	3.35	2.79
5.	4.24	4.80	5.96

**TABLE XI: PER CENT EFFECTIVENESS OF SAMPLE
EDGE SEALERS**

Sample No.	Group A	Group B	Group C
1.	90.3	88.0	86.0
2.	50.7	—	58.1
3.	75.0	84.5	60.4
4.	68.0	—	53.3
5.	0.0	0.0	0.0

Time in Days

LEGEND

- Sample 1
- Sample 2
- △ Sample 3
- ▽ Sample 4
- Sample 5

Grams of Water Per Foot of Average Edge Length

FIGURE 5: GAIN IN MOISTURE CONTENT OF EDGE SEALED WOOD SAMPLES

D. Evaluation of Water Vapor Barriers

One of the problems encountered in modern housing of tight construction is the condensation of moisture in the stud spacing. L. V. Teesdale, of the Forest Products Laboratory (7), gave the following explanation. Certain types of modern houses have interior and exterior sides of the exterior walls of duplicate construction and materials. Consequently, the resistance to the flow of vapor through the wall is equally divided between the interior and exterior side of the wall. Since the partial pressure drop of water vapor across any part of the wall is proportional to the resistance of that part of the wall, the partial pressure of water vapor in the stud spacing is an average of the water vapor partial pressure on both sides of the wall. During the winter months, in houses of tight construction, the rooms are kept at 72°F and 50 per cent relative humidity, corresponding to a partial pressure of 10.04 mm of mercury. Quite often the outside temperature will be at 32°F or lower with a relative humidity of 100 per cent corresponding to a partial pressure of 4.55 mm of mercury. Assuming the partial pressure of the vapor inside the stud spacing to be an average of the room and outside partial pressures, a partial pressure of 7.31 mm of mercury exists in the stud spacing. At temperatures of 44°F or lower in the spacing, moisture would then be condensed. This example, of course, is hypothetical but presents a clear picture of what actually happens.

In houses built along older designs the condensation problems rarely are met because of the loose construction of the exterior side of the wall resulting in low resistance to vapor flow.

If a vapor barrier of sufficient effectiveness were to be placed along the interior side of the wall, vapor condensation would be eliminated in the stud spaces. In investigating possible barriers, actual rates of vapor diffusion through wood samples were measured. A procedure for measuring vapor diffusion through films was described by Burr and Stamm (22) in 1941; The apparatus was designed to give maximum rates of vapor diffusion through a film by elimination of stagnant air layers on either side of the sample. A modified apparatus, using the same principles, was used in the vapor barrier investigation.

Apparatus

A tightly constructed box 4-1/2 feet by 2 feet by 2 feet made from 5/8 inch plywood was mounted over a motor. The motor was connected by a belt drive to a shaft that entered the bottom of the box at an angle of 75 degrees with the horizontal. Mounted on top of the shaft and inside the box was a wooden disk 15 inches in diameter. Ten 1-1/4 inch holes were counter sunk around the rim of the circular disk. The holes served as receivers of the 100 ml weighing bottles. Aluminum stirring rods equipped with an aluminum foil vane on the shanks were mounted in the weighing bottles so that as the wooden disks rotated, the rods would swing as pendulums agitating any solutions in

the bottles and circulating the air in the bottles. Thus, a wooden sample could be sealed in the bottles over a saturated salt solution and the stagnate air and liquid films in the sealed bottles eliminated. The box was equipped with a thermostat for temperature control, a fan for air circulation, a pan of water for humidity control, and a thermometer well for wet bulb readings. (See Figures 6,7,8 and 9).

Procedure

The purpose of the equipment just described was to make possible the establishment of a constant water vapor partial pressure drop across a wooden disk. This was done by means of exposing the opposite sides of the samples to different relative humidities at the same temperature.

About 25 grams of an aqueous saturated lithium chloride solution was placed in the weighing bottles. Sanded samples, 4.25 cm in diameter, of 1/4 inch, 3-ply Douglas fir, plywood were coated with the test vapor barriers and sealed in the tops of bottles with paraffin. Great care was used in making the seal. The bottles were then weighed and placed in the counter-sunk holes provided. The top was placed on the box, the thermostat was set for 85°F, and the motor and fan turned on. The samples were weighed each day when possible. Thus, in the weighing bottles, the temperature was 85°F and the relative humidity was 20 per cent. In the box the temperature was 85°F and the relative humidity was 100 per cent.

Figure 6. Picture of Weighing Bottles (interior view)

This figure shows the ten weighing bottles with the wooden samples sealed in place. The front bottle has been opened and tilted forward to show the stirring rods.

Figure 7. Picture of Weighing Bottle (exterior view)

This figure gives another view of Figure 6. The stirring
rod and aluminum foil vane are visible in the front bottle.

Figure 8. Interior of Vapor Permeability Apparatus

Figure 9. Vapor Permeability Apparatus Ready for Operation

Materials Tested

The coatings were applied to the faces of the disks. Five minutes air drying time was allowed between application of the successive coating. The materials tested are listed in Table XII.

Results

The gain in weight of the samples during the 16-day test period are shown in Table XIII. In order to calculate the rate of moisture diffusion through the samples, Table XIII was plotted as Figure 10 and 11. The final portion of the resulting curves was the portion of the plot representing equilibrium conditions. At this portion of the curves, the reciprocal of the slopes was calculated to give the rate of water vapor diffusion in grams per day. This rate was converted to the rate of water vapor diffusion through the samples in grams of water diffusion per day and the results listed in Table XIV. Table XV was computed to show the results of Table XIV as per cent effectiveness of the coatings. The original data is in Appendix B.

Discussion

The results of sample 4 should be rejected as an experimental failure, since this sample showed a larger rate of diffusion than did untreated wood. Probably an ineffective seal caused this error. The theoretical accuracy of the values listed in Table XIV were limited by the accuracy of Figure 10. Other experimenters have reported results for sample 6 and 7 as high as 99 per cent effectiveness. The sole reason for

TABLE XII: COMPOSITION OF SAMPLE VAPOR BARRIERS TESTED

Sample No.	Vehicle Content	Solids Content	Coat Cure	No. of Coats
1.	80 % spar varnish	20 % 300 mesh aluminum powder	air drying	2
2.	22.4 % naptha and 5.6 % toluene	52 % gilsonite resin 20 % 300 mesh aluminum powder	air drying	2
3.	16.8 % naptha 4.2 % toluene	39 % gilsonite resin 40 % aluminum powder	air drying	2
4.	80 % heat reactive phenolic varnish	20 % 300 mesh aluminum powder	air drying	2
5.	64 % ethyl cellulose 16 % nitro cellulose	20 % 300 mesh aluminum powder	air drying	2
6.		aluminum foil		1
7.		aluminum foil		1
8.	Blank			

* An aluminum foil 0.001 inches thick was coated with Bostick cement, a product of the B. B. Chemical Co. The foil was baked at 100°C for 1 hour. The foil was then bonded to the wood with penacolite 1131 at 40 PSI at 150°C for 8 minutes.

TABLE XIII: MOISTURE DIFFUSED THROUGH VAPOR SAMPLES

Grams of Water Diffused

Sample No.	1 Day	2 Days	3 Days	4 Days	6 Days	7 Days	9 Days	13 Days	14 Days	15 Days	16 Days
1	.0329	.0667	.0918	.1195	.1584	.1857	.2369	.2897	.3245	.3450	
2	.0326	.0682	.0926	.1144	.1409	.1595	.1927	.2121	.2150	.2165	
3	.0515	.0804	.1290	.1625	.2230	.2363	.2875	.3433	.3554	.3656	
4	.0375	.0758	.1064	.1626	.2273	.2205	.3467	.4825	.5112	.5434	
5	.0442	.0910	.1303	.1659	.2166	.2451	.3073	.3998	.4186	.4474	
6	.0400	.0805	.1146	.1512	.1950	.2230	.2441	.3348	.3434	.3520	.3530
7	.0420	.0919	.1339	.1759	.2347	.2630	.3172	.3584	.3692	.3682	.3687
8	.0406	.0686	.0972	.1267	.1632	.1905	.2375	.3190	.3372	.3564	

Time in Days

LEGEND

- Sample 2
- ▽ Sample 5
- Sample 6
- △ Sample 7

Gain in Weight in Grams of Water

FIGURE 10: VAPOR DIFFUSION CURVES (1)

FIGURE 11: VAPOR DIFFUSION CURVES (2)

TABLE XIV: RATE OF WATER VAPOR DIFFUSING THROUGH VAPOR BARRIERS

Sample No.	Diffusion Rate in Grams of Water per Day
1.	.0175
2.	.0009
3.	.0090
4.	.0306
5.	.0171
6.	.0009
7.	.0005
8.	.0180

TABLE XV: PER CENT EFFECTIVENESS OF VAPOR BARRIERS

Sample No.	Per Cent Effectiveness
1.	2.5
2.	95.0
3.	50.0
4.	—
5.	5.0
6.	95.0
7.	97.0
8.	0.0

testing these samples was to see whether aluminum could be successfully bonded to plywood to serve as a moisture barrier.

The following conclusions were reached:

1. The leafing properties of aluminum powder in an asphalt vehicle provides an effective vapor barrier.
2. Two coats of a good vapor barrier are sufficient protection.
3. Aluminum foil bonded to wood is the best vapor barrier.
4. The accuracy of the work is sufficient to recommend an aluminum-gilsonite lacquer (sample 2) or aluminum foil (samples 6 and 7) as a vapor barrier.

SUMMARY AND CONCLUSIONS

A number of paint formulations have been made and tested for water vapor resistance.

Edge Sealers

Of the coatings tested, all showed about equal resistance to water and water vapor. Of these the most desirable, as an edge sealer, was two coats of 40 per cent leaded zinc oxide and 60 per cent spar varnish enamel. However, the use of this enamel required a modification in the plant production schedule. As a second choice, a mixture of 33 per cent leaded zinc oxide and 67 per cent Arce primer paint No.156 was selected. The only advantage of using this formulation was the slightly faster drying time. If a slightly longer drying time were possible, the first coating would be far more desirable.

Vapor Barriers

Two barriers were found to have almost equal vapor resistance: (1) a gilsonite aluminum lacquer; and (2) a 0.001 inch thickness of aluminum foil. The first barrier is cheap and easily applied from a spray gun. Its effectiveness with time is not known but would be expected to decrease considerably as do all other such barriers.

The second barrier is somewhat more expensive and must be incorporated into the plywood during manufacture. However, by the use of aluminum plywood only in those sections of a house showing the greatest amount of water vapor condensation, this process becomes economically feasible. Hence, if a house had only six windows, only six sheets of plywood in the entire house would have the expensive aluminum as a vapor barrier.

It was recommended that the aluminum foil be placed between the first and second plys of the plywood. It was suggested that the lacquer vapor barrier be used in the other wall sections requiring less protection.

II. CORE VOID FILLERS FOR STRUCTURAL PLYWOOD

INTRODUCTION

The idea of a core void filler originated because of imperfect gluing of the center ply in a three-ply plywood during the war and at the present time. Very often, the center ply consisted of two pieces whose edges had not been trimmed to form a tight joint resulting in wide crevices called core voids. Quite often these voids extended longitudinally from one edge to the opposite edge of the panel, leaving an easy excess for water to enter the wood resulting in structural failures. Of course, a filler of some sort was necessary to plug these holes.

The filler was to be applied as the wood moved horizontally down a conveyor. Certain requirements were necessary before a filler could be successful. The filler

1. must be viscous enough not to leak out of the voids before hardening.
2. must harden rapidly at 120°F
3. must have a long pot life
4. must be paintable
5. must be hard upon drying.

In this section of the report the results of an investigation and recommendation of a core void filler are presented. This work was carried out as a portion of contracted research of the University of Louisville Institute of Industrial Research.

HISTORICAL

The specific problem of sealing holes in wood is covered almost entirely in the Patent literature only. In 1915 (39) a patent was issued for a wood substitute consisting of lime, plaster of paris, cement, sand, and water. In the same year Evans and Andrews (40) formulated a compound consisting of sawdust or cork dust, 50 to 70 parts; waste rope hair or animal hair, 10 to 20 parts; ferrous sulfate, 1 to 2 parts; calcium carbonate, 10 to 15 parts; and other miscellaneous salts impregnated with oils, glue, gum resins, or waxes.

Several more recent investigators have patented formulations using cellulose and cellulosic derivatives as the base of plastic wood. Kritehevsky and Schults (41) 1930 patented a formulation that could be applied without pressure and worked by hand. This consisted of celluloid, acetone, benzol, ethanol, and wood flour. A similar compound was discovered in 1937 (42) consisting of a cellulose derivative such as cellulose acetate in acetone and wood flour. Another similar patent, issued in 1937 to Esselen (43), was described as a putty-like compound that would harden on exposure to air to the hardness and rigidity of wood.

T H E O R E T I C A L

The historical section indicates that past core void fillers fall into two general classifications: (1) those using a cellulosic and solvent base with a wood flour binder; and (2) a hairy-like substance as a binder for a glue or wax. The investigation presented in this report was limited to the use of extended glue mixtures since such a mixture would be very hard and would lend itself to rapid heat curing. This section has been divided into three sections: (1) The adhesion of glue; (2) Synthetic glues; and (3) Glue extenders.

The adhesion of glue

Glue adhesion takes major forms, mechanical and specific (44). When glue is applied to wood, it gains access to the wood cavities where it solidifies. The resulting strength is credited to the interwinging or interlocking of two strong solids, wood and glue. This form of adhesion is called mechanical.

However, this does not explain the adhesion between two highly polished metal blocks. Two pieces of highly polished hard woods, such as ebony, having a minimum of crevices, have been successfully bonded together, indicating that another form of adhesion exists and is called specific adhesion.

Specific adhesion is the result of polarity. The causes of polarity have been discussed elsewhere in this report. It is sufficient to say that polar to polar and non polar to non polar bonds can be made, but that polar to non polar bonds cannot be made. Wood is polar, and synthetic glues are quite polar.

Synthetic glues

There are in existence many synthetic glues such as urea formaldehyde, phenol formaldehyde, resorcinol formaldehydes, melamine formaldehydes, vinyl resin and acrylic resin glues. Of these, the vinyl and acrylic resins are thermoplastic while the others are thermosetting.

The thermosetting formaldehydes are partially polymerized compounds of a resin and a formaldehyde. After application with a "catalyst" the glue further polymerizes and becomes thermosetting. The application of heat and pressure speeds up the chemical reaction.

Extenders

Extenders (45) are additional ingredients incorporated in liquid resin mixtures for any one of several reasons such as (1) to reduce cost, (2) to regulate flow characteristics, and (3) to reduce the curing temperature. Wheat and rye are often added to urea glues to reduce the cost of the glue. Dried blood, when added to phenolic glues, will regulate the flow characteristics and reduce the curing temperature of the resulting mixture.

E I P E R I M E N T A L

In order to evaluate the fillers tested, certain standards were arbitrarily formulated.

1. No shrinkage
2. Harder than wood
3. High viscosity
4. Quick drying
5. Paintable when wet
6. Weather resistance
7. No bleeding
8. Reasonable pot life

Experimental procedure

Holes with a 3/8 inch bore and one inch deep were cut in blocks of wood. The fillers, being tested, were forced into the holes and allowed to set. After 24 hours they were examined visually on the surface and checked internally for adhesion by cutting the blocks of wood through the axis of the holes.

Materials tested

Two types of glues were chosen for investigation: (1) urea-formaldehyde (uformite 430 and catalyst Q-92); and (2) resorcinol (amberlite PR 115 and catalyst P 117). These glues were extended with several fillers. The compositions of the core void sealers are listed in Table XVI.

Results

The results of the tests are listed in Table XVI. Table XVI has been subdivided into three groups. Group A was tested for an initial evaluation of urea-formaldehyde glues. However, even with a saw dust filler this glue was found to have considerable shrinkage. Urea-formaldehyde glues were discarded in favor of resorcinol glues which were known to shrink little upon drying.

TABLE XVI: CORE VOID FILLER COMPOSITIONS AND TEST RESULTS

Sample No.	COMPOSITION	Color	Hardness	Internal Shrinkage	External Shrinkage	Adhesion	Comment
1a	100 % ufermite	white	good	excess	excess	poor	poor
2a	70 % ufermite - 30 % sawdust	white	good	moderate	none	good	fair
1b	80 % amberlite - 20 % powdered wood	purple	medium	none	none	fair	fair
2b	68 % amberlite - 32 % powdered wood	purple	good	moderate	none	fair	fair
3b	60 % amberlite - 40 % powdered wood	brown	good	moderate	moderate	fair	fair
4b	80 % amberlite - 20 % kaolin clay	purple	brittle	moderate	moderate	fair	fair
5b	60 % amberlite - 40 % kaolin clay	brown	brittle	moderate	moderate	fair	fair
6b	40 % amberlite - 60 % kaolin clay	brown	brittle	moderate	moderate	fair	fair
7b	20 % amberlite - 80 % kaolin clay	brown	good	none	moderate	fair	fair
8b	80 % amberlite - 20 % asbestos	purple	good	none	moderate	good	good
9b	40 % amberlite - 60 % asbestos	purple	good	none	none	good	good
1c	70 % amberlite - 30 % sil-o-cel	purple	brittle	none	none	good	good
2c	60 % amberlite - 40 % sil-o-cel	purple	good	excess	excess	poor	poor
3c	55 % amberlite - 45 % sil-o-cel	brown	good	moderate	moderate	poor	poor
4c	50 % amberlite - 40 % sil-o-cel	brown	soft	none	none	poor	poor
5c	45 % amberlite - 55 % sil-o-cel	brown	soft	none	none	poor	poor

TABLE XVI: Continued

Sample No.	COMPOSITION	Color	Hardness	Internal Shrinkage	External Shrinkage	Adhesion	Comment
6c	40 % amberlite - 60 % sil-o-eal	brown	soft	none	none	poor	poor
7c	60 % amberlite - 40 % asbestos	purple	hard	none	none	good	good
8c	55 % amberlite - 45 % asbestos	purple	hard	none	none	good	good
9c	50 % amberlite - 50 % asbestos	purple	hard	none	none	good	good
10c	45 % amberlite - 55 % asbestos	purple	hard	none	none	fair	fair
11c	40 % amberlite - 60 % asbestos	purple	hard	none	none	fair	fair
12c	35 % amberlite - 65 % asbestos	purple	hard	none	none	poor	poor
13c	30 % amberlite - 70 % asbestos	purple	hard	none	none	poor	poor

Group B was the initial evaluation of resorcinol using various extenders, powdered walnut wood flour, kaolin clay, and short fibered asbestos. It was thought that the use of these extenders would give a good indication of the behavior of other commercially available extenders. In this particular group only the asbestos extended samples were satisfactory.

Asbestos is a fluffy material. In group C asbestos and another fluffy inert substance, sil-o-cel, were tested. In this group the asbestos extended fillers gave excellent results.

Discussion

In groups b and c of Table XVI were listed compositions of asbestos extended Amberlite glue from 80 per cent to 30 per cent Amberlite. Of these samples a range was found that appeared to be satisfactory, 60 to 50 per cent Amberlite. Therefore, splitting the difference a mixture of 55 per cent catalysed Amberlite PR 115 and 45 per cent asbestos was selected for further investigation as to pot life, bleeding characteristics, and time of cure.

The properties of the selected mixture were as follows:

1. Considerably harder than wood
2. Dries to semi hardness in 22 minutes at 120°F
3. Paintable while wet
4. Purple in color
5. Has a pot life at 72°F of at least 5 hours
6. Has a decreasing pot life with an increasing temperature
7. Has no surface or internal shrinkage

8. Will not bleed when heated at 135°F for two days or when soaked in water for 48 hours
9. Forms a strong bond with wood
10. Cannot be lightened in color by pigment addition
11. No detrimental effects from freezing at minus 9°C for 48 hours
12. Can be applied with a putty knife
13. Stains can be removed before hardening with a damp cloth
14. Has the consistency of putty

SUMMARY AND CONCLUSIONS

Several extended mixtures of Amberlite PR 115, a resorcinol glue, were extended as, core void fillers. Of these, a sample of 55 per cent catalysed Amberlite and 45 per cent short fibered asbestos was selected and recommended as a core void filler.

This mixture lends itself quite well to mass production methods in that it can be applied from a pressure gun, or it may be applied by hand.

No explanation could be given to account for the failure of the wood flour mixtures. Wood flour has been used successfully for several years as an extender. However, it may be possible that the large volume per unit surface area used in this work required the use of an inert extender that would plasticize the mixture. Asbestos would have served this purpose because of its fluffy nature. However, sil-o-cel, an equally fluffy material, was found to be far from successful.

L I T E R A T U R E C I T E D

- (1) Gardner, Henry A., "Papers on Paint and Varnish" 1st edition, pp 167-175. 1545 B Street N.W. Washington, D.C., 1920
- (2) Dunlap, M.E., Ind. and Eng. Chem., Ind. Ed., 18, 1230 (1926)
- (3) Forest Products Laboratory, Technical Note 181, Madison, Wisconsin (1925) (abs.only)
- (4) Payne, Henry F., Ind. and Eng. Chem., Ind. Ed., 32, 737, (1940)
- (5) Muckenfus, A.M., Ind. and Eng. Chem., Ind. Ed., 5, 535 (1913) (abs.only)
- (6) Browne, F.L., Ind. and Eng. Chem., Ind. Ed., 25, 838 (1933)
- (7) Teesdale, L.V., Forest Products Laboratory Technical Bulletin R 1196, Madison, Wisconsin (1941)
- (8) Teesdale, L.V., Better Homes and Gardens, 120 (1947)
- (9) Wray, R.I. and Van Vorst, A.R., Ind. and Eng. Chem., Ind. Ed., 25, 842 (1933)
- (10) American Paint and Varnish Manufacturers Association, New York Paint and Varnish Production Club Science Circular 546, Washington, D.C. (1937) (abs.only)
- (11) Kline, G.H., Jour. Res. Nat. Bu. of Stand., Vol 18 (1937) (abs.only)
- (12) Wing, Henry J., Ind. and Eng. Chem., Ind. Ed., 28, 786 (1936)
- (13) Klinds, R.H., Jour. Soc. Chem. Ind., 55, 229 (1936)
- (14) Charch, W. and Scroggie, A.W., Paper Trade Jour., 101, 201 (1935)
- (15) Edwards, J.D. and Wray, R.I., Ind. and Eng. Chem., Ind. Ed., 28, 549 (1936)
- (16) Gomar, G.L. and Miller, E.J., Ind. and Eng. Chem., Anal. Ed., 15, 737, (1937)
- (17) Payne, H.F. and Gardner, Wm. H., Ind. and Eng. Chem., Ind. Ed., 29, 893 (1937)
- (18) Doty, P.M., Acher, W.H. Capt., and Mark, H. Ind. and Eng. Chem., Ind. Ed., 16, 686 (1944)

- (19) Payne, H.F., "Protective and Decorative Coatings" 1st edition, Vol IV edited by Mattiello, J.J., pp 194-220. New York, John Wiley and Sons, Inc., 1944
- (20) Taylor, R.S., Herman, D.F., and Kemp, A.R., Ind. and Eng. Chem., Ind. Ed., 28, 1255 (1936)
- (21) Gardner, H.A., American Paint and Varnish Manufacturers Association Science Circular 369 (1930) (abs.only)
- (22) Gortner, R.A., "Outlines of Biochemistry" 2nd edition, New York, John Wiley and Sons, Inc. 1938 (abs.only)
- (23) Burr, H.K. and Stamm, A.J., Ind. and Eng. Chem., Anal. Ed., 13, 655 (1941)
- (24) Shuman, A.G., Ind. and Eng. Chem., Anal. Ed., 16, 58 (1944)
- (25) Tieman, Harry Donald, "Wood Technology" 2nd. edition, pp 35-56. New York, Pitman Publishing Co., 1942
- (26) Stamm, A.J., "Wood Chemistry" 1st edition, edited by Wise, Louis E., pp 449-543. New York, Reinhold Publishing Corporation, 1944
- (27) Forest Products Laboratory, "Wood Handbook", 1st edition, p 23. Madison, Wisconsin, 1935
- (28) *ibid.*, pp 234-239
- (29) Stamm, A.J. and Hansen, L.A., Jour. of Phy. Chem., 42, 209, (1938) (abs.only)
- (30) Seberg, G.O. and Stamm, A.J., Ind. and Eng. Chem., Ind. Ed., 23, 1271 (1931)
- (31) Nasson, O. and Richards, E.S., Proceeds of the Royal Society, A-78, 412, London, England (1906) abs.only
- (32) Urquhart, A.R., Jour. of Textile Institute, 20, T 125 (1929) (abs.only)
- (33) Urquhart, A.R. and Williams, A.M., Jour. of Textile Institute, 15, T 138 and T 433 (1924) (abs.only)
- (34) Glasstone, Samuel, "Textbook of Physical Chemistry" 2nd edition, pp 1258-1259, New York, D. Van Nostrand Co., 1946
- (35) Payne, H.F., Ind. and Eng. Chem., Anal. Ed., 11, 453 (1939)

- (36) Sheppard, S.E. and Newsome, P.T., Jour. of Phys. Chem., 33, 1817, (1929) (abs.only)
- (37) Wray, R.I. "Protective and Decorative Coatings" 1st edition, Vol II edited by Mattiello, J.J., pp 557-570. New York, John Wiley and Sons, Inc., 1942
- (38) Rose, Carlton H., "Protective and Decorative Coatings" 1st edition, Vol II, edited by Mattiello, J.J., pp 355-357. New York, John Wiley and Sons, Inc., 1942
- (39) Funck, J.G., U.S. Patent 1,268,000 May 28, 1918 (abs.only)
- (40) Evans, L.P. and Andrews, W., British Patent 122,861, Jan 28, 1918 (abs.only)
- (41) Kritchevsky, W.K., and Schwartz, Karl A., U.S. Patent 1,759,907, May 27, 1930 (abs.only)
- (42) Silberman, Emanuel M., U.S. Patent 2,095,652, October 12, 1937 (abs.only)
- (43) Esselen, Gustavus J., U.S. Patent 2,105,111, January 11, 1937 (abs.only)
- (44) Browne, F.L. and Brouse, Don, "Nature of Adhesion between Glue and Wood" Forest Products Laboratory Bulletin R 1128 Madison, Wisconsin (1929)
- (45) Perry T.D., "Modern Adhesives" 1st edition, p 63. New York, Pitman Publishing Corporation, 1944

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A P P E N D I X

Sample Calculations

I Water Immersion Testing

a. Weight of water gained by samples

Weight of sample and watch glass after soaking = 13.7524 g

Weight of sample and watch glass after soaking = 13.7160 g

Weight of water gained by the sample = .0094 g

b. Edge length converted to one foot

2 x edge length = 7.86 cm

2 x edge width = 7.68 cm

Edge perimeter = 15.54 cm

Edge perimeter in cm. x 15.54
2.54 x 12 =

Edge perimeter in feet = .510 ft.

c. Weight of water gained in grams per foot of average length

Weight of water gained = .0094 g

Edge perimeter = .510 ft

Weight of water gained in grams per foot = $\frac{.0094}{.510} = .018$

d. Per Cent effectiveness

Weight of water gained per foot of average edge

length of a blank sample = 2.11 g

Weight of water gained per foot of average edge

length of a coated sample = .018 g

Per cent effectiveness = $\frac{(2.11 - .018)}{2.11} \times 100 = 99.1$

II Vapor Barrier Evaluation

a. Water diffused after three days testing

Weight of sample and weighing bottle after three days testing =

72.9211 g

Weight of sample and weighing bottle before testing =

72.7872 g

Water diffused after three days testing =

.1339 g

b. Diffusion rate

From a plot of time in days versus water diffused in grams the reciprocal of the slope of the end portion of the curve was taken in grams per day =

.0005

c. Per cent effectiveness

Diffusion rate of a blank sample =

.02000

Diffusion rate of an untreated sample =

.0005

Per cent effectiveness = $\frac{(.0200 - .0005) 100}{.02} = 97.5$

APPENDIX B - WATER IMMERSION TESTING OF MOISTURE BARRIERS - GROUP A

Sample No.	Weight of Sample and Watch Glass Before Soaking in Grams	Edge length cm.	Edge Width cm.	Sample Perimeter in Ft.	Weight of Sample and Watch Glass After Soaking in Grams	Weight of Water Gained in Grams
1	13.2194	3.91	3.89	.512	13.3147	.0953
2	14.2547	3.62	3.91	.484	14.2566	.0019
3	13.6170	3.92	3.90	.514	13.6201	.0031
4	13.5718	3.89	3.91	.512	13.6991	.1273
5	13.5534	3.89	3.91	.512	13.5721	.0187
6	14.0444	3.90	3.61	.494	14.0602	.0158
7	14.8316	3.91	3.90	.513	15.1582	.3266
8	13.5632	3.85	3.91	.510	13.5781	.0149
9	13.7160	3.93	3.84	.510	13.7254	.0094
10	13.4337	3.89	3.91	.512	13.7586	.3249
11	13.6918	3.65	3.91	.496	13.7632	.0714
12	13.8005	3.62	3.91	.484	13.9100	.1095
13	13.2797	3.89	3.87	.510	13.5222	.2425
14	14.6899	3.91	3.91	.514	15.3471	.6572
15	14.6314	3.83	3.93	.513	14.6897	.0583
16	14.3844	3.90	3.91	.513	14.9251	.5407
17	13.0760	3.81	3.87	.504	14.1391	1.0631

APPENDIX B - CONTINUED

DRYING DATA FOR WATER IMMERSSED MOISTURE BARRIERS - GROUP A

Weight of Samples and Watch Glass in Grams

Sample No.	1 Day drying	2 Days drying	3 Days drying	4 Days drying	5 Days drying	6 Days drying	7 Days drying
1	13.2696	13.2572	13.2543	13.2494	13.2508	13.2608	13.2537
2	14.2569	14.2589	14.2597	14.2605	14.2626	14.2699	14.2657
3	13.6192	13.6208	13.6206	13.6215	13.6236	13.6261	13.6270
4	13.6482	13.6345	13.6273	13.6219	13.6229	13.6306	13.6244
5	13.5641	13.5664	13.5637	13.5645	13.5664	13.5708	13.5699
6	14.0589	14.0599	14.0604	14.0611	14.0619	14.0669	14.0668
7	15.0441	15.0135	14.9954	14.9838	14.9701	14.9754	14.9654
8	13.5699	13.5716	13.5712	13.5714	13.5740	13.5756	13.5761
9	13.7216	13.7244	13.7252	13.7265	13.7296	13.7314	13.7311
10	13.5406	13.4995	13.4881	13.4792	13.4793	13.4791	13.4765
11	13.7410	13.7341	13.7323	13.7292	13.7357	13.7389	13.7317
12	13.8651	13.8531	13.8519	13.8508	13.8543	13.8568	13.8490
13	13.3837	13.3395	13.3385	13.3323	13.3385	13.3517	13.3335
14	14.9314	14.8437	14.8167	14.7998	14.8008	14.8059	14.7850
15	14.6765	14.6759	14.6745	14.6736	14.6757	14.6777	14.6773
16	14.5775	14.4845	14.4611	14.4446	14.4457	14.4550	14.4290
17	13.3180	13.2061	13.1867	13.1751	13.1807	13.1931	13.1695

APPENDIX B - CONTINUED

WATER IMMERSION TESTING OF MOISTURE BARRIERS - GROUP B

Sample No.	Weight of Sample and Watch Glass Before Soaking in Grams	Edge Length cm.	Edge Width cm.	Sample Perimeter in Ft.	Weight of Sample and Watch Glass After Soaking in Grams	Weight of Water Gained in Grams
1	13.4459	3.88	3.91	.511	13.5706	.1247
2	14.0116	3.61	3.90	.494	14.0567	.0449
3	13.9939	3.63	3.92	.495	14.0267	.0328
4	14.3005	3.89	3.91	.511	14.5605	.2600
5	14.4196	3.92	3.67	.497	13.4538	.0340
6	14.0695	3.65	3.92	.496	14.1249	.0554
7	13.7905	3.91	3.85	.509	13.9787	.1882
8	14.0061	3.77	3.91	.504	14.0777	.0716
9	13.6277	3.91	3.92	.513	13.06718	.0441
10	13.7868	3.58	3.90	.491	14.4666	.6798
11	14.0803	3.88	3.90	.510	14.2607	.1804
12						
13	13.3491	3.94	3.91	.515	13.8309	.4818
14	13.4972	3.91	3.74	.511	14.2006	.7034
15	13.4474	3.92	3.90	.513	13.5976	.1502
16	13.7573	3.92	3.92	.514	14.3059	.3486
17	13.0385	3.92	3.88	.511	14.3050	1.2671

APPENDIX B - CONTINUED

DRYING DATA FOR WATER IMMERSED MOISTURE BARRIERS - GROUP B

Weight of Samples and Watch Glass in Grams

Sample No.	1 Day drying	2 Days drying	3 Days drying	4 Days drying	5 Days drying	6 Days drying	7 Days drying
1	13.5171	13.5064	13.4956	13.4920	13.4835	13.4816	13.4839
2	14.0386	14.0374	14.0406	14.0385	14.0379	14.0369	14.0379
3	14.0134	14.0161	14.0169	14.0167	14.0163	14.0149	14.0149
4	14.4577	14.4338	14.4191	14.4130	14.3995	14.3947	14.3962
5	13.4427	13.4432	13.4428	13.4408	13.4396	13.4394	13.4407
6	14.1143	14.1119	14.1127	14.1113	14.1093	14.1079	14.1087
7	13.9136	13.8996	13.8894	13.8838	13.8739	13.8696	13.8673
8	14.0665	14.0654	14.0657	14.0641	14.0621	14.0616	14.0609
9	13.6653	13.6641	13.6657	13.6646	13.6624	13.6634	13.6616
10	14.0099	13.9180	13.9079	13.8932	13.8788	13.8757	13.8867
11	14.1711	14.1607	14.1364	14.1539	14.1471	14.1491	14.1558
12							
13	13.5036	13.4547	13.4487	13.4436	13.4321	13.4253	13.4385
14	13.6982	13.6211	13.6071	13.5975	13.5836	13.5828	13.5919
15	13.4548	13.5471	13.5415	13.5372	13.5302	13.5263	13.5259
16	13.8861	13.8417	13.8393	13.8178	13.8100	13.8081	13.8178
17	13.2018	13.1926	13.1566	13.1568	13.1365	13.1445	13.1537

APPENDIX B - CONTINUED

WATER IMMERSION TESTING OF MOISTURE BARRIERS - GROUP C

Sample No.	Weight of Sample and Watch Glass Before Soaking in Grams	Edge Length cm.	Edge Width cm.	Sample Perimeter in Ft.	Weight of Sample and Watch Glass After Soaking in Grams	Weight of Water Gained in Grams
1	13.8271	3.89	3.72	.501	14.2274	.4003
2	14.1562	3.79	3.80	.499	14.1922	.0360
3	14.2846	3.90	3.82	.506	14.3399	.0553
4	13.3126	3.87	3.85	.510	13.8548	.5422
5	13.7048	3.87	3.87	.508	13.7396	.0348
6	13.5258	3.82	3.87	.505	13.5187	.0449
7	13.5070	3.81	3.85	.504	13.8901	.3831
8	13.6052	3.85	3.89	.508	14.0099	.4047
9	13.7109	3.88	3.87	.509	13.7654	.0545
10	13.2875	3.79	3.87	.504	14.3155	1.0270
11	13.6564	3.91	3.80	.507	14.1396	.4832
12	13.4034	3.74	3.91	.503	14.1757	.7719
13	13.3729	3.89	3.89	.510	14.8495	1.1166
14	13.7048	3.87	3.85	.506	14.8155	1.1107
15	13.6416	3.93	3.89	.514	13.8587	.2171
16	13.5234	3.90	3.72	.501	14.2990	.7656
17	13.2034	3.86	3.87	.507	14.9360	1.7326

APPENDIX B - CONTINUED

DRYING DATA FOR WATER IMMERSSED MOISTURE BARRIERS - GROUP C

Weight of Samples and Watch Glass in Grams

Sample No.	1 Day drying	2 Days drying	3 Days drying	4 Days drying	5 Days drying	6 Days drying	7 Days drying
1	14.0418	14.0084	13.9854	13.9756	13.9656	13.9600	13.9491
2	14.1856	16.9782	14.1835	14.1835	14.1844	14.1837	14.1827
3	14.3322	14.1277	14.3285	14.3270	14.3290	14.3263	14.3260
4	13.6370	16.3782	13.5465	13.5188	13.5101	13.4931	13.4771
5	13.7318	16.5243	13.7292	13.6296	13.7316	13.7309	13.7303
6	13.5594	16.3541	13.5552	13.5567	13.5558	13.5555	13.5548
7	13.7471	13.7202	13.6999	13.6859	13.6720	13.6672	13.6531
8	13.7571	16.5275	13.7217	13.7097	13.7101	13.7082	13.6996
9	13.7576	13.7576	13.7569	13.7565	13.7553	13.7546	13.7537
10	13.6151	13.4963	13.4419	13.4282	13.4224	13.4125	13.3982
11	13.8702	16.6359	13.8682	13.8141	13.8121	13.8053	13.7907
12	13.6137	16.3722	13.5574	13.5451	13.5497	13.5223	13.5307
13	13.7136	16.3995	13.5484	13.5186	13.5184	13.5071	13.4954
14	13.9649	16.6798	13.8356	13.8268	13.8250	13.8175	13.8041
15	13.8298	16.6194	13.8183	13.8133	13.8085	13.8061	13.8010
16	13.7391	16.4633	13.6297	13.6128	13.6110	13.6017	13.5885
17	13.6010	16.2166	13.3547	13.3254	13.3295	13.3218	13.3093

APPENDIX B - CONTINUED

WATER IMMERSION TESTING OF MOISTURE BARRIERS - GROUP D

Sample No.	Weight of Sample and Watch Glass Before Soaking in Grams	Edge Length cm.	Edge Width cm.	Sample Perimeter in Ft.	Weight of Sample and Watch Glass After Soaking in Grams	Weight of Water Gained in Grams
1	14.0761	3.63	3.87	.491	15.3262	1.2501
2	13.0868	3.89	3.67	.496	13.1665	.0779
3	13.4250	3.72	3.91	.500	13.4959	.0709
4	13.3617	3.82	3.90	.506	14.1474	.7859
5	13.9165	3.72	3.90	.500	13.9871	.0706
6	13.7094	3.88	3.88	.509	13.7434	.0340
7	13.4051	3.88	3.90	.510	15.1173	1.7122
8	13.6692	3.88	3.88	.509	13.7682	.0980
9	13.6143	3.88	3.91	.510	14.4077	.7934
10	13.2634	3.87	3.74	.499	14.9275	1.6641
11	13.4462	3.91	3.87	.510	14.7744	1.3282
12	13.2155	3.68	3.96	.500	14.7123	1.4968
13	14.2107	3.91	3.91	.512	15.6667	1.4566
14	13.5745	3.87	3.81	.503	15.0775	1.5430
15	13.5674	3.88	3.89	.510	14.0745	.5071
16	13.4686	3.82	3.90	.506	15.1706	1.7020
17	12.9843	3.86	3.78	.500	15.0759	2.1916

APPENDIX B - CONTINUED

DRYING DATA FOR WATER IMMERSSED MOISTURE BARRIERS - GROUP D

Weight of Samples and Watch Glass in Grams

Sample No.	1 Day drying	2 Days drying	3 Days drying	4 Days drying	5 Days drying	6 Days drying	7 Days drying
1	14.8053	14.6097	14.4787	14.3968	14.3764	14.3359	14.2882
2	13.1575	13.1518	13.1488	13.1465	13.1448	13.1417	13.1393
3	13.4917	13.4844	13.4837	13.4825	13.4813	13.4805	13.4803
4	13.8782	13.7748	13.6795	13.6471	13.6337	13.6028	13.5852
5	13.9816	13.9792	13.9791	13.9780	13.9769	13.9759	13.9742
6	13.7391	13.7391	13.7394	13.7419	13.7413	13.7415	13.7419
7	14.3709	14.1387	13.9214	13.7943	13.7554	13.6984	13.6609
8	13.7615	13.7594	13.7578	13.7579	13.7559	13.7544	13.7528
9	14.3144	14.2704	14.2265	14.1588	14.1632	14.1336	14.1082
10	13.8868	13.2631	13.4916	13.4496	13.4387	13.4160	13.4102
11	14.1475	13.9151	13.7649	13.7290	13.7229	13.6878	13.6669
12	13.9397	13.6813	13.5052	13.4571	13.4563	13.4246	13.4168
13	14.8527	14.6406	14.5112	14.4836	14.4808	14.4366	14.4269
14	13.9452	13.7778	13.7077	13.7020	13.6989	13.6699	13.6634
15	13.9771	13.9389	13.8951	13.8671	13.8554	13.8344	13.8212
16	13.9699	13.7385	13.6087	13.5926	13.5907	13.5591	13.5561
17	13.5606	13.2867	13.1391	13.1339	13.1367	13.1108	13.1118

APPENDIX B - CONTINUED

WATER IMMERSION TESTING OF MOISTURE BARRIERS - GROUP E

Sample No.	Weight of Sample and Watch Glass Before Soaking in Grams	Edge Length cm.	Edge Width cm.	Sample Perimeter in Ft.	Weight of Sample and Watch Glass After Soaking in Grams	Weight of Water Gained in Grams
1	12.9855	3.86	3.91	.510	14.8849	1.8994
2	13.3118	3.91	3.85	.510	13.8459	.5341
3	13.4020	3.92	3.87	.511	13.6487	.2467
4	13.2788	3.85	3.91	.510	15.0394	1.7606
5	13.1699	3.88	3.93	.513	13.6047	.4348
6	13.7572	3.88	3.92	.512	13.8259	.0687
7	14.1323	3.82	3.91	.506	15.9553	1.8230
8	13.7031	3.89	3.89	.510	13.9996	.2965
9	13.5861	3.85	3.93	.510	13.6392	.0531
10	13.0216	3.91	3.89	.512	15.2830	2.2614
11	13.9291	3.78	3.76	.494	15.7427	1.8136
12	13.2666	3.89	3.87	.510	15.4083	2.1417
13	13.2413	3.82	3.91	.506	15.3526	2.1113
14	13.4512	3.87	3.86	.506	15.6544	2.2032
15	14.2675	3.83	3.80	.500	15.8087	1.5412
16	14.1796	3.78	3.77	.495	16.6492	2.4696
17	14.2105	3.76	3.75	.494	17.4107	3.2002

APPENDIX B - CONTINUED

DRYING DATA FOR WATER IMMERSSED MOISTURE BARRIERS - GROUP E

Weight of Samples and Watch Glass in Grams

Sample No.	1 Day drying	2 Days drying	3 Days drying	4 Days drying	5 Days drying	6 Days drying	7 Days drying
1	13.7759	13.5934	13.4233	13.3158	13.2745	13.2486	13.2314
2	13.7751	13.7145	13.6753	13.6422	13.6237	13.6061	13.5938
3	13.6302	13.6250	13.6171	13.6105	13.6053	13.6014	13.5976
4	14.2986	14.1153	13.9396	13.8080	13.7386	13.6825	13.6456
5	13.6095	13.5992	13.5888	13.5804	13.5741	13.5685	13.5643
6	13.8241	13.8243	13.8244	13.8224	13.8228	13.8288	13.8235
7	15.3395	15.2034	15.0399	14.8956	14.8135	14.7464	14.6946
8	13.9727	13.9682	13.9571	13.9505	13.9434	13.9384	13.9339
9	13.6326	13.6329	13.6314	13.6316	13.6312	13.6312	13.6312
10	13.8832	13.5829	13.3695	13.2577	13.2328	13.2215	13.2106
11	14.8091	14.6094	14.4646	14.3575	14.2359	14.3090	14.2911
12	14.1287	13.9265	13.7195	13.5911	13.5618	13.5396	13.5246
13	14.0768	13.8554	13.6431	13.5329	13.5021	13.4883	13.4786
14	14.2965	13.9875	13.7665	13.6680	13.6472	13.6468	13.6395
15	15.3599	15.2351	15.0856	14.9815	14.9201	14.8586	14.8212
16	14.8704	14.6043	14.4658	14.3668	14.3506	14.3495	14.3412
17	15.3237	14.9219	14.5714	14.4413	14.4208	14.4095	14.4073

APPENDIX B - CONTINUED

VAPOR RESISTANCE TESTING OF MOISTURE BARRIERS

Sample No.	Weight of Sample Before Exposure in Grams	Edge Length in cm.	Edge Width in cm.	Sample Perimeter in feet
1	5.1390	3.71	3.73	.468
2	5.3652	3.94	3.91	.512
3	5.6586	3.71	3.73	.488
4	5.0782	3.72	3.69	.486
5	6.3512	3.90	3.87	.510
6	5.4869	3.91	3.91	.514
7	5.7546	3.79	3.73	.494
8	5.3250	3.72	3.79	.493
9	5.1308	3.73	3.81	.495
10	5.2449	3.91	3.92	.515
11	5.0975	3.71	3.75	.491
12	5.5079	3.71	3.72	.487
13	5.0618	3.72	3.73	.489

APPENDIX B - CONTINUED

VAPOR RESISTANCE TESTING OF MOISTURE BARRIERS

Weight of Samples Each Day During Testing in Grams

Sample No.	1 Day	2 Days	3 Days	4 Days	5 Days	6 Days	8 Days
1	5.6535	5.1672	5.1780	5.1874	5.1958	5.2075	5.2291
2	5.3828	5.1963	5.4043	5.4163	5.4252	5.4343	5.4599
3	5.6682	5.6800	5.6895	5.6962	5.7023	5.7121	5.7291
4	5.0969	5.1166	5.1317	5.1429	5.1547	5.1711	5.1983
5	6.3814	6.4151	6.4314	6.4479	6.4665	6.4880	6.5253
6	5.4706	5.4946	5.5125	5.5297	5.5470	5.5720	5.6090
7	5.8729	5.8919	5.9043	5.9141	5.9249	5.9408	5.9650
8	5.3359	5.3462	5.3560	5.3636	5.3709	5.3827	5.4005
9	5.5416	5.5373	5.6938	5.7430	5.7812	5.8100	5.8599
10	5.4598	5.5719	5.6209	5.6660	5.6850	5.7255	5.7553
11	5.1075	5.1191	5.1289	5.1366	5.1445	5.1554	5.1751
12	5.5813	5.5194	5.6653	5.6906	5.7378	5.7071	5.8679
13	5.3285	5.4097	5.4448	5.4864	5.4896	5.5402	-

APPENDIX B - CONTINUED

WATER IMMERSION TESTING OF MOISTURE BARRIERS

Sample No.	Weight of Sample and Watch Glass Before Exposure in Grams	Edge Length in cm.	Edge Width in cm.	Sample Perimeter in Ft.	Weight of Sample and Watch Glass After Exposure in Grams	Weight of Water Gained in Grams
Group A						
1	15.1358	3.94	3.87	.513	15.3428	.2070
2	13.9997	3.90	3.91	.513	14.2967	.297
3	14.2613	3.74	3.78	.494	14.6788	.4175
4	13.9078	3.92	3.98	.519	14.7708	.8630
5	14.9148	3.91	3.98	.517	16.7963	1.8815
Group B						
1	15.8891	3.91	4.00	.520	17.6867	1.7976
2	14.9697	3.92	3.89	.513	15.5024	.5327
3	13.5181	3.78	3.73	.493	13.8866	.3685
4	14.4419	3.81	3.72	.495	15.6112	1.1693
5	13.6891	3.72	3.79	.493	15.7734	2.0843
Group C						
1	13.5774	3.90	3.91	.513	16.0467	2.4693
2	13.5655	3.71	3.70	.487	16.4947	2.9175
3	13.3473	3.65	3.81	.490	14.0097	.6624
4	15.1292	3.94	3.94	.516	16.8582	1.7290
5	15.0760	3.98	3.88	.524	16.5361	1.4601

A - 3 days soaking

B - 5 days soaking

C - 7 days soaking

APPENDIX B - CONTINUED

EXPERIMENTAL DATA FOR EVALUATION OF VAPOR BARRIERS

Weight of Samples and Weighing Bottles in Grams

Sample No.	Sample Diameter in cm.	0 Days	1 Day	2 Days	3 Days	4 Days
1	4.25	72.9868	73.0197	73.0535	73.0786	73.1063
2	4.25	72.3177	72.3503	72.3859	72.4103	72.4321
3	4.25	72.2788	72.3303	72.3692	72.4078	72.4413
4	4.25	74.8479	74.8854	74.9237	74.9543	75.0105
5	4.25	76.8975	76.9417	76.9885	77.0278	77.0634
6	4.25	74.2143	74.2543	74.2948	74.3289	74.3655
7	4.25	72.7872	72.8292	72.8791	72.9211	72.9631
8	4.25	71.2093	71.2499	71.2779	71.3065	71.3360

APPENDIX B - CONTINUED

Weight of Samples and Weighing Bottles in Grams

Sample No.	6 Days	7 Days	9 Days	13 Days	14 Days	15 Days	16 Days
1	73.1452	73.1725	73.2237	73.2765	73.3113	73.3318	
2	72.4586	72.4772	72.5104	72.5298	72.5327	72.5342	
3	72.4818	72.5151	72.5663	72.6221	72.6342	72.6444	
4	75.0752	75.1134	75.1936	75.3304	75.3591	75.3913	
5	77.1141	77.1426	77.2048	77.2973	77.3161	77.3349	
6	74.4093	74.4373	74.4884	74.5491	74.5577	74.5663	74.5669
7	73.0219	73.0508	73.1044	73.1456	73.1514	73.1554	73.1556
8	71.3725	73.3998	71.4478	71.5283	71.5465	71.5657	

VITA

James Van Dyck Fear was born November 7, 1925, in Morgantown, West Virginia, the son of Olan De Witt Fear, Sr. and Marja Brown (Steadman) Fear. He received his primary and secondary education from the Morgantown Public Schools and Morgantown High School, Morgantown, West Virginia.

Mr. Fear entered West Virginia University in September, 1942, and in July, 1943, the University of Louisville, from which he received the degree Bachelor of Chemical Engineering in July, 1945.

He served three years in the Navy, received his commission as Ensign U. S. N. R. from the U. S. N. R. Midshipman School, New York, N.Y., and served aboard the U. S. S. Adria AF 30.

Upon release from the Navy, Mr. Fear received a fellowship with the University of Louisville Institute of Industrial Research. He obtained the degree of Master of Chemical Engineering in September, 1947.