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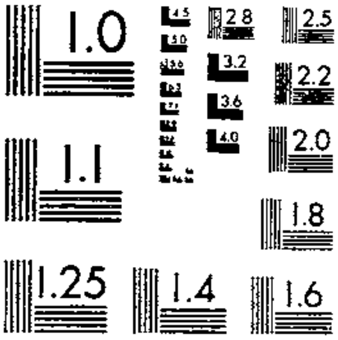
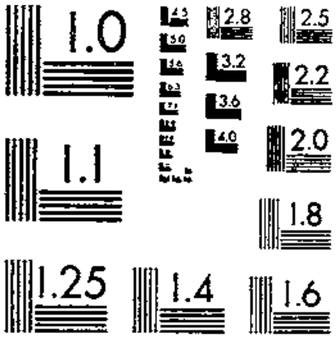


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

BUILDING DECAY
Associated With
RAIN SEEPAGE

By Arthur F. Verrall, *Principal Pathologist, Southern Forest Experiment Station, New Orleans, La.*
(Now Professor of Forestry, Stephen F. Austin State College
Nacogdoches, Texas)

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INTRODUCTION

Wood is a versatile material that has given long service on the exteriors of buildings throughout the United States. However, the trend is clearly toward the use of nonwood exteriors. Eighty-eight percent of the houses inspected by the Federal Housing Administration in 1962 were of wood frame construction, but only 32 percent had siding of lumber, plywood, shakes, or shingles (*16*).[1] Of course, many other houses, both frame and nonframe, had some exterior wood parts such as fascia, trim, and sash.

The trend to nonwood exteriors is partly because wood is difficult to maintain. This trouble has been accentuated by changes in designs and construction details which have increased moisture-induced problems such as stain, decay, and some forms of paint deterioration.

Most moisture problems in exterior woodwork result from condensation or rain seepage. Condensation occurs in cold weather (*1*, *24*) or in refrigerated buildings (*30*). In cold weather the problem can be alleviated by installing vapor barriers; in refrigerated buildings exterior woodwork is seldom affected. Neither of these types of condensation is considered here.

Rain seepage is a more widespread and less understood source of moisture. It may deleteriously affect any exterior woodwork. Most southern pine lumber and increasing amounts of other species are sapwood, and seepage may lead to fungus stain and decay. Such deterioration is less common with moderately decay-resistant woods such as heartwood of Douglas-fir and larch, and seldom occurs with highly resistant woods such as all-heart redwood, western redcedar, and cypress. However, seepage may result in decay of underlying sheathing and framing or such nonfungus problems as warping of the exterior woodwork. Thus, control of rain seepage is necessary regardless of the materials exposed on the surface of the building.

This paper presents information on rain seepage and its control. The studies were partly financed by the Housing and Home Finance Agency (under title III of the Housing Act of 1948, as amended); by the Pitman-Dunn Laboratories: Frankford Arsenal, Department of the Army; and by the Bureau of Yards and Docks, Department of the Navy. The data were obtained from extensive surveys of buildings and from experimental buildings or simulated building structures. Most of the data are for southern pine sapwood exposed in the Gulf States, where rain seepage hazard is high. This wood has low decay resistance (*2*, *7*) and only fairly fulfills the main requirements for exterior applications: Good painting and weathering characteristics, ease of working, and resistance to warp (*22*). These characteristics of southern pine make it suitable for rapidly determining the effects of rain seepage. Also, it is the wood most commonly used for exterior woodwork in the Southern States.

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[1] Italic numbers in parentheses refer to Literature Cited, p. 56.

SYMPTOMS OF RAIN SEEPAGE

Symptoms of rain seepage in exterior woodwork are most pronounced where water enters—at joints or splits. When much rain penetrates, it wets wood at some distance from the point of entry. Water which has entered at a joint may vaporize during the day and condense over wide surfaces during the night. Nevertheless, seepage is invariably more severe at joints. Any of the symptoms described below or in figure 1 show that leakage is occurring.

Rust stains around nailheads.—Rust developing from wet wood starts on the shank at the inner face of the siding and spreads outward. When it is visible on the surface, the shank is well corroded. Some nailhead rusting may develop when plain steel nails are used and when paints, including primer, contain zinc. When such rusting first occurs, the inner nail shank is bright. If galvanized nails are used, wetting of the wood can occur without rusting of nails. Therefore, absence of rust does not indicate lack of serious wetting.

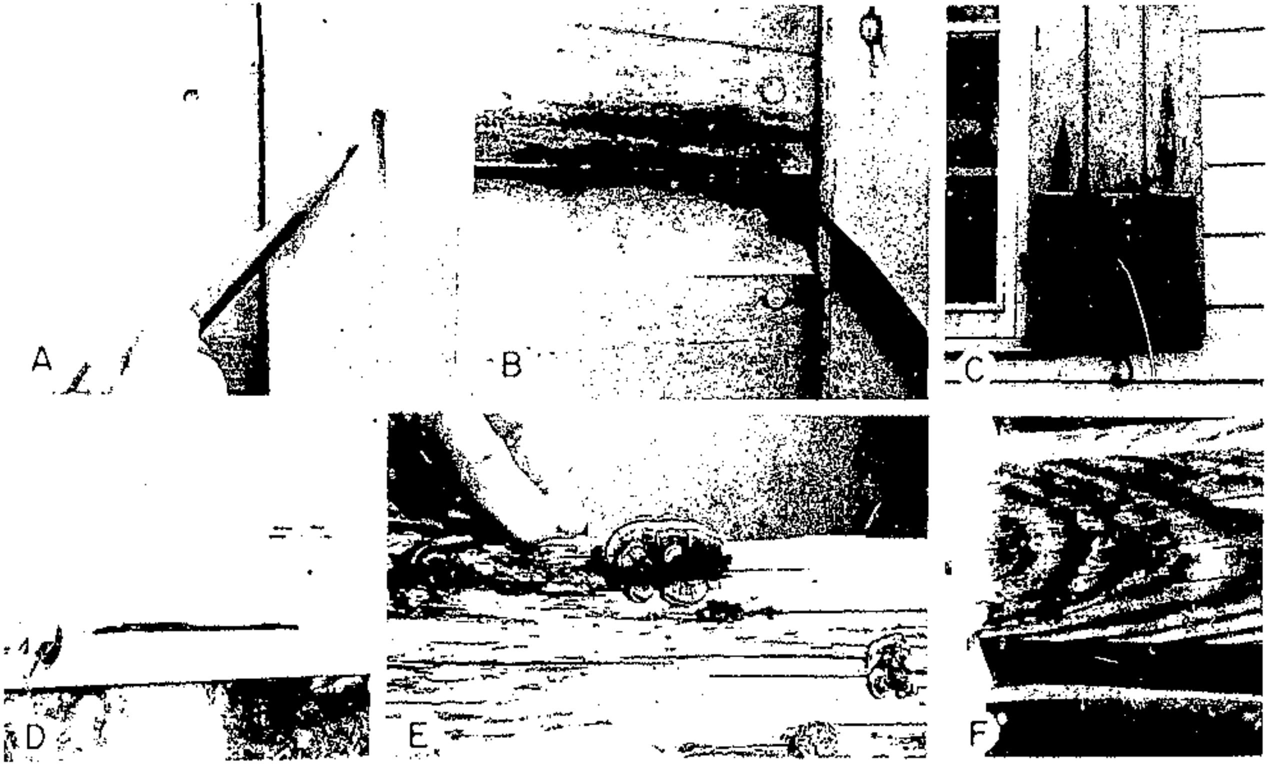
Paint failures.—Paint blistering and peeling is sometimes due to a high moisture content in wood. Paint failure that appears first at joints and is most pronounced there is usually due to rain seepage. General peeling can result from severe rain seepage, but frequently is due to other causes such as incompatible paints, primers containing zinc, repainting with oil paint over old films that are wet, or condensation. Southern pine and Douglas-fir, particularly if flat sawn, have more paint failure than the other woods commonly used on exteriors. Factors other than rain seepage affect paint performance, but woods that hold paint poorly have paint failures with much less rain seepage than that needed to promote decay.

Paint discoloration.—Gray or black discolorations of paint films, when limited to or most pronounced at joint and nail areas, are usually due to stain fungi growing into the paint from moist wood. Extensive and severe surface molding may occur without rain seepage. Much of it is associated with minute condensation films on the paint surface resulting from the cooling effects of heat radiation at night. Such surface molding has been particularly severe on the undersurfaces of unboxed eaves and on the roofs of carports thin enough to cool the undersurface. Much surface molding can be washed off, but sometimes it penetrates the paint sufficiently to resemble the stains associated with rain seepage; mold usually is more uniform over large areas than is stain.

Buckling.—Most commonly seen on siding, buckling usually indicates too much moisture. Alternate swelling and shrinkage also may result in splits in siding through which large volumes of water can enter.

Nail pulling.—Swelling and shrinkage caused by wetting and drying more severe than that occurring with normal fluctuations in atmospheric humidity will cause nails to back out. Nail pulling is most severe on walls that permit appreciable wetting but rapid drying between showers.

Fungus fruiting bodies.—Conks, brackets, or mushrooms indicate that wetting has continued sufficiently long for extensive internal decay, even though the surface of the lumber looks sound. Although fruiting bodies show that decay is present, extensive decay may occur without fruiting and be first noticed by softening of the wood or excessive shrinkage during dry weather.



[illegible]

FIGURE 1.—Rain seepage may be indicated by: *A*, Nail rusting; *B*, fungus stain coming through paint; *C*, paint peeling, particularly at joints; *D*, actual decay; *E*, fruiting bodies of decay fungi; or *F*, warping of siding and nail pulling.

FUNGI CAUSING DECAY IN EXTERIOR WOODWORK

The exterior woodwork of a building tends to be a high-temperature, xerophytic habitat.

The surface of siding exposed to the sun commonly reaches 110–139° F. in all parts of the United States (*13*). Temperatures back of exposed siding commonly reach 97–130° F. Preliminary observations at Gulfport, Miss., disclosed that the surface of roof sheathing exposed on the underside of unboxed eaves reaches 123° F. and may remain over 100° F. for 6 hours or more.

As shown later, the moisture content of wood siding will remain below 20 percent for long periods even in areas of high rainfall and when inadequately protected with roof overhang.

These factors (temperature and drying) probably influence the species of fungi becoming established in wood exteriors. Species that will grow at high temperatures and can withstand moisture contents too low for growth in the early stages following spore germination are those most likely to decay exterior woodwork. Of course, the temperature factor is lessened on the shaded portions of buildings. If improperly handled before it is put into a building, lumber may become infected by fungus species that would have difficulty in becoming established by spore inoculations after the building is complete.

Only a few reports of fungi causing decay of wood in buildings (*8, 11, 14, 20*) indicate the parts of buildings attacked.

Lenzites trabea Pers. ex. Fr. was the fungus that Hubert (*14*) most commonly isolated from decayed sash and door samples from various parts of the United States. Other isolates included *L. saepiaria* (Wulf. ex. Fr.) Fr., *Trametes serialis* Fr., and *Poria vaillantii* (Fr.) Cke.

A summary of the many decayed wood samples cultured or examined at the Forest Products Laboratory, Madison, Wis., and the Forest Disease Laboratory, Laurel, Md. (*11*), supplemented by isolations and numerous observations during the present studies, showed that at least 20 fungi are associated with decay of exterior woodwork. Those found more than once on various items were:

Lenzites saepiaria—exterior steps
L. saepiaria, L. trabea—porch trim and flooring
L. saepiaria, L. trabea—porch and step rails
L. saepiaria, L. trabea—window and door items
L. saepiaria, L. trabea, Poria spp.—siding

For all exterior woodwork, the frequency of occurrence for species found more than once was as follows: *Lenzites trabea*, 37; *L. saepiaria*, 15; *Poria* spp., 4; *Coniophora puteana* (Schum. ex. Fr.) Karst, 2; *Daedalea berkeleyi* Sacc., 2; and *Schizophyllum commune* Fr., 2.

Four of these; i.e., *Lenzites trabea, L. saepiaria, Schizophyllum commune,* and *Daedalea berkeleyi*, are high-temperature organisms which will grow at 42–46° C. (*15*). At least three (*L. trabea, L. saepiaria,* and *S. commune*) are xerophytic and can survive for long periods as mycelia in air-dry wood (*12, 18*) or as spores in a dry condition (*21*).

The ubiquitous mold, *Trichoderma viride* Pers. ex. Fr., commonly is the first fungus observed on rain-wetted wood in the Southeastern States. Competition from molds possibly is an additional factor restricting the number of decayers on exterior woodwork. *Trichoderma* frequently was isolated from the context of actively growing, fresh, young fruiting bodies of *Lenzites saepiaria*. When *L. saepiaria*, *L. trabea*, or *Daedalea berkeleyi* were grown on malt agar with *Trichoderma*, the mold and decayer either grew together without obvious antagonism or the decayer overran and obliterated the mold.

The effect of *Trichoderma viride* (2 isolates from Mississippi) on the rate of decay by *Lenzites saepiaria* (35 isolates from six States and Canada), *L. trabea* (2 isolates from Missouri and Wisconsin), and *Daedalea berkeleyi* (4 isolates from Florida) was studied with soil block tests (*10*).

French square jars with thin pine wafers on 1 inch of wet soil were inoculated with either decayers or *Trichoderma*. When the fungi were growing vigorously, 0.75-inch cubes of kiln-dried southern pine sapwood were surface-sterilized by dipping in boiling water and then placed on the fungus mats. After 2 weeks' incubation, some of the cubes were removed, some switched between jars with the mold and decayer, and the rest left undisturbed; thus, the four treatment categories were:

Two weeks incubation on the test fungus.
Two weeks on the mold plus remainder (4 to 6 weeks) on a decayer.
Two weeks on a decayer plus remainder on the mold.
Full test period on the original inoculant.

Three to five matched cubes were used for each category. Original and decayed weights were determined after drying at 100° C.

The three decay fungi tested undoubtedly will decay pine sapwood in the presence of *Trichoderma viride* (table 1). In seven of nine comparisons with mixed cultures the greatest decay occurred when the decayer was introduced first, and in eight of nine cases the decay exceeded that in pure culture. When the mold was introduced first, the rate averaged only slightly less than in pure culture.

None of the decay fungi commonly isolated from exterior woodwork are tolerant of copper or chlorinated phenols (*9, 33, 34*), the preservatives commonly used on wood to be painted.

SURVEYS OF BUILDINGS

During the past 25 years many hundreds of buildings were examined for evidence of rain seepage and decay. Most of the buildings were in the Southern and Eastern United States, Panama, and the Pacific islands. Some observations made by T. C. Scheffer (Forest Products Laboratory) in the Northern and Western United States are also included. The first surveys were specifically of siding, but other exterior woodwork was observed (*26*). In later surveys all wood parts of buildings were sampled. Much of the evidence was secured at military installations and at large public and private housing developments where many buildings of similar construction, design, and age could be examined.

TABLE 1.—*Effect of* Trichoderma viride *on the decay rate of kiln-dried southern pine sapwood* [1]

[Percent]

Incubation time (weeks)	Ovendry weight loss								
	Lenzites saep.	*L. saep.*	*L. saep.*	*L. trab.*	*Daedalea berk.*	*L. saep.*	*L. trab.*	*D. berk.*	*L. saep.*
Decayer only: [2]									
2	......	0.5	2.0	1.5	1.8	2.5	6.0	2.0	2.0
6	7.0	8.1	......	......	......	22.3	17.5	13.3	14.0
8	......	......	20.3	19.5	20.0	......	......	......	......
Mold, 2; then decayer, 6	4.6	5.4	16.7	16.0	15.3	18.5	19.0	17.0	18.0
Decayer, 2; then mold, 4	9.5	11.3	......	......	......	19.5	28.5	14.7	16.5
Decayer, 2; then mold, 6	......	......	29.0	25.5	23.7	......	......	......	......
Number of isolates of decay fungus	1	30	3	2	3	4	2	3	2
Study number [1]	1	2	3	3	3	4	4	4	5

[1] Comparison between columns should be made mainly within a single study.

[2] Samples subjected for 6 weeks to *Trichoderma* only were essentially undecayed.

These surveys were valuable in identifying the parts of buildings most subject to rain seepage. They did not establish the amount of decay because there was no way of determining whether repairs had been made to replace parts previously decayed.

The siding surveys (table 2) showed that serious decay may occur in the second or third year after construction. Early decay was usually associated with siding laid over sheathing, with siding abutted to trim, and with little roof overhang. As will be shown from experimental data, butt joints of siding to trim are most prone to leakage; lack of good roof overhang is the usual cause of woodwork exposure to rain seepage; and sheathing favors moisture accumulations during seepage.

Contractors, carpenters, and others present during construction of large housing projects were asked how the siding had been seasoned. Results were as follows:

Type of seasoning	Percent of locations with—	
	Serious decay (15 locations)	Essentially no decay (17 locations)
Kiln drying	0	29
Air drying	47	12
Unknown	53	59

TABLE 2.—*Condition of siding*[1] *on buildings in Southern and Eastern United States*

Location	Buildings	Age	Species	Type	Placement	Sheathing		Width of overhang		Gutters	Wood condition at construction[3]	Decay		Paint peeling[5]
						Paper[2]	Other	Gable	Eave			Amount[4]	Location of most decay	
	Number	*Years*						*In.*	*In.*					
Hialeah, Fla.	90	3.5	SY pine	119	To	Lam	DF plywood	2	8	No	AD-stained.	M–H	Gables	H
Miami, Fla.	112	3.5	do.	119	do.	do.	do.	2	8	No	do.	H	do.	M
Do.	206	3	Cypress	Bevel	do.	do.	Fiberboard	2	2	No	AD.	H	East, north, south.	M–H
Tampa, Fla.	30	3	SY pine	121	do.	F–15#	¾-inch pine	2	2	No	do.	M–H		H
Brunswick, Ga.	10	3	do.	105	do.	do.	do.					M		
Hogansville, Ga.	70	3.5	do.	119	do.	Lam	do.	3	4	No	AD-stained.	H	Gables	H
Fort Meade, Md.	2	8	do.	105	Under	Paper	do.	2	0	No		M	Eave sides	
Oak Ridge, Tenn.	30	4	do.	Bevel	To	F–15#	Fiberboard	2	8	Yes	AD-stained.	L–M	All sides	M
Brooklyn, Miss.	3	6–10	do.	105	do.	do.	¾-inch pine	2	5	Yes		L	South, west.	M
Do.	1	4	do.	105	do.	do.	do.	2	5	Yes		H	All sides	M
Do.	2	10	do.	105	do.	None	do	3	30	Yes		M	North gable.	O–M
Gulfport, Miss.	1	7	do.	105	do.	F–15#	None	6	6	Yes		H	South gable.	M
New Orleans, La.	10	7	do	105	To and under.[6]	Lam	¾-inch pine	2	10	No		M	Gables	M
Alexandria, La.	5	8	do.	Bevel	To	F–15#	do	18	18	No		M	Splash areas.	L
Kingsville, Tex.	100	2–3	do.	Drop V, cm.	do.	None[7].	Fiberboard	2	4	Yes	AD.	H	North, east	H
Miami, Fla.	40	4	Cypress	Bevel	do.	do.	do.	2	2	No	do.	+		M–H
Hogansville, Ga.	4	4	SY pine	105	do.	Lam	¾-inch pine	3	4	No	do.	+	Gables	
Sylacauga, Ga.	42	8	do.	105	Under	Paper	do	2	6	No	Kiln-dried.	0		M–H
North Charleston, S.C.	100+	10	SY pine	105	do.	F–15#		3	4	No		0		M–H
Fort Meade, Md.	Many	7	do.	105	do.	Paper	¾-inch pine		24	No		0		
Do.	do.	7	do.	105	do.	do.	do.	3	18	No		+		
Camp Shelby, Miss.	8	8–10	do.	Shiplap[8]	do.	None	None	2	24	No		+	Gables	L–H
Gulfport, Miss.	1	2	do.	105	Under	F–15#	do	5	2–10	No		+	2-inch overhang.	
Do.	1	10	do.	Bevel	To	do.	¾-inch pine	3	10	No	Kiln-dried.	+	Porch slab	
Jackson, Miss.	24	9–10	do.	105	Under	Lam	do.	3	36	No	Bright	+	Water table.	L
Do.	12	9–10	do.	105	do.	do.	do.	3	20	No		+	Gables	L

See footnotes at end of table.

TABLE 2.—*Condition of siding*[1] *on buildings in Southern and Eastern United States*—Continued

Location	Buildings	Age	Species	Type	Placement	Sheathing		Width of overhang		Gutters	Wood condition at construction [3]	Decay		Paint peeling [5]
						Paper [2]	Other	Gable	Eave			Amount [4]	Location of most decay	
	Number	*Years*						*In.*	*In.*					
Crossett, Ark.	2	16	SY pine	Clapboard	To	None	None	12	16	No	Kiln-dried	0		(Unpainted.)
Do.	100+	23–45	do.	Bevel–105	do.	do.	do.	15	15	No	do.	0		L
Do.	20	4	do.	do.	do.	do.	do.	2–3	7	Few	do.	+	Porch slab	H
Freeport, Tex.	59	7	do.	105	To and under.[6]	F–15#	do.		20	No		0		M–H
Houston, Tex.	30	3–4	do.	105	Under	None	do.	1	20	No		0		L–M
Lake Jackson, Tex.	101	7	do.	105	do.	F–15#	do.	20	12	No		+	Gables	L
Orange, Tex.	150	9	do.	105	do.			8	8	No		0		M

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[1] Siding was southern yellow pine sapwood or cypress with some sapwood. Drop siding is shown by standard pattern numbers. "To" indicates siding was abutted to trim; "under" means trim was placed over siding ends.

[2] "Lam." indicates laminated vapor-barrier paper, "F–15#" = 15-pound saturated felts; "paper" indicates it is present but of unkown type.

[3] AD and KD = air dried and kiln dried.

[4] 0 = none, + = trace, L = 2–4 boards, M = 5–10 boards, H = more than 10 boards.

[5] 0 = none, H = heavy, M = medium, L = light.

[6] Siding abutted to trim at corners (New Orleans) and windows (Freeport): At other parts trim is over siding ends.

[7] The fiberboard sheathing had a vapor-barrier surfacing.

[8] With joints overlapped to give a clapboard effect.

In no instance had seriously decayed siding definitely been kiln dried. In about half the locations the siding had been air dried, and in a fourth of the cases it was reported to have been stained at the time of attachment. Fungus infections increase the absorbency of wood (*32*), and wood with appreciable stain usually has incipient decay infections. Thus, stained wood is likely to wet more under a given exposure and also to have a decay fungus already present to start early decay. Studies have established that incipient infection in the bases of porch columns greatly increases the rate of decay (*32*). Experimental evidence will be presented to show that this applies to siding also. These findings do not indicate that the use of fungus-free siding will prevent decay, but they do suggest that lumber subject to rain seepage should be free of fungi at the time of construction.

Many buildings essentially free of decay had the same general design as those with decay. However, there were important differences: most buildings without decay had trim over the siding ends and had no sheathing. Also, at least some of the siding was kiln dried, and none was known to be stained when attached.

Where present, decay tended to be more prevalent at unprotected gable ends and on the sides facing most of the rains.

The data further show that paint peeling associated with rain seepage may be moderate to heavy where no decay occurs. This substantiates the often-heard report that wood siding is covered with asbestos and aluminum because of paint maintenance difficulties rather than decay.

Information from the survey and other observations make it possible to group the various items of exterior woodwork into two general hazard classes.

HIGH-HAZARD ITEMS

Porches and steps.—Exterior steps, fireladders, porches, stoops, and balconies have such a high seepage hazard that decay control must always be considered in their design. Included are all parts of steps, step rails, and newel posts. Porch flooring and framing are usually in this class, at least the outermost joists. Porch railings commonly decay. With columns the hazard is mostly at the base, where end grain is against the floor surface.

The roof edge.—Runoff may curl around the roof covering at the eave and wet fascia, molding, the edge of the sheathing, and rafter ends (fig. 2). Such wetting has been most severe with asphaltic coverings, either shingles or roll roofing. The latter is particularly dangerous when attached with exposed nails at the roof edge. Decay of these parts has been so extensive that the use of metal flashing at the roof edge is standard in areas of high rainfall and has become common elsewhere.

The horizontal joints in gravel stops commonly leak, allowing excessive waterflow over the fascia, or wall, depending on design (fig. 2). It is doubtful whether these joints can be effectively sealed on flat roofs for very long.

Rakeboards are less subject to seepage than are fascia. However, when rakeboard end at an eave return, seepage at that juncture may be heavy.

Clogged eave gutters and those too small to carry the roof runoff accentuate eave wetting. The water may flow over the back side or seep through holes for the fasteners. Likewise, leaky gutters are hazardous.

F-510269-72

FIGURE 2. Decay associated with roof runoff: *A*, Splash from sidewalk wetted sheathing and plate at the base of the wall (asbestos siding broken for inspection of sill); *B*, leaks in the horizontal joints of gravel stops are common; *C*, water from the roof runs down wall and wets window trim; *D*, sheathing decayed at roof edge when unprotected by a metal flashing.

Exposed structural members (fig. 3). Arches extending beyond the roof edge, rafters in reveals, exposed beam ends, bases of columns exposed to rainwetting, outer rafters used as rakeboards, or any other structural members exposed to rainwetting are hazardous. Douglas-fir arches exposed to the weather in New Orleans have required replacement within 4 years.

Decorative features. Planters, shutters, balustrades, and similar items usually are exposed to severe decay hazard (fig. 4).

Frames for screens. Seepage may be severe in door and window screens, particularly at the joints of styles and bottom rails.

Water tables. These are hazardous and should be avoided where rainfall is high.

F-510273-76

FIGURE [illegible].—Structural members protruding beyond the roof or otherwise exposed to rain seepage should be of decay-resistant material: *A*, Columns with high seepage hazard at the base; *B*, rafters exposed at ends; *C*, church arches exposed to rainwetting; *D*, roof beams projecting.

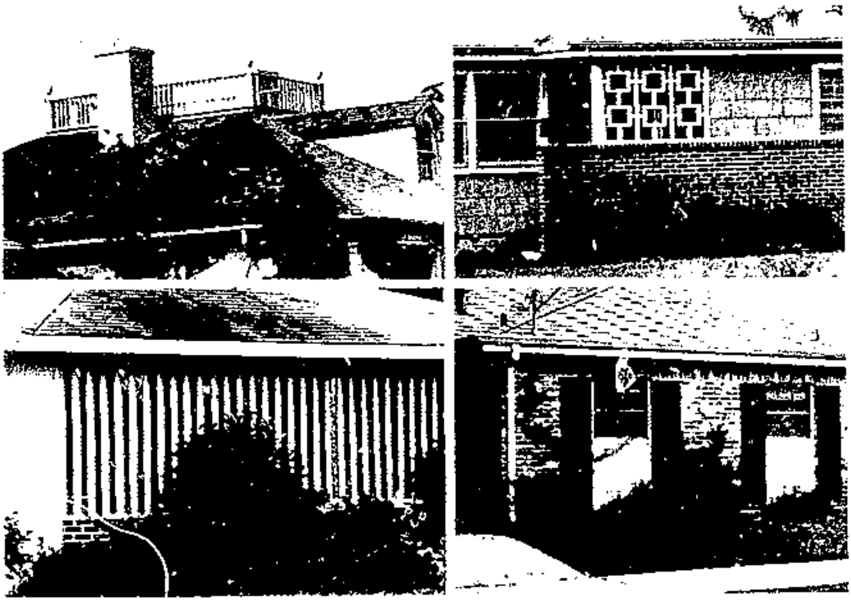

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FIGURE 3.—Much decorative woodwork such as balustrades, grills, and shutters is exposed to excessive rain seepage.

MODERATE- AND LOW-HAZARD ITEMS

Trim.—Most seepage problems have been at the base of window and door trim abutting sills where water can seep into the end grain. Decay also is frequent in trim around porch column bases and on the boxing for front beams of porch roofs with the soffit carried beyond the fascia instead of the fascia extending down and covering the outside edge of the soffit.

Sash and doors.—Outswinging casement windows and doors, however, have a high hazard when left open.

Siding.—The hazard to siding varies greatly with wall design. Hazard is increased by roof designs that permit concentrated runoff to strike the wall (fig. 2*C*) and by the absence of eave gutters over a walk or other hard surface adjacent to the wall. The splash from an unguttered roof will wet wood or other surfaces at least 2 feet up (fig. 2*A*). Siding abutted to a roof, as in dormers, has an above-normal seepage rate.

This classification primarily indicates how much attention should be given to fungus and moisture control in various exterior woodwork items. However, design and climate also affect the hazard in individual buildings.

At military bases buildings of the same general construction, age, and maintenance, but with different roof overhangs, often could be examined. The protection afforded woodwork varies with width of eave, and the amount of overhang needed for the same degree of protection against decay and paint peeling varies with locality (table 3).

The correlation between annual rainfall and amount of overhang needed is not good. For example, Corpus Christi, Tex., with an annual rainfall of about 25 inches, has as high a decay hazard as New Orleans, where rainfall averages 60 inches. However, much of the Corpus Christi rain is wind driven. Differences among the Pacific and Canal Zone bases probably are similarly explainable.

At the locations listed in table 2, the evidence is that eave gutters have only a minor effect in reducing rain seepage.

TABLE 3.—*Amount of roof overhang needed on 1-story building to protect exterior woodwork (exclusive of porches, steps, and roof edge)*

[Inches]

Location	Average annual rainfall	Overhang to give—		
		Good protection	Fair protection	Poor protection
Guam	91	60	36	24—
Oahu	17–25	36	...	...
Do	100+	36	24	12—
Panama Canal Zone:				
Pacific	71	30	18	12—
Atlantic	132	48	24	18—
Key West, Fla	38	30	18	12—
Green Cove Springs, Fla	51	30	18	12—
Orange, Tex	51	30	18	12—
Gulfport, Miss	59	30	18	12—
District of Columbia	42	30	...	...
Bainbridge, Md	44	24	...	...
Newport, R.I	40	...	12	4
Great Lakes, Ill	32	18	...	...
San Francisco, Calif., area	20	10	...	...
Port Hueneme, Calif	10	10	...	...

The effect of amount of roof overhang on decay and paint failure of window trim was determined at the naval base in Gulfport, Miss. All buildings were the same age and similarly constructed except for the amount of roof overhang. Siding was asbestos cement. There were no eave gutters.

Overhang	Windows	Percent of windows with—	
		Decay	Paint failure
Inches	*Number*		
2 to 4	60	23	83
18	40	15	58
22	176	5	53
72	72	0	0

In the Gulf States, several projects with severe siding decay were reexamined after 15 to 20 years. Most of the houses had been covered with asbestos-cement shingles (fig. 5), usually applied over the defective wood siding. No further trouble was reported or could be seen in the covered buildings. Apparently, such covering corrects a severe rain seepage problem. In the few cases seen, steel or aluminum siding has been effective. Probably

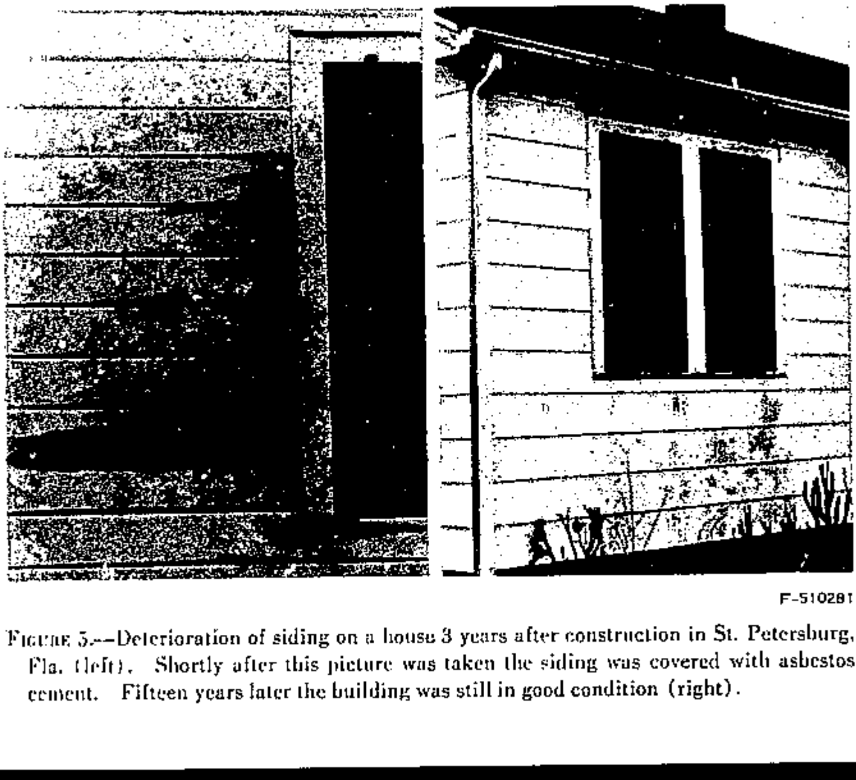

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FIGURE 5.—Deterioration of siding on a house 3 years after construction in St. Petersburg, Fla. (left). Shortly after this picture was taken the siding was covered with asbestos cement. Fifteen years later the building was still in good condition (right).

shingles of a naturally decay-resistant wood also would be effective. If winter condensation is associated with a wall moisture problem, covering old wood siding will decrease the vapor permeability on the cold side and thus aggravate the trouble, but this danger can be removed by putting an effective vapor seal on the warm side of the wall. In contrast, the decreased permeability of covered siding would lessen the chances of condensation with summer air conditioning.

EXPERIMENTAL EVIDENCE

Several studies were conducted in New Orleans, La., and Gulfport, Miss., to get information on the effect of design, paint, and water-repellent preservatives on the rate of decay. Steps and simulated porch and step rails were used for moderate- to high-hazard items and siding for low- to moderate-hazard items.

STEPS AND RAILS

The wood for these studies was kiln-dried southern pine sapwood. Where possible, it was matched among treatments. To minimize variability each test category was assigned the same number of pieces from each board. The size of the pieces needed for steps precluded matching of all categories. Instead, the untreated and treated units were matched separately from similar-appearing lumber from a single batch obtained at a sawmill.

Except as otherwise stated, the test units listed as painted were given two coats of a lead-zinc-titanium oil paint or, with the step test, a deck enamel. The samples were repainted at 2- to 4-year intervals.

Decay was rated periodically from external evidence, on the following scale:

0	None obvious.
20	Discolorations suggesting that decay has started.
40	Obvious decay but limited to a small area.
60	Decay general but unit still serviceable.
80	Advanced decay—wood would be replaced prior to normal repainting.
100	Complete failure.

Severe decay occasionally occurred without external evidence, particularly in painted units. Most reliance was placed on percentage of failures; i.e., proportion of units with a decay rating of at least 80.

With step rail and similar units made of 2- by 4-inch lumber, samples were removed after about 3 years and 6 or 7 years of exposure, and each piece was split longitudinally to expose a 2-inch-wide surface through the center. The decay ratings made on the exposed surfaces were based on the class of decay and the proportion of the area occupied by each class. Decay classes were assigned the following values:

0	Decay not apparent.
2	Decay definite but relatively light or spotty.
5	Decay general but the wood still serviceable.
10	Wood essentially destroyed.

The amount of decay in each class was estimated in area units—each unit being 10 percent of the freshly exposed surface. To obtain the decay rating, the numerical value assigned the decay class was multiplied by the number of area units affected, and the total points obtained were added.

Decay class		*Area units*		*Points*
0	×	4	=	0
2	×	2	=	4
5	×	4	=	20
		Rating	=	24

In this example, the rating is the total points, or 24. The maximum possible rating is 100 (10×10), and a unit was considered to have failed if the decay rating of either post or rail component was 80 or more.

Percentage of failure was plotted over length of exposure, expressed in years. The exposure time at which the curve crossed the 60-percent failure line was considered the average service life. Previous studies (*32*) had shown this to be a reasonable estimate of average service life.

In some studies, part of the material was treated with preservatives. Treating solutions were 5-percent pentachlorophenol in mineral spirits (formula WRP–7 minus paraffin wax (*6*)) or a water-repellent preservative (formula WRP–7 (*6*) or a commercial preparation with approximately the same toxic and water-repellent properties.)

Steps.—Because their decay rate is so high, most exterior steps are now constructed of nonwood materials. A study was designed to determine how much the hazard could be reduced by designs minimizing seepage and by a water-repellent treatment.

The steps were fully exposed to rain seepage. The carriages rested on concrete blocks 6 inches high.

Variations in designs included conventional notched carriages, unnotched carriages with side cleats to hold the treads, solid and split treads, and with and without risers (fig. 6).

Three points were clearly demonstrated (table 4). Designs that minimize seepage reduced decay, but not by a practical margin. Painting did not increase average service life; in two of the three comparisons, painted steps had lower service life. The 3-minute dip in the water-repellent preservative at least tripled the average service life.

The implications are clear. In areas of high rainfall, exterior wooden steps should be made of all heartwood of highly decay-resistant species or of preservatively treated wood. In regions of low rainfall, such woods as Douglas-fir heartwood will give acceptable service, particularly if designs minimize seepage.

Step and porch rails.—These have a high decay rate in areas with moderate to high rainfall. The effect of design on rate of decay was measured in four studies. Designs included: Step rails abutting or capping newel; secondary rails nailed to the flat surface of the post, crosslapped, or abutted to the edges of the post; three types of the triple joint of step and stoop rails to a common post; and stoop top rails solid or jointed over a post. There were 10 units in each test category. Unless otherwise noted units were painted with a titanium-lead-zinc oil paint. The units were nailed to the edges of elevated creosoted sills. After 3 years and 6 or 7 years of exposure, matched groups

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FIGURE 6.—Different step designs included conventional carriages with and without risers, solid and split treads, and cleated carriages.

TABLE 4.—*Effect of design on rate of decay of treated and untreated southern pine steps*

UNDIPPED

Design	Painted	Average service life	Proportion failed at 11.1 years
		Years	*Percent*
Conventional carriage:			
Solid tread	Yes	5.6	
	No	5.0	
Split tread	Yes	4.7	
	No	5.7	
With risers	(1)	5.2	
Without risers	(1)	5.2	
Cleated carriage, solid tread	Yes	3.4	
	No	4.6	
All types	Yes	4.6	
	No	5.4	

3-MINUTE DIP[2]

Design	Painted	Average service life	Proportion failed at 11.1 years
Conventional carriage:			
Solid tread	Yes		47
Split tread	Yes		8
With risers	(1)		11
Without risers	(1)		10
Cleated carriage, solid tread	Yes	11.1	

[1] Both painted and unpainted.
[2] Water-repellent preservative.

were removed for internal examination. Some preliminary results have been published (*25*).

In the triple joint of step and stoop rails to a common post (fig. 7), the design theoretically with the lowest seepage hazard (middle one) had appreciably less decay after 3 years. After 7 years the advantage had disappeared—all units had serious decay.

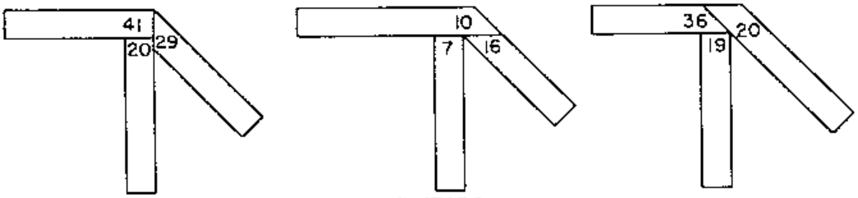
Step rails that capped the newel to promote drainage past the joint were significantly safer than step rails abutting the newel (fig. 8). The difference was still obvious after 7.2 years, even though decay occurred in all units. The difference was not marked in the unpainted series. After 4 years the unpainted abutted joints had an average rating of 61 and the capped units 49.

Joining a rail over a post greatly increased decay in both the rail and the post (fig. 9). Such joints are unavoidable at corners and with long rails.

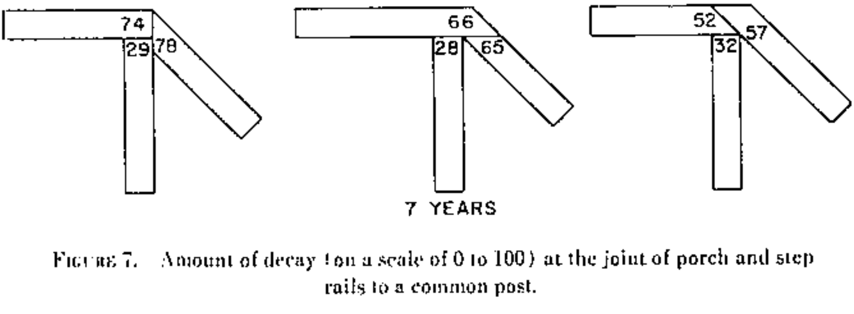
Three types of joints for attaching secondary rails to posts were tried (fig. 10). When the rail was sawed through and toenailed to the edge of the post, the rate of decay was high in both rail and post. The other two types—i.e., notching both the rail and post to produce a flush cross-lap joint and simply nailing the rail to the edge of the post—were safer the first 3 years but then developed objectionable amounts of decay in both posts and rails.

Further evidence was secured in a minor study on the effect of paint on moisture relationships and decay rate under high hazards. Small step-rail-to-newel units were exposed to rain seepage. Matched sets were: Unpainted except for exposed end cuts; carefully painted so that a continuous film covered the entire exterior of the assembled unit, including the joint; and painted except for a 1/8-inch strip adjacent to the joint, the purpose being to leave the joint unsealed.

During 3 months' exposure (fig. 11) the units with sealed joints absorbed very little water. The unpainted units absorbed considerable water during rains but lost it during dry weather. The painted units with open joints



3 YEARS



7 YEARS

FIGURE 7. Amount of decay (on a scale of 0 to 100) at the joint of porch and step rails to a common post.

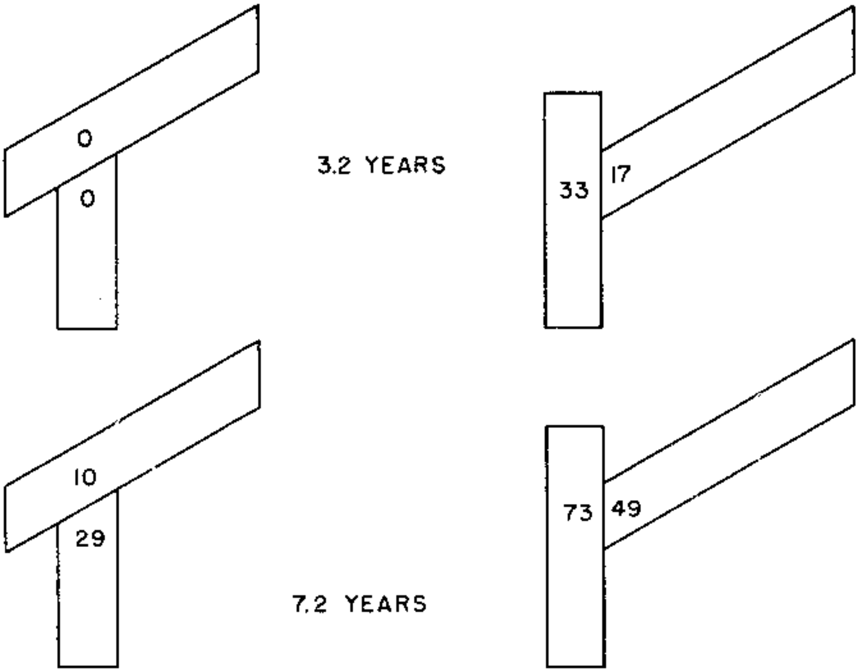


FIGURE 8.—Amount of decay (on a scale of 0 to 100) in painted step rails and newels when the rail abutted or capped the newel.

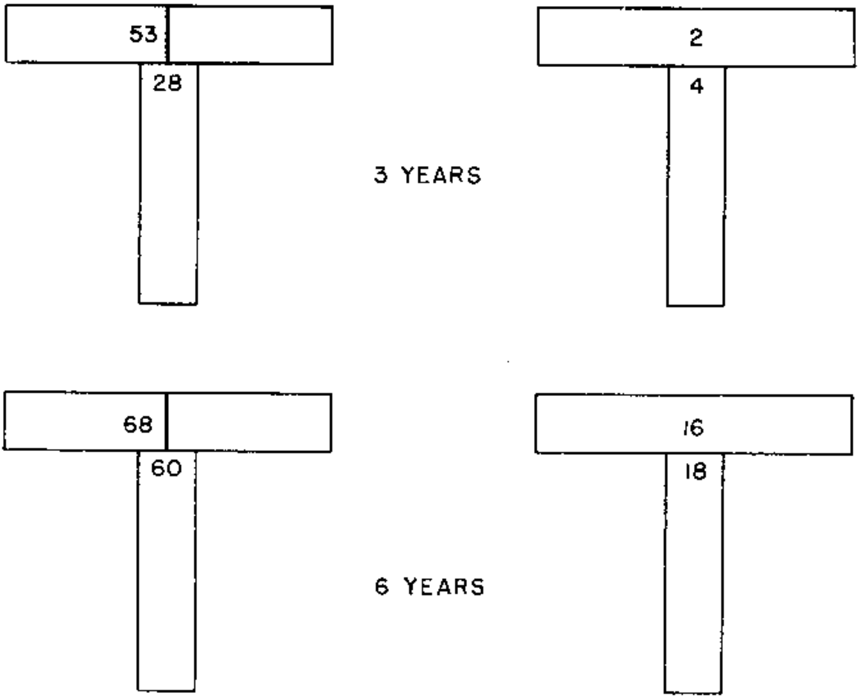


FIGURE 9.—Effect of joining a stoop rail over a post on the amount of decay (on a scale of 0 to 100).

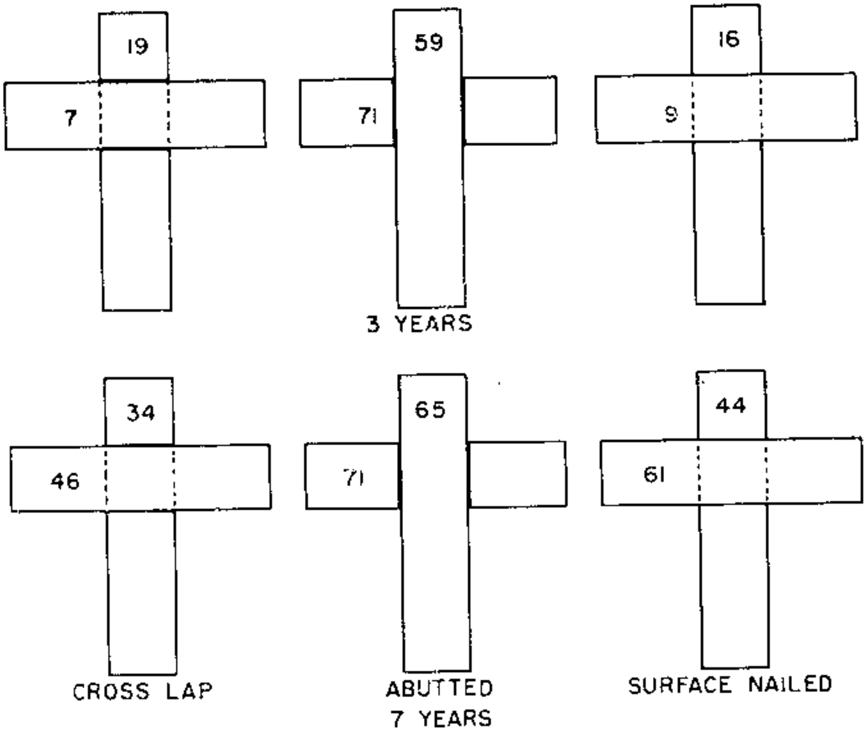


Figure 10.—Amount of decay (on a scale of 0 to 100) at joints of secondary rails when notched to form a flush cross-lap joint; sawed through and abutted to the edges of the post; or nailed to the flat surface of the post.

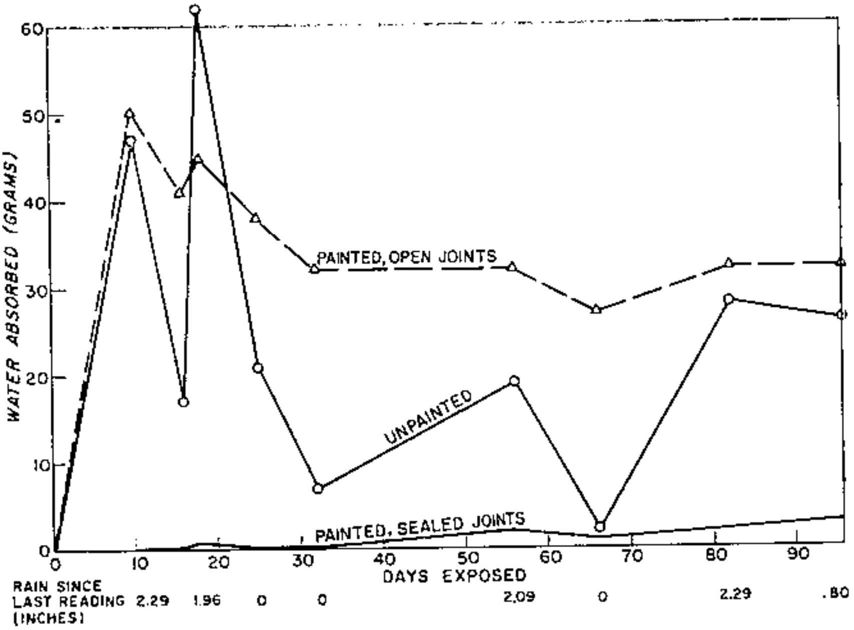


Figure 11.—Rain seepage into joints of step rails abutted to newels, expressed as water absorbed in excess of air-dry weight.

absorbed less water but retained so much between rains that they usually had a higher moisture content than the unpainted units.

After 3 years' exposure the internal decay ratings were: Unpainted, 70; painted with open joints, 49; and painted with sealed joints, 5. In the last case all decay was in one of the five units. The painted open-joint samples had more decay at the joint than did the unpainted series.

This study shows that an oil paint is sufficiently impervious to rain to keep the wood too dry to support decay, so long as joints are sealed. However, once the seal is broken, the paint tends to retard drying and, at least near the joint, favor decay.

Other data (32) show that oil-paint films do not have a consistent effect on the rate of decay on untreated wood and should not be considered in decay protection. However, when wood was dip treated with a preservative without a water repellent, painting was decidedly salutary.

Except for the step study, few data were secured on the effect of a water repellent on wood exposed to moderate to high hazards. Weights were taken on simulated boxes and boards of southern pine; some data were previously presented (*28*). Moisture uptake in treated boxes closely piled to restrict drying between showers (fig. 12) gradually rose to about 40 percent by the end of the first year (fig. 13). This is too high for building lumber. When boards were stacked so as to dry between showers, the water repellent kept the moisture content below 20 percent (fig. 13).

SIDING STUDIES

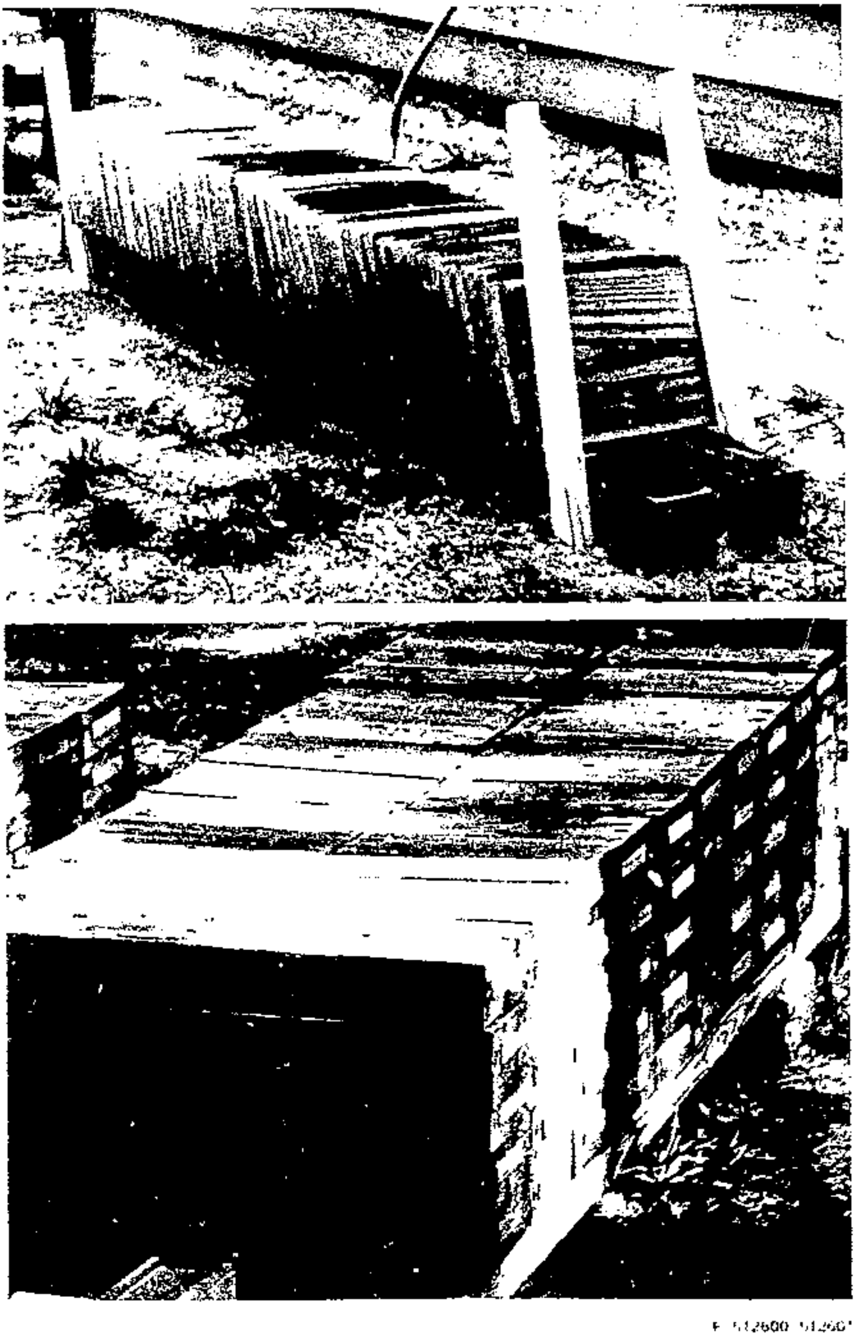
Factors influencing the wetting and drying of siding were evaluated in 11 studies, most of which included observations on paint peeling, staining, and decay.

All the siding was southern pine, mostly sapwood, kiln-dried, and essentially free of fungus stain. Two basic types were tested: (1) Bevel siding, 6 inches wide. For studies 2 and 4 the bevel siding was resawn 4/4 lumber; for study 3, standard bevel; and for studies 8, 10, and 11, ½-inch lumber applied as bevel siding. (2) Drop siding, pattern 105 with a shiplap joint. For studies 1 and 2 the siding was 8 inches wide; for all other studies, 6 inches. Where possible, matched pieces were attached in the same courses across all panels to be compared in each test.

The wood sheathing was 1- by 6-inch pine sapwood lumber attached horizontally. In studies 6 and 11, the sheathing was square edged; in study 7, both square edged and center matched.

Both breathing and vapor barrier sheathing papers were included: The breathing papers were rosin-sized kraft and asphalt-saturated but uncoated felts. The desired characteristic of a breathing paper is permeability to water vapor. The kraft (study 1) is essentially a wind barrier only and is highly permeable to water vapor. The felts were of very light weight in five studies—4.3 pounds per 108 square feet for studies 1 and 6 and 6.9 pounds per 108 square feet for studies 3, 5, and 7. For studies 8–11 the felt was 15 pounds per 108 square feet. This is commonly used in buildings, and the paper is the heaviest that is classed as breathing.

The vapor barriers were: (1) Asphalt-impregnated and coated roll roofing, 45 pounds (study 1), classed as a heavy-duty vapor barrier; (2) oilcloth



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[illegible] tests of the effectiveness of water-repellent preservatives on rain [illegible] to facilitate drying between showers; *bottom,* [illegible] wetting [illegible]

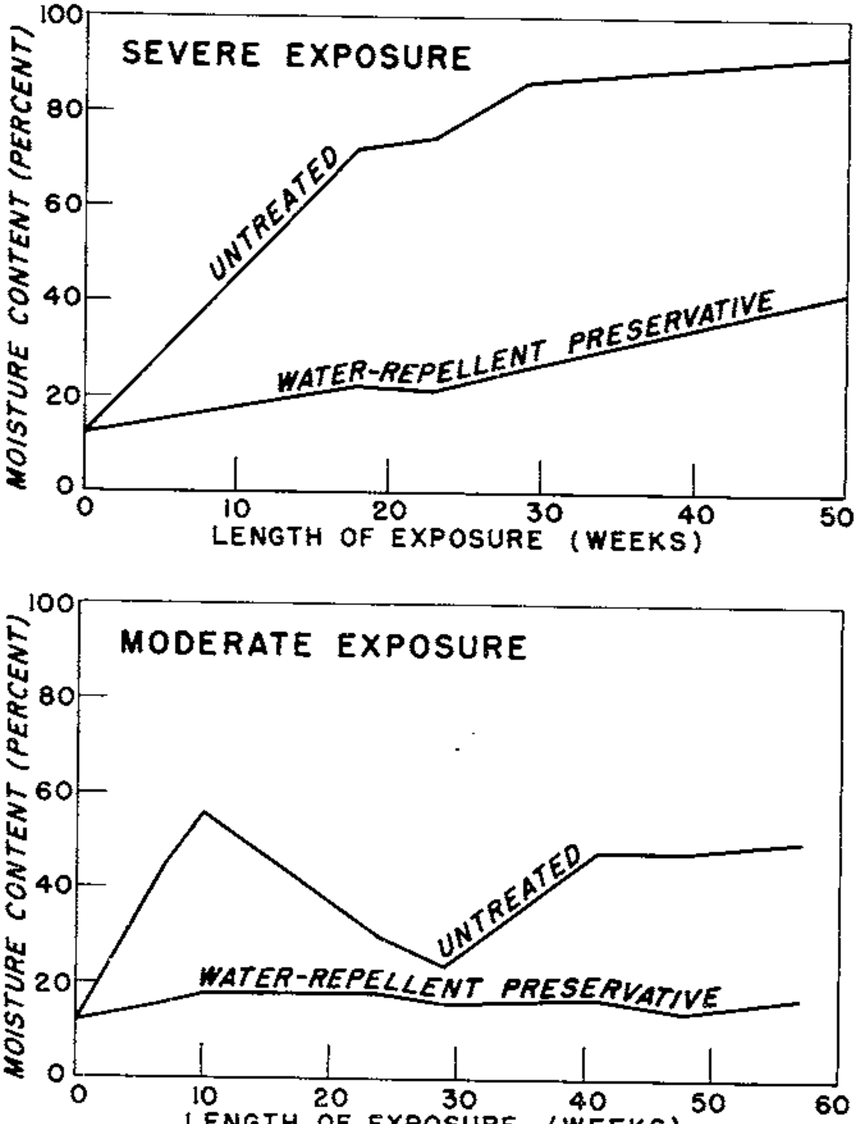

FIGURE 13.—Wetting of pine wood—untreated and that given a 3-minute dip in a water-repellent preservative. *Top,* under severe exposure. Simulated boxes are closely piled to restrict drying between showers (fig. 12 bottom). *Bottom,* under moderate exposure. Boards are stacked on edge to permit full exposure to rains, but considerable drying between rains (fig. 12 top).

backed with aluminum foil (study 5); and (3) laminated barriers (studies 4, 6, and 7) consisting of two layers each of kraft paper, asphalt, and closely spaced fibers. The last two are vapor barriers for ordinary use, not heavy duty.

Except for study 1, the siding was attached to 2- by 4-inch studs with or without sheathing papers or sheathing, and exposed (figs. 14, 15) under the eave of a roof. The panels for study 9 were exposed to the runoff from a roof 16 feet wide. The other study units were under a roof approximately 6 feet wide, and thus received less runoff. Most panels were 18 to 20 inches wide and without a center stud and had the siding ends abutted to corner trim; some had special corner designs (figure 16).

Except where otherwise stated, siding was given two coats of a zinc-lead-titanium paint, usually over the paint manufacturer's recommended prime coat. Some siding was treated with the same preservatives listed above under "Steps and Rails." Summaries of some of these studies have been published (*29, 31*).

Moisture contents (except for study 11) were determined with a resistance-type moisture meter used on fixed electrodes (large-headed copper roofing nails) inserted in the back of the siding as near each end as possible (fig. 14*E*). Except for the parts penetrating the siding, electrodes were insulated when inserted through sheathing.

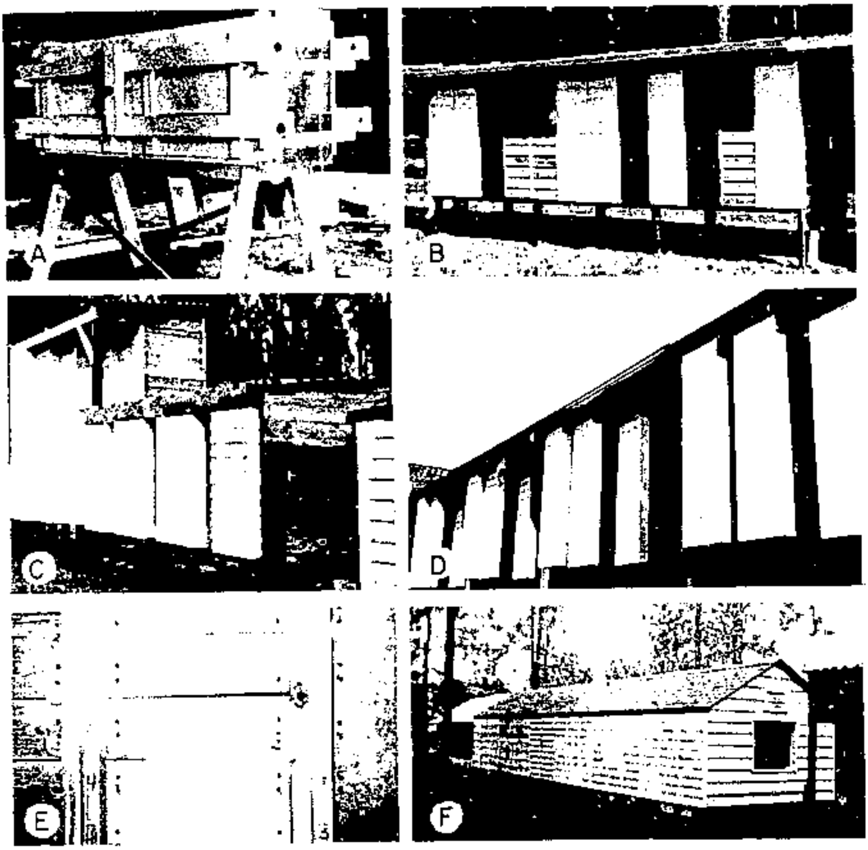

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FIGURE 14.—Some of the study exposures: *A*, Siding applied to box simulates wall construction (the panels are held in place with 2 by 4's); *B*, painted and unpainted siding under a 12-inch roof overhang; *C*, various roof overhangs and corner designs; *D*, roof overhang and gutters; *E*, electrodes inserted through sheathing from back; *F*, building with test panel sides.

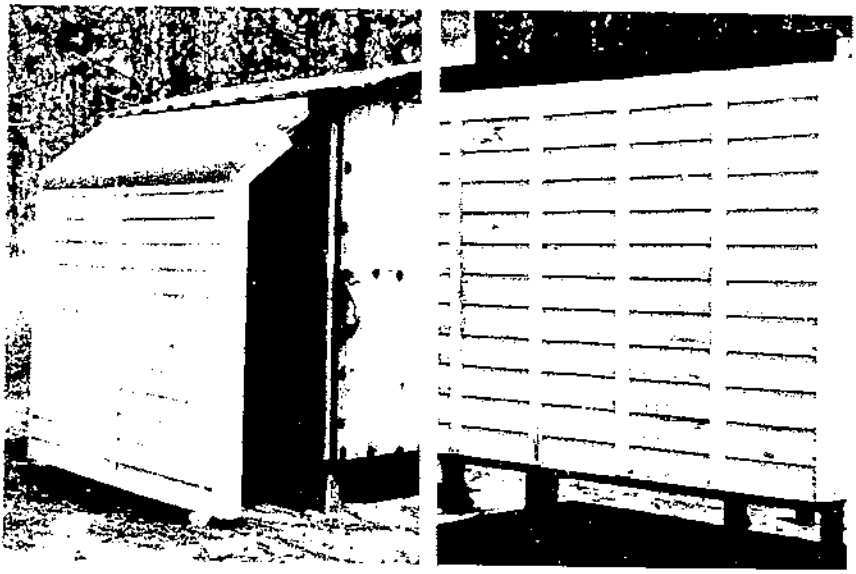

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FIGURE 15. Other study units: *Left*, Preliminary tests on end treatments; *right*, typical panel for studying water-repellent treatments.

To determine wetting patterns, moisture readings were taken 1 to 2 hours after day rains ended and the morning after night rains. When drying rates were desired, additional readings were taken at 24- to 48-hour intervals. Most moisture contents are expressed in broad ranges. Specific moisture readings are of doubtful value for contents above fiber saturation, where resistance meters measure only gross differences.

Study 1. This preliminary study on the effects of building papers and paint was conducted with drop siding consisting of four demountable panels on a box approximately 1.5 by 2 by 5 feet (fig. 14 *A*) in an open shed. Panels were soaked in water and then attached to determine drying rates. Moisture contents were determined by using the standard $^{5}/_{16}$-inch moisture meter contacters on the back of the siding. The first run was made before the siding was painted, the second after two coats of oil paint had thoroughly dried. The four panels were laid over asphalt roofing, a light asphalt breathing paper, and rosin-sized paper, and directly on the box.

The wet siding dried rapidly when unpainted, and the type of paper had essentially no effect on the rate (fig. 17).

After painting, the wet panels without paper and over the rosin-sized paper dried fairly fast, and the panel over the asphalt sheathing paper dried considerably more slowly. The panel over the vapor barrier did not dry (fig. 18); the increase in moisture after a slight initial drop represents not an increase in total water but merely a rearrangement within the wood.

This study clearly showed that siding with the usual oil paint film, when wetted by rain seepage, dries mainly to the inside, and that the type of sheathing paper can radically affect the rate of inward migration of water vapor.

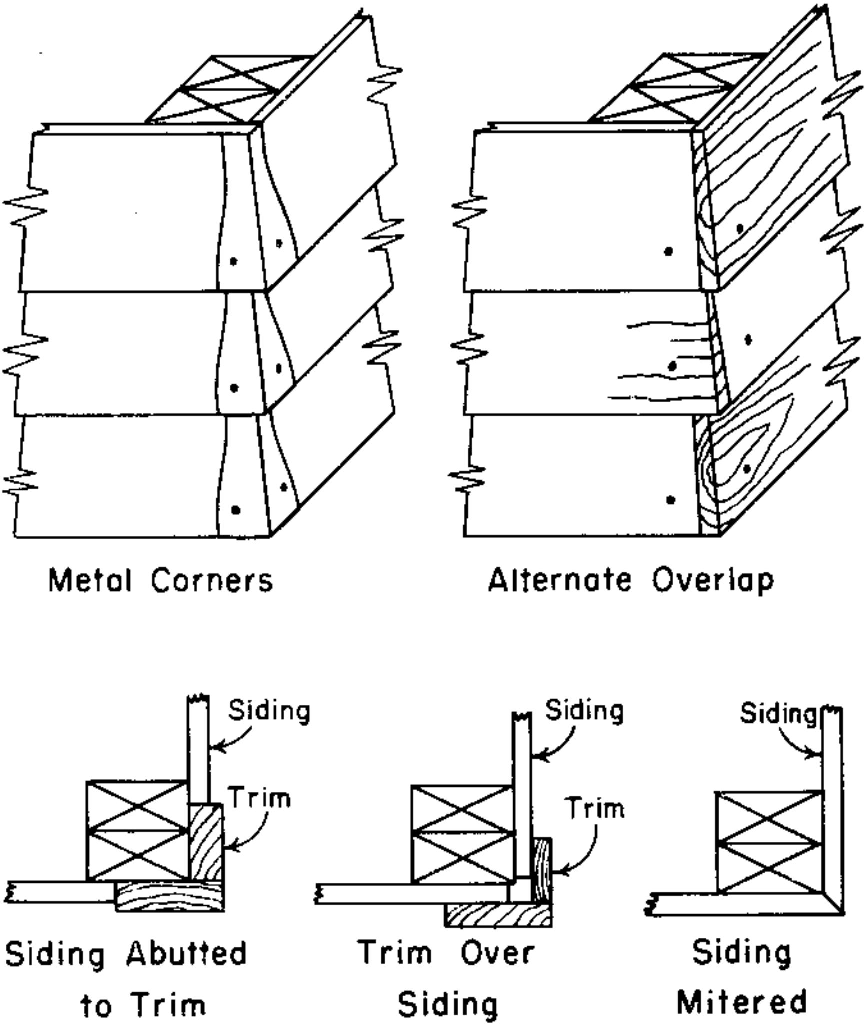

FIGURE 16.—Types of corner designs studied.

Study 2.—Bevel siding (untreated, with a 3-minute dip in 5-percent pentachlorophenol alone or with a water repellent, and with ends given a heavy coat of white-lead paint) was exposed to rainwetting (fig. 15). During 3 years of exposure the water repellent was effective in preventing wetting; the end paint reduced wetting somewhat; and the preservative without a water repellent had practically no effect (table 5).

Study 3.—Two tests were made with panels of painted bevel siding applied with different corners. In test 1 (fig. 16) the corner designs were alternate overlap, mitered, siding abutted to the trim, and trim laid over the siding end. In the second test the trim over the siding ends was replaced with metal corners (fig. 16).

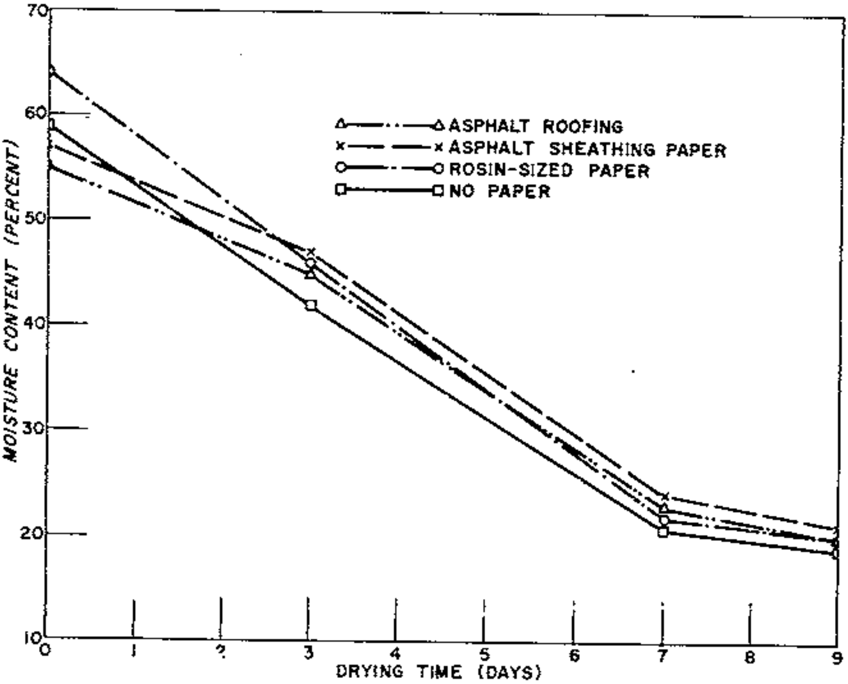

FIGURE 17.—Drying rate of wet unpainted siding over different sheathing papers without rigid sheathing.

TABLE 5.—*Effect of various end treatments on wetting of bevel siding*

[Percent]

Treatment	Average proportion of ends with moisture contents of—[1]		
	20–29	30–39	40+
3-minute dip in pentachlorophenol plus a water repellent	2	0	0
3-minute dip in pentachlorophenol	27	16	25
Ends painted	29	10	12
Untreated	34	18	19

[1] Averages of readings after 10 rains during a 3-year period.

Only the metal corners gave practical control of seepage (table 6). Ordinarily, trim is not placed over the ends of bevel siding, probably because trim merely touches the bottom drip edge of each siding piece and thus permits easy entry of rainwater. As shown later, this trim placement is satisfactory with drop siding. The effectiveness of the metal corners suggests that rainwetting under the conditions of this study was mainly at the end joints of bevel siding and not by capillary movement over the lap joint, as occurs under some conditions (see section "Physics of Water Entry").

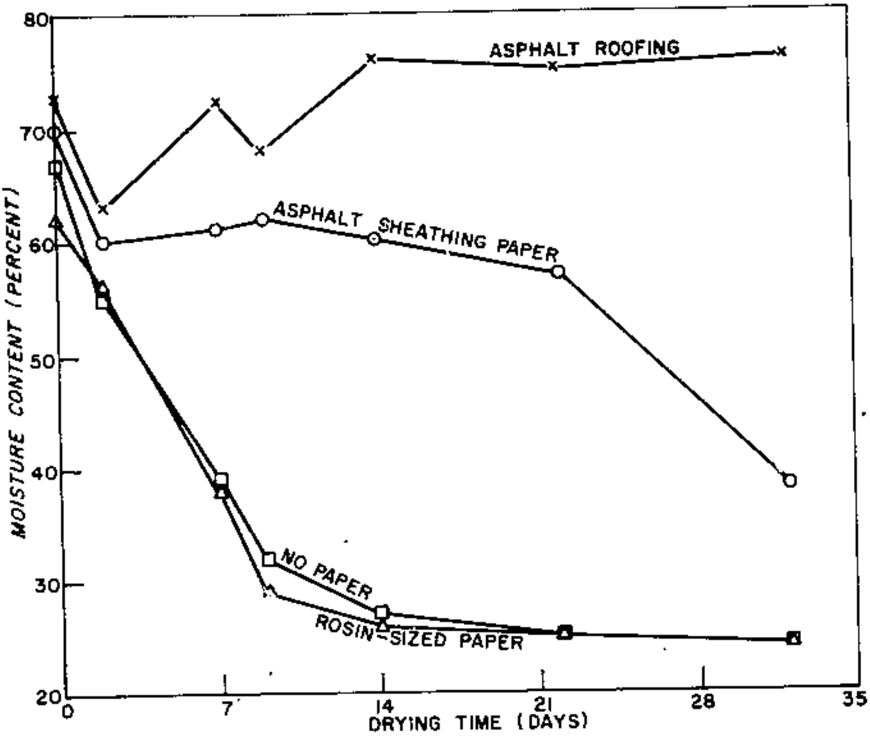

FIGURE 18.—Drying rate of wet painted siding over different sheathing papers without rigid sheathing.

Study 4.—Four 8-foot panels of painted drop siding were exposed with 3. 9, 15, and 24 inches of roof overhang (fig. 14*C*). No sheathing or paper was used under the siding during the first 15 months. Then a vapor barrier was added to increase moisture accumulations. All siding ends were abutted to the trim.

After 7 years' exposure, the siding was removed to determine the proportion of ends with decay, fungus stains, and water stains (table 7). Only the siding under the 3-inch overhang wetted sufficiently to promote decay. The panel with 9-inch overhang, however, had some fungus staining. The one with 15-inch overhang showed some wetting, as evidenced by water stains, but no fungus development. Under the 24-inch overhang the siding remained essentially dry, only the bottom boards showing wetting.

Study 5.—Four panels of painted drop siding abutted to the trim were exposed without roof overhang on the frames shown in figure 14*C*. The following factors were tested:

(1) Breathing paper versus vapor-barrier sheathing paper. Two panels had each type of paper laid directly on the studs.

(2) In one panel with each type of paper, the siding was placed directly against the paper, as in typical house construction. In the other panel of each paper, the siding was separated from the paper by furring strips. These were nominal 1-inch lumber strips 1½ inches wide nailed vertically to the studs and over the outside of the paper. The paper was terminated 2 inches

TABLE 6.—*Effect of various corner designs on wetting of bevel siding*

[Percent]

Test and corner design	Average proportion of ends with moisture contents of—		
	20–29	30–39	40+
Test 1, after 12 rains:			
Alternate overlap	6	4	57
Mitered	14	5	57
Abutted to trim	9	4	37
Trim over ends	13	4	22
Test 2, after 4 rains:			
Alternate overlap	28	11	39
Mitered	33	25	42
Abutted to trim	19	17	43
Metal corners	14	0	1

TABLE 7.—*Effect of roof overhang on condition of drop siding after 7 years' exposure*

Overhang length and siding affected	Proportion of ends decayed	Fungus stains	Water stains
	Percent		
3-inch overhang:			
Top 6 boards	0	Heavy	(1)
Middle 6 boards	33	do	(1)
Bottom 7 boards	67	do	(1)
9-inch overhang:			
Top 6 boards	0	None	Light.
Middle 6 boards	0	Light	(1)
Bottom 7 boards	0	Moderate	(1)
15-inch overhang:			
Top 6 boards	0	None	None.
Middle 6 boards	0	do	Light.
Bottom 7 boards	0	do	Do.
24-inch overhang:			
Top 6 boards	0	do	None.
Middle 6 boards	0	do	Do.
Bottom 7 boards	0	do	(2)

[1] Obliterated by fungus stain.

[2] Trace on ends; none on back.

Paint peeling after 5.5 years was as follows:

Roof overhang (inches)	*Number of boards with paint peeling*			
	None	*Light*	*Medium*	*Heavy*
3	0	6	7	6
9	2	12	4	1
15	4	11	4	0
24	5	13	1	0

from the top of the panel to permit air movement from the bottom of the panel up between the siding and paper and out to the back.

After 3 years decay was limited to the siding over the vapor barrier, where each board had some decay. It was mostly incipient but some was intermediate or approaching the final stage. The average distance that decay extended from siding ends was as follows:

	Ventilated (inches)	*Unventilated (inches)*	*Difference (inches)*
Vapor barrier	1.3	4.8	3.5 ± 1.77
Breathing paper	0	0	0

The degree of staining and molding on the backs of the siding indicated the amount of rainwetting. The average conditions were:

(1) Vapor barrier, unventilated. The siding was molded and stained entirely across the back except at the ends, where bleaching by decay had usually occurred.

(2) Vapor barrier, ventilated. The bleached ends shaded into a stained area about 3 inches wide. The central part of each board was clear. Thus, considerable wetting had occurred, but not so much as in the unventilated panel.

(3) Breathing paper, unventilated. One to two inches of mold and stain occurred on the ends of each piece. The rest was bright.

(4) Breathing paper, ventilated. Results were the same as for the ventilated panel. Apparently wetting was largely limited to the ends when breathing paper was used.

Under the severe conditions of this test (heavy flow of roof water over siding abutted to the trim), the breathing paper reduced the decay rate more than did an airspace between the siding and building paper. With the vapor barrier paper the use of furring strips limited the decay to the area under the furring strips. Even though this reduction is statistically significant, it is of little practical importance. In both panels over vapor barrier paper, decay of the siding ends would soon have required replacement of the boards, and it would have made little difference whether 2 or 6 inches had rotted off.

Study 6.—This study evaluated the effects of building paper, trim placement, sheathing, end treatments, and joint tightness on wetting and drying. Four panels of bevel siding and 12 of drop siding were replicated on the north and south sides of the back half of the building in figure 14*F*. All siding was painted. On each side there were two panels of bevel siding with breathing paper, two of which were relaid over wood sheathing after 2.5 (south side) and 3 years (north side); one panel of drop siding over breathing paper and with the trim over the siding ends; two panels of drop siding over a vapor barrier; two panels of drop siding over breathing paper; and one panel of drop siding without paper. Except for one panel on each side, all siding was abutted to the trim. The siding was not matched between north and south exposures.

The joints on one end of each panel with siding abutted to the trim were as tight as feasible; those on the other end had about a $^1/_8$-inch space between the siding end and the trim. Half the siding ends in each panel were left untreated, evenly divided between the tight- and open-joint ends. The other half of the ends were divided among two end treatments: a 3-minute dip in 5-percent pentachlorophenol and one coat of white-lead paint on the end grain.

Three months after construction 7.1 inches of rain fell in 3 days without appreciable wind, and 15 months after construction 11.9 inches fell in 2 days with gale winds. These rains were followed by 7 and 9 days of dry weather, respectively. Moisture contents showed that tightly carpentered joints did not exclude rain better than open joints (table 8). During the first rain some of the tight joints were still sealed by the paint, but by the second rain most paint seals had been broken by the working of the wood. Except for the first few months after painting, tight joints probably cannot be relied on to prevent rain seepage. The type of paper had no effect on the wetting or drying of ends with tight or open joints. Other studies show that some open joints permit large volumes of water to enter by gravity flow.

During the same rains, the end paint only sightly reduced water entry (table 9). Again the type of paper had little bearing.

TABLE 8.—*Moisture content of siding with open and tight joints of siding to trim and exposed without roof overhang (no rigid sheathing)*

[Percent]

Type of construction	Average moisture content		Proportion of ends with moisture contents above 25 percent	
	Immediately after rain	After 7–9 days' drying	Immediately after rain	After 7–9 days' drying
	After 7.1 in. of rain in 3 days with little wind			
Bevel siding, breathing paper:				
Tight joints	24	12	23	0
Open joints	28	12	39	0
Drop siding, no paper:				
Tight joints	19	13	0	0
Open joints	15	12	0	0
Drop siding, breathing paper:				
Tight joints	19	13	11	0
Open joints	21	13	25	0
Drop siding, vapor barrier:				
Tight joints	29	20	39	18
Open joints	29	18	32	11
	After 11.9 in. of rain in 2 days with gale winds			
Bevel siding, breathing paper:				
Tight joints	35	16	45	2
Open joints	31	15	16	0
Drop siding, no paper:				
Tight joints	24	16	29	0
Open joints	22	16	21	0
Drop siding, breathing paper:				
Tight joints	24	18	25	0
Open joints	22	16	21	0
Drop siding, vapor barrier:				
Tight joints	36	34	71	64
Open joints	37	32	68	54

TABLE 9.—*Wetting and drying of siding with various end treatments and exposed without roof overhang (no rigid sheathing)*

[Percent]

Type of construction	Average moisture content		Proportion of ends with moisture contents above 25 percent	
	Immediately after rain	After 7–9 days' drying	Immediately after rain	After 7–9 days' drying
	After 7.1 in. of rain in 3 days with little wind			
Bevel siding, breathing paper:				
Ends painted	22	10	20	0
3-minute dip in 5-percent pentachlorophenol	27	12	29	0
Untreated	28	12	36	0
Drop siding, no paper:				
Ends painted	16	12	0	0
3-minute dip in 5-percent pentachlorophenol	17	13	0	0
Untreated	17	12	0	0
Drop siding, breathing paper:				
Ends painted	21	12	19	0
3-minute dip in 5-percent pentachlorophenol	20	13	8	0
Untreated	23	13	21	0
Drop siding, vapor barrier:				
Ends painted	28	19	37	13
3-minute dip in 5-percent pentachlorophenol	22	16	25	0
Untreated	33	20	39	21
	After 11.9 in. of rain in 2 days with gale winds			
Bevel siding, breathing paper:				
Ends painted	29	15	40	0
3-minute dip in 5-percent pentachlorophenol	33	16	50	4
Untreated	35	16	55	0
Drop siding, no paper:				
Ends painted	22	15	13	0
3-minute dip in 5-percent pentachlorophenol	21	16	17	0
Untreated	24	16	36	0
Drop siding, breathing paper:				
Ends painted	22	16	25	0
3-minute dip in 5-percent pentachlorophenol	23	16	17	0
Untreated	24	17	50	0
Drop siding, vapor barrier:				
Ends painted	30	26	44	31
3-minute dip in 5-percent pentachlorophenol	36	35	83	58
Untreated	40	35	79	79

Since rains of 7 and 12 inches are infrequent, an effort was made to procure information under more typical conditions. Table 10 summarizes average moisture contents on 21 days following rains during the third year after construction. Indications are that:

> Water accumulation was greater on the windward side (south); thus, rain striking the wall adds to roof runoff in causing siding wetting.
>
> There was little difference between drop and bevel siding or between tight and open butt joints.
>
> Placing trim over drop siding reduced rain seepage.
>
> Water accumulations were importantly increased by wood sheathing, even with a breathing paper, and by a vapor barrier without wood sheathing.

The effect of the breathing paper on moisture accumulations is illustrated in figure 19, which shows all readings taken during a 6-month period of the third year, when rainfall was slightly above normal.

TABLE 10.—*Percent of siding ends in three moisture classes: Averages of readings taken 21 days after rains in the third year following construction*

[Percent]

Exposure and construction details	Untreated			Ends painted			Pentachlorophenol dip		
	20–29	30–39	40+	20–29	30–39	40+	20–29	30–39	40+
North side:									
Bevel siding	21	4	3	7	2	2	1	0	0
Drop siding	(1)	3	3	7	1	0	1	0	0
Open butt joints	14	6	10	8	2	2	8	1	9
Tight butt joints	13	3	8	13	1	1	7	2	8
Drop siding abutting trim	(1)	3	3	7	1	0	1	0	0
Trim over drop siding ends	0	0	0	0	0	0	0	0	0
Drop siding:									
No paper	0	0	0	0	0	0	0	0	0
Breathing paper	(1)	3	3	7	1	0	1	0	0
Vapor barrier	26	9	23	22	3	3	25	6	30
Average, north side	13	4	9	11	2	1	7	2	9
South side:									
Bevel siding	6	3	(1)	22	4	2	3	1	0
Drop siding	3	3	5	2	2	0	2	0	0
Open butt joints	12	10	15	18	12	10	8	2	8
Tight butt joints	17	8	13	8	8	8	10	5	6
Drop siding abutting trim	6	3	(1)	22	4	2	3	1	0
Trim over drop siding ends	5	0	0	0	0	1	0	0	0
Bevel siding plus breathing paper:									
Wood sheathing	23	11	17	23	5	3	13	1	12
No sheathing	6	3	(1)	22	6	2	3	1	0
Drop siding:									
No paper	14	4	16	6	8	4	0	0	0
Breathing paper	3	3	5	1	2	0	1	0	0
Vapor barrier	33	22	32	23	22	25	26	11	24
Average, south side	14	9	14	13	10	9	9	3	7
Average, north and south sides [2]	15	7	12	13	6	5	9	2	8

---

[1] Less than 0.5 percent.

[2] Includes all comparable panels with ends untreated, painted, or dipped in pentachlorophenol, some of which are not included in the averages for north or south sides.

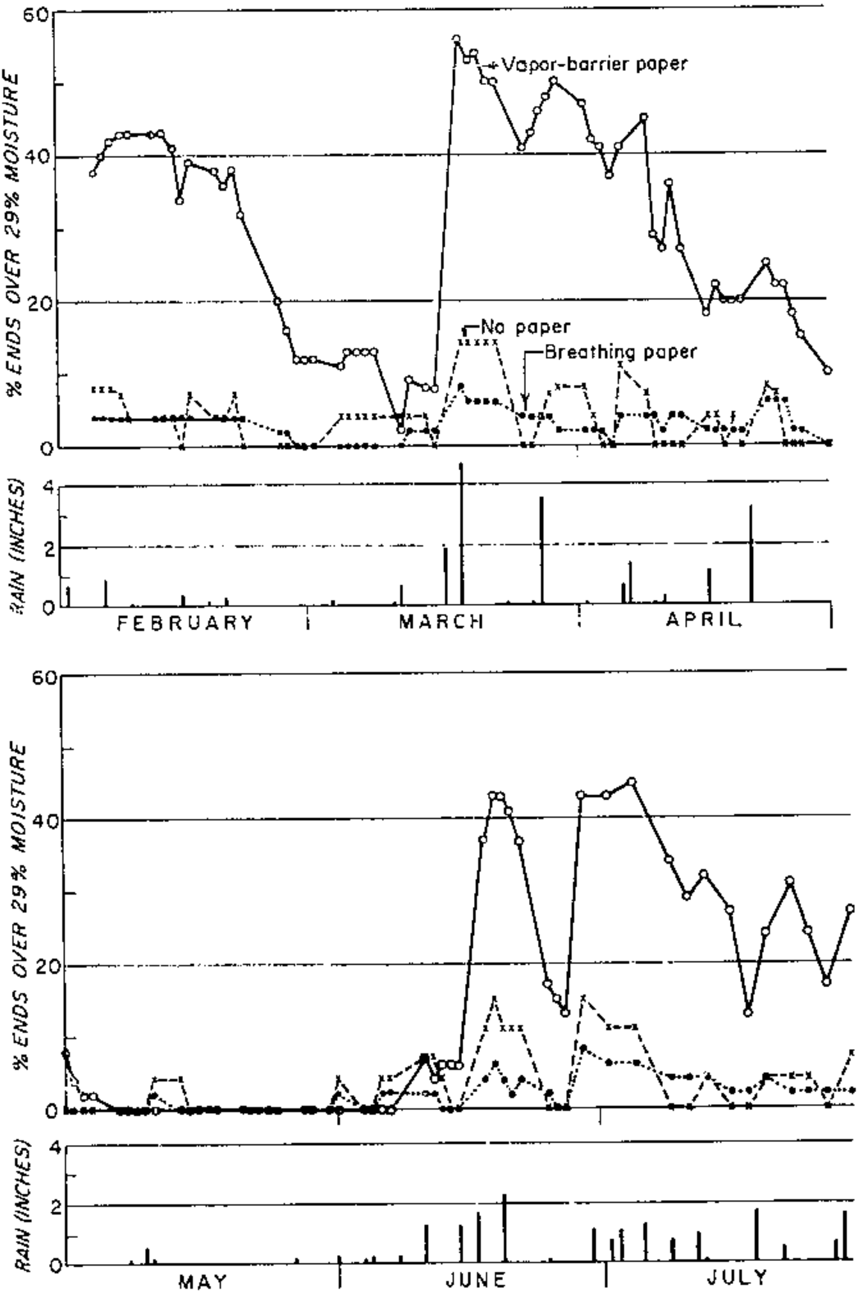

FIGURE 19.—Effect of vapor barrier and breathing papers on the moisture content of pine drop siding. Average readings during the third year after construction.

Decay ratings on the back sides of the siding after 7.8 years (table 11) indicated the same general relationship as shown by the moisture readings, with two exceptions: The 3-minute dip in pentachlorophenol reduced decay, even though objectionable amounts occurred on the treated wood over wood sheathing or the vapor barrier; and the end paint was more effective in reducing decay than in reducing wetting.

Study 7.—Eighteen panels of painted drop siding abutted to trim were exposed without roof overhang as an extension to the building of study 6 (forepart of fig. 14*F*). Treatments were duplicated on the north and south sides.

Three panels tested end treatments (3-minute dip in pentachlorophenol plus a water repellent, ends painted, and ends and back painted). The treatments were all included in each panel, equalized between east and west ends of the boards and top and bottom halves of the panels. One end of each board was left untreated. The siding was laid over breathing paper without sheathing.

Two panels had pine board sheating attached horizontally. The sheathing on the south side was square edged; on the north side, center-matched. One panel was without paper; one had a vapor barrier; and one had a vapor barrier but no sheathing.

TABLE 11.—*Amount of decay in siding after 7.8 years' exposure*

[Percent]

Type of siding and wall construction	Area decayed			Proportion of board ends					
				End dipped		End painted		No treatment	
	End dipped [1]	End painted	Untreated	Decayed	Failed [2]	Decayed	Failed	Decayed	Failed
Bevel siding, breathing paper, abutted to trim:									
Wood sheathing [3]	2	3	9	17	8	20	20	64	36
No sheathing	1	(4)	3	8	0	30	0	45	11
Drop siding, no sheathing, abutted to trim:									
No paper	0	(4)	2	0	0	25	0	57	7
Breathing paper	0	4	8	0	0	25	0	75	32
Vapor barrier	11	28	43	33	8	67	25	100	57
Drop siding, no sheathing, breathing paper, trim over siding ends	0	0	[5] 5	0	0	0	0	[5] 21	[5] 21

[1] 3-minute dip in 5-percent pentachlorophenol without a water repellent.

[2] With intermediate and final decay at end of siding.

[3] Wood sheathing was added 2.5 and 3 years after construction.

[4] Less than 0.5 percent.

[5] Decay was limited to boards at tops of panels and was associated with roof leaks.

In three panels one end of each board was infected prior to attachment. The infected ends were equalized between east and west ends and top and bottom halves. Four panels were infected with *Lenzites saepiaria* by soaking the board ends in water for 24 hours, spreading infected wood shavings over the wet ends, and bundling the siding in a vapor-barrier paper for 10 days. The boards showed small amounts of incipient decay and also some stain and mold. For the molded series the ends were soaked for 2 hours and inserted while wet into metal cans of pine shavings previously inoculated with *Trichoderma viride*. The entire unit then was wrapped in a vapor barrier for 3 weeks. The ends became well molded but developed no evidence of other fungi. The boards were thoroughly air dried and attached over a breathing paper. No sheathing was used.

Moisture readings over 5 years (table 12) showed that a vapor barrier and wood sheathing with or without a vapor barrier led to serious moisture accumulations. Even without a roof overhang the untreated siding laid over

TABLE 12.—*Effect of wood sheathing and building papers on the wetting of untreated drop siding exposed without roof overhang in the fall of 1950*

[Percent]

Year and construction	Average proportion of ends having moisture contents of—		
	20–29	30–39	40+
1951:[1]			
No sheathing, breathing paper	6	1	1
No sheathing, vapor barrier	16	2	2
Wood sheathing, vapor barrier	24	2	8
Wood sheathing, no paper	29	12	20
1952:[2]			
No sheathing, breathing paper	4	0	1
No sheathing, vapor barrier	18	1	3
Wood sheathing, vapor barrier	31	4	11
Wood sheathing, no paper	40	12	14
1953:[3]			
No sheathing, breathing paper	18	1	1
No sheathing, vapor barrier	61	6	5
Wood sheathing, vapor barrier	48	9	23
Wood sheathing, no paper	49	18	25
1954:[4]			
No sheathing, breathing paper	11	1	3
No sheathing, vapor barrier	41	5	0
Wood sheathing, vapor barrier	20	3	5
Wood sheathing, no paper	29	6	4
1955:[5]			
No sheathing, breathing paper	28	7	15
No sheathing, vapor barrier	35	33	21
Wood sheathing, vapor barrier	28	8	30
Wood sheathing, no paper	29	6	36

[1] Seven dates with 0.01–2.13 in. of rain in previous 10 days.
[2] Twelve dates with 0.42–5.93 in. of rain in previous 10 days.
[3] Seven dates with 0.99–5.08 in. of rain in previous 10 days.
[4] Six dates with 0.09–1.81 in. of rain in previous 10 days.
[5] Three dates with 3.47–7.85 in. of rain in previous 10 days.

the breathing paper remained reasonably dry for 2 years. The greater wetting during the third to fifth year probably was associated with greater absorbency caused by the development of mold and stain.

The 3-minute dip in the water-repellent preservative and the end plus back painting were highly effective in preventing rain seepage (table 13). End painting was somewhat less effective than end-plus-back painting.

The increased absorbency of the molded siding immediately resulted in greater wetting (table 14). The incipient decay infections did not affect moisture content until the second year. By the fifth year all siding apparently was infected.

At the end of 5 years the siding was removed, and the amount of decay on the back side was estimated (table 15). The data show that under heavy seepage decay is seriously increased by use of wood sheathing with or without a vapor barrier, use of a vapor barrier without rigid sheathing, and by preexisting fungus infections. No decay occurred in siding given a

TABLE 13.—*Effect of treatments on the wetting of drop siding exposed without roof overhang in the fall of 1950*

[Percent]

Year and treatment	Average proportion of ends having moisture contents of—		
	20–29	30–39	40+
1951:[1]			
Untreated	6	1	1
Ends painted	3	0	0
Ends and back painted	0	0	0
3-minute dip in water repellent	0	0	0
1952:[2]			
Untreated	4	0	1
Ends painted	1	0	0
Ends and back painted	0	0	0
3-minute dip in water repellent	0	0	0
1953:[3]			
Untreated	18	1	1
Ends painted	2	0	0
Ends and back painted	0	0	0
3-minute dip in water repellent	1	0	0
1954:[4]			
Untreated	11	1	3
Ends painted	2	0	0
Ends and back painted	0	0	0
3-minute dip in water repellent	0	0	0
1955:[5]			
Untreated	28	7	15
Ends painted	1	0	0
Ends and back painted	0	0	0
3-minute dip in water repellent	0	0	0

[1] Seven dates with 0.01–2.13 in. of rain in previous 10 days.
[2] Twelve dates with 0.42–5.93 in. of rain in previous 10 days.
[3] Seven dates with 0.99–5.08 in. of rain in previous 10 days.
[4] Six dates with 0.09–1.81 in. of rain in previous 10 days.
[5] Three dates with 3.47–7.85 in. of rain in previous 10 days.

TABLE 14.—*Effect of fungus infections prior to attachment on the wetting of drop siding exposed without roof overhang in the fall of 1950*

[Percent]

Year and type of infection	Average proportion of ends having moisture contents of—		
	20–29	30–39	40+
1951:[1]			
Uninfected	6	1	1
Trichoderma	17	1	0
Lenzites	6	1	1
1952:[2]			
Uninfected	4	0	1
Trichoderma	16	1	1
Lenzites	11	1	1
1953:[3]			
Uninfected	18	1	1
Trichoderma	41	3	1
Lenzites	44	4	3
1954:[4]			
Uninfected	11	1	3
Trichoderma	15	3	3
Lenzites	13	2	1
1955:[5]			
Uninfected	28	7	15
Trichoderma	23	11	5
Lenzites	25	6	17

[1] Seven dates with 0.01–2.13 in. of rain in previous 10 days.
[2] Twelve dates with 0.42–5.93 in. of rain in previous 10 days.
[3] Seven dates with 0.99–5.08 in. of rain in previous 10 days.
[4] Six dates with 0.09–1.81 in. of rain in previous 10 days.
[5] Three dates with 3.47–7.85 in. of rain in previous 10 days.

TABLE 15.—*Amount of decay in drop siding after 5 years' exposure*

[Percent]

Wall construction and siding treatment	Area decayed		Boards decayed	
	Total	Intermediate plus advanced	Total	Intermediate plus advanced
No sheathing, breathing paper:				
Untreated	20	3	79	46
Ends painted	1	(1)	21	(1)
Ends plus back painted	0	0	0	0
3-minute dip in 5-percent pentachlorophenol plus water repellent	0	0	0	0
No sheathing, vapor barrier	81	38	100	100
No sheathing, breathing paper:				
Inoculated with *Trichoderma*	30	8	100	75
Inoculated with *Lenzites saepiaria*	25	16	100	88
Wood sheathing, no end treatment:				
No paper	99	53	100	100
Vapor barrier	86	55	100	100

[1] Less than 0.5 percent.

3-minute dip in a water-repellent preservative or with end-plus-back painting, and only a small amount appeared in siding with end painting only.

The lasting qualities of the end treatments were demonstrated by spraying the panels with a garden hose when they were 9 and 12 years old (table 16).

TABLE 16.—*Effectiveness of end treatments in protecting siding after 9 and 12 years' exposure* [1]

[Percent]

Exposure period and treatment	Average moisture content	Proportion of ends having moisture contents of—			
		0–19	20–29	30–39	40+
After 9 years' exposure:					
Untreated	....	29	17	4	50
Water repellent dip	....	96	4	0	0
End paint	....	96	0	4	0
End plus back paint	....	100	0	0	0
After 12 years' exposure:					
Untreated	33	25	13	21	42
Water repellent dip	12	96	4	0	0
End paint	14	92	4	0	4
End plus back paint	12	100	0	0	0

[1] The 9-year readings were made after the panels had been sprayed from a garden hose for 24 hours; the 12-year readings were made after 45 hours of hosing.

Study 8.—Six panels each of drop and bevel siding were used to determine the effectiveness of inplace treatments and pretreatments with a water-repellent preservative. The siding was laid over a vapor barrier and abutted to the trim on two exposure units similar to the one shown in figure 15.

The treatments for the six panels of each siding pattern were as follows:

(1) The edge of the trim to which the siding was abutted was brushed with a water-repellent preservative before the paper was attached. The siding was dipped for 3 minutes in the same solution, attached, and painted when dry.

(2) The siding was sprayed with the water-repellent preservative after attachment and then painted when dry.

(3) The siding was brushed with the water-repellent preservative after attachment and then painted when dry.

(4) The face, but not ends or back, of the siding was primed. When dry, it was attached; and the joints sprayed with the water-repellent preservative. When the preservative had dried, the second coat of paint was applied. This regime simulated the treatment of old siding inplace.

(5) Similar to (4) but brush treated rather than sprayed.

(6) The siding was untreated but painted after attachment.

The sprayer had a nozzle with an orifice of 0.01 inch and operated at 25 pounds of pressure. One pass was made over each vertical and horizontal joint with the nozzle 2 or 3 inches from the joints. On nonprimed panels the entire surface was sprayed. For treatments 3 and 5 preservative was copiously applied with a 3-inch paintbrush to all joints and, with nonprimed panels, to the entire surface. Because of obvious ineffectiveness, the inplace treatments on the drop siding were redone after 9 months.

The panels were originally exposed without roof overhang, but after 1.5 years, on March 21, 1962, a 6-inch overhang was provided.

Moisture readings after seven rainy periods showed that the water repellent was more effective on the bevel than on the drop siding (table 17). The pretreatment was very effective on the bevel but permitted objectionable wetting of the drop siding. The 3-minute dip, however, did reduce paint peeling, staining, and decay on both types of siding (table 18 and fig. 20).

Inplace treatments are of doubtful value under severe exposure. Even a pretreatment with a water-repellent preservative, although affording considerable protection, should be supplemented by other means.

Study 9.—The effects of roof overhang, eave gutters, and inplace spraying with a water-repellent preservative were tested with 12 panels exposed under the eave of a building with a 16-foot pitched roof. The panels were 8 feet tall, with drop siding abutted to the trim, and laid over a 15-pound felt sheathing paper. Six panels, two each with 4, 8, and 20 inches of roof overhang, had eave gutters; six similar panels had no gutters (fig. 14*D*). The gutter added 2.5 inches to the listed roof overhang. All were painted.

TABLE 17.—*Effectiveness of a water-repellent preservative on moisture content of painted pine siding exposed without roof overhang*

[Percent]

Type of siding and treatment	Average proportion of ends with moisture contents of—					
	20–29	30–39	40+	20–29	30–39	40+
	During first 18 months[1]			During 19–42 months[2]		
Drop siding:						
Untreated	11	14	31	7	57	33
3-minute dip	15	1	0	10	23	17
Sprayed inplace:						
Before priming	14	23	28	7	47	37
After priming	15	9	1	20	23	10
Brushed inplace:						
Before priming	3	1	4	20	22	28
After priming	14	21	19	12	27	23
Bevel siding:						
Untreated	25	14	11	27	38	5
3-minute dip	0	0	0	2	0	0
Sprayed inplace:						
Before priming	0	0	0	25	3	15
After priming	8	4	8	25	48	5
Brushed inplace:						
Before priming	0	0	0	18	7	3
After priming	6	0	0	22	10	5

[1] Averages of 4 dates with 6.17, 2.83, 7.34, and 3.45 inches of rain during previous week.

[2] Averages of 3 dates with 4.88, 1.04, and 1.85 inches of rain during previous week.

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FIGURE 20. Condition of paint on siding after 30 months' exposure. Left panels (*A*, *B*) were given 3-minute dips in a water-repellent preservative. Right panel in *A* was untreated, in *B* was sprayed after attachment. (*C*) Back of siding was given 3-minute dip (left), sprayed after installation (center), and untreated (right).

TABLE 18.—*Stain, decay, and paint peeling on siding after 2.5 years' exposure*

[Percent]

Type of siding and treatment	Area stained	Area decayed	Boards with decay	Area with paint peeling
Drop siding:[1]				
3-minute dip	10	0	0	15
Sprayed:				
Before priming	50	15	50	6
After priming	42	2	30	15
Brushed:				
Before priming	44	0	0	26
After priming	56	22	80	10
None	64	32	100	33
Bevel siding:				
3-minute dip	6	0	0	6
Sprayed:				
Before priming	53	2	70	41
After priming	67	1	70	44
Brushed:				
Before priming	43	1	70	23
After priming	40	4	40	21
None	58	3	80	42

[1] Inplace treatments were remade after 9 months' exposure.

After 17 months, one panel of each test category was sprayed with a water-repellent preservative, applied from a coarse nozzle at 1 gallon per 100 square feet.

Moisture determinations were made during a 3-year period on 11 dates following rainy weather. Wetting decreased as width of eave increased (table 19). The panels with the gutters remained drier than those without them. The proportion of dry ends of the panels without gutters was plotted against width of eave (fig. 21). When the data for the guttered panels were inserted at 6.5, 10.5, and 22.5 inches, the points fell above the curves except for the 22.5-inch overhang. Approximately half the effect of the gutters resulted from the 2.5-inch increase in eave width afforded by the gutter.

After some of the panels had been sprayed with a water repellent, moisture readings were taken on four occasions following rainy periods. The repellent markedly reduced wetting on all panels (table 20), especially those with a gutter. The reduction probably was of practical proportions under the 8-inch eave and possibly under the 20-inch eave.

The siding was removed after 36 months and rated for stain and decay development on the back side and for paint peeling on the face. The typical condition of the backs is shown in figure 22. Objectionable amounts of stain developed throughout the untreated panels under the 4-inch eave and in the lower two-thirds of those under the 8-inch eave (table 21). Only small amounts of stain occurred under the 20-inch eave. The water repellent reduced but did not eliminate stain. However, the treatment was made after 17 months, by which time some stain probably had already developed.

TABLE 19.—*Wetting of untreated drop siding*

[Percent]

Exposure period and type of construction	Average proportion of ends with moisture contents of —		
	20–29	30–39	40+
During first 18 months after construction:[1]			
Without eave gutter:			
4-inch roof overhang	18	9	6
8-inch roof overhang	10	6	6
20-inch roof overhang	1	1	0
With eave gutter:			
4-inch roof overhang	13	5	1
8-inch roof overhang	8	3	2
20-inch roof overhang	([2])	0	0
During second 18 months after construction:[3]			
Without eave gutter:			
4-inch roof overhang	27	20	16
8-inch roof overhang	21	14	16
20-inch roof overhang	8	0	([2])
With eave gutter:			
4-inch roof overhang	26	19	10
8-inch roof overhang	14	8	5
20-inch roof overhang	6	1	([2])

[1] Average of readings on 5 dates with 1.24–6.17 in. of rain in previous week.

[2] Less than 0.5 percent.

[3] Average of readings on 6 dates with 1.04–7.34 in. of rain in previous week.

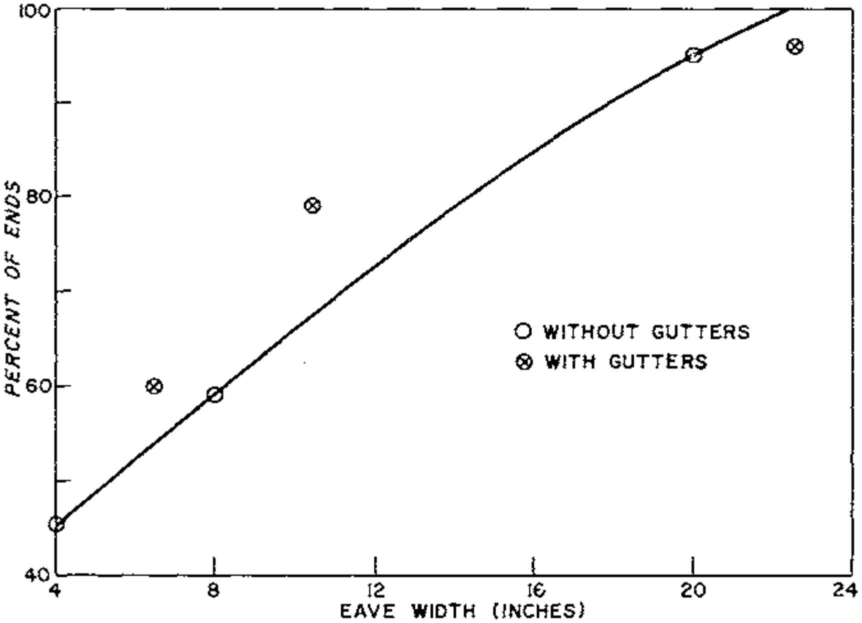

FIGURE 21.—Effect of gutters on rainwetting, as determined by proportion of siding ends with less than 20 percent moisture content. The curve is drawn through the points for panels without gutters.

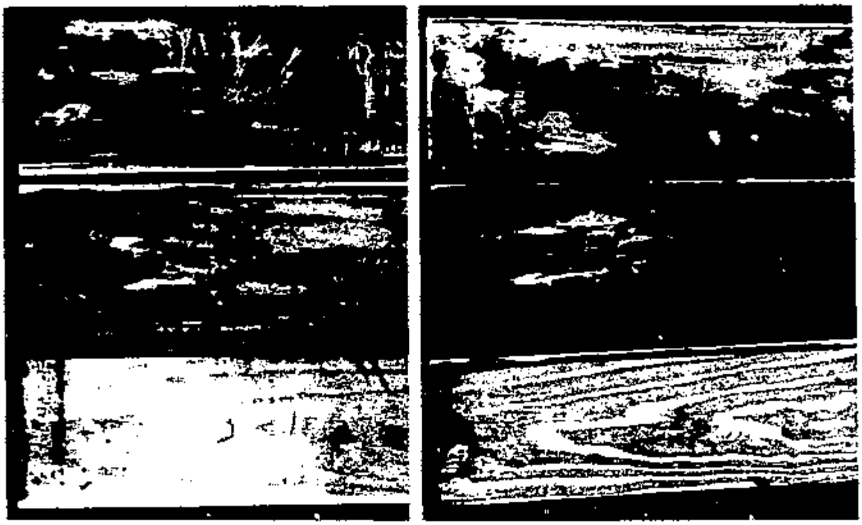

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FIGURE 22.—Stain and decay on the back of siding exposed for 36 months under eaves of 1 inch (top), 5 inches (center), and 20 inches (bottom). Boards shown at left were in the top third of 8-foot panels; those at right were in the bottom third.

TABLE 20.—*Wetting of drop siding sprayed inplace 17 months after attachment*

Percent

Treatment and construction	Average proportion of ends with moisture contents of—[1] 20–29	30–39	40+
Without eave gutters:			
1-inch roof overhang:			
Siding sprayed	17	5	1
Siding not sprayed	37	25	8
5-inch roof overhang:			
Siding sprayed	9	0	0
Siding not sprayed	28	21	12
20-inch roof overhang:			
Siding sprayed	0	0	0
Siding not sprayed	0	0	0
With eave gutters:			
1-inch roof overhang:			
Siding sprayed	20	3	2
Siding not sprayed	33	22	3
5-inch roof overhang:			
Siding sprayed	8	3	0
Siding not sprayed	21	8	1
20-inch roof overhang:			
Siding sprayed	0	0	0
Siding not sprayed	1	2	1

[1] Averages of 4 readings during second 18 months of exposure. Average rainfall for the 7 days prior to readings was 3.16 inches.

TABLE 21.—*Amount of stain, decay, and paint peeling on drop siding after 36 months' exposure*

Roof overhang and treatment [1]	Area stained	Area decayed	Area with paint peeling
4 inches:	TOP FIVE BOARDS		
With gutters:			
Treated	15	0	....
Untreated	32	0	4
Without gutters:			
Treated	22	0	....
Untreated	29	0	13
	MIDDLE FIVE BOARDS		
With gutters:			
Treated	33	0	....
Untreated	66	(2)	36
Without gutters:			
Treated	39	0	....
Untreated	78	3	29
	LOWER FIVE BOARDS		
With gutters:			
Treated	47	0	....
Untreated	80	2	42
Without gutters:			
Treated	73	(2)	....
Untreated	76	(2)	48
	AVERAGE, 4-INCH OVERHANG		
With gutters:			
Treated	32	0	....
Untreated	59	(2)	27
Without gutters:			
Treated	45	0	....
Untreated	61	(2)	30
8 inches:	TOP FIVE BOARDS		
With gutters:			
Treated	1	0	....
Untreated	3	0	1
Without gutters:			
Treated	2	0	....
Untreated	7	0	9
	MIDDLE FIVE BOARDS		
With gutters:			
Treated	10	0	....
Untreated	40	0	21
Without gutters:			
Treated	7	0	....
Untreated	65	(2)	31
	LOWER FIVE BOARDS		
With gutters:			
Treated	31	(2)	....
Untreated	47	13	27
Without gutters:			
Treated	26	0	....
Untreated	65	2	31

See footnotes at end of table.

TABLE 21.—*Amount of stain, decay, and paint peeling on drop siding after 36 months' exposure*—Continued

Roof overhang and treatment [1]	Area stained	Area decayed	Area with paint peeling
	AVERAGE, 8-INCH OVERHANG		
8 inches:			
With gutters:			
Treated	14	(2)	....
Untreated	30	5	16
Without gutters:			
Treated	12	0	....
Untreated	46	(2)	24
	TOP FIVE BOARDS		
20 inches:			
With gutters:			
Treated	1	0	....
Untreated	0	0	0
Without gutters:			
Treated	0	0	....
Untreated	(2)	0	0
	MIDDLE FIVE BOARDS		
With gutters:			
Treated	1	0	....
Untreated	4	0	2
Without gutters:			
Treated	2	0	....
Untreated	1	0	3
	LOWER FIVE BOARDS		
With gutters:			
Treated	5	0	....
Untreated	14	0	4
Without gutters:			
Treated	10	0	....
Untreated	5	0	4
	AVERAGE, 20-INCH OVERHANG		
With gutters:			
Treated	2	0	....
Untreated	6	0	3
Without gutters:			
Treated	4	0	....
Untreated	2	0	3

---

[1] Sprayed with water-repellent preservative after 17 months' exposure.

[2] Less than 0.5 percent.

Decay had not progressed far. It was absent in all panels under the 20-inch eave and was negligible in the treated panels under the 4- and 8-inch eaves.

Objectionable paint peeling occurred under the 4- and 8-inch eaves, but not under the 20-inch eave. Peeling on the treated panels was only slightly less than on the untreated panels, but the data is omitted from table 21 because the panels were not repainted after the treatment.

Study 10.—Previous studies had shown that oil paints retard outward drying of siding. Emulsion paints are now commonly used on exterior woodwork, and at least some are permeable to water vapor. This study was designed to determine if the vapor permeability of an emulsion paint is sufficient to affect the performance of siding subject to rain seepage. Three coats were applied to three panels of drop siding abutted to trim and laid over a 15-pound felt. The paint consisted of:

	Percent
Pigments, 33 percent:	
Titanium dioxide	67
Calcium carbonate	20
Silicates	13
Vehicle, 67 percent:	
Latex (solids)	32
Water	68

To insure greatest permeability, the paint was applied without special primer.

Three additional matched panels were painted with two coats of zinc-lead-titanium oil paint over a zinc-free primer and exposed without roof overhang (fig. 15).

During 11 months' exposure the following observations were made:

	Oil paint (percent)	*Emulsion paint (percent)*
Boards with paint blistering	22	0
Boards with objectionable fungus stain	25	28
Boards with decay	25	3

Because rainfall was scant, the vapor permeability of the paint films was tested by artificial spraying of the panels until the average moisture contents were about 35 percent. Then a plastic canopy that would prevent rainwetting but not interfere with drying was added. The panels with the emulsion paints dried significantly faster (fig. 23), but still not fast enough to prevent objectionable staining and decay, even with less than normal rainfall. An emulsion paint, however, should be a valuable adjunct to other protective features: permeability varies with paint formulation and type of primer.

Study 11.—A building in New Orleans, La., and one in Orange, Tex. (fig. 24), that had shown considerable paint peeling and minor decay in siding were used to determine the effectiveness of a spray with a water-repellent preservative prior to repainting. In both cases the seepage hazard was moderate to light.

The New Orleans building had 6-inch bevel siding on a 15-foot wall under a 16-inch eave (including a gutter). The loose paint was removed by scraping, but tight paint (8–10 mils thick) was left. When treated, the wood moisture content of the siding was 12 to 16 percent. A water-repellent preservative was sprayed on the east-facing wall with a garden sprayer and flat nozzle at 25 pounds pressure. Coverage was 218 square feet of surface per gallon. Cracks and joints were sprayed at a single pass. One section of sprayed wall

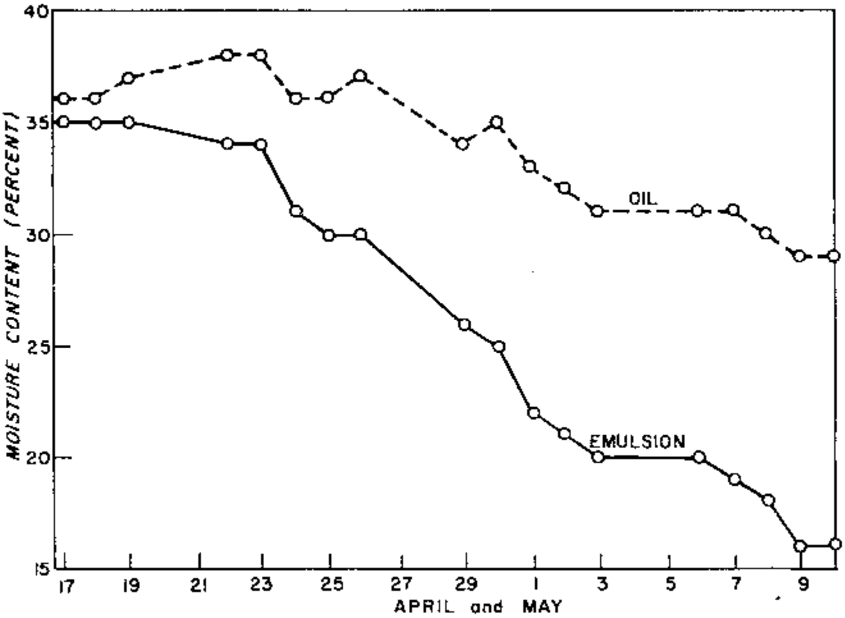

FIGURE 23.—Rate of drying of drop siding painted with oil-base and emulsion paint after artificial wetting.

was wiped after spraying; one section left unwiped; and a third section left unsprayed. Five days later the wall was commercially repainted with two coats of oil paint (TT–P–102).

The Orange building had 6-inch drop siding on a 10-foot wall under a 23-inch roof overhang without a gutter. The east-facing wall was prepared by scraping one section to remove loose paint; another section was stripped to bare wood with a paint remover. The water-repellent preservative was applied as in New Orleans but at 180 square feet per gallon. Two weeks later two coats of an oil paint were applied commercially.

Moisture readings were taken on the New Orleans building 21 months after treatment and after 2.29 inches of rain had fallen in the preceding 36 hours. The readings at Orange were taken 16 months after treatment and following 2.08 inches of rain in the previous 48 hours.

At New Orleans 20 percent of the treated ends wetted (table 22). Most of these ends had horizontal splits through which rain could enter by gravity flow. At Orange none of the treated ends became wet.

Four years after repainting, the New Orleans building showed severe peeling (fig. 25), irrespective of treatment. The peeling, however, was of the old, thick film and not on areas that had been scraped clean.

After 4.9 years there were striking differences between the treatments on the Orange building (fig. 26). Where the old film had not been removed, severe peeling occurred despite the treatment. On the section bared with paint remover, deterioration was much more pronounced on the untreated than on the treated parts.

This study suggests that inplace spraying is beneficial on walls showing rain seepage damage, provided the seepage is only light to moderate, no horizontal splits occur in the siding, and no thick paint films are present.

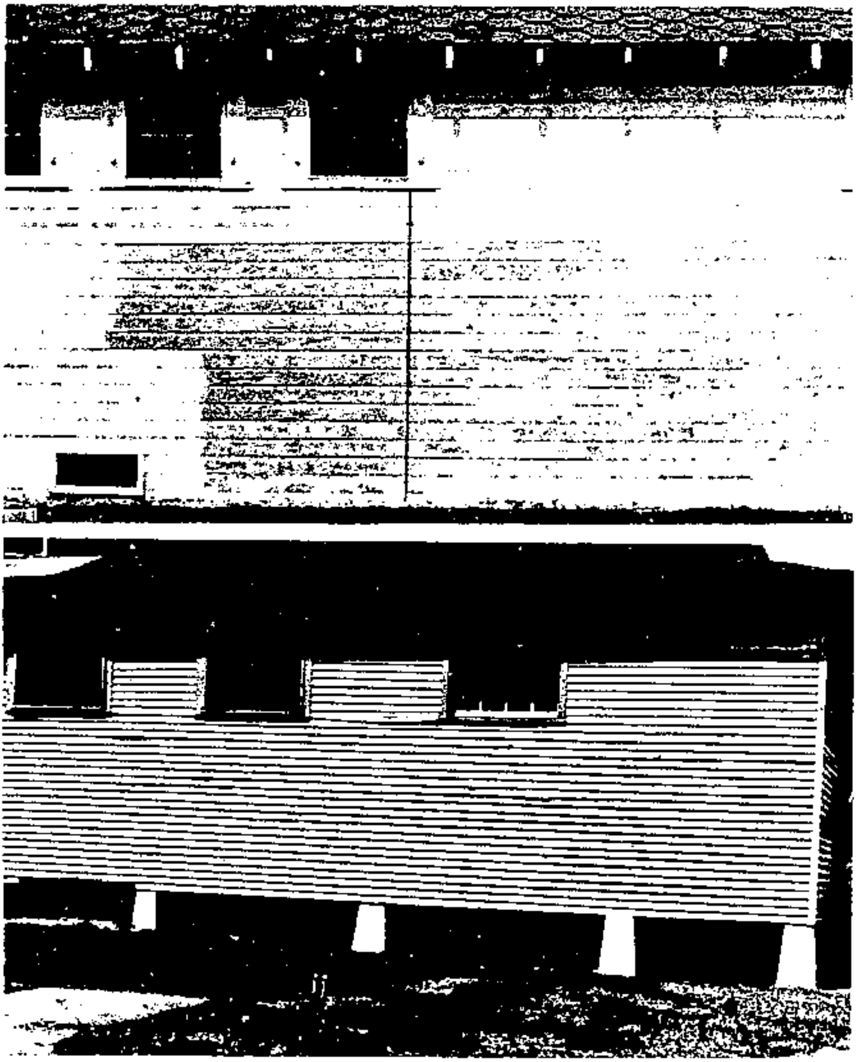

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FIGURE 24.—Buildings in Orange, Tex., (top) and New Orleans, La., (bottom) with paint peeling associated with rain seepage. They were used for studying spray application of water-repellent preservative.

PHYSICS OF WATER ENTRY

Rain tends to run in rivulets over siding and to accumulate in the channel formed by the edge of the trim protruding beyond the siding. It seems to enter lap joints by capillarity and butt joints by a combination of gravity flow and capillarity. Appreciable water may enter along nails after the paint or putty seal is broken. Large volumes of water obviously also can enter through horizontal splits in bevel siding.

The capillary movement of rainwater upward through horizontal joints in siding and its prevention with water repellents and siding designs has been

TABLE 22.—*Effect of a water-repellent preservative spray on siding with rain-seepage damage*

[Percent]

Location and treatment before repainting	Ends with moisture content of more than 20 percent	Average moisture content
New Orleans, La.:		
Scraped:		
Sprayed	20	16
Unsprayed	70	23
Orange, Tex.:		
Paint remover used:		
Sprayed	0	12
Unsprayed	28	19
Scraped:		
Sprayed	0	15

studied at the Forest Products Laboratory (*3*, *23*). In most studies the siding ends were set in white lead to remove them from the test. Experiments confirmed the preliminary reports of the current studies (*26*, *27*) that water repellents are highly effective in preventing rainwetting.

Teesdale (*23*) found that in Wisconsin water repellents protect bevel siding even when applied by brush to the lap joints after attachment. He further found that the wetting of bevel siding could be reduced appreciably by backdressing the lap area to provide a smooth surface in the same plane as the face of the siding, particularly when a horizontal groove was made on the back in the area covered by the lap joint. A drip cut on the butt edge was

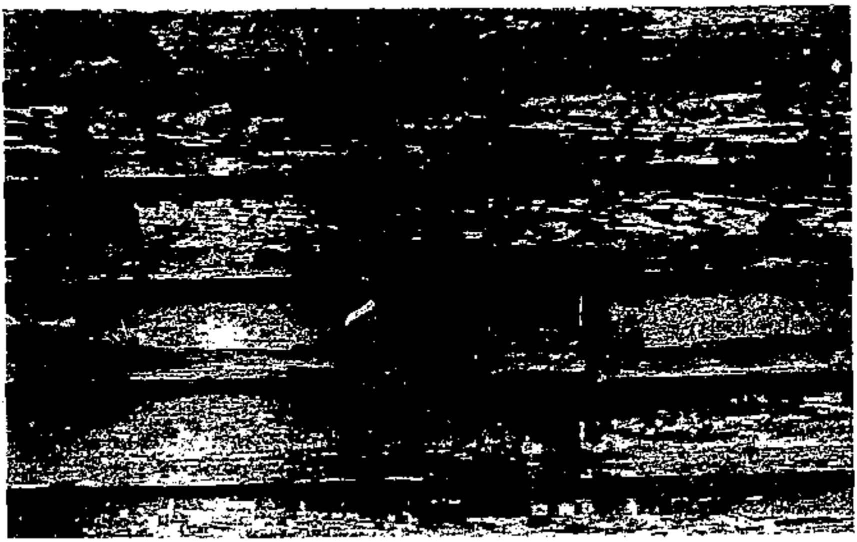

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FIGURE 25.—Paint on test panels of New Orleans building after 4 years. The remnants of the old film peeled badly with or without the water-repellent spray prior to repainting.

FIGURE 26. Condition of paint on the Orange, Tex., building 1.9 years after repainting: *Top*, sprayed with a water-repellent preservative; peeling of thick original paint. *Center and bottom*, old paint removed with a paint remover. Center was untreated and bottom sprayed with a water-repellent preservative prior to repainting.

ineffective. When water was applied with artificial winds of 40 m.p.h., ingress was only slightly greater than in still air.

More extensive studies started by Teesdale and completed by Anderson (3) again showed the effectiveness of water repellents and furnished several observations on the wetting of untreated siding:

(1) Both the amount of rainfall and its duration influenced the amount of wetting. Heavy, brief showers resulted in less wetting than less rainfall over prolonged periods.

(2) Wetting during a 5-year period was essentially the same whether the panels faced the wind or not. This might not have been true had roof overhang been provided. The important point is that normal wind in Madison, Wis., had no direct effect on water penetration.

(3) A vapor-barrier sheathing paper greatly favored water retention.

(4) Tongue-and-groove, Douglas-fir drop siding (pattern 106) resisted wetting more than rabbeted southern pine drop siding or rabbeted western redcedar bevel siding (Dolly Varden pattern).

Two simple studies were made at Gulfport, Miss., to further elucidate how rain wets the back of siding.

In the first, the panels were 18 inches wide and consisted of six or seven courses of siding applied to studs without paper. The siding included southern pine sapwood 105 drop siding, southern pine sapwood one-half-inch boards (surfaced four sides) applied as bevel siding with 1-inch overlap, and standard heartwood western redcedar bevel siding with 1-inch overlap. All panels were painted.

A fine stream of water was applied without pressure to the face of the top board and allowed to run down the panel. The amount of back wetting was estimated at one-half to 4 hours.

Wetting was most rapid when the water was applied at the butt joint of siding to trim (table 23). The rabbeted joint of the drop siding wet rapidly, but little water spread over the exposed back. The pine bevel siding wetted only by water which ran along the horizontal joint and entered the butt joint. In contrast, the cedar bevel siding wetted rapidly by capillary movement over the lap as well as at the butt joint.

Both species and roughness, as well as siding pattern, may have influenced the results of this study. The back of the cedar siding and the rabbet of the drop siding were rough—all other surfaces were smooth.

A second study included the effects of roughness and wood species on capillary movement over the surface. Twelve-inch lengths of 2-by-4's of southern pine sapwood, Douglas-fir heartwood, western redcedar heartwood, and redwood heartwood were ripped lengthwise to remove one-fourth-inch thickness of wood from one edge. This gave pieces with one smooth and one rough (freshly sawed) edge. One sample from each of five boards of each species was stood on end in one-half inch of water, and the capillary rise on the surface was measured at intervals of 5, 10, and 15 minutes.

With all species the capillary rise was significantly more (0.05 level) on the rough surfaces (table 24). On both rough and smooth surfaces the rise was significantly greater (0.05 level) on the cedar and redwood than on pine and Douglas-fir. Neither the cedar and redwood nor the pine and Douglas-fir were significantly different.

TABLE 23.—*Wetting of the back of painted siding by a fine stream of water applied to top board and allowed to run down the face of the panels*

[Percent]

Duration of watering	Porportion of back wet		
	Pine drop	Pine bevel	Cedar bevel
Water applied at center:			
30 minutes	1	0	8
1 hour	2	0	28
2 hours	3	0	51
3 hours	4	(1)	60
4 hours	5	(1)	68
Water applied at butt joint to trim:			
30 minutes	4	(1)	50
1 hour	7	(1)	72
2 hours	8	1	83
3 hours	10	2	....
4 hours	10	2	....

[1] Less than 1 percent.

TABLE 24.—*Capillary rise*[1] *of water in wood columns standing on end in water*

[Millimeters]

Species	Unplaned			Planed		
	5 min.	10 min.	15 min.	5 min.	10 min.	15 min.
Douglas-fir heartwood	52	69	78	12	19	25
Southern pine sapwood	61	72	80	14	22	27
Western redcedar heartwood	84	110	124	33	41	48
Redwood heartwood	72	92	102	21	40	48

[1] Each value is an average of five samples.

DISCUSSION AND RECOMMENDATIONS

The hazard from rain seepage varies from practically none in desert areas to very high along the gulf coast. For practical purposes, however, the United States can be divided into three hazard zones (fig. 27) based on observed conditions of buildings, length of the warm season, and amount of precipitation as rain. Melting snow on roofs increases seepage only slightly.

In areas of low to moderate hazard the most important consequences of seepage are paint failure and warping; in the high-hazard areas decay also is a common effect.

In the high-hazard zone extreme care is needed in designing buildings to prevent seepage. As will be pointed out, some relaxation in design is possible in the moderate zone; in the low-hazard area seepage is generally minor, and damage can be prevented by simple means.

Rainwater enters through joints, splits, or other openings by gravity flow

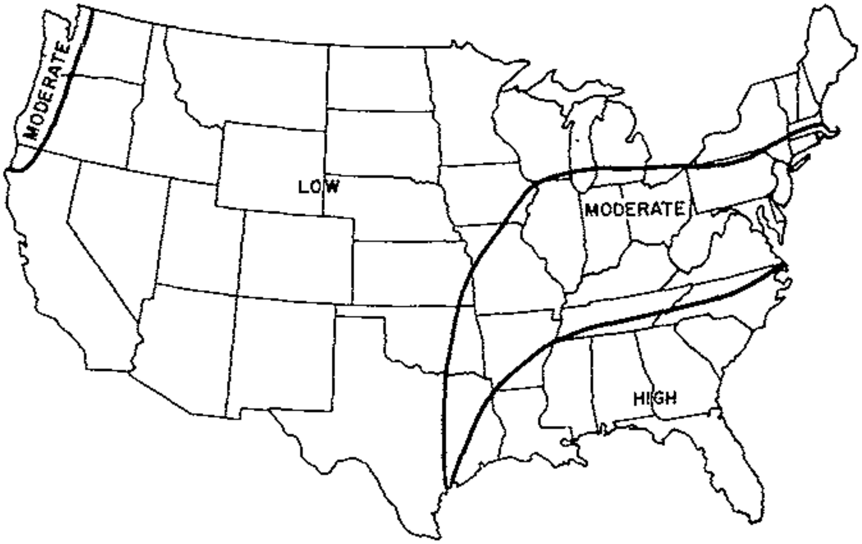

FIGURE 27.—Hazard zones for rain seepage.

or capillarity. Accurate carpentering to produce tight joints will not prevent serious seepage by capillarity during prolonged rain. For example, the tight machine-made joints in high-quality wood sash form effective capillaries through which rainwater enters the wood, accounting for the frequent occurrence of stain and decay in sash. Tight joints, however, reduce the amount of water entering by gravity flow. The amount of capillary movement varies with wood species and smoothness of the surface.

Water penetration can be reduced or prevented by sealing joints with caulking compounds or paint. Caulking must remain pliable; too frequently it shrinks from the edges of the crack it fills. Paint seals joints for even a shorter period, and tends to reduce drying once leakage starts. It should not be depended on to prevent decay. Paint does reduce wetting associated with surface checking and ring separation. It is used primarily for appearance and protection against weathering, not for preventing rain seepage at joints. However, the back and end priming of siding and trim does significantly reduce wetting.

NEW CONSTRUCTION

Best protection involves one or more of several principles: (1) Designing buildings so that minimum rain reaches the exterior surface other than the roof, (2) favoring exterior surface details that promote rapid drainage past joints; i.e., avoid water-trapping features, (3) designing walls so that water that penetrates siding can dissipate inward, (4) applying water repellents or priming with white lead paint the back and unexposed ends of wood likely to be subject to rainwash, and (5) using preservative-treated or naturally decay-resistant woods.

The most important design factor determining the amount of rain striking the exterior walls is roof overhang, both at eaves and gables. The amount needed varies from practically none to 5 feet (table 3) and is determined mainly by the amount of rainfall and the velocity of accompanying winds. In the high-hazard zone a building with a hipped roof is superior to one with gables. Single-story houses with hipped roofs and 30 inches or more of roof overhang are now common in high-rainfall areas.

Eave gutters also are beneficial. About half their effect seems to be from an extension of eave width; presumably the rest is by removal of roof runoff so that wind cannot blow it against the wall. The slab-on-ground foundation has greatly reduced the usual clearance between wood siding and the soil, thus increasing the splash problem. A good roof overhang with eave gutters will prevent most splash damage. In many circumstances, eave gutters are valuable in preventing roof runoff from flowing over nearby walls (fig. 2) or from striking roofs, porches, balconies, or other flat surfaces below.

There are several means of restricting the entry of water that does reach the building surface. Flashing is a well-developed item for protecting door, window, and other openings, the roof edge, and the juncture of siding and roofs (*4*). Flashing leads water past points where it can penetrate the structure. In the case of siding, experience and experiments show that wetting can be materially reduced by placing corner trim over the ends of drop siding or using metal corners on bevel siding. Careful carpentering to avoid splits is necessary.

Features that favor moisture trapping can be avoided. For example, the standard notched step carriage is safer than one with cleats (table 4), and capping the newel with a step rail is safer than abutting the rail to the edge of the newel (fig. 8). However, design alone must not be relied upon to protect such high-hazard features as steps and porches in areas where rainfall is heavy. It will help, but decay-resistant materials should provide the main protection. Non-moisture-trapping features are most effective under low to moderate hazard. The niceties of design in this respect, such as the use of a cant strip on the gable edges of roofs and the proper design of drip caps (*4*), are being lost in modern house construction.

The surest means of preventing the entry of water that reaches woodwork is a water-repellent treatment. If applied as a dip to preshaped wood before attachment, a high degree of protection results. With moderate protection from rainwetting of exterior walls, water repellents are effective even when applied by spray or brush to all joints after the wood is in place. Under severe conditions these inplace treatments are much less effective than preattachment dips. Based on labor costs, the most feasible alternative is the use of stock treated before reaching the building site, coupled with inplace retreatment of all end surfaces to insure protection of untreated wood exposed when the lumber is cut to size. One disadvantage of water repellents has appeared. In buildings inadequately protected against winter condensation in walls, water collects as droplets on the back of the siding, instead of being absorbed. Since these droplets may dissolve extractives from redwood and western redcedar siding, they often discolor the exterior paint as they run down. This occurrence can be prevented by treating only the lap and end joints after attachment or by providing a vapor seal on the inner wall surface.

The priming of ends and backs of siding and trim with an oil paint also significantly reduces rain seepage.

Rain that enters wood will not dry rapidly by vapor moving through the joints by which the liquid water entered. The usual oil paints greatly retard drying of the wood beneath them. Some of the newer emulsion paints have a higher vapor permeability, but not enough to insure sufficiently rapid drying to avoid fungus activity when appreciable seepage occurs. Therefore, wood exteriors that become wet must dry mainly to the inside. Hence, sheathing papers under wood siding should be breathing paper of high vapor permeability. Wood sheathing, and probably some sheet materials, seriously reduce inward drying when moderate to severe seepage occurs, and thus favor moisture accumulations in siding even when no sheathing paper is present. Thus, in areas of high rainfall the walls of buildings with wood exteriors over sheathing must be designed to prevent all but minor rain-wetting. More leeway in the use of sheathing may be possible if the siding is laid on 1-inch nailing strips to provide ventilation between it and the sheathing.

Decay and other problems associated with moisture seepage are accentuated by the use of fungus-infected lumber. Fungi—particularly the mold *Trichoderma*, a common inhabitant of coniferous lumber—greatly increase the absorptiveness of wood. Lumber that is appreciably stained probably also has invisible incipient decay infections. These may persist for long periods in dry wood and revive on rewetting. It is difficult to determine if lumber is free of all fungus infections, but reasonable assurance can be had by selecting only bright, kiln-dried lumber for woodwork exposed on the surface of buildings. Normal kiln-drying schedules do not affect decay resistance (*5*, *17*, *19*).

CORRECTING EXISTING STRUCTURES

Minor seepage frequently can be alleviated by simple means; severe seepage may require major changes in the building. The following methods can be used to reduce seepage:

1. When paint peeling or discoloration is restricted to areas near joints, a water-repellent preservative applied to the joints by brush or spray may prevent further damage. The preservative should be applied copiously, to wet all unpainted wood exposed in the joint. The excess should be wiped from painted surfaces, and repainting delayed a week or more after treatment. Inplace treatments are particularly effective in correcting minor seepage in siding, screens, screen doors, and window and door trim.

2. The addition of eave gutters will help if roof overhang is inadequate or if roof runoff strikes a wall or splashes up from the ground, sidewalk, or porch roof, and discolors woodwork. Defective gutters or downspouts should be repaired or replaced.

3. Pieces of wood with splits, particularly siding, should be replaced if located where they are wet by rain.

4. If decay occurs in fascia and other roof-edge members, replacement with all heartwood of a decay-resistant wood or pressure-treated wood is best in regions of heavy rainfall. Elsewhere a moderately decay-resistant wood or one dipped in a water-repellent preservative probably is satisfactory.

When reroofing, a roof-edge flashing or gravel stops should be added or existing ones redesigned to provide an effective drip edge. Where evidence of leakage occurs at the edge of flat roofs, horizontal lap joints in gravel stops should be checked and resealed as often as necessary to keep them tight.

5. Good protection can be given to windows, porches, and steps by adding canopies or awnings. Where considerable decay occurs and an effective covering (awning) cannot be added, the structure should be replaced with decay-resistant wood or other material. Inplace treatments have not shown promise for prolonging the service life of porches and steps in areas of appreciable decay hazard. The exception is the porch column where decay is essentially limited to the base. Here, an inplace treatment is effective.

6. Where heavy seepage in siding has resulted in appreciable decay, inplace treatments with water repellents usually are ineffective. It is best to replace the siding with decay-resistant wood given a water-repellent treatment. All-heart redwood and western redcedar are satisfactory, and so are less decay-resistant species impregnated with a suitable preservative. Covering the wood with asbestos-cement shingles over a water-resistant building paper is equally effective and often cheaper. Very likely some of the metal sidings and wood shingles (redwood or western redcedar) would also serve. Such coverings, however, must not be used if winter condensation is a problem—unless an effective vapor seal can be added near the inner face of the wall. In contrast, vapor-resistant coverings on the outer face of walls will help reduce any summer condensation associated with air conditioning.

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