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PORIA INCRASSATA ROT: PREVENTION AND CONTROL IN BUILDINGS
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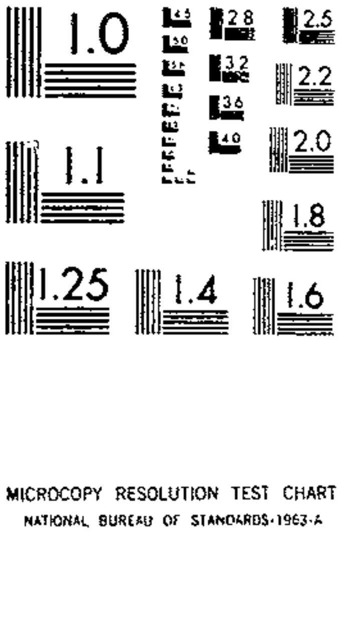

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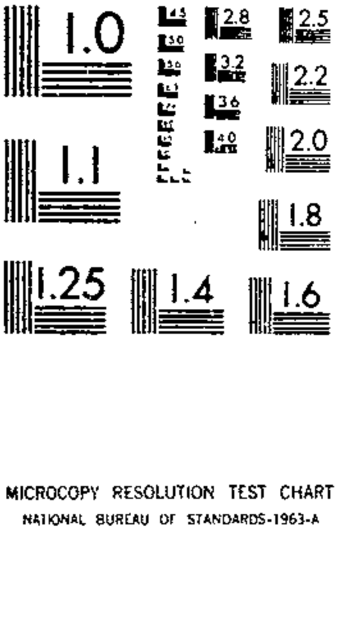

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NATIONAL BUREAU OF STANDARDS-1963-A

Poria Incrassata Rot:

Prevention and Control in Buildings

by Arthur F. Verrall[1]

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INTRODUCTION

The water-conducting fungus, *Poria incrassata* (Berk. and Curt.) Burt, causes the most spectacular decay of wood in buildings in the United States. It produces large, tough, water-conducting strands (rhizomorphs) which, when rooted at a constant and abundant supply of moisture, can wet wood of a variety of species many feet away. Thus the fungus can destroy wood normally too dry to decay. Attacks are not frequent, but the rapidity of attack and the extent of damage make this pathogen an important enemy of wood in service.

Once *Poria incrassata* is well established, it may destroy large areas of flooring and walls every year or two unless the causes are found and removed. Fortunately, control usually is simple (permanent elimination of the water supply).

The fungus occurs primarily in the Southern United States but sometimes as far north as Canada. Its counterpart in Europe, and to a lesser extent in Northern United States, is *Merulius lacrymans* Fr. In general the same control measures apply to both fungi.

This bulletin reviews the literature on *Poria incrassata* and summarizes 30 years' experience with its control in the South.

CLASSIFICATION

The water-conducting or building *Poria* was first described as *Merulius incrassatus* by Berkley and Curtis in 1849 from a sporophore on a pine stump in South Carolina. In 1917 Burt transferred the fungus to *Poria*: *Poria incrassata* (Berk. and Curt.) Burt (*4*).[2]

Several mycologists have questioned Burt's decision. Overholts (*34*) stated in 1942 that "the dark color of the spores, yet at the same time the failure of the tissue to darken with KOH, and the pale color of the subiculum make this species an anomaly in either of the colored sections of the genus." About the same time Murrill (*33*) erected the genus *Meruliporia*, which remains a monotypic genus including only *M. incrassata* (Berk. and Curt.) Murrill. Donk (*15*) in 1948 transferred the fungus to *Serpula*. The most recent taxonomic discussions place the fungus in *Poria* (*11*) or *Meruliporia* (*8*).

Until there is agreement among mycologists it seems best to retain Burt's name, which is generally used by pathologists.

The literature contains good descriptions of sporophores (*3, 8, 24, 29*) and rhizomorphs (*24*), and of the appearance and behavior of the fungus in culture (*3, 11, 24*).

[2] Italic numbers in parentheses refer to Literature Cited, page 24.

DISTRIBUTION

Poria incrassata has been reported chiefly in the United States. Only three occurrences have been established elsewhere, in Ontario (*3*) and British Columbia (*18*). A fungus resembling it was found fruiting on an imported softwood in a kitchen sink in Sydney, Australia, in 1916 (*39*), but absence of spores prevented a positive identification.

Humphrey in 1923 (*24*) stated that the fungus was spreading rapidly in the South and on the west coast, but there is little evidence today of geographic spread. More likely, prevalence in a given area has increased or waned with changes in building designs and practices.

Figure 1 gives the relative prevalence in terms of number of cases reported. The map is based on published accounts, observations by the author, and correspondence with those who have encountered the fungus in buildings or have herbarium material. Most reports are from the Southeastern States.

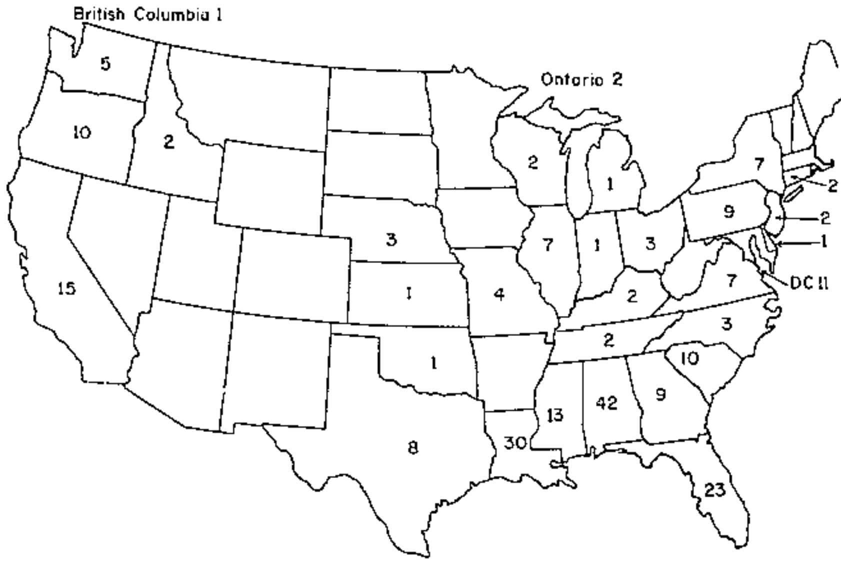

Figure 1.—Number of occurrences of *Poria incrasata* reported since 1849.

Up to 1913, *Poria incrassata* had been reported only from four collections made in the woods (*24*):

> On a pine stump in South Carolina by Curtis in 1849;
> On pine bark and wood at Selkirk, N. Y., by Peck in 1888;
> On dead limbs of *Pinus nigra* at Newfield, N. J., by Ellis; and
> On a rotten prostrate trunk of *Thuja plicata* at Shelton, Wash., by Humphrey in 1910.

The herbarium at the Pacific Southwest Forest and Range Experiment Station, Berkeley, Calif., contains collections from the bark of living *Sequoia sempervirens* (D. Don) Endl. in Humbolt and Santa Cruz Counties. The same herbarium contains a third collection from the bark of a downed tree of the same species. All collections were made in 1924.

In recent years the fungus was found attacking ammunition boxes stored on the ground in pine woods in Mississippi (*49*) (fig. 2). It was isolated from a dead Virginia pine near a woods site where the soil had been artificially inoculated (*14*), from a bridge timber near Gainesville, Fla., and from test stakes in Wisconsin and Mississippi (*17*).

It probably occurs more frequently in the woods than the literature indicates. As it is sensitive to drying it may not commonly fruit in the open; further, the fruiting bodies deteriorate rapidly, reducing the chance of observation.

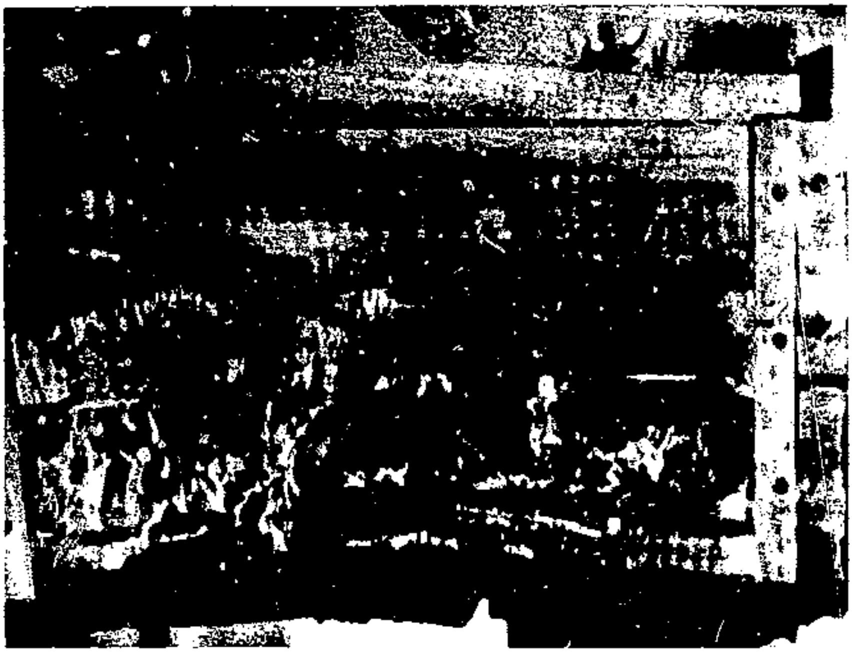

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Figure 2.—Ammunition box decayed by *Poria incrassata*.

Humphrey (*24*) mentioned two instances and Baxter (*3*) one instance of infections in yards for air-seasoning lumber. The author observed it on pile foundations in both hardwood and pine yards at Clarks, La. Very likely the fungus is more prevalent in air-seasoning yards than these observations indicate. Because of the openness of yards, however, infections probably are fewer and less extensive than in covered storage sheds.

The fungus was first recorded as a building decayer in 1913, when Ames (*2*) reported it (as *Poria atrosporia*) from Auburn, Ala. Humphrey found it in lumber storage sheds in Alabama and Mississippi in 1914 (*25*).

Since then it has been reported attacking buildings in 29 States and the District of Columbia (*8*, *17*, *19*, *23*, *24*, *27*, *31*, *37*, *42*, *48*, *51*, *53*).

Some occurrences are probably missed, because frequently the only fungus isolated from final decay is a *Penicillium*, probably in the *Penicillium divaricatum* group. Whether this mold is parasitic on the aging mycelium of *Poria incrassata* or whether some of the degradation products of *Poria* rot are particularly attractive to *Penicillium* is not known.

PHYSIOLOGY

Poria incrassata differs in several important characteristics from most other building decay fungi. Its ability to attack wood of most species and to conduct water to the decay site accounts for its destructiveness. Its extreme sensitivity to drying affords a basis for simplified control (see p. 21).

Woods Attacked

In buildings, *Poria incrassata* has attacked lumber of several species. southern pine, ponderosa pine, Douglas-fir, western redcedar, redwood, cypress, juniper, white fir, hemlock, oak, red gum, magnolia, and maple (*3*, *17*, *24*, *37*, *42*, *45*).

It has also attacked wood of eastern white pine (*49*), Austrian pine (*24*), and Virginia pine (*14*).

Humphrey (*24*) grew *Poria incrassata* in the laboratory on the wood of 13 genera of conifers and 25 genera of broadleaf trees. Severe decay developed in heartwood of most species, including *Castanea dentata* (Marsh.) Borkh., *Juglans nigra* L., *Quercus alba* L., *Robinia pseudoacacia* L., *Taxodium distichum* (L.) Rich., and *Sequoia sempervirens*. Only the heartwood of *Chamaecyparis nootkatensis* (D. Don) Spach, *Libocedrus decurrens* Torr., and *Taxus brevifolia* Nutt. showed appreciable resistance.

More recently Diller and Koch exposed 40 North American and exotic woods to *Poria incrassata* under field conditions (*13*). Several tropical hardwoods were resistant. All the North American species were attacked, but the heartwood of *Juniperus virginiana* L., *Sequoia sempervirens*, *Maclura pomifera* (Raf.) Schneid., and *Pinus palustris* Mill. showed moderate resistance.

Neither study was comprehensive enough to establish the relative susceptibility of species. Scheffer (*41*) found high variation in resistance of individual western redcedar trees. When the various reports are considered along with other laboratory studies (*22*, *44*) and instances of extensive decay of all-heart cypress in buildings (*2*, *19*, *24*, *37*), it is obvious that *Poria incrassata* can severely attack the common construction woods, even those generally classed as high in natural resistance.

Temperature Relations

The cardinal temperatures (degrees C.) for *Poria incrassata* are:

	Minimum	*Optimum*	*Maximum*
Humphrey and Siggers (*26*)	Less than 12	24–30	34
Leutritz (*28*)	Less than 21	26–28	Above 35
Davidson and Lombard (*11*)	—	24–26	34–36

These cardinal temperatures place *Poria incrassata* in the intermediate temperature group of fungi tested by Humphrey and Siggers. In contrast, *Merulius lacrymans*, the European water conductor, is a low-temperature decayer and *Lenzites saepiaria* (Wulf.) Fr., *L. trabea* (Pers.) Fr., and *Daedalea berkeleyi* Sacc., which commonly decay exposed woodwork, are high-temperature fungi.

Poria incrassata is more sensitive to high temperatures than most decay fungi. Chidester (*6, 7*) found that it was killed in moist wood at temperatures only moderately above air-temperature maxima and considerably below those required for commercial kiln-drying of lumber (table 1).

TABLE 1.—*Effect of applying heat to infected wood with moisture contents above fiber saturation*[1]

Fungus	External temperature	Duration of heating	Time for interior wood to reach external temperature	Proportion of sticks with fungus dead
	°C.	*Minutes*	*Minutes*	*Percent*
Poria incrassata	40	155	21	100
Do.	45	55	24	86
Do.	50	30	30	100
Lenzites saepiaria	50	625	24	0
Do.	60	625	27	75
Lenzites trabea	50	625	24	0
Do.	55	625	24	0
Trametes serialis	55	625	24	100

[1] From Chidester (*6, 7*).

Water Requirements

The rot caused by *Poria incrassata* is often called "dry rot," presumably because the fungus, by conducting water, attacks wood that is normally dry. During active decay, however, the wood is moist to the touch. Decay caused by many other fungi in wood made wet by rain seepage is alos called dry rot. Between rains the wood so attacked may be dry for long periods (*50*), during which these infections remain dormant. In contrast, *P. incrassata* survives only a short time in dry wood. Regardless of the fungus alluded to, the term dry rot is a misnomer.

Poria incrassata is extremely sensitive to drying. It was viable in only 53 of 105 samples of rotted wood received at the U.S. Forest Products Laboratory. In naturally infected wood, it could not survive 32 days of air-drying. All artificial infections were dead in 1 day at 30 percent relative humidity, in 5 days at 65 percent, and in 10 days at 90 percent (*42*). Findlay and Badcock (*20*) reported that both *P. incrassata* and *Merulius lacrymans* are sensitive to drying. In contrast, such fungi as *Lenzites trabea* and *L. saepiaria* lived at least 9 years in wood at 12 percent moisture content. These findings plus observational evidence led to the simplified control measures later described in this bulletin (p. 21).

Merulius lacrymans and several other fungi produce considerable metabolic water (*30, 32*)—Miller (*32*) calculated that the amount approximates the quantity theoretically available from the degradation of cellulose to H_2O and CO_2. That *Poria incrassata* also produces metabolic water was shown by a simple laboratory demonstration. Pieces of southern pine (0.5 by 1.5 by 3 inches) were placed in jars containing a limited amount of water and covered loosely to permit aeration. Some pieces were inoculated with small agar disks containing *P. incrassata*, and some were left uninoculated as checks. After 2 years on a laboratory shelf the inoculated pieces were wet and the fungus was still alive; uninoculated pieces had dried below the fiber saturation point.

However, extensive observations in infected buildings and unpublished studies by Scheffer at the U.S. Forest Products Laboratory strongly suggest that only under unusual conditions, i.e., in a continuously saturated atmosphere, can *Poria incrassata* maintain itself on metabolic water alone. Metabolic water was not sufficient to maintain the fungus in heavily infected pieces of 2 by 4 southern pine sapwood placed in relative humidities of 90 and 95 to 97 percent. Also, when uninfected nominal 2-inch lumber with initial moisture contents of 30 to 50 percent was exposed to relative humidities of 65, 75, 90, and 95 to 97 percent, the measured evaporation rates were greater than could be compensated by the amount of metabolic water likely to be produced by an infection.

The mass of evidence from both laboratory and field observations is that in most cases *Poria incrassata* can survive only with a constant outside source of moisture, usually conducted by the fungus to the area of active decay. Severe infections invariably have an abundant outside moisture source. Nonetheless, metabolic water cannot be completely ignored in control practices.

Tolerance to Toxicants

In addition to attacking most woods classed as naturally resistant, *Poria incrassata* tolerates many copper fungicides. Soil-block tests show it resistant to chromated copper arsenate (*28*, *38*), copper naphthenate (*9*, *16*, *38*), acid copper chromate (*9*), copper chromate (*10*), and copper-chrome-arsenate (*10*). Of the copper fungicides tested, only copper 8-quinolinolate was effective (*9*). Among noncopper fungicides, creosote (*9*, *28*), fluor-chrome-arsenate-phenol (*9*, *21*), and sodium fluoride (*35*) are effective, while rosin amine-D pentachlorophenate is not (*9*). Pentachlorophenol is intermediate in effectiveness (*5*, *9*). Results with zinc chloride are somewhat conflicting: in soil-block studies, the fungus was tolerant (*38*); in agar test it was highly sensitive (*28*, *36*, *38*).

Young (*52*) showed that *Poria incrassata* is more tolerant of copper sulfate in agar at pH 2 than at pH 6.

Da Costa and Kerruish (*10*) tested 35 species of *Poria* against two copper fungicides in soil-block studies. All species causing white rot were inhibited by both fungicides. Most brown rotting species, including *P. incrassata*, were highly tolerant of copper chromate, and four (*P. vaillantii* (Fr.) Cke., *P. incrassata*, and two unidentified species) showed appreciable tolerance of copper-chrome-arsenate.

In ground tests at Gulfport, Miss., and Madison, Wis., *Poria incrassata* has been isolated from southern pine stakes pressure-treated with copper naphthenate, chromated copper arsenate, fluor-chrome-arsenate-phenol, and chromated zinc arsenate (*17*).

Practical significance of the tolerance to copper fungicides is uncertain. No failures of preservatively treated wood in buildings have been reported. In soil-block and stake tests the treated wood was subjected to attack under conditions more conducive to decay than are likely to occur in buildings. At present, there is little justification for excluding any commonly accepted preservative in construction. In repairing damage by *Poria incrassata*, however, wood treated with a noncopper fungicide should be used.

That the fungus can spread over the surface of treated wood was shown in the current studies by laboratory and field tests. Southern pine sapwood pressure-treated with 8 pounds of creosote (American Wood Preservers' Association No. 1), southern pine sapwood pressure-treated with fluor-chrome-arsenate-phenol, untreated pine sapwood, and boat-grade cypress heartwood were all obtained from commercial sources. The *Poria incrassata* isolate was from a severe case of rot in Selma, Ala.

For the laboratory phase, three pieces of each wood (0.5 by 1.5 by 3 inches) were placed on end in 0.5 inch of sterile water in individual glass jars and inoculated with *Poria incrassata* growing on wheat kernels. After 5 days' incubation at room temperature the inoculum on the creosoted wood was dead; that on wood treated with the inorganic salt had spread up to 0.9 inch over the wood; that on the untreated wood had covered much of the surface (fig. 3,*A*). No decay occurred in any of the treated wood over a 2-year period.

For the field phase, five stakes (2 by 3 by 18 inches) of each wood were placed with one-third their length in the soil under hardwood shade and enclosed in a wooden box with a leaky cover to permit rain seepage (fig. 3,*C*). Five 4- by 4-inch concrete posts were used to determine if the fungus would spread over concrete. Pine chips were scattered over the soil as feeder blocks, and a few pieces of test wood were laid horizontally on them. The plot was then inoculated with *Poria incrassata* growing on wheat kernels.

After 8 months, mycelium had spread over the surface of the samples laid horizontally, including the creosoted ones (fig. 3,*B*). The toxicity of creosote in one study and not in the other may have been due to its vapors, which were confined in the culture jars but dissipated in the field.
Observations at 27 months showed:

Cypress heartwood. Rhizomorphs on the belowground parts of three of five stakes. Heavy mycelial growth on the aboveground part of one and heavy decay in all five.

Creosoted pine. Rhizomorphs belowground on four of five stakes. All five sound.

Pine treated with fluor-chrome-arsenate-phenol. Rhizomorphs belowground on two of five stakes. Decay medium in three and heavy in two.

Concrete. Rhizomorphs belowground on all.

Untreated pine. All essentially destroyed. A few rhizomorphs observed at 10 months.

Thus creosote, even though giving complete protection against decay, did not prevent spread of mycelial fans and rhizomorphs over the surface. The decay in the salt-treated wood may have followed leaching. Usually this preservative is not recommended for use in soil contact in areas of high rainfall.

The amount of surface mycelial growth on the aboveground parts of stakes was small, even though decay extended to the top of the untreated pine and cypress stakes. The mycelial development shown in figure 3 occurred on the undersides of samples resting on the feeder chips. This restricted surface growth is further evidence of the sensitivity of *Poria incrassata* to drying.

Typically, infections of *Poria incrassata* in buildings start in basements or crawl spaces where wood is in contact with the soil or with moist concrete or bricks. First, papery mycelial fans, whitish with a yellow tinge, grow over the surface of moist wood (fig. 4,*A*), or more commonly between sub- and finish floors, between joists and subfloors, or in other protected places. If sufficient water is available, the mycelium spreads rapidly for distances up to 25 feet, destroying framing, sheathing, paneling, flooring, and other cellulosic materials.

When wood with intermediate to final decay is dried, it usually shrinks severely (fig. 5). For this reason, dry weather may cause wide cracks to open between flooring boards (fig. 6). Such cracks, or depressed areas in painted woodwork, may be the first evidence of infection.

Irregular vine like rhizomorphs branching in the soil or extending to some other constant supply of water may appear on foundations, framing, or the underside of flooring (fig. 4,*B*). They are dirty white, sometimes with a yellow tinge, or with age brown to black. They commonly are ¼- to ½-inch wide but sometimes reach 2 inches. They have a dense outer layer and a porous interior containing enormous hyphae that probably act as water-conducting tubes (fig. 7). Rhizomorphs may be inside brick walls with loose mortar or inside hollow blocks, or may be absent. If they are lacking, the mycelial fans appear to assume the function of conducting water. Fans tend to develop mycelial strands resembling incipient rhizomorphs.

Fruiting bodies do not always form in buildings. When they do occur they are found on well-rotted wood in such places as cupboards or the underside of flooring. They are succulent, flat, up to ½-inch thick, and pale olive gray with a dirty white to pale yellow margin when young. With age they become dry and brown to black. The surface is covered with fine pores. The fast growth of mycelial mats and rhizomorphs over the wood surface undoubtedly subjects more volume of wood to attack in a given time than does hyphal growth within the wood. Baxter (*3*) reports that cultures grew almost twice as fast in darkness as in light. Much of the surface spread in buildings is in the dark.

Contents of buildings are also attacked. Damage has been reported to the wooden parts of a pipe organ, to documents, and to building papers (*24, 25*). The author has found infections that had spread to woolen carpets, linoleum, oilcloth, canvas, and cellulosic electrical conduits and insulation. Humphrey (*24*) reported that boxes of hardware had become heavily matted with mycelium and that stored galvanized fencing had been corroded, apparently by an acid action on the galvanizing.

All building infections reported in this bulletin were called to the author's attention. In his examinations of hundreds of buildings in random surveys of public housing, military installations, and private housing (*50*) over a period of 25 years, no *Poria incrassata* was found. The surveys included many buildings with features known to be associated with attack—such as forms left under steps, siding touching the soil, and unprotected sills in dirt-filled porches. Attacks by termites or other decay fungi were frequent.

The rarity of *P. incrassata*, even in circumstances favoring attack, makes it difficult to induce building owners to apply the preventive or corrective measures that may avoid extensive damage.

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Figure 3.—*Poria incrassata* on treated wood and untreated cypress heartwood. *A*, Growth on southern pine after 5 days in culture jars: *left*, untreated; *center*, pressure-creosoted; *right*, pressure-treated with fluorchrome-arsenate-phenol. *B*, Mycelium on untreated cypress heartwood *left* and creosoted pine *right* after 8 months in the field plot shown in *C*. *C*, Enclosed field plot (with cover removed) of stakes in artificially inoculated soil.

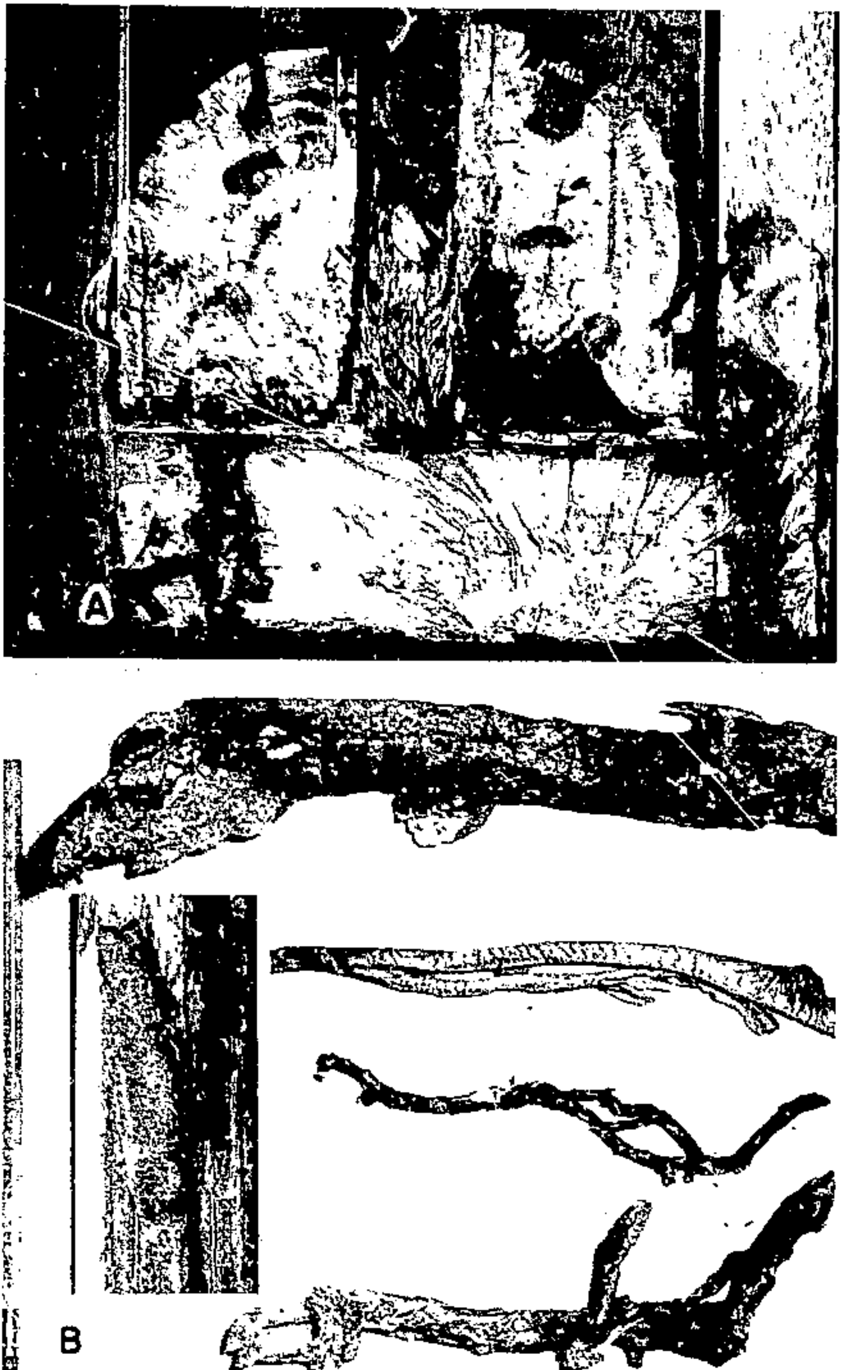

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Figure 4.—*A*, Large mycelial fan of ***Poria incrassata*** that developed between two doors in storage. *B*, Water-carrying rhizomorphs removed from a foundation; inset shows sporophore on a decayed beam.

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Figure 5.—Framing, flooring, joists, and trim of house decayed by *Poria incrasata.*

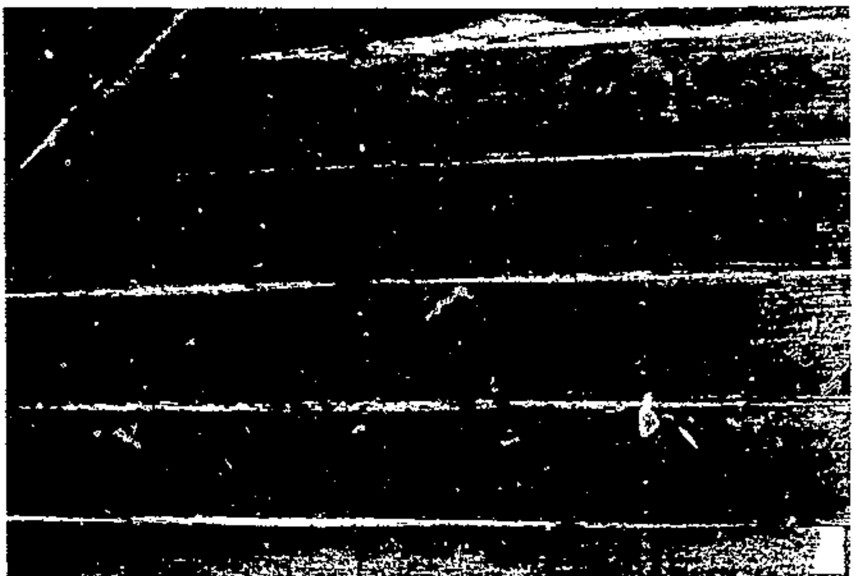

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Figure 6.—During dry weather, shrinkage cracks in floors often outline extent of attack by *Poria incrassata.*

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Figure 7.—Section through a rhizomorph, showing dense rind and porous interior with giant hyphae for conducting water.

Large Buildings

Many authors have reported damage by *Poria incrassata* in lumber storage sheds and surmised that infected lumber from such sheds is a common means of bringing the fungus into buildings (*3, 19, 24, 25, 48, 51*).

Observations were made on infections in seven lumber sheds in Florida and Louisiana. Three were dry-lumber sheds at producing mills; four were at retail yards. All were of open construction, to allow movement of air.

In six of the seven sheds surface water ran under the lumber piles, providing a constant source of moisture in the soil. With one exception, the infections were not in the buildings themselves but in wood foundations for lumber piles or bins. The foundations were pine, either untreated or brushed with creosote, and heartwood of cypress. At one yard some lumber was stored on 4-inch steel rails resting on decayed wood footings. *Poria incrassata* had not crossed the rails into the stored lumber as it had in adjacent piles with wood sills. In one shed, replacing decayed wood footings with concrete extending 4 to 8 inches aboveground stopped further attack although the fungus remained alive in the soil. Where ventilation is poor and humidities high, concrete or steel barriers probably should be higher than 8 inches.

In many of the yards air could circulate under and around the piles. This ventilation appeared to reduce surface growth of the fungus on foundations, but as long as soil moisture was abundant, rot extended 5 to 8 feet up through stored lumber.

The prevention or control of attacks in lumber sheds is simple. The soil should be kept dry by drainage, filling, and installation of roof gutters. Footings should be of concrete. Footings of wood pressure-treated with creosote or pentachlorophenol also are satisfactory if the soil is dry, but heart cypress and other normally decay-resistant woods are not suitable.

Control in one shed was attained by draining, filling under the piles with cinders, and soaking the cinders in infected areas with creosote. New footings of untreated wood remained sound.

Table 2 summarizes infections found in eight large closed buildings. Four of the buildings had wood joists set into brick walls. None of the joist ends were ventilated, but it is unlikely that such ventilation alone would have affected the course of decay appreciably.

The plank flooring of the warehouse at Langdale, Ala., had been replaced several times prior to the inspection. The crawl space was entirely enclosed, had a wet soil and a nearly saturated atmosphere, and contained considerable wood debris. A small stream flowed along the outside of one foundation wall. It is uncertain whether the fungus entered on moist, heavy, structural wood and formed rhizomorphs over the 3 feet of wet brick to the soil or grew the other way from infected debris. It may also have entered along a direct soil-to-joist wood contact that had disappeared before the examination was made. The fungus had little difficulty in growing vigorously under the prevailing moist-chamber conditions. Control was attained by increasing ventilation and spraying the brick foundations with an oil solution of pentachlorophenol.

In the store at Columbus, Ga., the joists were set in a brick wall at outside soil level. A narrow space between this and an adjoining store was wetted by roof runoff. The floor had been replaced repeatedly. The recommendations were to replace the floor with pressure-treated wood or a concrete slab and to reduce wetting by improving drainage and installing eaves gutters.

A defective downspout wetting a brick wall provided the moisture in

TABLE 2.—*Poria incrassata in large buildings*

Location	Type of building	Date			Crawl space	Cause and location of rot
		Built	Rot found	Inspected		
Langdale, Ala.	Warehouse	1890	?	1959	Wet, no ventilation.	Beams set in moist brick wall with creek outside. Some wood debris. Joists and flooring rotted. Previous replacement.
Columbus, Ga.	Store	1910?	?	1950	Moist, poor ventilation.	Joists at outside groundline rotted where set in brick wall wetted by roof runoff. Flooring previously replaced.
Metairie, La.	School	1935	1936	1938	Wet, little ventilation.	Joists rotted where set into brick wall.
New Orleans, La.	Store	1900?	?	1940	Moist, no ventilation.	2 × 4 floor joists resting on soil. Floor previously replaced.
New Orleans, La.	School	1869	1961	1963	Dry, good ventilation.	Joists rotted where set into brick wall wetted by leaky downspout. Adjacent pantry recently remodeled. Forms for concrete floor may have been left.
Gulfport, Miss.	Motel	1917	1940	1940	(Slab on ground)	Remoldeled in 1937. Untreated plates on unprotected slab. Leaky plumbing. Extensive rot in wall.
Hattiesburg, Miss.[1]	School	1926	1929	1929	Wet, poor ventilation.	Wood debris piled up to joists. Joists and flooring rotted.
Cherry Point, N. C.	Apartment	1944	1946	1948	Moist, poor ventilation.	Green lumber, excessive floor washing. Joists and flooring rotted for second time.

[1] Original inspection by R. M. Lindgren.

the New Orleans, La., school. The wall was 12 inches thick and made of absorbent brick and mortar that remained wet between rains. Rhizomorphs were imbedded in the mortar but extended no more than a foot beyond the joist ends; there were no ground connections. A few years before the decay occurred the floor of the adjoining room had been replaced with a concrete slab; possibly some forming lumber was left through which the fungus entered. Though the crawl space was dusty dry and well ventilated, and had a 3-foot clearance, the fungus advanced 10 feet in the joists and flooring. It did not, however, reach any exposed wood surface in the crawl space; the joists and subflooring had sound shells (fig. 8). In contrast, extensive surface growth was found in other buildings with wet crawl spaces. The use of steel joints and sterlization of

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Figure 8.—Joist rotted by *Poria incrassata* in a dry crawl space; a sound shell of wood remains.

the foundation with pentachlorophenol stopped the attack. Wood joints would have been satisfactory if the downspout had been repaired.

In the New Orleans store untreated pine joists were set on the soil rather than suspended. The logical solution, a concrete floor, prevented further decay.

In the school at Hattiesburg, Miss., extensive decay was centered at a pile of lumber ends left in the wet, poorly ventilated crawl space. The pile reached a joist. Removal of the debris, ventilation, and sterilization of the surface of the foundation probably would have prevented further damage, but pressure-treated joists, sills, and subflooring also were installed.

The apartment building at Cherry Point, N. C., had, at the time of inspection, no soil contacts. It was postulated (*48*) that the fungus was getting sufficient moisture from seepage through the floor, which reportedly was regularly swabbed with large volumes of water. A beam supporting the joist centers extended in one place almost to the soil. The original infection may have started at a soil contact that was broken during the first replacements. Regardless of how the fungus entered, it had maintained itself without a soil contact for 18 months since the first replacements were made. Increased ventilation and cessation of excessive floor washing prevented further attack.

Houses

Records on the occurrence of *Poria incrassata* in houses are summarized in table 3. When the attacks occurred most of the houses were only a few years old or had received recent structural changes. This circumstance strongly supports the view that infected lumber is an important means of introducing the fungus into buildings (*19, 24, 25, 51*). Baxter (*3*) suggests that the occurrence of *P. incrassata* in the North may be largely due to the importation of infected lumber.

Very likely infected lumber is not the only means of spread. The house at Dothan, Ala., had a recent addition but the decay started in an older part where a coal pile on wet soil had been in contact with the siding. The fungus may have been introduced on the coal. The infection was adjacent to the bathroom, where a plumbing leak constantly wetted the substructure and allowed the fungus to exist after the coal had been removed.

House-to-house spread was probable at Port St. Joe, Fla. Only 5 of 237 houses of similar design were infected, and all 5 were within a half block of each other. The ammunition boxes infected in south Mississippi (*49*) were piled 100 feet down a gentle slope from where the soil had been experimentally inoculated with *Poria incrassata* 10 years before the boxes were exposed. The boxes were not infected when exposed. Possibly surface drainage or field mice spread the fungus to them.

For all the houses listed in table 3, the probable points of entry were: Dirt fills 21 percent of the cases; wood piers 21 percent; joists and sills 21 percent; wood on groundline concrete slabs 15 percent; siding and sheathing 12 percent; and forms for concrete 6 percent. In the remainder the point of entry was not apparent.

Constant sources of moisture were: Soil, 78 percent of the cases; rain seepage, 16 percent; moist concrete, 12 percent; and leaky plumbing, 9 percent. Sometimes two or more factors were operative.

The surface of the soil was wet under 56 percent of the houses with crawl space, moist under 8 percent, dry under 12 percent, and undetermined under 24 percent. Drying the crawl space by drainage is safer than reducing humidity with a soil cover. The fungus can maintain itself in wet soil under a cover (*12*) and will attack covers containing cellulose fibers (*1*).

Crawl-space ventilation was less important than previously suspected. Ventilation was good under 68 percent of the houses, fair under 16 percent, and poor under 16 percent. However, some of the most destructive attacks occurred where the crawl-space soil was wet and ventilation was poor. Severe damage was found in houses with the best substructure ventilation, i.e., open-pier foundations, but here an abundance of water was supplied by well-developed rhizomorph systems.

When condensation in the crawl-space is an important source of moisture, either ventilation or a soil cover should be provided (*12*). Even without condensation, the lack of ventilation helps to maintain an almost saturated atmosphere, so that metabolic water may become decisive; the Covington, La., house (table 3) and the Langdale warehouse (table 2) probably are examples. Thus humidity control in the crawl space (or basement), either by ventilation or soil cover, is desirable but often will not alone prevent attack.

Sometimes the constant source of water occurs away from the point of initial attack. The fungus undoubtedly entered the Mobile, Ala., house through a sill in direct contact with a dirt fill. The fill was reasonably dry, and extensive decay was limited to a side wall at right angles to the sill, where rain seepage wetted the wood adjacent to a chimney. At Selma, the fungus appeared to enter through forms left under the front porch slab. At the time of inspection the chief water supply was through rhizomorphs rooted at a side pier where a defective downspout wetted the soil and pier.

The house at Covington included an unusual feature. The building paper placed between the concrete block foundation and the wood sill had not been trimmed, and it hung over the inside face of the foundation, reaching the soil in many places. A dense fungus mat formed on the paper. The fungus may have entered through the paper, since asphalt paper is an excellent culture medium for isolating *Poria incrassata* from the soil.

PREVENTION AND CONTROL

Recommendations for control were made to the owners of many infected buildings, and the structures were reexamined soon after control measures were completed and again after 3 to 10 years. This experience formed the basis for the prevention and control measures suggested here.

Prevention

Adherence to the practices listed below usually insures safety from attack.

1. *Use uninfected dry lumber.* Average moisture content of construction lumber should be 6 to 12 percent, depending on locality and type of lumber (*46*). No individual piece should be above 14 percent. *Poria incrassata* can exist only for very short periods at these moisture contents (*42, 45*). No decay should be evident; early infections in stored lumber seldom cause appreciable color change but can be detected by whitish mycelium between piled boards and by softening of the wood.

TABLE 3.—*Poria incrassata in houses*

Location	Built	Altered	Decay found	Inspected	Type of construction	Crawl space	
						Soil surface	Ventilation
Alabama							
Dothan	1920	1944	1946	1948	Crawl space, frame	Wet	Good
Mobile	1880	Yes	?	1940	do.	Dry	do.
Selma	1858	1930?	1937	1940	do.	Wet	do.
Florida							
Jacksonville[1]	1926	No	?	1931	do.	?	do.
Do.[1]	1922?	No	?	1931	do.	?	do.
Do.[1]	1925?	No	?	1931	do.	?	Poor
Lake Wales[1]	1922?	Yes	?	1931	Basement, frame		
Do.[1]	1922?	No	?	1931	do.		
Orlando[1]	1925?	No	?	1931	Slab-on-ground, frame		
Penny Farms[1]	1927	No	?	1930	do.		
Pensacola[1]	1927	No	1930	1931	Crawl space, frame	?	Good
Port St. Joe	1935	No	?	1940	do.	Wet	do.
Tampa[1]	1928?	No	1929	1931	do.	?	do.
Do.[1]	1928	No	1931	1931	do.	?	Poor
Georgia							
Bainbridge	1931?	No	1941	1941	Crawl space, brick veneer	Dry	Good
Louisiana							
Baton Rouge	1935?	No	?	1940	Crawl space, frame	Wet	Fair
Covington	1954	No	1957	1963	Crawl space, brick veneer	do.	Poor
New Orleans	1888	1930's	1942	1942	Crawl space, frame	do.	Good
Do.	1900?	Yes	1937	1937	See remarks; frame		
Do.	1840?	Yes	?	1941	Slab-on-ground, brick		
Do.	1930?	No	?	1937	Crawl space, frame	Moist	Good
Do.[1]	1920	No	1933	1933	do.	do.	do.
Southport	1910?	Yes	1940	1941	See remarks; frame		
Mississippi							
Gulfport	1926	No	?	1944	Crawl space, frame	Wet	Fair
Meridian	1890?	Yes	1937	1940	do.	do.	do.
South Carolina							
Marion	1893	1947	1950	1951	Crawl space, brick	do.	Good
Texas							
Denison	1898	1950	1950	1951	Crawl space, frame	do.	Poor
Terrell	1935?	No	1939	1940	do.	Dry	Fair

[1] Original inspections by C. A. Richards, R. M. Lindgren, or T. C. Scheffer. All were reinspected during

Wood-soil contacts	Source of water	Remarks
None	Wet soil, leaky plumbing	Decay centered where coal was piled against siding. Small plumbing leak adjacent.
Dirt-filled porch	Rain leak in wall	Dirt-filled porch was added at unknown date. Unprotected sill. Leak at fireplace chimney next to fill.
Forms under porch slab, lattice	Leaky downspout	Concrete porch added in 1930. Soil dry except at leaky downspout.
Dirt-filled porch	Soil	Unprotected sill at fill.
Joist to stump	do.	Joist resting on stump at rot center.
Sill	do.	Sill below outside grade in part.
None	Moist concrete basement	Decay centered at unventilated wood closet added in basement at unknown date.
Dirt-filled porch	do.	Decay in partition wall plate in basement and in unprotected sill at fill.
None	Moist slab	Untreated pine plates. No membrane under or over slab.
None	Rain leaks, wet slab	Several houses: rain leaks in some; untreated plates and nailing strips on slab without moisture proofing.
Wood piers	Soil	Untreated wood pier foundation.
Wood piers	do.	Five houses in one square: 232 similar houses not affected. Pier foundation of round cypress and fat pine. Previous repairs.
Dirt-filled porch	Rain leak	Roof leak between house and porch wetted unprotected sill at fill.
Joists	Soil	Soil hump reached joists.
Dirt-filled porch	do.	Unprotected sill at dirt fill; apparently rain leaked into fill.
Joists, dirt-filled porch, siding	Soil, leaky plumbing	Soil humps reached joists; unprotected sill at dirt fill. Flowerbeds up to siding.
None (see remarks)	Wet soil	Planters. Sill near outside grade, bricks soaked by rain, standing water in crawl space. Asphalt paper from sill to soil.
Joists, lattice	Wet soil, defective downspout	Decay centered where fireplace was removed; rubble pile to sill soaked by downspout water.
Wall plates, nailing strips	Soil	Apartment made in elevated crawl space with plates and nailing strips on cinders. Decay at coal bin.
None	do.	Untreated nailing strips in unprotected slab. Floors repeatedly replaced.
Dirt-filled porch	do.	Unprotected sill at dirt soil.
Step forms, debris	do.	
Siding, nailing strips	Soil, watered flowerbed	Elevated crawl space made into living space with creosoted nailing strips on cinder fill. Flowerbed soil over siding.
Sheathing	Soil	Wood sheathing to ground. Previous flooring replacements evident.
Dirt-filled porch	Soil, leaky plumbing. Surface water running into crawl space	Dirt-filled porch with unprotected sill added 1925–1930. Surface water ran into crawl space.
Wood support ?	Soil, defective downspout	Termite damage repaired in 1947; decay in replaced beam apparently was supported by wood post near defective downspout.
Joists, piers, skirting	Soil, green lumber	Studio added in 1949. Decay centered here, where joists and skirting touched soil. Osage orange piers sound.
Skirting, door frame	Soil	Skirting extended to ground. Rear door frame extended to ground.

the 1940's by the author.

2. *Control soil moisture.* Grade building sites so that surface water drains away from the foundation. Eaves gutters and downspouts also help, provided that arrangements are made to drain runoff away from the building. No surface water, condensation from air conditioners, or other water should run into crawl spaces. Sometimes subsurface drainage is necessary to insure a dry site.

When it is not feasible to maintain a dusty dry surface in crawl spaces through drainage, a soil cover should be installed (*12*). Six-mil polyethylene film and 55-pound (or heavier) smooth-surface roll roofing are effective and durable. The crawl-space soil should be covered, but little or no overlap is needed at joints.

With a dusty-dry soil or a soil cover, the amount of ventilation opening through foundations can be greatly reduced. Otherwise, vent openings totaling at least 1/150 of the crawl-space surface should be provided, spaced to avoid pockets of dead air.

3. *Remove all forms and grade stakes* for pouring concrete steps, porch slabs, and foundations. Remove any asphalt felts or other materials containing cellulose fibers, as well as wood forming.

4. *Remove wood debris and stumps* from under buildings.

5. *Avoid dirt-filled porches and terraces.* Self-supporting slabs with a ventilated space below are preferable. Dirt fills are safe, however, if the porch slab is below all wood framing or if the soil is enclosed in a separate foundation wall with sufficient space between the wall and the sill to permit inspection and ventilation. Because dirt fills encourage termite attack, they should be well treated with an insecticide (*40*).

6. *Elevate and waterproof slab-on-ground construction.* The top of the slab should be at least 12 inches above grade in Southeastern United States and 8 inches elsewhere. Water- and vapor-proof membranes should be used under slabs. Although slab construction is safer than previously thought, pressure-treated plates are advisable.

7. *See that basements are dry.* Many modern basements are too dry for much danger of attack, but certain precautions are warranted. Unless pressure-treated, bases of columns, plates for finished partitions, and stringers for enclosed stairs should rest on concrete footings extending at least 3 inches above the floor. Unenclosed plates and stringers are relatively safe in a dry basement. If the basement is damp, only pressure-treated wood should be used in contact with the walls and floor—even with 3-inch concrete footings.

8. *Use treated wood.* The need for treated wood varies with climate, soil moisture conditions, and building design. Climate has its greatest effect on decay associated with rain seepage, and least on decay by *Poria incrassata.*

In all parts of the United States pressure-treated wood or all heartwood of the most decay-resistant woods (redwood, cedars) should be used for the following items:

Sleepers in or on concrete laid on ground.
Sills or plates on concrete on ground.
Framing and sheathing in walls and floors of shower stalls.
Framing and sheathing in cold-storage rooms.
Wood used below first-floor joists in damp basements.

Similar wood should be used for critical items in regions with 25 inches or more of rain (not total precipitation) annually, or where swamps or seepage keeps the soil wet:

- Frames for access doors in foundation walls.
- Frames for outside doors into basements.
- Furring strips belowgrade.
- Sills or plates on concrete or masonry foundations less than 8 inches abovegrade.
- Wood piers in crawl spaces with concrete footings less than 8 inches abovegrade.
- Joists set into brick or concrete walls less than 8 inches abovegrade.

For wood in contact with the soil or continuously wet concrete or masonry, pressure treatment is a necessity. Naturally decay-resistant woods cannot be relied on.

Buildings of accepted design, such as houses conforming to the Federal Housing Administration's Minimum Property Requirements, are safe from the attacks of water-conducting fungi so long as the tenants do not nullify the design. Some dangerous practices are:

- Building up flowerbeds so that soil touches siding.
- Wetting wooden walls when sprinkling lawns. This practice has been sufficient, in new slab-on-ground houses whose owners were trying to establish lawns and shrubbery, to permit development of rhizomorphs connecting the sheathing and the soil.
- Letting plumbing leak for protracted periods. Promptly repaired leaks are not serious.
- Allowing downspouts to become clogged or rusted through.
- Piling wood or other cellulosic material in crawl spaces or against sides of a house.

Control

Most previous recommendations for the control of *Poria incrassata* apparently were based on an assumption that *metabolic* water is decisive and that all traces of the infection must be eliminated. This assumption led to the common recommendation for the removal of all visibly infected wood (*23*, *24*, *25*, *31*, *37*, *51*). In addition, most authors suggested that all apparently sound wood within 2 to 3 feet of visible infection also be removed. Such control is very expensive.

The observational and experimental evidence summarized in this bulletin strongly suggests that *conducted* water is usually decisive, and that even when metabolic water is important, increased ventilation will obviate drastic measures. It is not known who first postulated simplified controls, but they were initially described in 1940 (*47*).

In simplified control, the fungus' water supply is removed so that the infected wood dries and the fungus dies. Only wood too weak to support its load is replaced.

Should the source of water be in doubt, however, all infected wood should be replaced with pressure-treated wood.

When the fungus becomes established, any predisposing conditions must be corrected. Otherwise repeated replacements may be necessary every few years.

The first step in controlling an attack is to locate and remove the source of water. Invariably the fungus receives its water in the general area where decay occurs and usually where it is most severe.

Look for dirt-filled porches or terraces; forms left under concrete steps or on foundations; or stumps, debris, or other wood that makes a direct bridge from the soil to the house or acts as an infection center from which rhizomorphs extend to the building. Break all such wood-soil contacts, and also remove asphaltic papers or other cellulosic materials making bridges. If necessary, regrade the crawl space or soil outside the house to provide wood-soil clearance.

See that surface water drains away from the outside foundation and not into the crawl space. Unless the crawl space is dusty dry, provide drainage, ventilation, or soil cover as described earlier under "Prevention." Polyethylene films are better than roll roofing where *Poria incrassata* is present.

If the crawl space cannot be kept dry, follow up the other corrective treatments by using chemicals to kill the fungus in the soil. The chemicals should be applied both under the house and in a narrow trench around the outside of the foundation. Limited tests suggest that those most likely to be effective in wet soil are 5-percent sodium fluoride in water or 5-percent sodium pentachlorophenate in water. *Note*: These chemicals may kill shrubbery if they come in contact with the roots.

On a dirt-filled porch or terrace, open the foundation and remove the soil from the sill area. The resulting tunnel should be sufficient to permit inspection of the entire sill area under the slab. Ventilate the tunnel. If the sill needs replacement, use pressure-treated wood. Termite-control operators are familiar with the techniques of excavating fills.

Look for and repair plumbing leaks. In shower stalls, a completely new watertight lining may be needed. If the framing and sheathing for the floor and wall of a shower are exposed while repairs are being made, replace them with pressure-treated wood. The most dangerous leaks are fine leaks that are undetected but furnish a constant source of water; severe breaks usually are found and corrected before serious wetting occurs.

When walls or floors are opened to determine the extent of damage, leave them open until the infected wood dries. Sometimes it is necessary to remove tile and linoleum to permit drying of wood below.

Rhizomorphs and other fungus growths should be scraped from concrete and brick foundations. A steel brush is effective after the larger rhizomorphs have been removed by hand. The cleaned surfaces should be thoroughly painted with a preservative. The treatment should include concrete exposed in excavating fills or by removal of forms, edges of slabs, and foundation walls and piers. Watch these treated areas and re-treat if any evidence of new growth appears.

When rhizomorphs are hidden inside concrete blocks or in loose mortar in brickwork, insert a metal shield between the foundation and wood to break the fungus' contacts with a water supply. Or replace a few layers of loose bricks, using a cement mortar.

When an attack occurs in a slab-on-ground house that does not meet waterproofing and ground-clearance standards (12 inches from outside grade to the plate in the South and 8 inches elsewhere), replace all basal plates with pressure-treated wood and use nonwood floors. Provide as much outside clearance as possible and chemically treat the slab edge and adjacent soil.

Attacks seldom occur in a slab house with adequate waterproofing and ground clearance. Excessive wetting of the house wall during lawn sprinkling or establishment of elevated flowerbeds may lead to attack, with rhizomorphs growing over the outside edge of the slab. In these cases, remove the rhizomorphs and chemically treat the slab edge and adjacent soil. If excessive watering is then avoided, the fungus usually will die. But to be safe, replace badly decayed parts of the basal plates with pressure-treated wood.

If extensive attacks occur in basements, replace wood in contact with walls and floors with pressure-treated wood. Do not permit enclosed stairs, partitions finished on both sides, cupboards, and wood paneling on exterior walls in moist basements.

Where preservatively treated wood is called for, use creosote, pentachlorophenol, or noncopper inorganic salts applied under pressure according to Federal Specification TT-W-571. Creosote is particularly effective and is recommended where its odor and color are acceptable.

For nailing strips, subflooring, studs, or other wood onto which finish items are nailed, use a clean paintable treatment. Oily treatments should be avoided, as the oil may creep along nails and discolor trim, flooring, and wallboard.

The chemicals mentioned also are suitable for painting infected foundations, for brushing on old wood before new treated wood is put in contact with it, or for brushing surfaces of fresh cuts in treated wood.

Although all heartwood of decay-resistant species is acceptable in well-designed new houses, do not use it in repairing after an attack. Chemically treated wood is much safer.

Caution: The chemical repellents and fungicides mentioned in this bulletin are poisons. Read and follow closely the directions and precautions on the container label. Improper handling or application can injure plant or animal life, and might contaminate water supplies.

PROTECT

Use Pesticides Safely

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U.S. DEPARTMENT OF AGRICULTURE

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