NATIONAL BUREAU OF STANDARDS REPORT

7173

CRITERIA FOR WATERPROOFING SYSTEMS SHOWER PANS IN RESIDENTIAL DWELLINGS

by

Thomas H. Boone

and

Edgar H. MacArthur

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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Sponsored by

Federal Housing Administration

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1. INTRODUCTION

It has been the practice for many years to specify only sheet metal (mainly copper and asphalt-protected lead) for certain waterproofing functions in dwellings since the behavior of the metals under a variety of long-time service conditions is well known. In recent years, other materials such as plastic sheets, built-up membranes, metal foil laminates, and non-metallic materials have also been used. These latter materials have been used extensively because of their ease of handling and lower cost. But, because of apprehension as to their ability to perform the functional requirements over an extended period of time, they have been continually under careful scrutiny.

This report attempts to give criteria based on laboratory performance instead of service history on shower pan materials (see Section 4). If the service history of a product is known to be at variance with the selection criteria in this report, naturally the service history should be given the most weight.

During this study, attention has been given to reported inadequacies of some materials although no direct evidence was ever presented. The most common opinion was that large percentages of shower pan failures were caused by poor workmanship and not by poor material selection. If this is true, little value will be gained by criteria based on laboratory performance.

The prime function of a shower pan is to prevent water from escaping through the construction. Since the replacement or repair of a faulty shower pan plus the repair of water damaged ceilings and walls is a costly undertaking, it is of paramount importance that a shower pan continue to perform well for the life of the structure.

2. SELECTION OF CRITERIA

The properties considered and a discussion of their importance for the intended application as shower pan systems are as follows:

1) Water resistance
   a) absorption
   b) wetting and drying cycles
   c) waterproofness

2) Temperature resistance
   a) maximum service temperature (140°F)
   b) minimum service temperature (25°F)

3) Resistance to surrounding conditions
   a) alkalies
   b) fungi
   c) insects and rodents

4) Strength
   a) tensile strength
   b) elongation
   c) bursting strength
   d) folding endurance

5) Toughness
   a) abrasion resistance
   b) puncture resistance (fast or impact, and slow)
   c) tearing strength

6) Other properties
   a) flame spread
   b) odor
   c) aging

1) Water resistance:

This is the fundamental requirement of a shower pan material. To have good water resistance, a material must combine the following basic factors: 1) insolubility in water, 2) low water absorption, and 3) waterproofness. Insolubility implies that the material will not be attacked or degraded under conditions of continuous immersion in water. Absorption of water by a material may cause swelling and often reduces strength. When the swollen material dries, shrinkage occurs. Alternate wetting and drying produces a swelling and shrinking cycle which constitutes a fatigue process that eventually weakens the material.

Assuming that a shower pan is exposed to a wetting and drying cycle each day of the year, the ability to withstand this exposure is quite important. However, the duration of the test in a laboratory is short. The water absorption of a material, based on weight gain over the dry weight, might give an indication of durability in this respect for certain materials.

Waterproofness is obviously of prime importance and should be evaluated after the material has been exposed to conditions which will be encountered in use, such as folding, indentation, and alkali soaking (see test results in Table 1).

TABLE 1. HYDROSTATIC PRESSURE TEST[1/]

Material	Water Leakage, hours					
	Original	After Indentation[2/]	After Folding[3/] at 24°F.	40°F.	70°F.	After Soaking[4/]
Polyvinyl chloride	>48	>48	>48	>48	>48	>48
Polyvinylidene chloride	>48	>48	>48	>48	>48	>48
Polyethylene	>48	>48	>48	>48	>48	>48
8 layers of paper	>48	>48	<1	<1	>48	>48
4 layers of paper	>48	>48	<1	<1	<1	<1
Paper & polyethylene	>48	>48	>48	>48	>48	>48
Protected copper	>48	>48	>48	>48	>48	>48
Copper	>48	>48	>48	>48	>48	>48
Lead	>48	>48	>48	>48	>48	>48

1/ According to Section 2.3 of specification.

2/ According to Section 2.4 of specification.

3/ According to Section 2.5 of specification.

4/ According to Section 2.6 of specification.

2) Temperature resistance

The ability of a shower pan material to resist the effects of the maximum expected service temperature (140°F) is difficult to evaluate in the laboratory. Exposure of a material to this temperature in the laboratory is of little value since too long a time is required for effects to appear. Any attempt to accelerate the test by using a higher temperature is unrealistic, since some materials (mainly plastics) can withstand the maximum expected temperature indefinitely, but might be rapidly degraded by the higher temperature.

Evaluation of low temperature properties is important since the materials may be handled and/or installed at low temperatures.

3) Resistance to surrounding conditions

It is necessary that shower pan materials be resistant to alkalies present in concrete receptors. Short term tests in the laboratory with an alkaline solution of concentration equal to the maximum to which the materials would be subjected should show suitability for long exposures.

Moisture and warmth in shower areas provide an environment which often supports the growth of microorganisms. Cellulose products and some plasticizers, which often are incorporated into plastics, may be highly susceptible to fungal attack. Tests for resistance to selected microorganisms should be made.

Although rodents and certain insects are capable of causing damage to plastic films and paper protected products, they have a decided preference for products used in other areas of residential dwellings.

4) Strength

Tensile strength, elongation, and bursting strength, while secondary in importance to water resistance, are nevertheless properties which could be considered. The wide variations in materials used, however, make it difficult to use the results of strength tests as selection criteria. A related property, puncture resistance, is more applicable to the intended use and the results of puncture tests are more meaningful. (See test results in Table 2.)

5) Toughness

In regard to abrasion, it is felt that the lack of a standard procedure, differences in materials, and the difficulty in evaluating test results make it difficult to state an abrasion requirement. In most cases, only extreme mishandling would damage the materials. On the other hand, a good

TABLE 2. DROP-PUNCTURE TEST[1/]

Material	Resistance to Puncture, feet		
	24°F.	40°F.	75°F.
Polyvinyl chloride, 20 mils	>5	>5	>5
Polyvinyl chloride, 60 mils	>5	>5	>5
Polyvinylidene chloride, 28 mils	>5	>5	>5
Polyvinylidene chloride, 56 mils	>5	>5	>5
Polyethylene, 4 mils	1/2	1/2	1/2
8 layers of paper	2	2	2
4 layers of paper	1	1	1-1/2
Paper and polyethylene	1/2	1/2	1/2
Copper, 5 oz., asphalt-protected	>5	>5	>5
Copper, 3 oz., paper-protected	2-1/2	2-1/2	2-1/2
Copper-lead, paper-protected	1-1/2	1-1/2	1-1/2
Copper, 10 oz.	>5	>5	>5
Lead, 0.055 in.	>5	>5	>5

[1/] According to Section 2.7 of specification.

resistance to puncture would prevent damage to the shower pans such as might result from accidental dropping of tools. A property related to this is tearing. In general, the material with good puncture resistance will have good tearing resistance.

6) Other properties

The small quantity of material involved and the location of the shower pan in the structure indicate that there is no purpose in considering flame spread. If a material supports fungal growth, an objectionable odor might be of some concern, and the deterioration of the materials of great concern. Unpleasant and penetrating odor of the materials themselves seems highly unlikely.

Aging under high temperature has already been discussed. Aging in relation to life expectancy is the most desirable means to use in selecting material. Under this criteria, only a relative few have passed the test of age. There is extreme doubt on the part of many about the service life of some of the products in use.

3. MATERIALS

Types of shower pans investigated logically fall into four groups: 1) metals, 2) papers, 3) plastics, and 4) laminated products made up of two or more of the first three. A large variety of these materials was studied in order to help in the selection of the performance requirements. The various materials will be described in terms of the properties that have been discussed.

1) Metals

Aluminum and aluminum alloys are attacked by alkalies associated with concrete and should therefore not be used as shower pan materials where moisture is present.

Copper is relatively unaffected by alkalies. So far as corrosion is concerned, copper shower pans, 10-ounce or heavier, based on extensive service life and laboratory tests, should have a high order of durability.

Lead has a very long history of useful application when exposed to the atmosphere. Under this environment, a protective film of basic lead carbonate or sulphate is formed and the surface may become more noble. A lead shower pan laid without protection under concrete may become severely corroded, especially when the concrete is excessively damp.

Zinc or zinc alloys in contact with damp concrete are generally attacked and therefore should not be used as shower pans.

2) Papers

Papers in themselves are not suitable for this condition of use. However, with multiple layers bonded with asphalt, reinforcing fibers, suitable fungicides and plastic films, their properties are greatly improved. Each material must be judged by performance tests.

3) Plastics

Among the older plastic materials, polyvinyl chloride has been widely used as a moisture barrier material. Polyvinyl chloride has excellent resistance to moisture and to chemicals that might be present in a shower area. Its fungal resistance is good. Rodent-repellent chemicals for vinyl chloride plastics are available if required.

Polyvinylidene chloride - vinyl chloride copolymer (Saran) is a tough, moisture-resistance material with generally good aging resistance and good resistance to fungi.

Conventional polyethylene possesses excellent moisture and chemical resistance. However, the other properties, in thicknesses of 4, 6 and 8 mils, are poor in comparison with plastics such as polyvinyl chloride, Saran, and even most other materials used as shower pans. It has been observed that plastic films of this type are permitted by the F.H.A. as thru-wall flashings in masonry construction, as well as under concrete slabs. The low order of toughness found in this study would question the use of polyethylene in shower pan areas although this same film is being used in areas of potentially abusive treatment.

The new high-density polyethylenes that have come into prominence recently are superior to conventional polyethylene in many physical and chemical properties. They are characterized by improved heat resistance, greater rigidity and tensile strength, increased puncture resistance and greater resistance to environmental cracking. The other so-called linear polyethylene may also have better physical properties and therefore should be judged by laboratory or service performance.

The service life of rubber is longer when completely out of contact with oxygen and protected from sunlight. From the viewpoint of resistance to an alkaline environment, rubber has a high order of durability and is not subject to extraction of plasticizer like PVC. The material is tough and of a selected thickness should serve as an adequate shower pan.

The polypropylenes are a new family of thermoplastics with unique and superior properties beyond those of the high-density polyethylenes. They are of great interest for the future, but are not yet ready for wide use in waterproofing systems.

4) Laminated Products

Paper-laminated products have already been discussed. One of the metals used extensively in laminated sheet is electrolytic copper in 1- to 5-ounce gage (0.002- to 0.007-in. thick). This thin sheet metal is usually protected on one or both sides with kraft paper, cotton, or asphalt, or a combination of these. With the exception of the copper sheet with a relatively thick bituminous coating (approximately 1/16-in.) on each side, the coatings serve only to give the sheet metal rigidity and mechanical protection during application. Under damp conditions they will deteriorate rapidly. The bituminous coating serves as protection during application as well as in use under shower receptors.

Certain laminated products built on the job site, such as three layers of fifteen-pound asphalt impregnated felt with hot asphalt thoroughly mopped under, between, and on top of the layers, provide a tailored and durable waterproofing system.

4. PROPOSED SPECIFICATION FOR SHOWER PANS IN RESIDENTIAL DWELLINGS

1. <u>REQUIREMENTS</u>:

The shower pan shall meet the following requirements:

1.1 <u>Resistance to indentation</u>: After subjection to indentation according to Section 2.4, the material shall show no visible water penetration within 48 hours when tested in accordance with Section 2.3.

1.2 <u>Resistance to folding</u>: After subjection to folding at 24 ±2°F according to Section 2.5, the material shall show no visible water penetration within 48 hours when tested in accordance with Section 2.3.

1.3 <u>Resistance to alkali</u>: After exposure to the solution stated in Section 2.6 for 72 hours, the material shall show no visible water penetration within 48 hours when tested in accordance with Section 2.3.

1.4 <u>Resistance to puncture</u>: When tested in accordance with Section 2.7, the material shall withstand a 3-foot drop without piercing.

1.5 <u>Resistance to fungus</u>: When tested in accordance with Section 2.8, the test samples shall show no evidence of growth of the test organisms.

2. SAMPLING AND TEST PROCEDURES:

2.1 Sampling: The rolls or sheets which are to be inspected or from which test units are to be taken shall be selected at random. In each roll thus selected, test units shall be taken from a portion not including the first or last foot of the rolls, or in the case of flat sheets, not including portions within 6 inches of the edges.

2.2 Rejection procedures: If two or more specimens of any one test unit fail to meet a particular requirement, the material shall be rejected. If only one specimen of any test unit fails to meet a particular requirement stated above, another quantity of material of the same roll or sheet shall be subjected to the required test. If one or more specimens fail in the repeated test, the material shall be rejected.

2.3 Hydrostatic pressure test:

2.3.1 Scope: This method is intended for use in determining the ability of the shower pan material to prevent water leakage.

2.3.2 Specimens: Three specimens, 3- by 3-inches, of the thickness supplied by the manufacturer, shall make up each test unit.

2.3.3 Apparatus: The apparatus, illustrated in Figure 1 and known as the A.A.T.C.C.-type specimen holder for hydrostatic pressure test, shall consist essentially of a pressure tube connected to a specimen holder. The inner diameter of the pressure tube shall be 2.0 inches and the outer diameter 3.0 inches, with a means for introducing water from below the specimen. An extension tube shall be connected to permit a water head of 2 feet with a cut-off valve or other suitable device at the water inlet to the pressure tube, in order to isolate the sample until the desired head is reached.

2.3.4 Procedure: Clamp the test specimen face down in the holder, which has been previously filled with water. Take care to avoid trapped air between the specimen and the water. If necessary, apply grease on lower rim of holder to prevent leakage between rim and specimen. Apply water pressure.

2.3.5 Results: Record time in hours at the first sight of water penetration under a 2-foot water head.

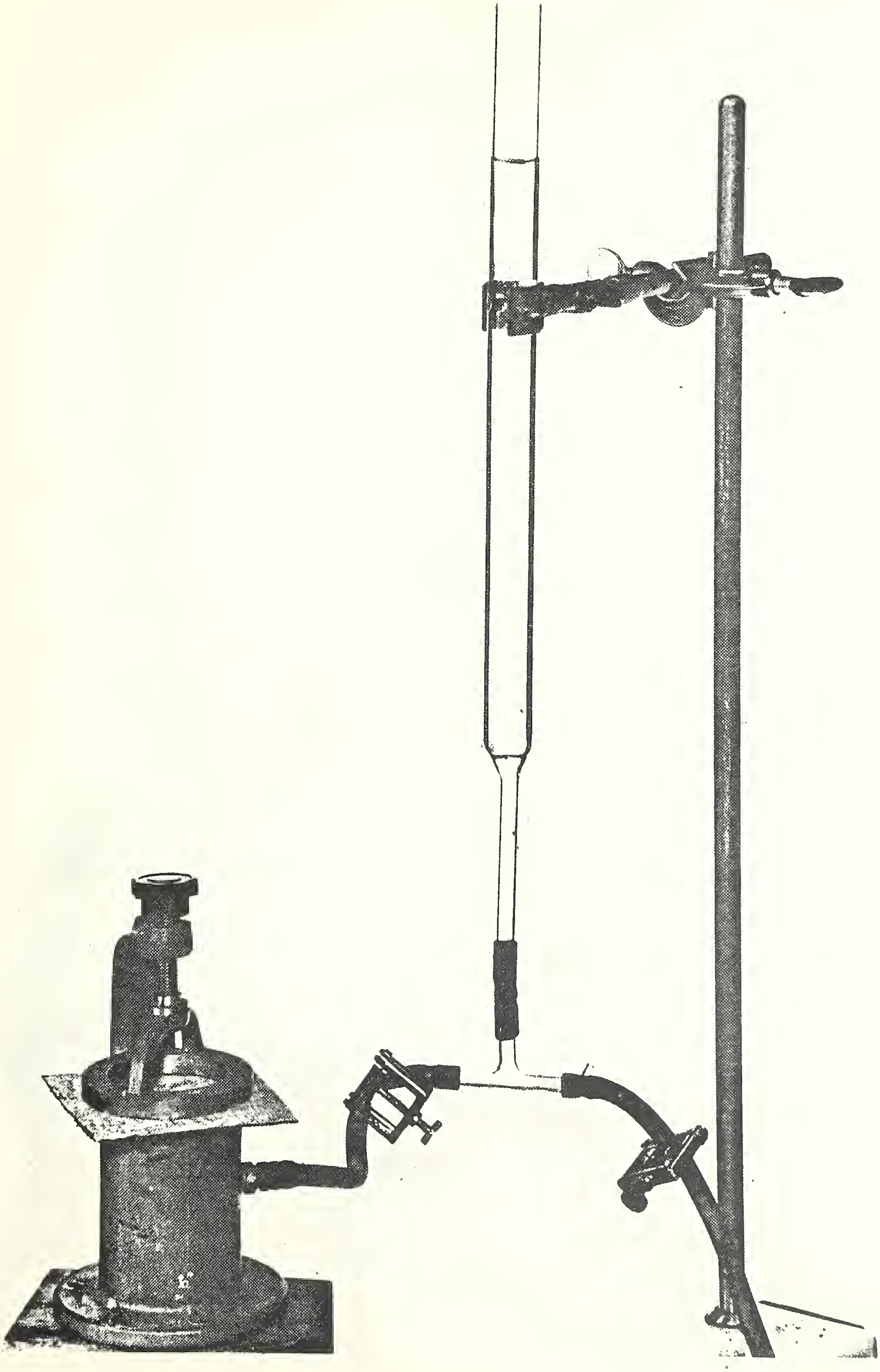

FIGURE 1. HYDROSTATIC PRESSURE APPARATUS.

2.4 Indentation test:

2.4.1 Scope: This method is intended for use in determining the ability of the shower pan materials to withstand nail-head indentation without impairing waterproofness.

2.4.2 Specimens: Same as Section 2.3.2.

2.4.3 Apparatus: The apparatus shall consist of an indenter, acting under a total weight of 120 pounds, a smooth steel or glass plate for supporting the specimen, and a rigid form for supporting the weight and indenter. The indenter shall consist of a 0.178-inch diameter steel bar with edges buffed smooth, but not rounded, rigidly supported vertically in such a manner that the face of the lower end (foot) shall contact the specimen perpendicularly when the specimen is placed in a horizontal position on the plate. The face of the indenter foot shall be flat and buffed smooth.

2.4.4 Procedure: The specimen shall be placed on the supporting plate of the apparatus with the bottom surface up, and the indenter foot lowered gently until it contacts the surface. Within one to two seconds, the total load of 120 pounds shall be applied to the specimen and maintained for a period of 3 minutes.

2.4.5 Results: Each specimen of the test unit shall be tested for water leakage according to Section 2.3 above, with the water contacting the specimen on the side opposite the indentation.

2.5 Folding test:

2.5.1 Scope: This method is intended for use in determining the ability of the shower pan materials to withstand corner folding without impairing waterproofness.

2.5.2 Specimens: Same as Section 2.3.2.

2.5.3 Apparatus: A 10-pound weight, a 1/4-inch mandrel, and a chamber maintained at 24 ±2°F.

2.5.4 Procedure: The specimen, weight, and mandrel shall be placed in the chamber and all tests shall be performed therein. After exposure to 24 ±2°F for two hours, the specimen shall be bent over the mandrel 180°. The bend shall be made in the middle of the specimen and shall be

completed within one second. The specimen shall be removed from the mandrel without unfolding, placed on a smooth, hard surface, and the weight placed on the folded specimen for 30 seconds so that the weight is evenly distributed over the entire specimen. Then remove the weight, unfold the specimen, and repeat the above procedure (bending and placing of weight), except that the bend shall be made with the same side up, but at an angle of 90° to the first. NOTE: The surface intended to be toward the shower shall be down when bending over the mandrel.

2.5.5 Results: After folding, each specimen of the test unit shall be tested for hydrostatic pressure leakage according to Section 2.3 above, with the water contacting the specimen on the surface intended to be toward the shower receptor.

2.6 Alkali soaking test:

2.6.1 Scope: This method is intended to assess the effect of alkalies on the ability of the specimen to function as a shower pan. The concentration selected is believed to be the strongest to which a shower pan will be subjected in service.

2.6.2 Specimens: Same as Section 2.3.2.

2.6.3 Apparatus: An air oven or constant temperature bath for maintaining the required temperature throughout the heating medium during the test period shall be used.

2.6.4 Procedure: A solution made by dissolving 5.0 grams of reagent grade sodium hydroxide and 5.0 grams of reagent grade potassium hydroxide in one liter of distilled water shall be placed in a beaker and maintained at a temperature of 150°F. (66°C.) measured in the solution. The specimen shall be immersed in the solution for 72 hours. The solution shall be changed every 24 hours, the new solution being warmed to 150°F. (66°C.) before replacing the old.

2.6.5 Results: Each specimen of the test unit shall be tested for water leakage according to Section 2.3 above, with the water contacting the specimen on the surface intended to be toward the shower receptor.

2.7 Puncture test:

2.7.1 Scope: This method is intended for use in determining the resistance to mechanical damage which might occur during installation of the shower pan.

2.7.2 Specimens: Cut six 10- by 10-inch specimens from each sample.

2.7.3 Apparatus: Specimen holder - A wooden frame, 10- by 10-inch outside measurement and 6- by 6-inch opening, shall consist of two parts, each 3/4-inch, 5-ply plywood, held together with four thumb screws, one on each side. The contact face of each part shall be surfaced with sandpaper to prevent slipping of the sheet under test.

Impact dart - a 200-gram steel dart, as described in Figure 3 of American Standard Safety Code for Safety Glazing Materials for Glazing Motor Vehicles Operating on Land Highways, ASA Z26.1-1950 shall be used. (See Figure 2.)

2.7.4 Procedure: Place a single specimen between the upper and lower parts of the specimen holder and tighten the thumb screws. Suspend the impact dart vertically above the center of the specimen with a distance of two feet between the nose of the dart and the surface of the specimen. Release the dart for one free fall on each specimen.

2.7.5 Results: Test three specimens with one side up, the other three with the opposite surface up.

2.8 Fungus-resistance tests:

2.8.1 Scope: This test method is intended to determine the resistance of shower pan materials to the growth of Chaetomium globosum and Aspergillus niger.

2.8.2 Apparatus, medium, and test fungi:

2.8.2.1 Autoclave: Autoclave capable of maintaining an exhaust temperature of 122 ±2°C. (251 ±3.6°F.) at a pressure of 15.5 ±0.5 pounds per square inch for sterilizing of medium and glassware.

2.8.2.2 Petri dishes: Petri dishes, 10 centimeters in diameter, for use in qualitative tests.

2.8.2.3 Sterile room: A dust-free room in which to inoculate the specimens. Sterilamps, antiseptic spray, or air filtered under pressure, may be used to maintain sterile conditions.

2.8.2.4 Incubation chamber: An incubation chamber capable of maintaining a temperature of 29 ±1°C. (84.5 ±1.8°F.) and a relative humidity of over 90 percent.

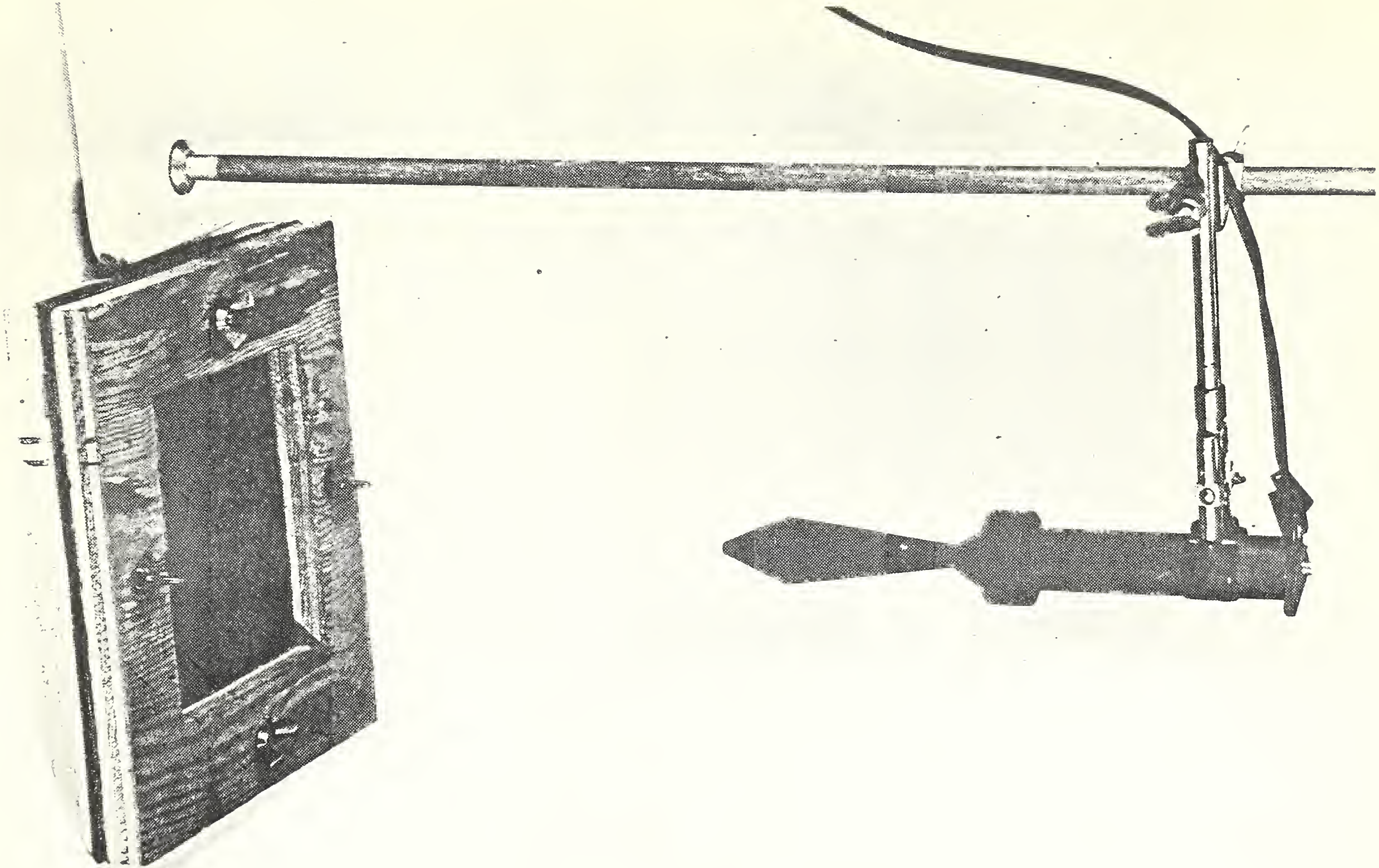

FIGURE 2. PUNCTURE RESISTANCE APPARATUS.

2.8.2.5 Culture medium: A culture medium of the following composition:

$NaNO_3$	3.0 g.
K_2HPO_4	1.0 g.
$MgSO_4 \cdot 7H_2O$	0.5 g.
KCl	0.25 g.
Agar	15.0 g.

Distilled water to make 1000 ml.

The pH shall be 5.5 to 6.5; if otherwise, adjust to that range with HCl or NaOH. After mixing, the above ingredients shall be sterilized by autoclaving for 15 minutes at 15 psi (121°C). Under sterile conditions, the medium shall be poured into petri dishes and allowed to solidify.

2.8.2.6 Chaetomium globosum test fungus: The first fungus used in this test shall be Chaetomium globosum, A.T.C.C. 6205.* Stock cultures of this organism shall be carefully maintained on strips or squares of sterile porous filter paper or blotting paper on the culture medium specified in 2.8.2.5, and promptly renewed if there is evidence of contamination. The culture may be kept for not more than 4 months in a refrigerator at approximately 3° to 10°C. Subcultures incubated at 29 ±1°C. (84.5 ±1.8°F.) for 7 to 21 days shall be used in preparing the inoculum. In preparing an inoculum, use the subcultures in a ripe-fruiting condition and add about 10 ml. of sterile, distilled water containing about 0.005 percent of a non-toxic wetting agent. Force the spores into suspension by brushing with a sterile camel's-hair brush (or other suitable means) and dilute to 100 ml. with sterile water.

2.8.2.7 Aspergillus niger test fungus: The second fungus used in this test shall be Aspergillus niger, A.T.C.C. 6275.* Stock cultures of this organism shall be carefully maintained on a potato-dextrose agar medium and promptly renewed if there is evidence of contamination. The cultures may be kept for not more than 4 months in a refrigerator at approximately 3° to 10°C. Subcultures incubated at 29 ±1°C. (84.5 ±1.8°F.) for 10 to 14 days shall be used in preparing the inoculum as specified in 2.8.2.6.

2.8.3 Procedure:

2.8.3.1 Preparation of test specimens: Twelve specimens of 1-1/2 inches square, selected at random, shall be cut from the shower pan sample. Six of these specimens shall be used for test with Chaetomium globosum and six specimens with Aspergillus niger. With each test fungus,

*Cultures of the fungi may be obtained from the American Type Culture Collection, 2112 M. Street, N. W., Washington 7, D. C.

three of the specimens shall have one surface exposed and three of the specimens, the opposite surface exposed.

2.8.3.2 Inoculation: Under aseptic conditions, dip each specimen in 70 percent ethanol for a few seconds, rinse thoroughly in distilled water, and place firmly on the center of the solidified agar medium contained in the 10 cm. petri dish. With a sterile pipette, or other suitable means, distribute approximately 1.5 ml. of inoculum over the surface of the specimen and surrounding medium.

2.8.3.3 Controls: Five untreated specimens of blotting paper shall be tested along with the test specimens of each fungus to check the viability of the inoculum. At the end of the incubation period, the controls shall be covered with the fungus growth. Absence of such growth requires repetition of the test.

2.8.3.4 Incubation: The period of incubation shall be 14 days at a temperature of 29 ±1°C. (84.5 ±1.8°F.) and a relative humidity of not less than 90 percent.

2.8.4 Results: At the end of the 14-day incubation period, the test specimens shall be examined microscopically (approximately 18X magnification). The shower pan sample shall be considered to have failed to meet the requirements of this specification when any of the test specimens show evidence of growth of the test fungi.

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