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NBS TECHNICAL NOTE 808

Potential Systems for Lead Hazard Elimination: Evaluations and Recommendations for Use

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[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D.C. 20234.
[2] Part of the Center for Radiation Research.
[3] Located at Boulder, Colorado 80302.
[4] Part of the Center for Building Technology.

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National Bureau of Standards
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SI Conversion Units

The conversion factors and units contained in this report are in accordance with the International System of Units (abbreviated SI for Systeme International d'Unites). The SI was defined and given official status by the 11th General Conference on Weights and Measures which met in Paris in October 1960. For assistance in converting U.S. customary units to SI units, see ASTM E 380, ASTM Standard Metric Practice Guide, available from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pa. 19103. The conversion factors for the units found in this Standard are as follows:

Length

1 in = 0.0254* meter

1 ft = 0.3048* meter

1 mil = 0.001* in

Area

1 in^2 = 6.4516* x 10^{-4} $meter^2$

1 ft^2 = 0.09290 $meter^2$

Volume

1 in^3 = 1.638 x 10^{-5} $meter^3$

1 liter = 1.000* x 10^{-3} $meter^3$

Mass

1 grain = 6.479 x 10^{-5} kilogram

1 ounce-mass (avoirdupois) = 2.834 x 10^{-2} kilogram

1 pound-mass (avoirdupois) = 0.4535 kilogram

Pressure or Stress (Force/Area)

1 inch of mercury (60°F) = 3376 $newton/meter^2$

1 $pound\text{-}force/inch^2$ (psi) = 6894 $newton/meter^2$

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* Exactly

Energy

1 inch-pound-force (in-lbf) = 0.1130 joule

Plane Angle

1 degree (angle) = 1.745×10^{-2} radian

Power

1 watt = $1.000^{*} \times 10^{7}$ erg/second

Temperature

°C = 5/9 (Temperature °F - 32)

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* Exactly

Abstract

The National Bureau of Standards is providing technical support to the Department of Housing and Urban Development which is required by Public Law 91-695 (the Lead Paint Poisoning Prevention Act) to carry out a research program to evaluate and make recommendations regarding technology for the removal of the lead based paint hazard from the Nation's housing.

Potential hazard elimination methods have been identified by means of a survey of available technology. This report describes testing and evaluation methodologies used to determine (1) the suitability for use of a series of removal and lead barrier systems, (2) the results of this evaluation, and (3) recommendations concerning the use of said systems.

Paint removal systems were evaluated in terms of the hazards that they present in the course of their use. Both the flammability and the toxicity of the solvents found in removers were considered. Covering systems were evaluated for their suitability for use as barrier layers over lead bearing paints in housing. The effectiveness of covering systems in protecting children from leaded paint, their fire hazard properties and functional properties which are related to their serviceability were considered in making this evaluation. The properties of the systems were assessed in terms of minimum acceptable performance levels and recommendations are given for their use in a field evalution program.

Key Words: Abrasion; adhesion; colorfastness; covering materials; flash point; flame spread; impact resistance; lead paint poisoning; materials; performance; properties; scratch resistance; smoke generation; toxic combustion products; toxicity; washability; water vapor permeance.

Potential Lead Hazard Elimination Systems: Evaluations and Recommendations for Use

David Waksman, John B. Ferguson, McClure Godette, Thomas Reichard

1. Introduction

Public Law 91-695, the Lead Based Paint Poisoning Prevention Act of 1971, required the Department of Housing and Urban Development (HUD) to carry out a research program to evaluate, and make recommendations regarding, technology for the removal of the lead based paint hazard from the Nation's housing.

The major responsibility for implementing the research activities of its lead paint program was assigned, by HUD, to the National Bureau of Standards (NBS) and particularly to the Bureau's Center for Building Technology (CBT). The Lead Paint Poisoning Project was established by CBT to carry out the research mission under the sponsorship and general direction of the HUD Office of Research and Technology.

For the purposes of this investigation the intent of PL 91-695's instruction to evaluate methods for the removal of the lead paint hazard was interpreted as referring to techniques that would eliminate the hazard either by actual removal of the lead paint or by installation of a barrier material that would present a reasonable degree of inaccessibility to the lead paint remaining beneath it.

Previous NBS Reports and publications have dealt with the nature and extent of the problem, methods for the detection of leaded paints in housing and potential solutions to the problem caused by the presence of leaded paints in housing [1,2,3,4]*.

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* Figures in brackets indicate references given on page 127.

Both the presence of leaded paint and its accessibility to children should be considered in defining a hazard. The presence of lead bearing paint, by itself, is a necessary, but not a sufficient condition.

This publication is concerned with an evaluation of removal and covering methods proposed to make leaded paints inaccessible to children.

As a result of an extensive survey and communications with the building materials industry, a wide range of systems, techniques and materials have been identified as potential means of eliminating the health problem caused by leaded paints. Since little technical information is available regarding the effectiveness of these methods in achieving that objective, a testing and evaluation program was initiated in order to determine their properties and to make recommendations concerning their use.

The scope of this program included a study of the functional properties, effectiveness, and problems involved in the use of both removal and covering systems. Health and safety factors, including flammability and toxicity, were also considered.

The test procedures used for evaluation are described in detail in this report and recommendations are made concerning the applicability of the systems investigated. A variety of products were selected for evaluation with the intent of building up a data bank that could be used to screen products having characteristics similar to those already evaluated, thereby minimizing the amount of future testing required. It is hoped that this program will establish a basis that can be used to evaluate all interior surface covering systems.

Properties of systems that are related to their application include ease of use and the fire hazards and toxicity associated with solvents used in the process of carrying out the work. Properties that determine the effectiveness of a system as a barrier to keep children from leaded paints include impact resistance and adhesion. Properties that affect the health and safety of the occupants of a residence include fire hazard properties such as flame spread, smoke generation and the toxic combustion products produced. Functional properties that affect the serviceability of a system include abrasion resistance, scratch resistance, and washability. Minimum recommended performance levels were set for those properties where sufficient data was available to establish such levels.

This program was specifically designed to evaluate the problems and hazards involved in the application of paint removal and covering methods and the performance of coverings. No attempt was made to evaluate the structural properties of interior wall systems. When complete interior wall systems are replaced, the requirements specified in the "Guide Criteria for the Evaluation of Operation BREAKTHROUGH Housing Systems" [5] and/or the HUD Minimum Property Standards [6] should be referred to.

The products discussed in this publication are described in generic terms, and in no case does the data reported herein constitute an endorsement of any specific product. It was intended that the systems be representative of broad generic classes of products. Variations in

formulations and manufacturing processes may invalidate this assumption in some cases. Since laboratory tests cannot predict all of the problems that can be encountered when using a hazard elimination method in actual buildings, field evaluations should be carried out in housing before definitive recommendations are made as to the suitability of a specific method.

2. General Discussion of Properties Evaluated

2.1. General Comments

Paint removal systems which may contain flammable or toxic solvents were evaluated in terms of the hazard that they present when they are used. Flash point and toxic volatile components were therefore determined. Surface covering systems (coverings, liquid coatings and adhesives) were subjected to the complete range of evaluation procedures described below. Detailed test procedures are given in Appendix A for those properties that are not strictly judgmental in nature.*

Problems that could be encountered in field applications of the systems were determined and noted during the fabrication of test specimens. Application procedures recommended by the respective material suppliers were closely followed, and only those materials (coverings, adhesives, etc.) that they specifically recommended were used. Recommendations for improvements in the systems evaluated are made in those cases where it was felt that such modifications would improve their usefulness.

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* Test procedures are given in Appendix A for items marked with a (+).

2.2. Pre-Test Treatment to Simulate Aging

Systems that appear to have very desirable properties when they are newly installed can deteriorate when they are in use over extended periods of time. For this reason, the properties of the proposed surface covering systems were determined after exposure to accelerated aging conditions in addition to their measurement in the "as new" condition. Large changes in properties measured before and after aging were considered as signs of potential system instability.

The aging conditions that could be expected in dry areas of a residence, such as bedrooms and living rooms, were simulated by subjecting test specimens to dry heat at 160°F and approximately 4% relative humidity (rh) prior to testing. Moist aging conditions such as those that could be expected in bathrooms and to a certain degree in kitchens were simulated by exposing test specimens to either a water soak at 73°F or to 95% rh at 160°F prior to testing. The specimen conditioning procedures used prior to testing are described in detail in the test procedures given in Appendix A. In addition to the changes in physical properties that were measured by using the above-mentioned test procedures, observations of visible deterioration were also recorded.

Since very little is known about the correlations that exist between accelerated aging procedures such as those described above and actual in-use deterioration, it was not possible to predict expected

lifetimes for the systems investigated on the basis of these procedures. In spite of this obvious deficiency, the accelerated aging procedures described in this report are of considerable value in determining the relative stability of interior covering systems. Care was exercised to ensure that the conditions used were reasonable and not excessively severe since causing all specimens to fail would defeat the purpose of the aging which is to determine the relative stability of covering systems.

2.3. Critical Properties

Those properties that either are required for a covering system to perform effectively as a barrier to leaded paints, or can affect the health and safety of workers and the occupants of a residence are defined as critical.

2.3.1. Adhesion (+)

Covering materials can be self-adhering, as is the case with liquid coatings (such as paints). Sheets and films can be adhesive applied, mechanically fastened, or a combination of the two. The strength and durability of the attachment method are very important properties since the effectiveness of covering systems in providing a barrier to leaded paints is dependent on their remaining in place.

When covering systems are properly attached by means of mechanical fasteners, attachment problems would normally not be expected. However, when self-adhering or adhesive applied systems are installed, problems can arise due to the inherent instability of many currently used adhesive systems (as compared to systems that are mechanically attached to sound substrates).

Properties that should be required of an adhesive applied system include:

a. the development of an initial bond strength high enough to support a covering,

b. a bond strength that is high enough to resist the efforts by children to pull off the covering, and

c. long term stability under the in-use conditions to which the system will be subjected.

These properties were evaluated for this program by means of the test procedures that are discussed in section A.2. of Appendix A.

2.3.2. Fire Hazard Evaluation (+)

Many of the hazards to which workers and the occupants of residences are exposed are related to fires.

Hazards associated with the flash point of solvents found in paint removers, liquid coatings and adhesives are normally important only during the short period of time when the hazard elimination work is being carried out, since the solvents will evaporate in a relatively short time. Problems associated with the combustion of covering materials will remain as long as those materials remain installed.

Properties that determine the fire hazard potential of the hazard elimination systems include the flash point of solvents, and the flame spread, smoke and toxic product levels generated during the combustion of covering systems.

The standard fire hazard evaluation procedures that are currently used to evaluate surface covering systems are based on their installation on asbestos cement board (ACB). For this reason, the values obtained by testing coverings applied on ACB should normally be used to determine compliance with code regulations. [Values for coverings applied on plywood were also obtained in the course of this investigation since many residences contain considerable amounts of wood-based products (e.g. cellulose-fiber-based wallboard and plywood paneling), that can affect the fire hazard values obtained for thin coverings.] Decisions should be made by responsible local authorities as to whether the original substrate materials encountered in housing units comply with applicable code regulations and as to whether or not the newly applied covering systems used in combination with these substrates will be acceptable. In general, if the combustible substrate surface area (e.g. wood trim) is low as compared to the noncombustible surface area (e.g. plaster walls) the values obtained by testing on an ACB substrate are more meaningful. If the combustible surface area is high (e.g. if wood wainscoting is present) the values obtained by testing with plywood are probably more significant.

Code requirements are usually based on the use for which an area is intended. The requirements are frequently most stringent for exit areas (such as hallways) and furnace areas, moderately high for kitchens, and less demanding for areas such as bedrooms and living rooms.

The toxic combustion products generated by the materials used in building construction are of considerable importance since many of the deaths that occur in fires have been attributed to smoke and toxic gases [7]. Unfortunately, the exact significance, in actual fires, of the toxic combustion product levels, as measured by means of small scale tests, has not yet been established. These tests do not take into account the ease with which a material burns, or thermally decomposes. In addition, care has to be taken in interpreting the meaning of the results of such tests since the amounts of toxic gases produced by a building component such as a wall covering may be insignificant when they are compared to the amounts generated by furnishings and other combustible materials found in a residence. For these reasons, small scale tests can only be used to indicate potential problems that can occur during actual fires in housing.

One means of directly utilizing the toxic combustion product data generated by means of small scale fire tests is provided by The BOCA Basic Building Code [8] which states that, "Interior finish materials that give off smoke or gases more dense or more toxic that that given off by untreated wood or untreated paper under comparable exposure to heat or flame shall not be permitted." Thus, a clear basis for comparison of the toxicity of various covering systems is established for those localities that adhere to the BOCA code; several other codes are worded similarly. However, the fact remains that the types and amounts of toxic combustion products generated by sources other than coverings may be more significant than those generated by covering materials.

2.3.3. Supported Impact Resistance (+)

Normal usage of habitable space does not subject the surfaces of a dwelling unit to severe impact forces. However, when a residence contains a child, a covering system installed as a barrier to leaded paints may have to withstand intentional abuse in addition to the accidental impact and abuse that normally occurs.

The supported impact test phase of this program was designed to measure the relative resistance of surface coverings, installed on commonly used substrates, to onslaughts of this type.

The type of impact failure encountered is dependent on the nature of the covering material. For example, flexible non-reinforced coverings, such as paint or plastic films, generally deform up to the point at which they tear. Brittle cementitious coverings crack and crumble, and reinforced products, such as many of the vinyl wall coverings, commonly fail by virtue of reinforcement fiber tearing.

Specimens were tested both in the "as new" condition, and after being subjected to accelerated aging to ensure that the degree of protection afforded by a covering does not deteriorate excessively with time.

2.3.4. Unsupported Impact Resistance (+)

Coverings should be capable of maintaining their effectiveness as a barrier layer to leaded paints even if there is subsequent localized delamination from the surfaces to which they are adhered. In addition, coverings used to cover voids (i.e., where they are unsupported) should be resistant to tearing and puncture. Water leaks and similar causes of

deterioration that can cause localized delamination of applied protective coverings are a common occurrence in old buildings. The resistance of unsupported surface coverings to tearing and impact is one of the factors that determine the ability of covering systems to protect children from leaded paints.

An unsupported impact test procedure was devised to measure the resistance of unbacked coverings to penetration by a falling weight. The test was intended to simulate the puncture and tearing forces that unsupported coverints can be subjected to in actual housing. Accelerated aging procedures were used to simulate the deterioration in properties due to normal use conditions.

2.3.5. Toxicity of Volatile Solvents

Many of the solvents found in paint removers, liquid coatings, and adhesives give off toxic fumes when they evaporate. These fumes can present a health hazard to both workers and the occupants of a residence. In some cases, the hazards presented are so high that they preclude the use of a material; in other cases they require that a residence be vacated by the occupants and that proper precautions be taken by workers while the solvent fumes are present.

The solvents listed as components by the respective material suppliers were compared with lists of known hazardous solvents to determine if problems due to toxic fumes could be created when the products are used.

2.3.6. Toxicity of Installed Systems

Covering materials used as protective barriers to prevent the ingestion of leaded paints by children should be evaluated to ensure that they themselves do not create a toxicity problem.

Because of the bio-medical aspects of toxicity, a study of the toxicity of installed covering systems was beyond the scope of this project. When any question about the toxicity of materials exists, animal feeding experiments by qualified medical research personnel should be conducted.

2.4. Functional Properties

Functional properties are those properties that are desired for satisfactory serviceability of a covering system, but are not directly related to its effectiveness as a protective barrier to leaded paints or to the health and safety of workers and housing occupants.

2.4.1. Abrasion Resistance (+)

Covering materials should be capable of withstanding the abrasive forces encountered in cleaning and other normal household activities. Abrasion resistance is related to properties such as the hardness, resiliency, and cohesion of the surface. For this reason, the results of abrasion tests can be interpreted as a relative measure of the durability of a covering material as well as its ability to resist direct abrasive forces. A considerable amount of judgment is required in the interpretation of abrasion test results, because of variations in the thickness, texture, and composition of covering systems. For example, an abrasion weight loss that is considered a failure for a thin, smooth textured paint coating may be acceptable when thick coatings, heavy wall coverings and rough textured fabrics are used. Procedures used to evaluate

the abrasion resistance of several covering systems and the results of these evaluations are discussed in subsequent sections of this report.

2.4.2. Scratch Resistance (+)

Scratch resistance is somewhat related to abrasion resistance in that it is dependent on many of the same properties. It also is a measure of the durability of a material as well as its ability to resist direct gouging forces. The scratch resistance of several covering systems both before and after accelerated aging was measured in this program.

2.4.3. Washability (+)

Washability is a measure of the relative ease with which soil can be removed from the surfaces of coverings and the effect of this cleaning action upon the finished surface. Bathrooms, kitchens, and hallways require a material that is easy to clean due to the soiling problems that are present in these areas. Somewhat less stringent requirements can be set for surface coverings used in other living areas of a residence.

Ease of soil removal, resistance to staining and resistance to polishing were observed after attempting to remove a standard soiling medium with the combination of a standard soap solution and either a brush or a sponge. The effects of surface deterioration caused by normal aging were simulated by accelerated aging procedures in the course of this evaluation program.

2.4.4. Water Vapor Permeance (+)

The water vapor transmission of a covering system is one of the properties that determine where it can be used effectively

in a residence. Coverings with a very low permeability should be used where direct contact with water is likely (e.g., normally tiled areas above bathtubs and in shower stalls).

If adequate ventilation is provided, either low permeability or high permeability coverings can be used in other areas of a residence where contact with water vapor is likely (e.g. bathroom areas other than those where direct contact with water is likely). When poor ventilation is provided in such areas, low permeability coverings should be used.

Porous, high permeability coverings "breathe" and permit the moisture that builds up in the wall structure to diffuse out. Nonporous low permeability coverings, in addition to keeping moisture out of the wall structure, are generally much easier to clean than are porous materials.

In normally dry areas of a residence (e.g. bedrooms) permeability is not a decisive factor and properties such as ease of application, serviceability, cost, etc. are probably more important.

The permeability properties of several covering systems were measured in the course of this program to determine where they could be used.

2.4.5. Colorfastness (+)

Colorfastness can be related to both the stability of coloring pigments found in a surface finish and to the chemical stability of other components found in the surface covering.

A condensed moisture aging procedure* was used to determine the

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* See section A.10.1 of Appendix A.

colorfastness of materials that are likely to have some direct contact with water on a regular basis. Surfaces likely to be exposed to high humidity conditions were evaluated by means of a water vapor aging procedure, and the effects of sunlight and long term aging under dry conditions were determined by an ultraviolet light-heat aging procedure.

2.4.6. Maintainability

Factors that should be considered when evaluating the maintainability of a surface covering include its resistance to damage, the probability that it will be exposed to forces that can cause damage, and the ease with which minor damage can be repaired. The properties previously discussed in section 2. are a measure of the resistance of a material to damage. The location in which a covering is used will determine its exposure to potentially damaging forces (e.g. exposure to moisture normally occurs in bathrooms and kitchens, and damage caused by impact is less likely above a certain height).

The ease with which minor damage can be repaired varies widely with the type of material being considered. For example, it is very easy for the average homeowner to repair minor indentations, deep scratches and gouges in gypsum board with spackling compound and then repaint the repaired area. Plastic coverings may require the use of special patching compounds to fill in damage, and may also require the use of special paints to cover up the damaged areas. Certain plastic surfaces are not paintable and replacement of the damaged covering is the only possible recourse. A proper repair job may require skilled labor when textured or patterned finishes, such as those found on many prefinished products, are damaged.

3. Tentative Recommended Evaluation Criteria*

3.1. Critical Properties

3.1.1. Adhesion

At the present time, not enough information is available to make an absolute correlation between the bond strength required of a covering applied to a substrate and the strength required to prevent a child from removing the protective covering. The bond strengths required for coverings applied over leaded paints can be considerably higher than those required for normal usage since a permanent barrier to the hazard is required.

The important factors to consider in establishing bond strength requirements for coverings applied as barriers to leaded paints are:

a. the possibility that a child may be able to remove certain coverings by peeling or pulling,

b. the possibility that the bonding may be effective on less than 100% of the surface that is being covered, and

c. the environmental conditions to which a covering is exposed in normal service.

A minimum tensile bond strength value of 20 psi was established for the actions of children (item a.). A safety factor requiring an adhesive bond strength not less than 100 times the weight of the covering was established to compensate for poor bonding (item b.), and various environmental

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* Testing shall be performed as specified in Appendix A of this publication

pre-test treatments were established to meet the needs of item c. (For all of the systems considered to date, the 20 psi requirement is more severe than the safety factor of 100.)

In cases where the properties of an adhesive are obviously unsatisfactory or where an adhered system is obviously unstable when subjected to certain aging conditions, unequivocal recommendations concerning their use can be made.

The performance criteria listed below were established on the basis of the requirement that an in-place barrier covering system should be capable of withstanding damage caused by active children, in addition to supporting its own weight when it is exposed to conditions simulating in-use aging.

Tentative Recommended Performance Levels*

A. If additional support is not provided during installation, the covering system shall be capable of supporting its own weight.

B. The tensile bond strength (under the expected service conditions in occupied dwellings) shall be considered "satisfactory" if it is not less than 20 psi, and capable of supporting 100 times the weight of the covering. For use in normally dry areas of a residence, the values obtained after curing at 73°F and 50% rh and after aging at 160°F and 4% rh should be used. In areas where frequent contact with water vapor is likely, the values obtained after aging at 160°F and 95% rh should be used in addition to those for dry areas. In areas where direct contact with water is likely, the values obtained after aging in water at 73°F should be used in addition to those for areas where contact with water vapor is likely.

C. Covering systems that do not meet these requirements shall be rated as "unsatisfactory" for those areas where they do not comply.

3.1.2. Fire Hazard Evaluation

3.1.2.1. Flame Spread

Code requirements are usually based on the use to which an area is subjected. Those areas such as furnace rooms where exposure to fire is more likely, and exit areas, where the degree of resistance to fire determines the amount of time that the occupants of a building have to leave a residence, usually have more strict flame spread requirements than other areas of a residence.

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*These levels assume that the covering will be installed in such a manner that a child will not readily gain a handhold on the covering so that it can be pulled off, and that the covering is installed over a sound, clean substrate.

The failure of surface covering systems to meet flame spread requirements may, in some cases, be due to the failure of a thin surface covering to effectively protect a previously existing combustible surface rather than due to the inherent combustion properties of the surface covering.

Tentative Recommended Performance Levels

In the absence of applicable code regulations, the requirements of one of the major model codes (BOCA [8], AIA [9], Southern [10], or Uniform [11], the HUD Minimum Property Standards (MPS) [6], or the Rehabilitation Guide for Residential Properties (HUD PG-50) [12] should be followed. Each of these codes is explicit with regard to the allowable flame spread values for interior finish materials.

Products that comply with allowable flame spread values stated in the HUD MPS, which are listed below in table 1, shall be considered acceptable for the purposes of this investigation when tested in accordance with the procedures specified in ASTM E-84 [13] or the procedures given in section A.3.1. (Robertson [14] has demonstrated that the values obtained by these two methods show good correlation.)

3.1.2.2. Smoke Generated

Although most codes have not yet addressed themselves to the problem of smoke generation resulting from fires in housing, several local codes (e.g., San Francisco [15], Philadelphia [16], New York City [17], and the State of Michigan [18] do have criteria on smoke-intensity endpoints. In addition, the HUD MPS's [6] as well as the HUD Operation

Table 1

Flame Spread Rating Limitations of Interior Finishes

Location Within Building	Surface Flame Spread Rating - Maximum Range	Flame Spread Classification
Enclosed Stairways and Other Vertical Openings	0-25	Class A
Corridors or Hallways and Other Exits	0-75	Class A or B
Within Living Unit except for Kitchen Space	0-200	Class A, B or C
Kitchen Space Within Living Unit	0-75	Class A or B
Public Rooms and Entrance Spaces	0-75	Class A or B
Service Rooms, enclosing Heat Producing or Other Mechanical Equipment, and all Other Fire Hazardous Areas	0-25	Class A

BREAKTHROUGH program [5] have incorporated smoke generation criteria. The states of Oklahoma, South Carolina, and West Virginia incorporate the HUD MPS's in their requirements for industrialized housing [19]. Some building codes e.g. BOCA, require that "smoke and products of combustion produced in burning be no greater than those obtained from untreated wood when burned under similar conditions," (as discussed by the ASTM E-5 Subcommittee IV on Fire Tests of Materials and Construction [20]). This is an implicit smoke generation criterion. Studies conducted at NBS on untreated wood as a part of this program have shown that specific optical density values of 350-500 are not unusual for the smoke generated by cellulosic materials.

Tentative Recommended Performance Levels

A. In the absence of local code regulations, surface coverings yielding smoke specific optical densities of 350-500, when tested in either the flaming or smoldering modes, as specified in section A.3.2. of this publication, shall be classified as "potential problems". If the specific optical densities are greater than 500, the material shall be classified as "hazardous".

B. The specific optical densities obtained by testing on plywood substrates shall be used when coverings are to be applied on combustible surfaces. The values obtained on ACB shall be used if the coverings are to be applied on noncombustible surfaces.

3.1.2.3. Toxic Combustion Products

Many codes have not yet addressed themselves to the problem of limiting the concentrations of gaseous products of combustion. The BOCA model code [8], which is one of the codes listing requirements, states that "interior finish materials that give off smoke or gases more toxic than that given off by untreated wood or untreated paper under comparable exposure to heat or flame shall not be permitted."

No materials shall be given the classification of "hazardous" because the significance, in actual fires, of toxic combustion product levels, as determined by means of small scale fire tests is difficult to ascertain. The amounts of toxic combustion products generated by even the complete combustion of thin surface covering materials may be outweighed in an actual fire by the quantities of toxic gases generated by the combustion of furniture and other burnable items found in a residence. Another factor that should be considered in the analysis of test data is the ease with which toxic combustion products are given off; either by ignition or by thermal degradation.

Tentative Recommended Performance Levels

When tested as described in section A.3.3. of Appendix A, in either the flaming or non-flaming modes, materials which exhibit concentrations of CO, HCl, NO and NO_2, and HCN that appear to be of a level that is described as a potential life safety problem in the current technical literature shall be classified as "potentially hazardous".

For the purposes of this investigation, those materials that yield toxic combustion product levels greater than those listed by Gross et al [21], which are given below, shall be classified as "potentially hazardous".

These levels represent a potential danger to life on short term exposure (2 to 5 minutes).

Hazardous Combustion Product Levels [21]

	concentration in ppm
a. CO	10,000
b. HCl	1000 - 2000
c. HCN	200 - 300
d. $NO + NO_2$	200

Note: Carbon monoxide gas concentrations of 9000 ppm (in the flaming mode) were obtained for the painted plywood standard substrate used to simulate a combustible surface in this testing program. These values are in reasonable agreement with those provided by Gross et al above.

3.1.2.4. Flash Point

Tentative Recommended Performance Levels

A. When tested in accordance with the procedures specified in section A.3.4., of this publication, solvents shall be classified as "extremely flammable" if they have a flash point below 20°F, and as "flammable" if they have a flash point above 20°F and up to and including 80°F.

These classifications are given in the Federal Hazardous Substances Labeling Act [22].

According to Levinson [23], "if the flash point is above 100°F, the solvent is considered to be relatively safe using normal precautions".

(Normal precautions would include not using the solvent in the presence of heat or an open flame and providing adequate ventilation, when specified by the manufacturer.)

3.1.3. Supported Impact Resistance

The 18 in-lbf impact resistance requirement recommended as a tentative minimum performance level in this publication was based on both the impact strength requirement specified in ASTM C 587 [24], for veneer plaster applied on a gypsum board substrate and on unsupported impact tests conducted on 3/8 in thick gypsum wallboard at NBS (see section A.5. of this report for a description of the NBS test procedure and apparatus).

The ASTM specification states that when the specimen is "struck by a polished steel ball, 1 1/2 inches in diameter weighing 7.8±0.1 oz, dropped freely from a height of 36 in there shall be no cracking or loss of bond beyond the impact area". Tests performed in our laboratories (as specified in section A.4. of Appendix A) on veneer plaster in conjunction with a bonding agent showed that cracking and loss of bond beyond the impact area is the type of failure that is normal for veneer plaster. Other coverings have different failure modes. Unsupported impact tests performed on 3/8 in thick gypsum board showed no tearing of the paper on the bottom surface at 18 in-lbf, but tearing commonly occurred at 20 in-lbf. Tests performed at NBS on 3/8 in thick gypsum wallboard, supported by the die of the apparatus specified in section A.4. showed that tearing of the bottom paper surface did not occur at 20 in-lbf and that it began to occur at 22 in-lbf. The gypsum

board was tested without being subjected to accelerated aging procedures in all cases. The 3/8 in thick gypsum board is the minimum normally recommended by the gypsum industry for use without support.

On the basis of this information the criteria given below were established.

The test data obtained for covering materials applied on a gypsum substrate should be used if the covering is to be applied on plaster or gypsum board wall surfaces. The data for plywood substrates should be used if wood or similar solid surfaces are to be covered.

Tentative Recommended Performance Levels

A. Coverings capable of withstanding an impact force of 18 in-lbf without showing signs of failure, as defined by section A.4. (G), shall be considered "acceptable". Those materials not meeting this requirement shall be classified as "probably not acceptable", if they withstand 12 in-lbf and as "unacceptable" if they fail below that value.

B. Systems intended for use in normally dry areas shall meet the requirements specified in A. when tested after curing for 7 days at 73°F and 50% rh and after aging for 7 days at 160°F and 4% rh.

C. Systems intended for use in moist areas where direct contact with moisture is unlikely should meet the requirements in A. after aging for 7 days at 160°F and 95% rh in addition to the treatments specified in B. above.

D. Systems intended for use in areas where direct contact with water is likely should meet the requirements in A. after soaking for 7 days in water at 73°F in addition to the treatments specified in B. and C. above.

3.1.4. Unsupported Impact Resistance

The unsupported impact resistance test described in section A.5. of Appendix A was designed to indicate the resistance of covering materials to tearing and bursting when they are unsupported. A basis for the comparison of the values obtained is being developed in the course of actual testing. Preliminary results indicate that covering materials can be grouped into 3 classes on the basis of their resistance to failure.

Tentative Recommended Performance Levels

A. Coverings capable of withstanding an impact force of 18 in-lbf, without showing signs of failure, as defined by section A.5. (F) shall be classified as "good". Those materials not meeting this requirement shall be classified as "acceptable" if they withstand 2 in-lbf and as "probably unacceptable" if they fail below this value.

Coverings intended for use in normally dry areas shall meet the above requirements when tested after curing for 7 days at 73°F and 50% rh and after aging for 14 days at 160°F and 4% rh.

B. Materials intended for use where moist conditions are prevalent should meet the above requirements after aging for 14 days at 160°F and 95% rh in addition to the treatments specified in A. above.

3.1.5. Toxicity of Volatile Solvents

Testing shall be performed as specified in Section 191.1 of Part 191, Subchapter D of the Federal Hazardous Substances Labeling Act [22]. Substances shall be classified as (a) "highly toxic", (b) "toxic", (c) "irritants", (d) "corrosive" or (e) "strong sensitizers" if they cause the reactions listed in the respective subsections of Section 191.1.

Certification of the degree of toxicity should be required of the respective material suppliers.

The average concentration of a toxic vapor which can be tolerated during an 8 hour day with no ill effects is known as the Threshold Limit Value (TLV). Values for the TLV of many gases and vapors have been established by the Occupational Safety and Health Administration [25].

3.1.6. Toxicity of Installed Systems

Testing shall be performed as specified in Section 191.1 of Part 191, Subchapter D of the Federal Hazardous Substances Labeling Act [22]. Substances shall be classified as (a) "highly toxic", (b) "toxic", (c) "irritants", (d) "corrosive" or (e) "strong sensitizers" if they cause the reactions listed in the respective subsections of Section 191.1. Certification of the degree of toxicity should be required of the respective material suppliers.

3.2. Functional Properties

These criteria are intended to point out potentially undesirable properties. The fact that some of these criteria are not met does not necessarily mean that the systems are unsatisfactory for use as protective barriers over leaded paint.

3.2.1. Abrasion Resistance

The criteria listed below are primarily intended for the evaluation of smooth surface finishes. In the case of textured surfaces, a combination of the test data and observations of the amount of visible wear should be used to determine whether or not a system will give satisfactory performance.

Tentative Recommended Performance Levels

A. The abrasion resistance of smooth surface finishes shall be considered acceptable, when tested as specified in section A.6. if:

a. the average weight loss of six specimens tested for 500 cycles does not exceed 60 milligrams.

b. none of the six specimens wears through the covering layer.

B. There shall be no appreciable damage to the wearing surface affecting appearance or function, e.g. cutting and/or tearing of the fibers of textile materials, or smoothing of textured surfaces.

C. Systems intended for use in normally dry areas should meet the requirements specified in A. and B. after curing for 7 days at 73°F and 50% rh, and after aging in dry heat for 7 days at 160°F and 4% rh.

D. Systems intended for use in moist areas where direct contact with water is not likely should meet the requirements specified in A. and B. after aging for 7 days at 160°F and 95% rh in addition to the treatments specified in C. above.

E. Systems intended for use in areas where direct contact with water is likely should meet the requirements specified in A. and B. after soaking in water at 73°F for 7 days in addition to the treatments specified in C. and D. Above.

Coverings meeting the above requirements shall be classified as "acceptable" for their intended areas of use. Those that do not meet them shall be classified as a "potential problem".

3.2.2. Scratch Resistance

The criteria listed below are primarily intended for the evaluation of smooth surface finishes. In the case of textured surfaces a combination of the test data and observations made of the amount of visible damage should be used to determine whether or not a system will give satisfactory performance.

Tentative Recommended Performance Levels

A. The scratch resistance of coverings shall be considered acceptable when tested as specified in section A.7. if:

a. in the case of coverings with reasonably smooth, planar surfaces the scratch width is less than 20 mils (0.020 in),

b. in the case of textured surface finishes there are no visible signs of appreciable damage affecting appearance or function, and

c. in the case of finishes with protruding fibers there is no visible damage to the fibers such as cutting or tearing.

B. Systems intended for use in normally dry areas should meet the requirements specified in A. after curing for 7 days at 73°F and 50% rh, and after aging in dry heat for 7 days at 160°F and 4% rh.

C. Systems intended for use in moist areas where direct contact with water is not likely should meet the requirements specified in A. after aging for 7 days at 160°F and 95% rh in addition to the treatments specified in B. above.

D. Systems intended for use in areas where direct contact with water is likely should meet the requirements specified in A. after soaking in water at 73°F for 7 days in addition to the treatments specified in B. and C. above.

Coverings meeting these requirements shall be classified as "acceptable" for their intended areas of use. Those that do not meet them shall be classified as a "potential problem".

3.2.3. Washability

Both ease of cleaning and the changes in appearance that occur when a surface is cleaned were determined by means of the test procedures given in section A.8. of this publication. The percent retention of directional reflectance is an indicator of the cleanability of a surface, and percent gloss retention is related to the changes in appearance of a surface caused by wear that occurs during the cleaning process.

Tentative Recommended Performance Levels*

A. Coverings shall be classified as "good" for their intended area of use if, with the use of either a brush or a sponge:

a. the percent gloss retention is not less than 85% nor greater than 125% of the original gloss, and

b. the percent retention of directional reflectance is not less than 90% and not greater than 120% of the original reflectance.

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* Percentages should be rounded off to the nearest 5% when determining compliance.

B. Coverings shall be classified as "acceptable" for their intended area of use if, with the use of either a brush or a sponge:

a. the percent gloss retention is not greater than 125% of the original gloss, and

b. the percent retention of directional reflectance is not less than 90% and not greater than 120% of the original reflectance.

C. Those coverings that do not meet the above requirements shall be classified as "potentially unacceptable" for their intended area of use.

D. Test values obtained at 73°F and 50% rh shall be used to classify materials for use under dry conditions at normal room temperatures. Test values obtained at 160°F and 4% rh shall be used to classify materials for use where exposure to heat under dry conditions is likely. Test values obtained at 160°F and 95% rh shall be used to classify materials for use under moist conditions.

3.2.4. Water Vapor Permeance

For the systems evaluated to date, the differences obtained when specimens were subjected to various aging conditions were not found to be significant. Therefore, for these systems the effects of aging do not appear to be significant when this property is measured.

Tentative Recommended Performance Levels

A. In areas where there is direct contact with water or where there is prolonged contact with water vapor and no direct path for the vapor to escape, coverings shall be classified as "acceptable" if they have a vapor permeance not greater than 0.09 perms when tested as specified in section A.9. of this publication. Specimens subjected to all of the pre-test treatments shall be used.

B. In areas where there is prolonged contact with water vapor and a direct path for the vapor to escape (e.g., adequate ventilation is provided), coverings shall be classified as "acceptable" if their water vapor permeance is either less than 0.09 perms or greater than 1.5 perms when tested as specified in section A.9. of this publication. Specimens subjected to all of the pre-test treatments shall be used.

C. In normally dry areas, there are no water vapor permeance restrictions.

D. Materials not meeting these requirements shall be classified as "potentially unacceptable" for use in those areas where they do not comply.

3.2.5. Colorfastness*

3.2.5.1. Condensed Moisture Aging

Tentative Recommended Performance Levels

Specimens shall be classified as "acceptable" if, when tested as specified in section A.10.1. of Appendix A, they have:

A. a yellowness index difference not greater than 0.05 (in the case of white materials** only),

B. a color change-lightness index difference not greater than 2.0, and

C. a percent gloss retention not less than 80% of the original.

Specimens not meeting these requirements shall be classified as "potentially unacceptable" for use in moist areas.

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* All percentages are to the nearest 5%.

** White materials are defined as those materials having more than 80% initial directional reflectance.

3.2.5.2. Water Vapor Aging

Tentative Recommended Performance Levels

Specimens shall be classified as "acceptable" if, when tested as specified in section A.10.2. of Appendix A, they have:

A. a yellowness index difference not greater than 0.05 (in the case of white materials only).

B. a color change-lightness index difference not greater than 1.8, and

C. a percent gloss retention not less than 85% of the original.

Specimens not meeting these requirements shall be classified as "potentially unacceptable" for use where prolonged exposure to water vapor is likely.

3.2.5.3. Ultraviolet Radiation Aging

Tentative Recommended Performance Levels

Specimens shall be classified as "acceptable" if when tested as specified in section A.10.3. they have:

A. a yellowness index difference not greater than 2.5 (in the case of white materials only),

B. a color change-lightness index difference not greater than 3.0, and

C. a percent gloss retention not less than 80% of the original.

Specimens not meeting these requirements shall be classified as "potentially unacceptable" for use where prolonged exposure to sunlight is likely.

4. Description of Products Evaluated

4.1. Paint Removal Systems

4.1.1. Water Wash Paint Remover

A paint remover containing methylene chloride and methanol. It can be applied with a brush, and removed together with the paint that it softens by wiping it off with a water soaked applicator.

4.1.2. Alkaline/Solvent Paint Remover

A biodegradable, thixotropic liquid that can be applied by brush, spray or roller and is normally removed together with paint by rinsing with a high-pressure, low-volume water spray. The product is biodegradable and contains a chlorinated hydrocarbon solvent which has a TLV of 500 ppm.

4.2. Unfinished Covering Materials

These materials would normally be finished with a paint coating or a wall covering material after they are installed.

4.2.1. Asbestos-Cement Board

A 1/8 inch thick unfinished asbestos-cement sheet product complying with the requirements of Federal Specification SS-B-755a, Type F [26] (flexible). This thickness of the material is intended primarily for application over a solid backing. Application would normally be via mechanical fasteners.

4.2.2. Gypsum Wallboard

A 3/8 inch thick unfinished gypsum wallboard product complying with the requirements of Federal Specification SS-L-30c, Type III, Grade R, Class 1, Form a [27]. Application would normally be via mechanical fasteners or a combination of mechanical fasteners and adhesives, as specified by the manufacturer.

4.3. Prefinished Covering Materials and Coatings

These products provide a final finish in the course of their application, and require no further decorating.

4.3.1. Acrylic-Polyvinyl Chloride Sheet

An acrylic-polyvinyl chloride thermoplastic sheet material having a nominal thickness of 0.028 in, together with a water-based contact-type adhesive recommended by the manufacturer for use where a Class I Fire Hazard Classification is required. Application was in accordance with the materials supplier's recommendations.

4.3.2. Gypsum Impregnated Jute Fabric

A wall covering system consisting of a jute fabric impregnated with crystallized gypsum and a water-based adhesive provided by the manufacturer. Application techniques similar to those used to apply vinyl wall coverings were used in accordance with the materials supplier's recommendations.

4.3.3. Urethane Varnish

A single component, flat finish, clear polyurethane varnish containing a volatile mineral spirits solvent. The coating was applied with a brush, in accordance with the manufacturer's recommendations.

4.3.4. One Component Epoxy Paint

A system comprised of a clear glaze primer-sealer coat followed by a pigmented semi-gloss cover coat. Both coatings were single component water-based epoxy-acrylate formulations. Brush, roller and spray application were tried, in accordance with the materials supplier's recommendations.

4.3.5. Vinyl Counter Top Material

A system consisting of a 1/16 inch thick smooth textured, sheet vinyl counter top material applied with a water-based adhesive produced by the same manufacturer. Application was in accordance with the manufacturer's instructions.

4.3.6. Vinyl Wall Covering-Light Duty

A fabric reinforced vinyl coated wall covering conforming to Federal Specification CCC-W-408 [28], Type I (Light Duty) applied with a wheat paste-type adhesive. Commonly accepted installation techniques were used, per the manufacturer's instructions.

4.3.7. Veneer Plaster with Bonding Agent

A system consisting of a liquid bonding agent which is applied on painted and unpainted surfaces and then covered with a thin veneer of finish plaster. Application was in accordance with the bonding agent manufacturer's instructions for a one coat process. The veneer plaster can either be painted after installation, or pigmented prior to installation and used without a paint top coat. The unpainted product was tested since it was thought to be indicative of the worst case that could be encountered. Since many of the functional properties (scratch resistance,

abrasion resistance, washability, etc.) are dependent on the surface finish provided; a good quality paint cover coat can be used to improve these properties.

4.3.8. Vinyl Wall Covering-Medium Duty

A fabric reinforced vinyl coated wall covering, with a polyvinyl fluoride film overlay, meeting the requirements of Federal Specification CCC-W-408 [28], Type II (Medium Duty). The covering was applied with a heavy duty adhesive on a primed surface, using commonly accepted methods for hanging vinyl wall coverings, as recommended by the manufacturer of the wall covering.

4.3.9. Nylon Formulated One Component Paint

A nylon formulated water emulsion paint, brush applied and cured in accordance with the manufacturer's instructions. Brush, roller, or spray techniques can be used to apply the coating.

4.3.10. Nylon Formulated Two Component Paint

A two component synthetic plastic coating containing an organic solvent. Two coats were brush applied in accordance with the manufacturer's instructions. The coating can be applied with either a brush or a roller.

4.3.11. Nylon Formulated Two Component Paint with Flexible Primer

A system consisting of a two component primer coating designed to promote flexibility, followed by a coat of the paint described in 4.3.10., as recommended by the manufacturer. Brush or roller application can be used.

4.3.12. High Build Textured Spray Coating-Fine Texture

A viscous latex based high build aggregate filled coating, providing a finish comparable in texture to sand-finished plaster. Spray equipment capable of handling viscous liquids is required for its application.

4.3.13. High Build Textured Spray Coating-Medium Texture

A medium texture high build coating similar to the product described in 4.3.12. above.

4.3.14. Two Component Epoxy Paint

A two component water-based epoxy formulation. The two components were blended and then brush applied. Brush, roller, or spray application procedures may be used.

4.3.15. Cementitious Coating-"Orange Peel" Texture

A viscous portland cement-acrylic resin mixture that can be spray applied with a hopper gun or similar equipment designed to handle viscous liquids.

4.3.16. Cementitious Coating-Medium Texture

A sand aggregate filled portland cement-acrylic resin composition coating similar to the product discussed in 4.3.15.

4.3.17. Plywood Paneling-Prefinished

A lauan mahogany, 4 mm thick, plywood paneling product, having a multiple coat catalyzed varnish finish. The paneling was installed with a paneling adhesive recommended by the manufacturer.

4.4. Other Methods

These additional approaches to eliminating the hazards caused by lead-based paints have been identified. Although they have not yet been subjected to a detailed evaluation program by NBS they are, for the sake of completeness, worthy of mention,

4.4.1. Propane Torch Heat Softening*

Open flame burning with a propane gas torch to blister and soften leaded paints prior to scraping.

4.4.2. Sanding*

Removing leaded paints with abrasive impregnated paper or cloth. Either manual or machine sanding can be used.

4.4.3. Air Abrasive Paint Removal*

Paint removal using sand blast-type equipment in combination with a sand, glass bead, or iron shot abrasive medium. Vacuum dust collection equipment is available for use in conjunction with this approach.

4.4.4. High Intensity Heat Lamps*

A radiant heat lamp, containing a high intensity quartz-bromine lamp bulb, that can be used to blister and soften paint so that it can be removed with a putty knife, scraper, or wire brush.

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* Cautions: (1) Sanding and air abrasive paint removal methods create hazardous leaded dust. Adequate protection and provision for its collection should be provided. (2) The uncontrolled use of heating devices to soften leaded paints can cause the paints to give off lead fumes in addition to creating a fire hazard. Care should be taken to avoid charring the paint and adequate fire protection should be provided. (3) Electrical devices can require more current for their operation than a house's wiring can handle.

4.4.5. Heat Blower Guns*

An electrically heated air blower that can be used to blister and soften paint prior to its removal by scraping.

4.4.6. Melamine Coated Hardboard

High pressure laminates consisting of a melamine layer laminated to a cellulosic backing. Water resistant products of this type are available for use in areas where direct contact with water is likely, and water resistant adhesive systems are commercially available.

4.4.7. Decorative Vinyl Films-Self Adhering

Heavy gauge pre-decorated vinyl films backed with a pressure sensitive adhesive that can be applied directly on clean, solid surfaces. Additional adhesives and solvents are not required.

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* Cautions: (1) Sanding and air abrasive paint removal methods create hazardous leaded dust. Adequate protection and provision for its collection should be provided. (2) The uncontrolled use of heating devices to soften leaded paints can cause the paints to give off lead fumes in addition to creating a fire hazard. Care should be taken to avoid charring the paint and adequate fire protection should be provided. (3) Electrical devices can require more current for their operation than a house's wiring can handle.

5. Test Results

5.1. Adhesion

The results of the tensile bond test used to evaluate adhesion are given in table 2. The highest dry bond strength values were obtained for paint-type coatings and the lowest values were obtained for the wheat paste adhesive used in combination with the light duty vinyl wall covering.

All covering systems, with the exception of the paints, showed considerable deterioration in their bonding properties when tested after moisture aging. The veneer plaster and both light and medium duty vinyl wall coverings delaminated in the course of the pre-test treatment.

Similar behavior was found for the prefinished plywood paneling and both of the cementitious coatings. Drying the moisture aged specimens, prior to testing, appeared to reestablish a good bond in several cases.

The vinyl counter top material delaminated when it was allowed to dry after moisture aging. The bond strength of the adhesives used with both the acrylic-polyvinyl chloride sheet material and the gypsum impregnated jute fabric appeared to drop considerably as a result of the water treatment processes.

Initial bond strength tests were carried out on coverings adhered to a painted ACB substrate (painted with a primer coat followed by an enamel coat). Abnormally low bond strength values were obtained after moisture aging because of incompatibility between the primer used and the ACB which resulted in deterioration of the primer and subsequent paint failure. This type of failure was not observed after dry

TABLE 2. ADHESION (TENSILE BOND PROPERTIES)

PRODUCT EVALUATED	BOND STRENGTH (psi) [Average of 5]										
	Development of Bond Strength @ 73°F & 50% rh					Bond Stability with Accelerated Aging					
						Dry Aging	Water Vapor Aging	Water Soak Aging			
						7 days @ 160°F & 4% rh	7 days @ 160°F & 95% rh	7 days in 160°F water		7 days in 73°F water	
	0 to 1 hour	1 day	3 days	7 days	28 days	Tested @ 73°F	Tested Moist	Tested Dry	Tested Wet	Tested Dry	Tested Wet	Tested Dry
Acrylic-Polyvinyl Chloride Sheet	18*	57*	51*	27*	38*	22	5	6	3	3	5	-
Gypsum Impregnated Jute Fabric	<2*	20*	21*	24*	25*	31*	<2*	6*	<2*	<10*	5*	-
Urethane Varnish	-	147*	153*	110*	142*	280	202	924	75	853	140	-
One Component Epoxy Paint	122*	181*	-	>181*	>143*	451	>182	309	>344	>461	>178	-
Vinyl Counter Top Material	-	12	19	35	69	30	26	d	18	d	33	d
Vinyl Wall Covering Light Duty	-	-	2	3	3.5	d	d	d	d	d	d	d
Veneer Plaster with Bonding Agent**	-	45 [8]	43 [11]	47 [15]	59 [39]	50 [21]	d	d	d	d	d	d
Vinyl Wall Covering Medium Duty	-	-	56	>39	>20	>41	d	d	-	-	d	d
Nylon Formulated One Component Point	-	133	175	229	310	>345	>377	>524	-	-	>290	-
Nylon Formulated Two Component Paint	-	178	291	405	1105	>218	342	1560	>221	1085	>306	-
Nylon Formulated Two Component Paint w/ Flexible Primer	-	905	474	1052	959	>993	>422	>473	-	-	481	1332

Notes:
>= the specimen bond strength is greater than this value; premature failure occurred in the test fixture bond.

* Indicates painted asbestos cement board used as a substrate.
Phenolic board was used as a substrate for all other tests.
** Indicates products with curing periods greater than the standard 7 days. For each of these products, the actual age [days] of the specimens when tested is indicated by the bracketed numbers under the test value.
d = Specimen delaminated during pre-test treatment.
- = Not tested

TABLE 2. ADHESION (TENSILE BOND PROPERTIES) (cont.)

PRODUCT EVALUATED	BOND STRENGTH (psi) [Average of 5]										
	Development of Bond Strength @ 73°F & 50% rh					Bond Stability with Accelerated Aging					
						Dry Aging	Water Vapor Aging		Water Soak Aging		
						7 days @ 160°F & 4% rh	7 days @ 160°F & 95% rh		7 days in 160°F water		7 days in 73°F water
	0 to 1 hour	1 day	3 days	7 days	28 days	Tested @ 73°F	Tested Moist	Tested Dry	Tested Wet	Tested Dry	Tested Wet	Tested Dry
High Build Textured Spray Coating-Fine	-	28	40	72	156	153	89	178	b	b	212	-
High Build Textured Spray Coating-Medium	-	32	41	69	118	183	184	351	b	b	179	-
Two Component Epoxy Paint (16)	-	>436	918	1326	2380	1123	251	1452	>170	1044	>402	1592
Cementitious Coating-** "Orange Peel" Texture (17)	-	61 [1]	50 [3]	60 [2]	54 [27]	61 [35]	d	d	-	-	d	d
Cementitious Coating** Medium Texture (23)	-	-	463 [3]	>150 [7]	209 [28]	543 [35]	24 [35]	d	-	-	44 [35]	273 [36]
Plywood Paneling-Prefinished (18)	-	69	154	150	191	170	d	d	-	-	d	56

Notes:
** Indicates products with curing periods greater than the standard 7 days. For each of these products, the actual age [days] of the specimens when tested is indicated by the bracketed number under the test value.
- = Not tested
b = covering softened and blistered during Pre-test Treatment
> = the specimen bond strength is greater than this value; premature failure occurred in the test fixture bond.
d = specimen delaminated before it could be tested.

conditioning. Tests were repeated for moisture aged specimens using the phenolic board substrate specified in the adhesion test procedure (section A.2.) and the problem was alleviated. Since the manufacturer of the gypsum impregnated jute fabric did not recommend his product for use in moist areas, this product was not retested with a phenolic substrate.

5.2. Fire Hazard Evaluation

Test results are given in table 3 for the fire hazard properties discussed below.

5.2.1. Flame Spread

The painted ACB which was intended to simulate a relatively noncombustible substrate (e.g., painted plaster) had a low flame spread rating (essentially zero). The painted plywood substrate, which was intended to simulate a worst case condition, had flame spread values of about 300 (this is considerably above the 150 to 200 range normally obtained for unpainted plywood).

With the exception of prefinished plywood paneling, all of the coverings applied on the painted ACB substrate had flame spread values below 25 (vinyl counter top material had a value of 26, which can be rounded off to 25). This indicates that many thin coverings do not contribute significantly to the spread of a fire when they are applied on noncombustible substrates.

Several coverings applied on painted plywood yielded significantly lower flame spread values than those obtained for uncovered painted plywood. The two component nylonated coatings were the only exceptions to

TABLE 3. FIRE HAZARD EVALUATION

PRODUCT EVALUATED	FLAME SPREAD		SMOKE GENERATION				TOXIC PRODUCTS (ppm)																				FLASH POINT (°F)
			Plywood		ACB		Plywood									ACB											
							Flaming					Smoldering				Flaming					Smoldering					
	Plywood	ACB	Flaming	Smoldering	Flaming	Smoldering	HCl	CO	HCN	NO & NO_2	SO_2	HCl	CO	HCN	NO & NO_2	SO_2	HCl	CO	HCN	NO & NO_2	SO_2	HCl	CO	HCN	NO & NO_2	SO_2	
Painted Plywood** Test Substrate	*** 303	NA	272	408	NA	NA	8	9000	6	20	0	6	2000	5	3	20											NA
Painted ACB** Test Substrate	NA	0	NA	NA	22	20											0	200	1	10	0	4	100	1	8	20	NA
Water Wash Paint Remover																											92°F (Remover)
Alkaline/Solvent Paint Remover																											95°F (Remover)
Gypsum Wallboard**	NA	14	NA	NA	13	37	0	200	0	3		0	130	0	*												NA
Acrylic-Polyvinyl Chloride Sheet	67	6	404	461	172	117	2400 e	1000	5	10		1600 e	1000	2	10	20	1800 e	500	2	10	0	1800 e	340	2	15	0	>212°F (Adhesive)
Gypsum Impregnated Jute Fabric	114	16	316	367	106	84	16	4000	5	15		12	1500	10	10	0	0	1000	2	7	0	12	400	2	8	0	>212°F (Adhesive)
Urethane Varnish	233	2	200	337	63	43	8	3000	5	20	40	4	3000	6	4	20	0	200	2	20	0	2	100	2	15	0	97°F (Varnish)
One Component Epoxy Paint	173	5	333	576	88	62	2	2200	*	*		3	1150	5	*		0	120	1	*		2	100	*	10		>212°F (both ctgs.)
Vinyl Counter Top Material	87	26	152	261	271	253	1600	1200	1	*		1400	440	*	*		1200	560	1	*		1000	240	1	8		>212°F (Adhesive)
Vinyl Wall Covering Light Duty	109	3	179	363	40	29	45	1500	*	*		80	1400	2	6		140	360	1	*		78	130	1	*		>212°F (Adhesive)
Veneer Plaster with Bonding Agent	1	1	17	1	3	1	2	750	2	10	20	0	100	0	4	0	2	200	0	10	20	0	50	0	0	0	>212°F (bonding agent)

Notes:

* The value obtained by the first test was negligible, and therefore the complete test sequence was not performed.

** Tested without an additional substrate.

*** Unpainted plywood normally has lower flame spread values than those obtained for this painted product (150 to 200 for the unpainted product).

e = Value verified by selective ion electrode. All other values measured by colorimetric tubes.

SO_2 was not measured for those products in which it was not expected to be found

NA = Not Applicable.

TABLE 3. FIRE HAZARD EVALUATION (cont.)

PRODUCT EVALUATED	FLAME SPREAD		SMOKE GENERATION				TOXIC PRODUCTS (ppm)																		FLASH POINT (°F)
			Plywood		ACB		Plywood									ACB									
							Flaming					Smoldering				Flaming					Smoldering				
	Plywood	ACB	Flaming	Smoldering	Flaming	Smoldering	HCl	CO	HCN	NO & NO_2	SO_2	HCl	CO	HCN	NO & NO_2	SO_2	HCl	CO	HCN	NO & NO_2	SO_2	HCl	CO	HCN	NO & NO_2	SO_2	
Vinyl Wall Covering-Medium Duty	116	2	340	48	176	153	165	3100	9	33		200	3200	12	1		235	320	4	*		185	400	2	*		>212°F
Nylon Formulated One Component Paint	175	2	258	320	29	24	*	3500	3	17		3	2400	3	10		0	310	0	1		0	24	0	0		>212°F
Nylon Formulated Two Component Paint	327	7	383	466	101	87	45	9000	*	15		30	4200	2	8		75	500	2	13		60	80	1	*		140°F (both parts A & B)
Nylon Formulated Two Component Paint w/ Flexible Primer	341	2	308	492	57	39	0	2650	5	17		5	1800	3	10		2	60	0	1		6	370	2	9		140°F (All ingredients)
High Build Textured Spray Coating-Medium Texture	217	1	291	438	9	11	*	2900	*	13		2	2200	3	8		*	200	*	3		*	20	4	*		>212°F
High Build Textured Spray Coating-Medium Texture	270	1	416	358	27	21	2	4200	2	11		2	1700	3	8		0	250	4	3		8	20	*	*		>212°F
Two Component Epoxy Paint	281	1	242	459	26	25	0	3000	2	20		0	2600	5	10		0	200	1	8		0	10	0	*		>212°F (both parts A & B)
Cementitious Coating-"Orange Peel" Texture	60	1	247	187	86	38	0	2250	2	8		0	775	2	9		0	350	0	4		0	50	0	0		NA
Cementitious Coating-Medium Texture	59	2	463	203	99	60	0	2750	*	14		0	550	2	8		0	650	0	3		0	100	*	*		NA
Plywood Paneling-Prefinished	142	78	366	416	95	229	0	4625	26	30		0	4250	11	1		*	2800	26	28		*	1800	15	1		NA

Notes:
* = The value obtained by the first test was negligible, and therefore the complete test sequence was not performed.
** = Tested without an additional substrate.
*** = Unpainted plywood normally has lower flame spread values than those obtained for this painted product (150 to 200 for the unpainted product).
e = Value verified by selective ion electrode. All other values measured by colorimetric tubes.
SO_2 was not measured for those products in which it was not expected to be found.
NA = Not Applicable.

this trend. Both the thickness of the covering material and its composition appear to affect this change in flame spread.

In addition to the decrease in flame spread that was observed when coverings were tested on a painted ACB substrate instead of on a painted plywood substrate, differences were observed in the type of burning that occurred during the test. Several coverings that flamed openly when they were applied on painted plywood smoldered without open flaming when they were tested on painted ACB. This difference in combustion properties for gypsum impregnated jute fabric applied on painted plywood and painted ACB substrates is illustrated in figures 1 and 2 respectively.

5.2.2. Smoke Generated

As can be seen in table 3, there is no clear-cut pattern to the smoke generation results obtained for coverings applied on the painted plywood standard substrate.

Coverings applied on painted plywood that yielded smoke generation values that were higher than the uncovered painted plywood in both the flaming and nonflaming test modes included: the acrylic-polyvinyl chloride sheet, the one component epoxy paint, the medium duty vinyl wall covering, the two component nylon formulated paint (both with without a flexible primer), the fine texture high build spray coating and the prefinished plywood paneling. Lower values in both the flaming and nonflaming test modes were obtained for the urethane varnish, the vinyl counter top material, the light duty vinyl wall covering, the veneer plaster, the one component nylon formulated paint, and the orange peel

Figure 1. Flame spread test of gypsum impregnated jute fabric on a painted plywood substrate - Open flaming.

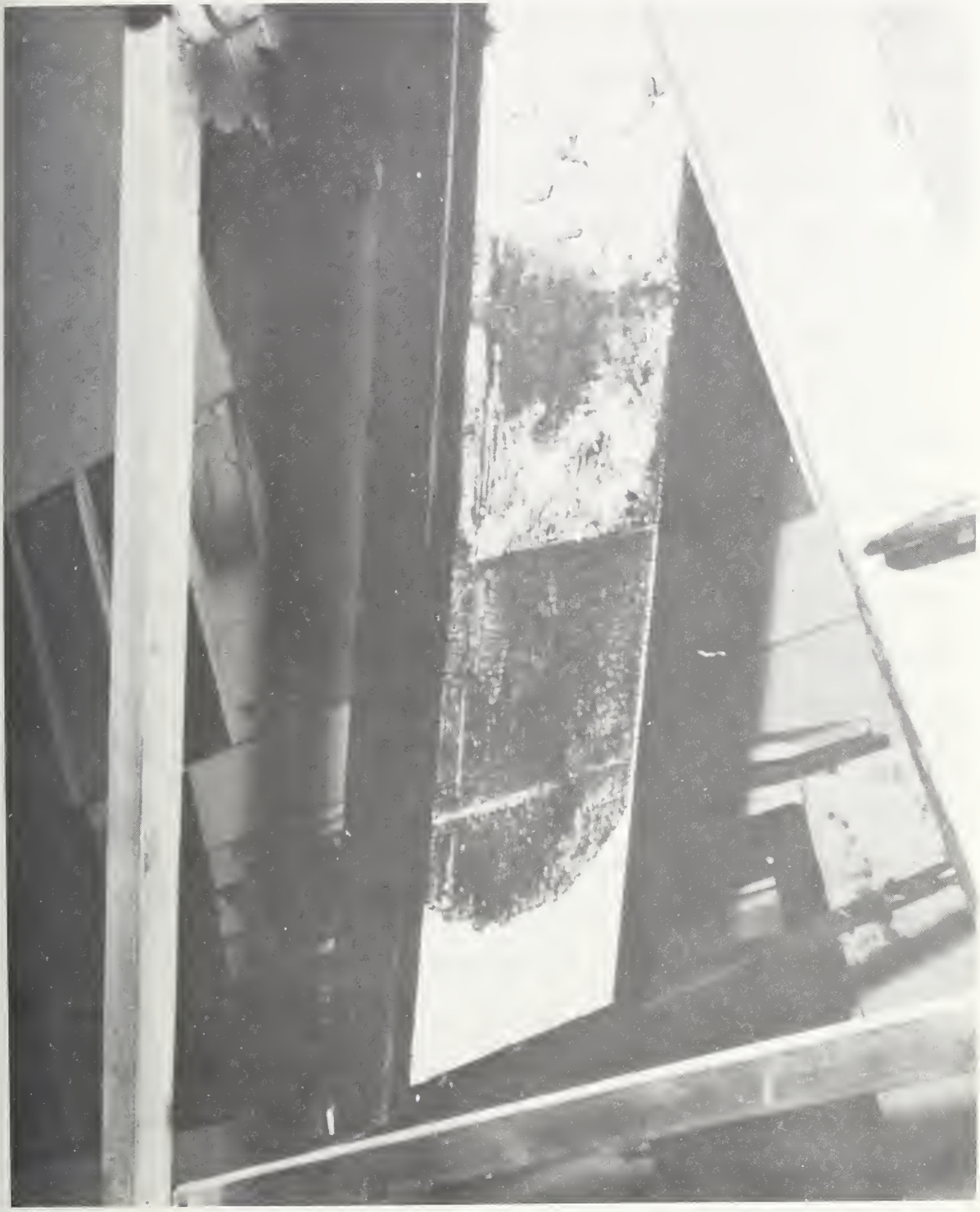

Figure 2. Flame spread test of gypsum impregnated jute fabric on a painted ACB substrate - Charring without open flaming.

texture cementitious coating. Coatings that yielded lower values in only one of the two test modes included the gypsum impregnated jute fabric, the medium texture high build spray coating, the two component epoxy paint, and the medium texture cementitious coating.

Values obtained for coverings applied on painted ACB substrates were considerably below levels that were considered to be hazardous in every case.

5.2.3. Toxic Combustion Products

Relatively high HCl gas concentration values (in the 1,000 to 2,000 ppm range) were obtained for the acrylic-polyvinyl chloride covering and the vinyl counter top material, both of which are relatively thick coverings, 0.028 in and 1/16 in, respectively. Since there is some question about the accuracy of the colorimetric indicator tubes when high levels of HCl gas are present, the results obtained for the acrylic-polyvinyl chloride material were checked by means of a selective ion electrode technique. The presence of relatively high levels of HCl was verified by this procedure.

The painted plywood standard substrate, by itself, gave off relatively high amounts of CO (9000 ppm in the flaming mode). This is typical of the level that can be expected when tests are conducted on cellulosic materials.

With the exception of the acrylic-polyvinyl chloride material and the vinyl counter top material, coverings applied on the ACB substrate yielded considerably lower toxic combustion product levels than those applied on plywood.

Relatively nonhazardous toxic combustion product levels were obtained for the remainder of the covering materials tested on both the plywood and ACB substrates.

5.2.4. Flash Point

All but five liquid products had flash points above 212°F and can be considered relatively safe as far as flash point is concerned. The two paint removers and the urethane varnish had flash points in the 90 to 100°F range and both two component, nylonated paints had flash points of 140°F.

5.3. Supported Impact Resistance

The results of testing covering systems applied on both painted gypsum wallboard and painted plywood substrates are summarized in table 4. Specimens were tested on both a solid steel plate support and on a die which provided a void directly beneath the impact area.

Since test values obtained after aging specimens at 160°F and 4% rh appeared to be considerably below those obtained for specimens subjected to the other pre-test treatment conditions used, a study was conducted of the impact properties of uncovered gypsum wallboard as a function of the aging condition to which it is subjected.

When the product was tested over a die after dry heat aging (with cracking of the bottom layer of paper being considered an end point) there was some slight deterioration in its impact properties. Indentation measurements showed that the depth of the dent obtained with specimens subjected to dry heat aging was approximately twice that

TABLE 4. SUPPORTED IMPACT RESISTANCE

PRODUCT EVALUATED	Maximum Impact Force Withstood Before Covering Failure (in-lbf)*								COMMENTS (Including Failure Mode Description)
	Pre-test Treatment and Supporting Substrate Used								
	Room Temperature Cure 7 days min. @ 73°F & 50% rh		Dry Heat Aging 7 days @ 160°F & 4% rh		Moist Heat Aging 7 days @ 160°F & 95% rh		Water Soak Aging 7 days in 73°F water		
	Plywood	Gypsum	Plywood	Gypsum	Plywood	Gypsum	Plywood	Gypsum	
Asbestos-Cement Board	-	(80+)****	-	(80+)****	-	(80+)****	-	(80+)****	No failure was observed when tested on a steel plate.
Gypsum Wallboard	-	20 **** (80+)****	-	16 **** (80+)****	-	18**** (80+)****	-	20**** (80+)****	An end point of tearing of the bottom paper surface was used.
Acrylic-Polyvinyl Chloride Sheet	80+ (80+)	80+ (80+)	80+ (80+)	80+ (80+)	80+ (80+)	80+ (80+)	80+ (80+)	80+ (80+)	No failure observed.
Gypsum Impregnated Jute Fabric	80+ (80+)	80+ (80+)	80+ (80+)	48** (74)**	80+ (80+)	68 (80+)	80+ (80+)	72 (76)	Covering failed by tearing of fibers.
Urethane Varnish	18 (18)	4 (4)	16 (20)	2 (<2)	18 (20)	4 (4)	18 (20)	4 (6)	Coating failed by cracking which exposed substrate.
One Component Epoxy Paint	40 (38)	8 (6)	36 (36)	2 (2)	32 (34)	6 (8)	36 (36)	10 (8)	Coating failed by cracking which exposed substrate.
Vinyl Counter Top Material	80+ (80+)	80+ (80+)	80+ (80+)	40 ** (50)**	***	58 (80+)	***	78 (80+)	Covering failed by cracking.
Vinyl Wall Covering Light Duty	80+ (80+)	20 (26)	80+ (80+)	8 (12)	80+ (80+)	16 (18)	***	***	Covering failed by cracking and exposing substrate.
Veneer Plaster w/Bonding Agent	-	78 (80+)	-	48 (80+)	-	2 *** (2)***	-	2 *** (4)***	The plaster cracked outside the impact area.
Vinyl Wall Covering-Medium Duty	80^{+} (80^{+})	72 (80^{+})	80^{+} (80^{+})	38 (80^{+})	***	***	***	***	Covering failed by tearing.
Nylon Formulated One Component Paint	78 (74)	8 (8)	80^{+} (78)	2 (2)	56 (58)	6 (8)	80^{+} (80^{+})	10 (8)	Covering failed by cracking..
Nylon Formulated Two Component Paint	78 (66)	10 (8)	14 (30)	2 (2)	14 (18)	6 (8)	70 (60)	8 (8)	Covering failed by cracking.
Nylon Formulated Two Component Paint w/ Flexible Primer	14 (16)	2 (4)	-	-	-	-	-	-	Covering failed by cracking was not aged since the primer did not enhance the properties

Notes:
80+ means that failure was not observed.
* Number without ( ) indicates supported by a die.
Number in ( ) indicates steel plate support.
** Gypsum substrate cracked and crumbled at a lower impact force.
*** Specimens delaminated during conditioning.
**** The product was tested without the use of a gypsum or plywood supportive substrate.
- Not tested

TABLE 4. SUPPORTED IMPACT RESISTANCE (cont.)

PRODUCT EVALUATED	Maximum Impact Force Withstood Before Covering Failure (in-lbf)*								COMMENTS
	Pre-test Treatment and Supporting Substrate Used								
	Room Temperature Cure		Dry Heat Aging		Moist Heat Aging		Water Soak Aging		
	7 days min. @ 73°F & 50% rh		7 days @ 160°F & 4% rh		7 days @ 160°F & 95% rh		7 days in 73°F water		
	Plywood	Gypsum	Plywood	Gypsum	Plywood	Gypsum	Plywood	Gypsum	(Including Failure Mode Description)
High Build Textured Spray Coating-Fine Texture	40 (40)	12 (10)	64 (54)	2 (2)	26 (28)	6 (10)	66 (80^+)	10 (12)	Covering failed by cracking
High Build Textured Spray Coating-Medium Texture	44 (56)	14 (12)	54 (56)	2 (2)	78 (80^+)	10 (10)	68 (80^+)	4 (6)	Covering failed by cracking
Two Component Epoxy Paint	18 (-)	10 (8)	20 (-)	2 (2)	14 (-)	4 (4)	14 (-)	6 (4)	Covering failed by cracking
Cementitious Coating-"Orange Peel" Texture	80^+ (76)	16 (18)	80^+ (80^+)	2 (2)	***	***	***	***	Covering failed by cracking
Cementitous Coating-Medium Texture	78 (78)	16 (20)	80^+ (80^+)	2 (4)	***	10 (16)	***	***	Covering failed by cracking
Plywood Paneling-Prefinished	80^+ (80^+)	80^+ (80^+)	80^+ (80^+)	80^+ (80^+)	***	***	80^+ (80^+)	80^+ (80^+)	No failure observed.

Notes:
*** = Specimens delaminated during conditioning.

obtained for gypsum board subjected to other aging conditions. This indicates that the dry heat aging procedures, used for coverings applied on gypsum wallboard were probably too severe and that lower values obtained for coverings applied on this substrate may be due to a deterioration in the properties of the substrate rather than those of the covering. Because of this deterioration in its impact properties, the impact resistance values obtained for coverings applied on gypsum wallboard, after aging at 160°F and 4% rh should not be used to determine whether a covering is suitable for use. Since this type of deterioration was not observed for any of the other substrate-pre-test treatment combinations used, the other test values measured should not be affected by substrate deterioration.

The organic coatings, which did not contain an aggregate (urethane varnish, both the one component and two component epoxy paints and both the one component and two component nylon formulated paints) exhibited relatively low impact resistance, for all pre-test treatment conditions, when tested on the gypsum wallboard substrate. Considerably higher values were obtained for these coverings applied on a plywood substrate. This is due to the fact that gypsum wallboard indents much more readily than plywood.

Impact resistance values in the 12 to 18 in-lbf range were found for the high-build, textured spray coatings and the cementitious coatings, applied on gypsum wallboard, after room temperature curing. Moist-heat

and water-soak aging caused decreases in the impact resistances of the high-build coatings and caused the cementitious coatings to delaminate from the gypsum substrate. Considerably higher impact resistance values were measured for these coatings applied on plywood substrates; however, moist aging conditions caused the cementitious material to delaminate from this substrate as well.

All of the factory manufactured sheet and film-type covering materials showed good impact resistance, on both test substrates, when they were tested after room temperature curing. However, in virtually every case studied, the adhesive bonded coverings delaminated when specimens were exposed to moist aging conditions. This is most likely due to hydration of the adhesive bond (the adhesives that were recommended for use with these coverings by their respective manufacturers were aqueous emulsions).

Veneer plaster was not tested with a plywood substrate since its properties do not lend themselves to woodwork applications. This system performed quite well on a gypsum wallboard substrate, after room temperature curing; however, its bond was destroyed by moisture aging.

Typical failure modes are illustrated in figures 3 to 8 for urethane varnish, one component nylon formulated paint, orange peel textured cementitious material, veneer plaster, vinyl counter top material and the medium duty vinyl wall covering, respectively.

Figure 3. Supported impact test of urethane varnish applied on a painted gypsum wallboard substrate - Failure by cracking through the coating in the impact area at 8 in-lbf after room temperature curing.

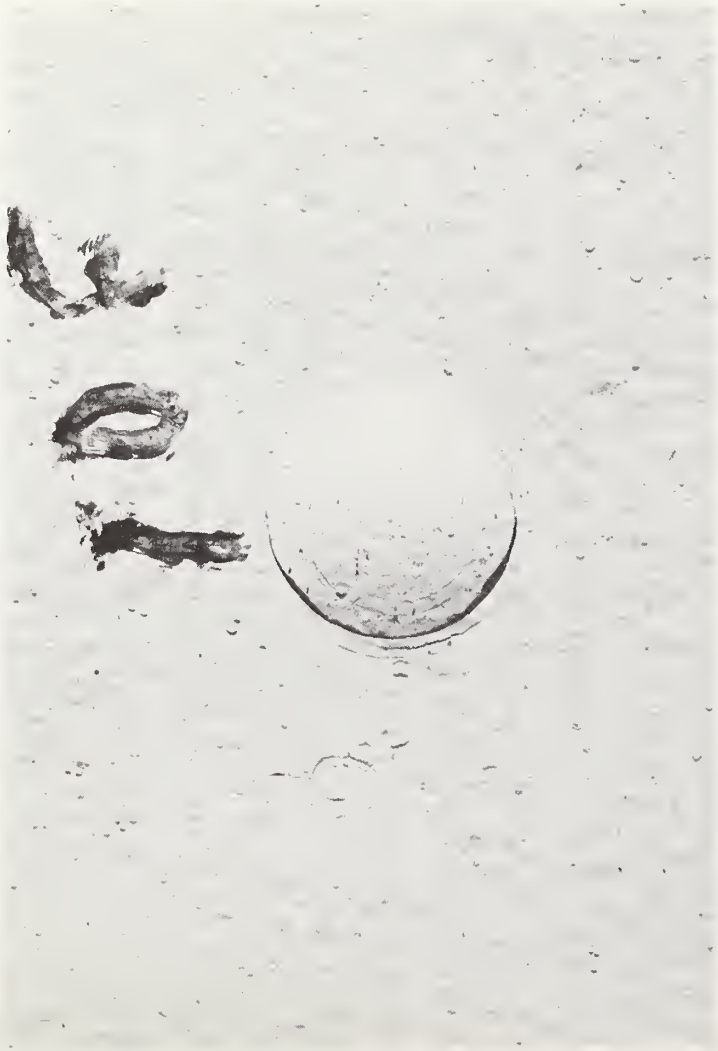

Figure 4. Supported impact test of one component nylon formulated paint applied on a painted gypsum wallboard substrate. Failure by cracking through the coating in the impact area at 10 in-lbf after room temperature curing.

Figure 5. Supported impact test of "orange peel" textured cementitious material applied on a painted gypsum wallboard substrate. Failure by cracking through the coating in the impact area at 16 in-lbf after room temperature curing.

Figure 6. Supported impact test of veneer plaster applied with a bonding agent on a painted gypsum wallboard substrate - Failure by cracking and delamination of the plaster outside the impact area at 80 in-lbf after room temperature curing.

Figure 7. Supported impact test of vinyl counter top material applied on a painted gypsum wallboard substrate - Failure by cracking through the covering in the impact area at 60 in-lbf after moist heat aging.

Figure 8. Supported impact test of medium duty vinyl wall covering applied on a painted gpysum wallboard substrate - Failure at 74 in-lbf by tearing through the reinforcement fabric after room temperature curing.

5.4. Unsupported Impact Resistance

The results of impact tests performed on coverings, without the provision of a supportive substrate, are summarized in table 5.

Several materials (urethane varnish, both of the epoxy paints, the nylon formulated paints, the high build textured spray coatings, the cementitious coatings, veneer plaster and the light duty vinyl wall covering) had very low impact resistance (<1 in-lbf) when tested in this manner. When low test values were obtained for coverings aged at room temperature and humidity, further aging under accelerated conditions was not carried out.

Two failure points were recorded for prefinished plywood paneling, asbestos cement board and gypsum wallboard. The first value is the maximum force resisted before there was complete penetration through the product. Failure was determined by a lack of resistance to penetration through the covering. This value is believed to be indicative of the force that would be required for a child to punch through the barrier presented by these materials. The second failure point recorded was the force required to produce cracks in the bottom surface of the board product. These cracks were probably caused by deflection of the boards during the impact process, but are not believed to be indicative of the force required for a child to punch through the barrier covering.

Several materials (gypsum wallboard, ACB, acrylic-polyvinyl chloride sheet, medium duty vinyl wall covering, prefinished plywood paneling, and vinyl counter top material) withstood an impact force of 18 in-lbf

TABLE 5. UNSUPPORTED COVERING IMPACT STRENGTH

PRODUCT EVALUATED	Maximum Impact Force Withstood Before Covering Failure (in-lbf)						
	Pre-test Treatment						
	Room Temperature Aging		Dry Heat Aging		Moist Heat Aging		Comments
	7+ days @ 73°F & 50% rh		14 days @ 160°F & 4% rh		14 days @ 160°F & 95% rh		(including failure mode)
Asbestos Cement Board	18	(4)	18	(5)	18	(5)	At 18 in-lbf there was complete penetration. At 5 in-lbf cracks appeared in the bottom surface.
Gypsum Wallboard	38	(18)	18	(16)	36	(18)	@ 38 in-lbf there was complete penetration. At 18 in-lbf cracks appeared in the bottom surface.
Acrylic-Polyvinyl Chloride Sheet	38		62		38		Covering failed by stretching and tearing in the impact area.
Gypsum Impregnated Jute Fabric	12		12		12		Failure by fiber tearing. Fiber discoloration in moist aging.
Urethane Varnish	<1		--		--		Coating failed by tearing.
One Component Epoxy Paint	<1		--		--		Coating failed by tearing.
Vinyl Counter Top Material	24		24		26		Coating failed by tearing.
Vinyl Wall Covering Light Duty	<1		--		--		Covering failed by tearing of fibers and vinyl.
Veneer Plaster w/Bonding Agent	<1		--		--		The plaster cracked apart.
Vinyl Wall Covering-Medium Duty	22		18		22		Covering failed by tearing through reinforcement fabric.
Nylon Formulated One Component Paint	<1		<1		<1		Covering failed by tearing.
Nylon Formulated Two Component Paint	<1		<1		<1		Covering failed by brittle fracture.
Nylon Formulated Two Component Paint w/ Flexible Primer	<1		<1		<1		Covering failed by brittle fracture.

TABLE 5. UNSUPPORTED COVERING IMPACT STRENGTH (cont.)

PRODUCT EVALUATED	Maximum Impact Force Withstood Before Covering Failure (in-lbf)			
	Pre-test Treatment			
	Room Temperature Aging	Dry Heat Aging	Moist Heat Aging	Comments
	7+ days @ 73°F & 50% rh	14 days @ 160°F & 4% rh	14 days @ 160°F & 95% rh	(including failure mode)
High Build Textured Spray Coating-Fine Texture	<1	<1	<1	Covering failed by brittle fracture.
High Build Textured Spray Coating-Medium Texture	<1	<1	<1	Covering failed by brittle fracture.
Two Component Epoxy Paint	<1	<1	<1	Covering failed by brittle fracture.
Cementitious Coating-"Orange Peel" Texture	<1	<1	<1	Covering failed by brittle fracture
Cementitious Coating-Medium Texture	<1	<1	<1	Covering failed by brittle fracture
Plywood Paneling-Prefinished	32 (22)	32 (22)	d	Covering failed by tearing of wood fibers.

Notes:
d = Specimen delaminated (could not be tested)

without complete penetration (two of these materials, plywood paneling and acrylic-polyvinyl chloride sheet were adversely affected by moisture). They are probably suitable, from the standpoint of impact resistance, for use as barriers in areas where adequate support is not provided. The gypsum-impregnated jute fabric, which withstood about 12 in-lbf, is probably acceptable for bridging small voids.

Typical failure modes are shown for several of the covering materials that failed at less than 1 in-lbf (one component nylon formulated paint, two component nylon formulated paint, medium texture cementitious material and light duty vinyl wall covering) in figures 9 to 12, respectively. Failures that occurred for several of the better performing materials (gypsum impregnated jute fabric, vinyl counter top material, medium duty vinyl wall covering, and acrylic-polyvinyl chloride sheet) are illustrated in figures 13 to 16 respectively.

5.5. Abrasion Resistance

Test results for abrasion resistance are tabulated in table 6. Many of the covering systems evaluated were severely affected by moist heat aging to the point where they could not be tested.

Abrasion weight-loss values below 60 mg (the maximum value considered acceptable) were measured for acrylic-polyvinyl chloride sheet, urethane varnish, both one and two component epoxy paints, vinyl counter top material, medium duty vinyl wall covering, prefinished plywood, the two component nylon formulated paints and the medium texture cementitious coating.

TABLE 6. ABRASION RESISTANCE

PRODUCT EVALUATED	Weight Loss in Milligrams [avg. of 6]											
	Pre-test Treatment											
	Room Temperature Cure			Dry Heat Aging			Moist Heat Aging			Water Soak Aging		
	7+ days @ 73°F & 50% rh			7 days @ 160°F & 4% rh			7 days @ 160°F & 95% rh			7 days in 73°F Water		
	Wt. loss Avg., mg	No. Tests	Std. Dev.	Wt. loss Avg., mg	No. Tests	Std. Dev.	Wt. loss Avg., mg	No. Tests	Std. Dev.	Wt. loss Avg., mg	No. Tests	Std. Dev.
Acrylic-Polyvinyl Chloride Sheet	13	6	0.8	26	5	4.4	18	5	1.2	24	6	4.2
Gypsum Impregnated Jute Fabric	82	6	10.1	86	6	8.3	87	5	4.9	84	6	10.2
Urethane Varnish	21	5	2.6	21	6	1.1	19	5	1.7	28	6	1.2
One Component Epoxy Paint	31	6	4.4	30	6	9.0	22	6	3.9	36	6	4.1
Vinyl Counter Top Material	14	6	1.0	12	6	1.7	*	--	--	12	6	1.6
Vinyl Wall Covering Light Duty	97	6	27.9	62	5	3.0	*	--	--	*	--	--
Veneer Plaster w/Bonding Agent	**	--	--	**	--	--	**	--	--	**	--	--
Vinyl Wall Covering-Medium Duty	23	6	2.2	19	5	2.5	*	*	*	*	*	*
Nylon Formulated One Component Paint	63	6	2.5	67	6	1.5	70	6	5.2	61	6	2.8
Nylon Formulated Two Component Paint	46	5	1.9	40	6	3.7	55	6	7.1	38	6	1.6

Notes:
* Covering delaminated during Pre-test Treatment.
** Excessive covering wear filled the abrader wheels to an extent such that the test could not be performed.

TABLE 6. ABRASION RESISTANCE (cont.)

PRODUCT EVALUATED	Weight Loss in Milligrams [avg. of 6]											
	Pre-test Treatment											
	Room Temperature Cure			Dry Heat Aging			Moist Heat Aging			Water Soak Aging		
	7+ days @ 73°F & 50% rh			7 days @ 160°F & 4% rh			7 days @ 160°F & 95% rh			7 days in 73°F water		
	Wt. loss Avg., mg	No. Tests	Std. Dev.	Wt. loss Avg., mg	No. Tests	Std. Dev.	Wt. loss Avg., mg	No. Tests	Std. Dev.	Wt. loss Avg., mg	No. Tests	Std. Dev.
Nylon Formulated Two Component Paint w/ Flexible Primer	56	6	2.0	-	-	-	-	-	-	-	-	-
High Build Textured Spray Coating-Fine Texture	135	6	9.9	88	6	6.1	*	*	*	102	6	3.1
High Build Textured Spray Coating-Medium Texture	187	6	24.0	134	6	22.2	131	5	14.1	157	6	12.2
Two Component Epoxy Paint	48	6	3.4	10	5	5.8	34	6	3.2	29	4	2.7
Cementitious Coating-"Orange Peel" Texture	98	6	6.3	65	5	8.9	153	5	11.8	74	6	19.0
Cementitious Coating Medium Texture	32	6	4.0	10	5	3.1	69	6	10.4	25	6	6.6
Plywood Paneling-Prefinished	37	6	3.9	42	6	3.6	w	w	w	32	6	5.2

Notes:
w = Not tested-specimens warped during Pre-test Treatment
* = Covering delaminated during Pre-test Treatment.
- = Not tested with aging since the flexible primer did not improve the impact properties of system (14).

Figure 9. Unsupported impact test of one component nylon formulated paint after room temperature curing - Failure at <1 in-lbf by stretching and tearing that was typical of flexible paints (alkyd, one component epoxy, and one component nylon formulated).

Figure 10. Unsupported impact test of two component nylon formulated paint after room temperature curing - Failure at <1 in-lbf by cracking that was typical of brittle paints (two component epoxy and two component nylon formulated).

Figure 11. Unsupported impact test of medium texture cementitious material after room temperature curing - Failure at <1 in-lbf by cracking that was typical of brittle coatings (both cementitious materials and veneer plaster).

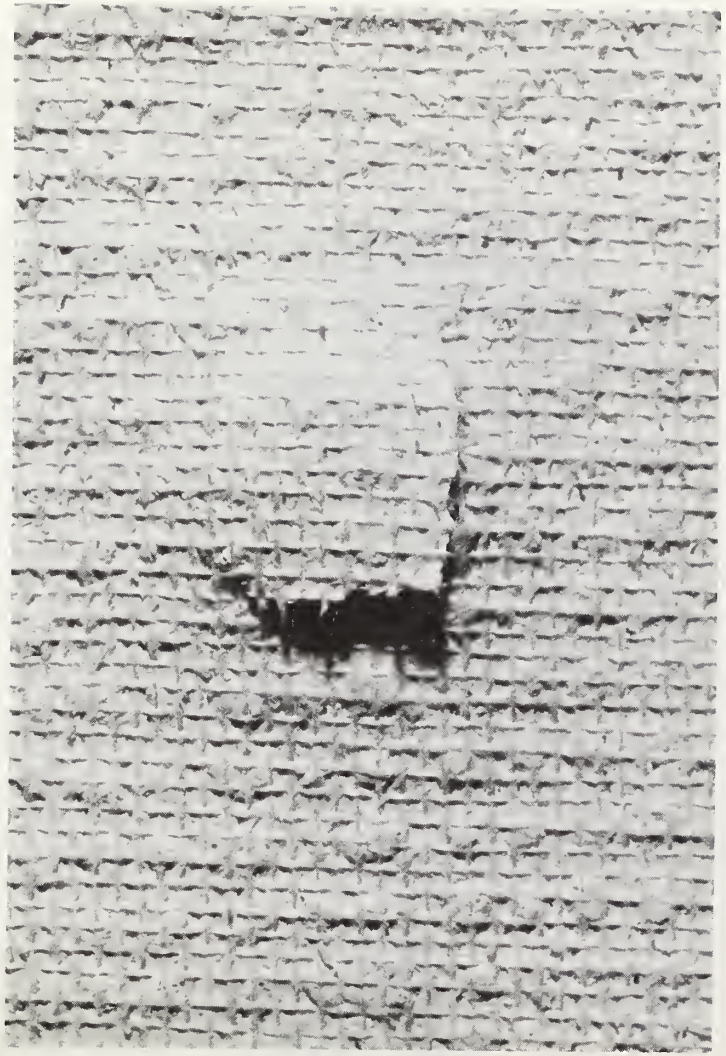

Figure 12. Unsupported impact test of light duty vinyl wall covering after room temperature curing (bottom view) - Failure at <1 in-lbf by tearing through reinforcement fibers.

Figure 13. Unsupported impact test of gypsum impregnated jute fabric after room temperature curing (bottom view) - Failure at 14 in-lbf by tearing through reinforcement fibers.

Figure 14. Unsupported impact test of vinyl counter top material after dry heat aging - Failure at 26 in-lbf by tearing through the covering (no stretching).

Figure 15. Unsupported impact test of medium duty vinyl wall covering after room temperature curing - Failure at 24 in-lbf by tearing through reinforcement fabric.

Figure 16. Unsupported impact test of acrylic-polyvinyl chloride sheet material after dry heat aging - Failure at 64 in-lbf by stretching and tearing.

The one component nylon formulated paint yielded test values slightly above 60 mg and the veneer plaster abraded away at such a fast rate that the abrasive wheels were continually plugged. Although consistent test results could not be obtained, the abrasion resistance of unpainted veneer plaster is obviously unacceptable. The deep wear pattern obtained for this material is shown in figure 17. Wear rates measured for the orange peel texture cementitious coating and the fine and medium texture high build spray coatings, both of which contained a soft, porous, vermiculite-type filler, were unacceptably high; the wear pattern observed for the medium texture spray coating is shown in figure 18. The hard aggregate filler used in the medium texture cementitious coating appeared to improve the abrasion resistance of the mixture considerably. The values obtained for the gypsum impregnated jute fabric were undesirably high, but the texture and the nature of this material may make this type of testing procedure invalid. The same comment is also true for the textured light duty vinyl wall covering that was tested. The wear pattern observed for the light duty vinyl wall covering is shown in figure 19.

5.6. Scratch Resistance

The results of scratch width measurements are given in table 7.

The texture of the gypsum impregnated jute fabric precluded scratch width measurements on this material; however, some minor fiber tearing was observed when the test was conducted. With the exception of the prefinished plywood paneling and the unpainted veneer plaster, the

TABLE 7. SCRATCH RESISTANCE.

PRODUCT EVALUATED	Scratch Width (in mils) [on a phenolic board substrate]			
	Pre-test Treatment			
	Room Temperature Cure	Dry Heat Aging	Moist Heat Aging	Water Soak Aging
	7+ days @ 73°F & 50% rh	7 days @ 160°F & 4% rh	7 days @ 160°F & 95% rh	7 days in 73°F water
Acrylic-Polyvinyl Chloride Sheet	9.7	10.4	9.81	10.7
Gypsum Impregnated Jute Fabric	*	*	*	*
Urethane Varnish	6.8	6.8	7.3	6.5
One Component Epoxy Paint	10.7	10.5	9.0	10.1
Vinyl Counter Top Material	11.7	10.3	10.7**	11.4
Vinyl Wall Covering Light Duty	14.0	19.4	19.6	**
Veneer Plaster w/Bonding Agent	27.0	29.7	30.8	27.5**
Vinyl Wall Covering Medium Duty	4.7	4.8	**	**
Nylon Formulated One Component Paint	7.4	9.0	8.5	7.5
Nylon Formulated Two Component Paint	12.8	13.3	12.0	11.9
Nylon Formulated Two Component Paint w/ Flexible Primer	9.7	-	-	-

Notes:
- Not tested with aging since the flexible primer did not improve the impact properties of the system.
* Test could not be performed because of the nature of the surface.
** The coverings delaminated from the standard phenolic substrate. The values given were obtained with a gypsum board substrate.

TABLE 7. SCRATCH RESISTANCE (cont.)

PRODUCT EVALUATED	Scratch Width (in mils) [on a phenolic board substrate]			
	Pre-test Treatment			
	Room Temperature Cure	Dry Heat Aging	Moist Heat Aging	Water Soak Aging
	7+ days @ 73°F & 50% rh	7 days @ 160°F & 4% rh	7 days @ 160°F & 95% rh	7 days in 73°F water
High Build Textured Spray Coating-Fine Texture	26.5	13.2	14.3	14.0
High Build Textured Spray Coating-Medium Texture	18.2	16.9	13.5	13.0
Two Component Epoxy Paint	9.3	8.8	8.4	8.8
Cementitious Coating-"Orange Peel Texture"	15.2	14.1	10.4	13.1
Cementitious Coating-Medium Texture	16.3	19.5	13.3	13.7
Plywood Paneling-Prefinished	21.8	28.8	w	24.5

Notes:
w = Not tested; specimens warped during Pre-test Treatment.

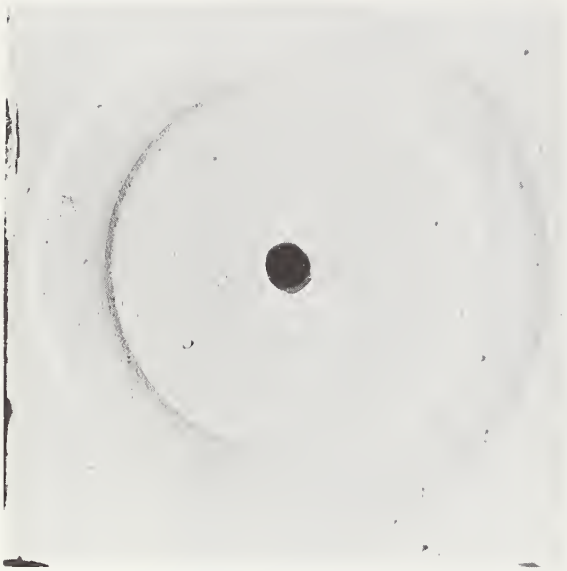

Figure 17. Abrasion wear pattern observed for veneer plaster after testing.

Figure 18. Abrasion wear pattern observed for the medium texture high build spray coating after testing.

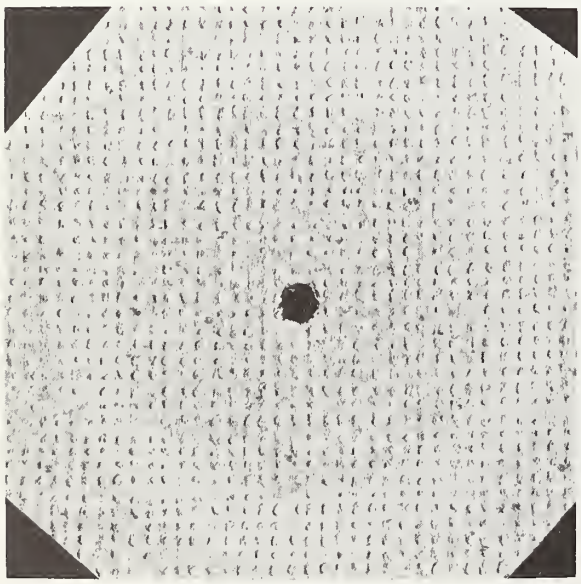

Figure 19. Abrasion wear pattern observed for the light duty vinyl wall covering after testing.

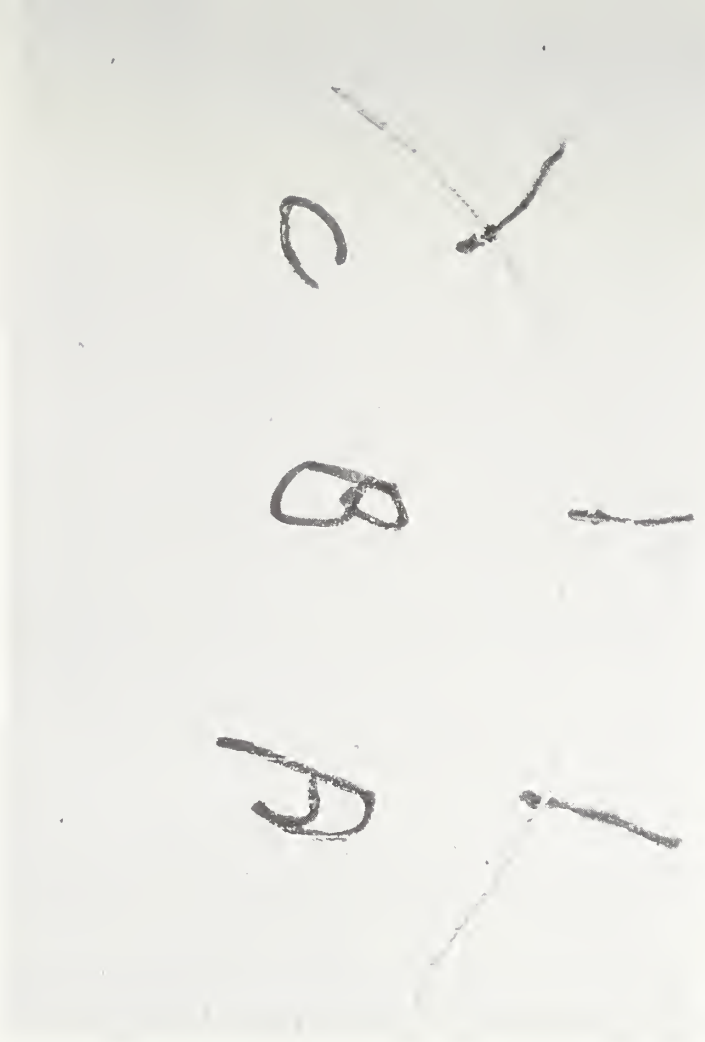

Figure 20. Scratch pattern observed for veneer plaster

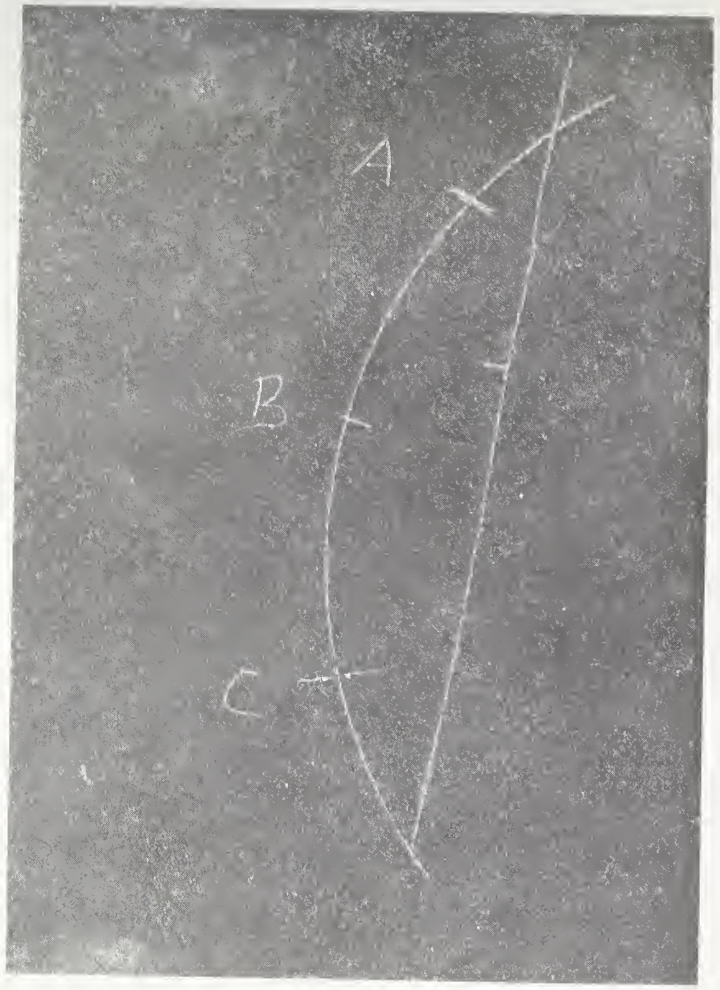

Figure 21. Scratch pattern observed for the vinyl asbestos floor tile comparison standard.

other coverings tested appeared to have acceptable scratch resistance (Note: several coverings delaminated as a result of moisture aging and could not be tested for this reason). The type of deep, wide, scratch obtained for veneer plaster is shown in figure 20; this can be compared with the scratch pattern obtained for the floor tile standard, which is shown in figure 21.

5.7. Washability

The washability properties of the coverings being evaluated are summarized in table 8.

The acrylic-polyvinyl chloride sheet material was easy to clean with a sponge and very little damage to the surface was observed during the cleaning process with this type of applicator; cleaning with a brush appeared somewhat less desirable. Similar behaviour was also observed for the medium duty vinyl wall covering and several of the smooth textured paints (the two component nylon formulated paints and the two component epoxy paint). The appearance of a marginal latex paint surface, after testing, is shown in figure 22. The excellent washing properties of the medium duty vinyl wall covering, which has a fluorinated hydrocarbon surface film designed to promote ease of cleaning, are illustrated in figure 23.

The gypsum impregnated jute fabric, light duty vinyl wall covering, veneer plaster and both the fine and medium texture high build spray coatings and cementitious coatings were very difficult to clean. Several of the textured surfaces can be cleaned most readily with a brush;

PRODUCT EVALUATED		WASHABILITY						WATER VAPOR PERMEANCE			COLORFASTNESS								
		Aging Conditions						Aging Conditions			Condensed Moisture Aging			Water Vapor Aging			UV Radiation Aging		
		73°F, 50% rh		160°F, 95% rh		160°F, 4% rh		73°F, 50% rh	160°F, 95% rh	160°F, 4% rh	100°F, 95% rh			120°F, 95% rh			145°F Carbon arc		
		% Rentention		% Retention		% Retention		Water Vapor Trans-mission (perms)	Water Vapor Trans-mission (perms)	Water Vapor Trans-mission (perms)	A*	B* (ΔL)	C* (%)	A*	B* (ΔL)	C* (%)	A*	B* (ΔL)	C* (%)
		Brush	Sponge	Brush	Sponge	Brush	Sponge												
Acrylic-Polyvinyl Chloride Sheet	Gloss	70	92	**	**	96	95	0.09	0.087	0.09	***	-1.3	98	***	-1.0	83	***	-1.4	66
	Refl.	80	87	**	**	91	95												
Gypsum Impregnated Jute Fabric	Gloss	38	78	69	69	42	75	42.0	41.8	40.9	***	1.4	89	***	-12.4	87	***	9.9	59
	Refl.	45	71	46	55	32	36												
Urethane Varnish	Gloss	51	105	92	90	69	86	0.73	0.73	0.79	***	2.2	93	***	-12.4	94	***	-15.5	125
	Refl.	76	95	66	81	72	82												
One Component Epoxy Paint	Gloss	48	48	41	41	46	49	0.052	0.048	0.054	0.004	t	78	0.24	t	90	0.06	t	87
	Refl.	80	97	81	88	90	94												
Vinyl Counter Top Material	Gloss	86	82	92	96	125	120	0.023	0.020	0.020	0.008	tt	95	0.033	tt	95	0.009	tt	89
	Refl.	103	99	102	100	100	105												
Vinyl Wall Covering Light Duty	Gloss	100	101	98	98	95	98	0.79	0.83	0.77	***	2.1	58	***	1.1	89	***	2.8	94
	Refl.	76	81	69	71	69	78												
Veneer Plaster w/Bonding Agent	Gloss	92	95	95	94	95	94	41.2	40.8	41.0	-0.02	tt	97	-0.04	tt	95	-0.01	tt	95
	Refl.	36	37	48	51	51	65												
Vinyl Wall Covering-Medium Duty	Gloss	54	100	56	88	55	90	0.2	0.36	0.18	***	-4.0	99	***	-0.4	95	***	-6.5	98
	Refl.	100	100	96	96	94	97												
Nylon Formulated One Component Paint	Gloss	78	80	84	90	80	40	8.4	8.6	8.4	-0.11	tt	79	0.17	tt	89	-0.01	tt	80
	Refl.	72	94	90	73	90	74												
Nylon Formulated Two Component Paint	Gloss	80	85	85	90	80	95	0.33	0.20	0.23	-0.17	tt	88	-0.20	tt	86	-0.06	tt	78
	Refl.	75	90	92	95	88	88												
Nylon Formulated Two Component Paint w/ Flexible Primer	Gloss	75	82	86	95	85	95	0.070	0.085	0.10	-0.21	tt	90	-0.23	tt	89	-0.05	tt	80
	Refl.	100	100	100	100	100	100												
High Build Textured Spray Coating-Fine Texture	Gloss	96	97	96	90	95	98	4.6	4.0	4.5	-0.15	tt	93	0.15	tt	95	0.02	tt	90
	Refl.	65	68	70	73	75	80												

Notes:

* A = Yellowness Index Difference (White Materials Only)
B = Color Change-Lightness Index Difference (Δ L)
C = % Gloss Retention

** Test could not be run; the covering buckled and delaminated from the substrate.

*** Test run for white finishes only (greater than 80% initial directional reflectance.)

t The coating was clear (test for colors only)

tt The covering was white (test run for colors only)

TABLE 8. WASHABILITY, WATER VAPOR PERMEANCE AND COLORFASTNESS (cont.)

PRODUCT EVALUATED		WASHABILITY						WATER VAPOR PERMEANCE			COLORFASTNESS								
		Aging Conditions						Aging Conditions			Condensed Moisture Aging			Water Vapor Aging			UV Radiation Aging		
		73°F, 50% rh		160°F, 95% rh		160°F, 4% rh		73°F, 50% rh	160°F, 95% rh	160°F, 4% rh	100°F, 95% rh			120°F, 95% rh			145°F Carbon Arc		
		% Retention		% Retention		% Retention		Water Vapor Transmission (perms)	Water Vapor Transmission (perms)	Water Vapor Transmission (perms)	A*	B* (ΔL)	C* (%)	A*	B* (ΔL)	C* (%)	A*	B* (ΔL)	C* (%)
		Brush	Sponge	Brush	Sponge	Brush	Sponge												
High Build Textured Spray Coating-Medium Texture	Gloss	95	99	90	90	95	98	13.9	12.9	13.2	-0.01	tt	88	0.06	tt	90	0.05	tt	89
	Refl.	65	55	65	75	78	56												
Two Component Epoxy Paint	Gloss	75	83	71	87	92	100	0.40	0.55	0.18	0.05	tt	83	0.04	tt	88	0.01	tt	79
	Refl.	94	96	93	92	85	95												
Cementitious Coating-"Orange Peel" Texture	Gloss	95	99	97	95	96	98	4.4	3.6	3.2	0.11	tt	93	0.16	tt	90	0.03	tt	94
	Refl.	64	50	60	55	70	50												
Plywood Paneling-Prefinished	Gloss	40	34	9.2	7.4	26	33	8.0	10.5	7.0	***	0.04	7.2	***	0.04	5.8	***	-0.45	37
	Refl.	100	100	76	76	95	93												
Cementious Coating-Medium Texture	Gloss	95	99	97	90	95	98	8.50	6.50	6.0	-0.25	tt	90.	-0.20	tt	94.	0.05	tt	89
	Refl.	55	48	60	70	75	4												

Notes:
* A = Yellowness Index Difference (white materials only)
B = Color Changes-Lightness Index Difference (ΔL)
C = % Gloss Retention
*** = Test run for white finishes only (greater than 80% initial directional. reflectance)
tt = The covering was white (test run for colors only).

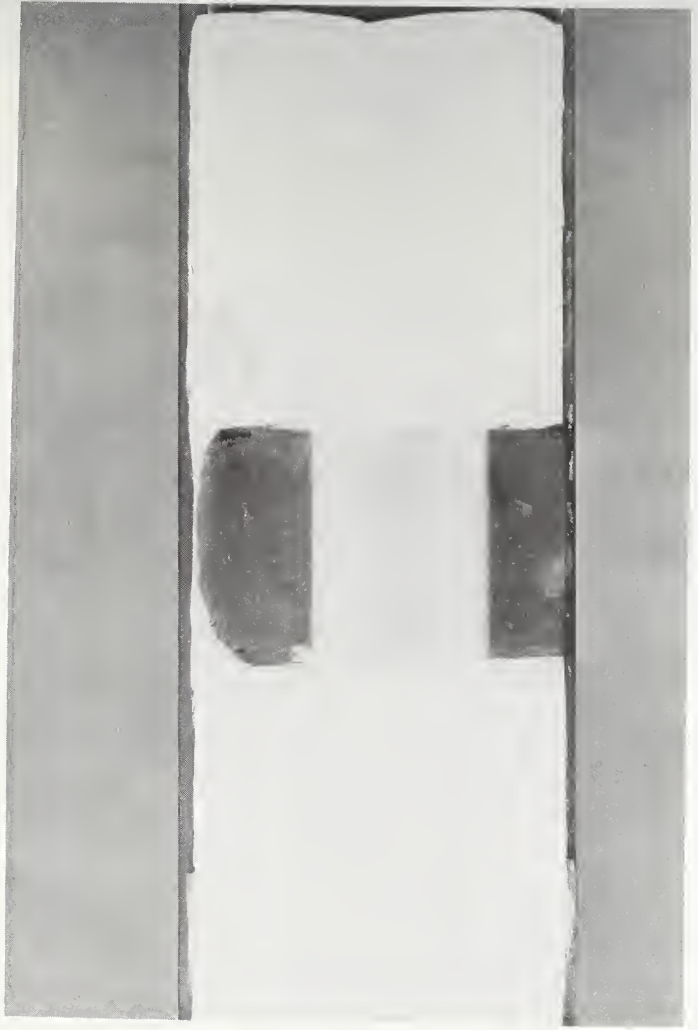

Figure 22. Appearance of a marginal latex paint surface after washability testing - Brush applicator.

Figure 23. Medium duty vinyl wall covering after washability testing - Specimen on the left with a sponge applicator; specimen on the right with a brush applicator.

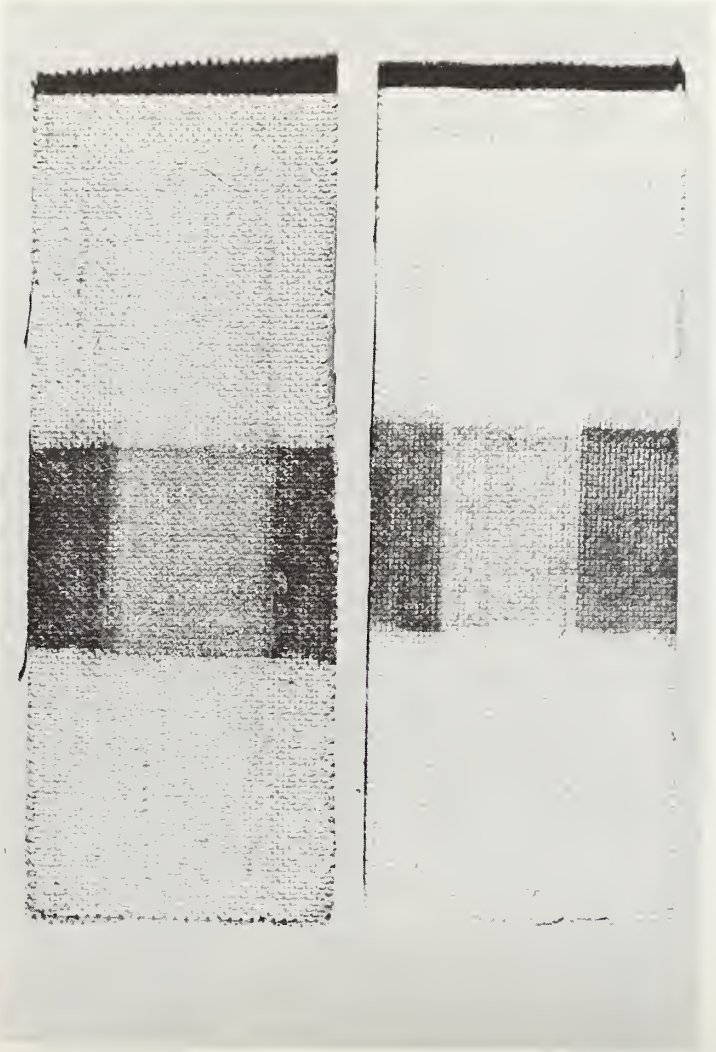

Figure 24. Gypsum impregnated jute fabric after washability testing - Specimen on the left with a sponge applicator; specimen on the right with a brush applicator.

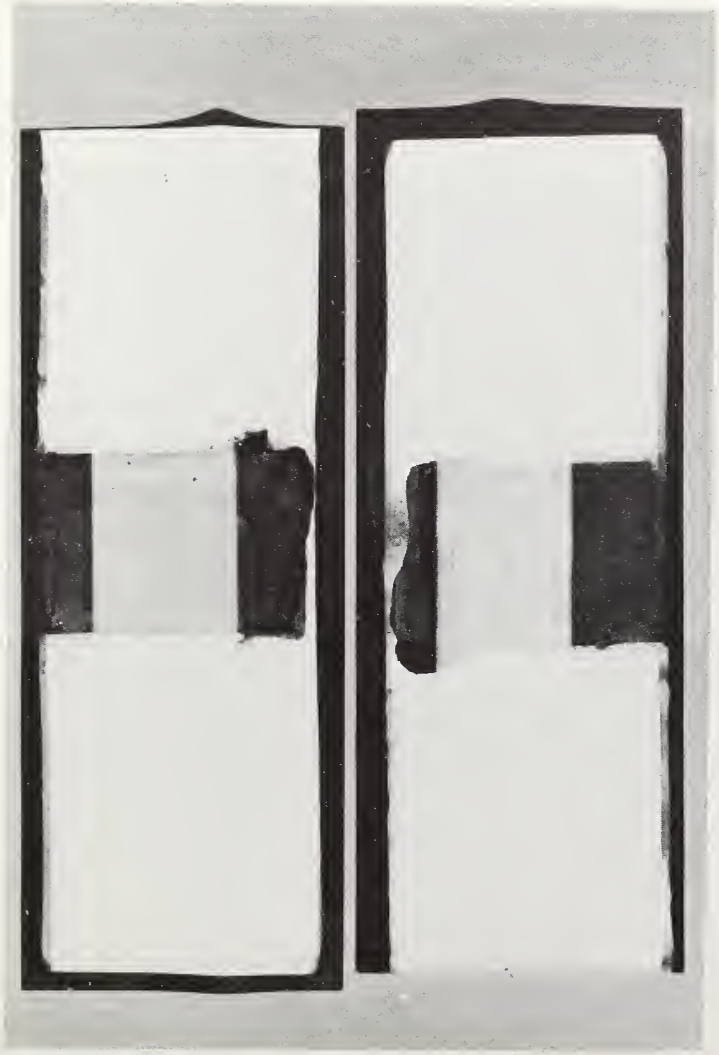

Figure 25. Fine texture high build spray coating after washability testing - Specimen on the left with a sponge applicator; specimen on the right with a brush applicator.

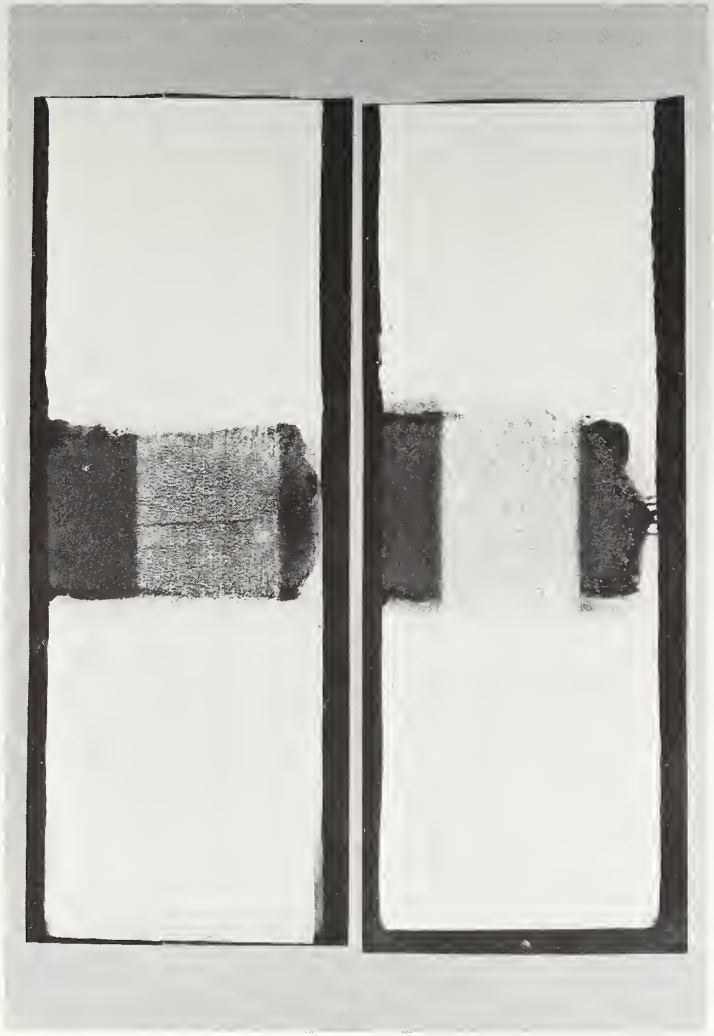

Figure 26. Medium texture high build spray coating after washability testing - Specimen on the left with a sponge applicator, specimen on the right with a brush applicator.

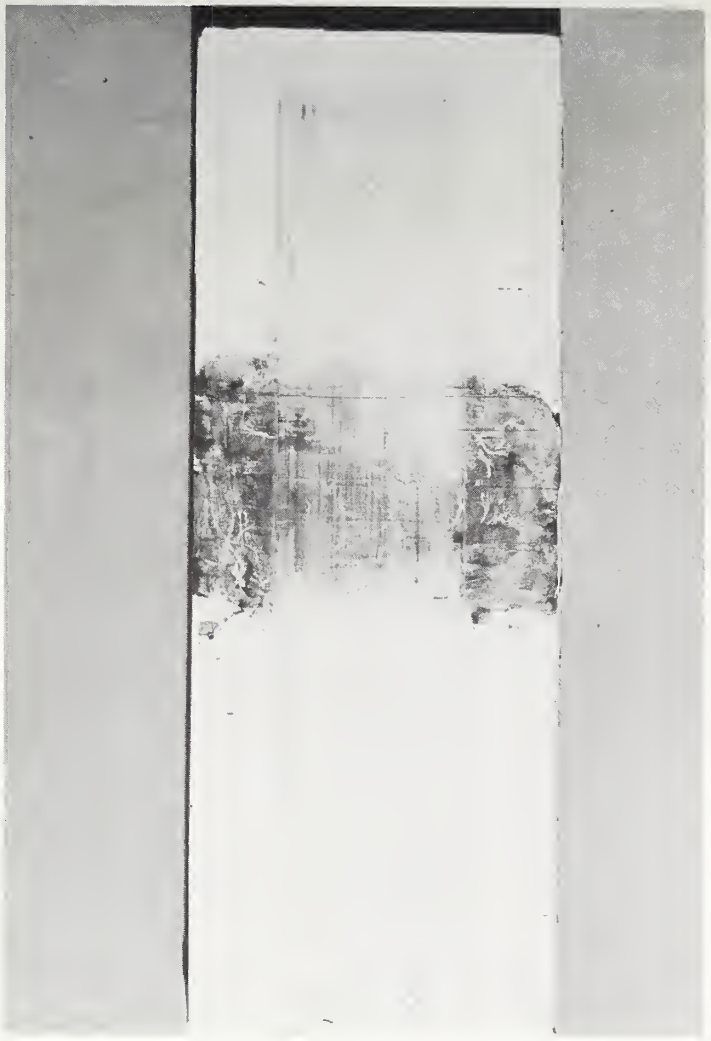

Figure 27. Veneer plaster test specimen after washability testing with a brush applicator.

this is shown, for gypsum impregnated jute fabric and the fine and medium texture high build spray coatings in figures 24 to 26, respectively. The difficulty in cleaning the porous veneer plaster surface is illustrated in figure 27 (this property would be improved considerably if the surface was coated with a good quality paint).

Urethane varnish specimens show good cleanability with a sponge after curing at room temperature; however, this property deteriorated somewhat as a result of temperature and moisture aging. The one component epoxy paint lost a considerable amount of gloss during the cleaning process, indicating surface abrasion; however, the coating was relatively easy to clean. Excellent washability properties were found for the vinyl counter top material and the prefinished plywood paneling was easy to clean, but its surface lost a considerable amount of gloss during the cleaning process.

5.8. Water Vapor Permeance

The values for water vapor transmission given in table 8 can be grouped into three categories. The acrylic-polyvinyl chloride sheet material, the one component epoxy paint, and the vinyl counter top materials had values of less than 0.09 perms; the two component nylon formulated paint with a flexible primer was on the borderline. Both the light and medium duty vinyl wall coverings two component epoxy paint, two component nylon formulated paint and urethane varnish had values between 0.09 and 1.5 perms, and the remainder of the coverings had values above 1.5 perms; veneer plaster and gypsum impregnated jute fabric had values considerably above 1.5 perms (about 40 perms).

5.9. Colorfastness*

Test results that were used to evaluate the color stability of the covering systems considered in this investigation are given in table 8.

5.9.1. Condensed Moisture Aging

Materials that showed minimal changes as a result of this test included acrylic-polyvinyl chloride sheet, gypsum impregnated jute fabric, both the one and two component epoxy paints, the vinyl counter top material, the medium texture high build spray coating, and veneer plaster.

White coverings that yellowed excessively included the one and two component nylon formulated paints, the fine texture high build spray coating, and both the orange peel and medium texture cementitious coatings. The clear urethane varnish darkened considerably during the aging process, and other coverings that showed considerable changes included both the light and medium duty vinyl wall coverings, and prefinished plywood paneling.

5.9.2. Water Vapor Aging

Materials that showed minimal changes when exposed to this test included the acrylic-polyvinyl chloride sheet, the vinyl counter top material, both the light and medium duty vinyl wall coverings, veneer plaster, and the two component epoxy paint.

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* The values given in this section were measured on specimens that were subjected to the aging conditions that are an inherent part of the colorfastness test method. Changes in color that were observed when specimens used for other tests were subjected to various pre-test treatments are recorded under observations in section 6 of this publication.

White coverings that yellowed excessively included one component epoxy paint, the one and two component nylon formulated paints, the fine and medium texture high build spray coatings and the orange peel and medium texture cementitious coatings. The gypsum impregnated jute fabric darkened considerably, as did the clear urethane varnish, and the prefinished plywood paneling surface finish was adversely affected.

5.9.3. Ultraviolet Radiation Aging

Materials that showed minimal changes as a result of exposure to UV radiation included both the one and two component epoxy paints, the vinyl counter top material, the light duty vinyl wall covering, veneer plaster, the one and two component nylon formulated paints, the fine and medium texture high build spray coatings and the orange peel and medium texture cementitious coatings.

Prefinished plywood paneling, urethane varnish, acrylic-polyvinyl chloride sheet, gypsum impregnated jute fabric and the medium duty vinyl wall covering were adversely affected.

6. Summary of Properties and Recommendations

The product ratings and recommendations given in this section are based on the evaluation criteria given in section 3. When these criteria are in conflict with applicable local code requirements the criteria should be superseded by the local regulations.

The recommendations for use given below do not constitute complete approval of the systems evaluated. A further field evaluation program under actual use conditions is necessary before such approval is given. The testing and evaluation program documented in this report was designed to screen out systems that appeared to offer promise as solutions to the problem caused by lead bearing paints in housing.

Although the systems that are discussed in this publication were evaluated in terms of their suitability for use in interior applications, some also lend themselves to exterior use.

6.1. Paint Removal Systems

Paint removers were evaluated in terms of the hazards that are created when they are used. Both the toxicity and the flammability of volatile solvents were considered.

6.1.1. Water Wash Paint Remover

A. Toxicity of Volatile Solvents: Contains methylene chloride and methanol and is harmful if it is ingested or if considerable quantities of its vapors are inhaled.

B. Flash Point: Is somewhat hazardous, but above the "flammable" range.

C. Recommendations for Field Evaluation: Recommended for use in occupied dwellings only if (1) small areas are treated, (2) the work area is adequately ventilated, (3) occupants are kept out of the work area, and (4) the fumes are not exposed to open flames or very hot objects.

The product can be used in unoccupied dwellings to treat large surface areas if items (2) and (4) above are observed.

6.1.2. Alkaline/Solvent Paint Remover

A. Toxicity of Volatile Solvents: The product contains both a chlorinated hydrocarbon solvent and an alkali. It is harmful if it is ingested or if considerable quantities of its vapors are inhaled.

B. Flash Point: Is somewhat hazardous, but above the "flammable" range.

C. Recommendations for Field Evaluation: Recommended for use in occupied dwellings only if (1) small areas are treated, (2) the work area is adequately ventilated, (3) occupants are kept out of the work

area, and (4) the fumes are not exposed to open flames and very hot objects.

The product can be used in unoccupied dwellings to treat large surface areas if items (2) and (4) above are observed.

6.2. Unfinished Covering Materials

These materials are intended for use as a barrier layer over leaded paints.

6.2.1. Asbestos Cement Board

I. Observations:

a. Ease of Application: Easy to install over flat surfaces with mechanical fasteners and/or adhesives. Scoring and snapping should be used since the product is difficult to saw and potentially hazardous asbestos dust is caused by sawing. Holes can be punched out with dies to avoid creating dust.

b. Stability During Accelerated Aging: No deterioration was observed in the product. Paint primers should be selected very carefully to avoid deterioration of the paint bond when moisture is present.

c. Toxicity of Volatile Solvents: Not evaluated since an adhesive was not specified.

d. Maintainability: Easy to patch or replace damaged areas and then repaint.

II. Test Results:

a. Adhesion: Not evaluated since an adhesive was not specified. Should be adequate if mechanically fastened in accordance with accepted practice.

b. Fire Hazard:

i. Flame Spread: "Acceptable" for use in all areas when installed on substrates similar to those tested.

ii. Smoke Generated: "Acceptable" for use in all areas when installed on substrates similar to those tested.

iii. Toxic Combustion Products: "Acceptable" for use in all areas when installed on substrates similar to those tested.

iv. Flash Point: Not evaluated since an adhesive was not specified.

c. Supported Impact: "Acceptable" for use where adequate support is provided.

d. Unsupported Impact: "Acceptable" for use over small to medium voids. A thicker material, recommended by the manufacturer for installation over furring strips, should be used if large voids are covered.

e. Abrasion Resistance: Not evaluated since this property is a function of the final surface finish provided.

f. Scratch Resistance: Not evaluated since this property is a function of the final surface finish provided.

g. Washability: Not evaluated since this property is a function of the final surface finish provided.

h. Water Vapor Permeance: Not evaluated since this property is a function of the final surface finish provided.

i. Colorfastness: Not evaluated since this property is a function of the final finish provided.

III. Recommendations for Field Evaluation:

Recommended for use to cover flat (planar) surfaces in all areas of both occupied and vacant dwellings. Thicker materials (3/16 in to 1/4 in) should be used if large voids are to be covered. Mechanical fasteners are most desirable unless proven adhesives are supplied. Because of the carcinogenic potential of fine asbestos dust, snapping and scoring and punching out holes with dies should be used when possible. Workers exposed to dust should wear respirators and a dust collection system should be provided. Dust producing cutting operations should be conducted outside the dwelling.

6.2.2. Gypsum Wallboard

I. Observations:

a. Ease of Application: Easy to install over flat surfaces with mechanical fasteners and/or adhesives. Straight cuts can be accomplished by scoring and snapping and the product is easily cut by sawing.

b. Stability During Accelerated Aging: There was no visible deterioration. Some deterioration in impact resistance was observed as a result of dry heat aging, but not enough to affect its effectiveness as a barrier. The product has very low strength while it is wet.

c. Toxicity of Volatile Solvents: Not evaluated since a specific adhesive was not recommended.

d. Maintainability: Easy to patch or replace damaged areas and then repaint.

II. Test Results:

a. Adhesion: Not evaluated since a specific adhesive was not recommended. Should be adequate if accepted practice is followed.

b. Fire Hazard:

i. Flame Spread: "Acceptable" for use in all areas when installed on substrates similar to those tested.

ii. Smoke Generated: "Acceptable" for use in all areas when installed on substrates similar to those tested.

iii. Toxic Combustion Products: "Acceptable" for use in all areas when installed on substrates similar to those tested.

iv. Flash Point: Not evaluated since a specific adhesive was not recommended.

c. Supported Impact: "Acceptable" for use in all areas when installed on substrates similar to those tested.

d. Unsupported Impact: "Acceptable" for use in all areas when installed over voids as well as solid substrates.

e. Abrasion Resistance: Not evaluated since this property is a function of the final surface finish provided.

f. Scratch Resistance: Not evaluated since this property is a function of the final surface finish provided.

g. Washability: Not evaluated since this property is a function of the final surface finish provided.

h. Water Vapor Permeance: Not evaluated since this property is a function of the final surface finish provided.

i. Colorfastness: Not evaluated since this property is a function of the final finish provided.

III. Recommendations for Field Evaluation:

Recommended for use to cover flat (planar) wall areas of both occupied and vacant dwellings. Since the impact resistance values obtained

for materials applied on a gypsum wallboard substrate were much lower than those obtained with plywood, the product would not be recommended for use as a covering in areas where wood is commonly used. In addition, the product is not suitable for use in areas where direct contact with water is likely. Mechanical fasteners or the combination of such fasteners with adhesives would be the most desirable attachment procedure.

6.3. Prefinished Covering Materials and Coatings

These materials are intended for use as a barrier layer over leaded paints.

6.3.1. Acrylic-Polyvinyl Chloride Sheet (1)

I. Observations:

a. Ease of Application: Care must be exercised when positioning the covering, since a contact-type adhesive is used; especially when applying large sheets. No other problems are anticipated.

b. Stability During Accelerated Aging: Buckling and delamination observed when subjected to moisture aging (160°F, 95% rh); see figure 28.

c. Toxicity of Volatile Solvents: No problem: the adhesive contains an aqueous solvent.

d. Maintainability: A damaged area could be cut out and replaced with another piece of the same covering, however, the color and pattern match may not be perfect. The covering can be painted with special paints intended for vinyls; however, ordinary alkyd and latex paints are not satisfactory according to the covering manufacturer.

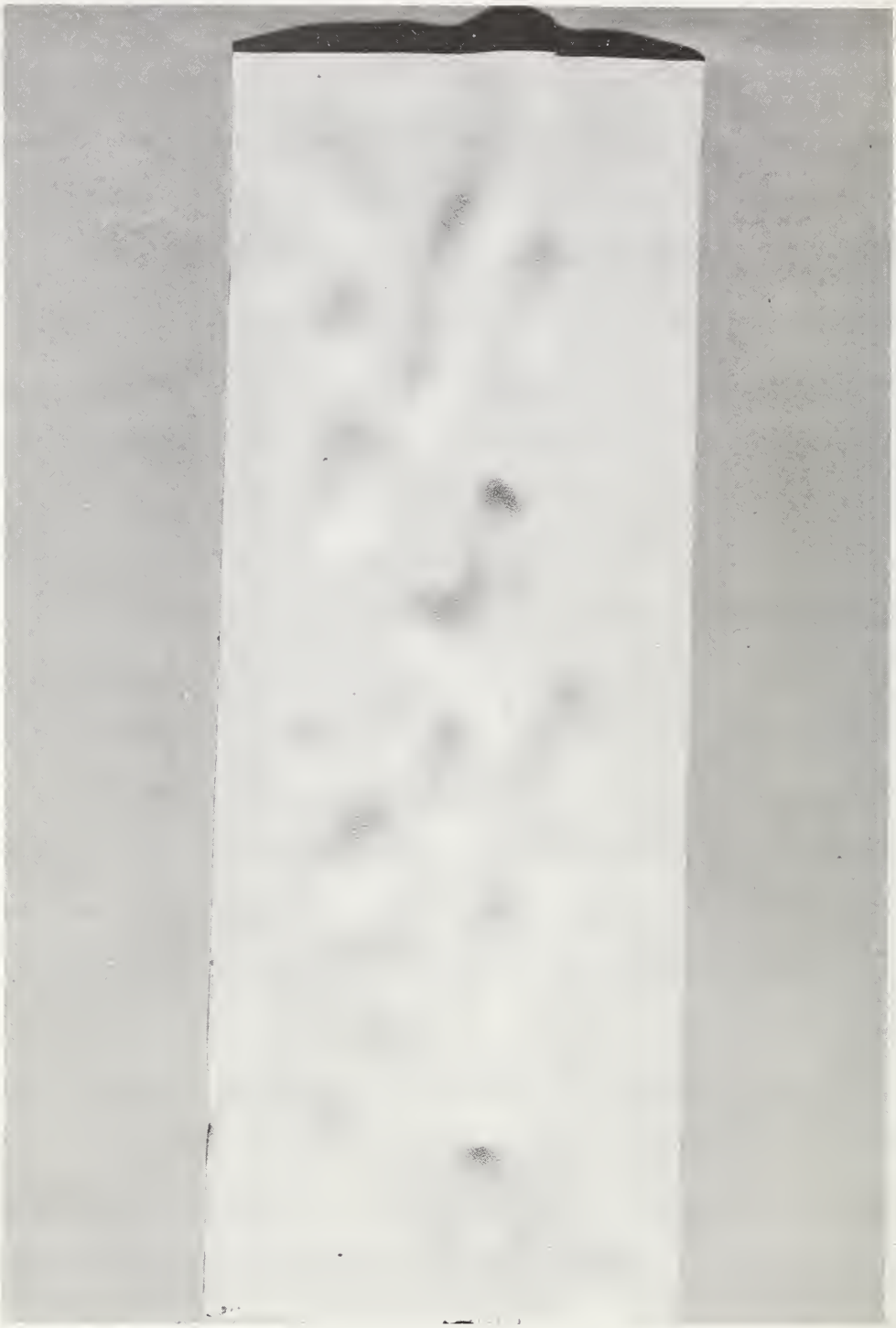

Figure 28. Acrylic-polyvinyl chloride sheet test specimen after moisture aging at 160°F and 95% rh. (Note the warping and buckling).

II. Test Results:

a. Adhesion: "Satisfactory" at 73°F, 50% rh and at 160°F, 4% rh. "Unsatisfactory" at 160°F, 95% rh and when water soaked.

b. Fire Hazard:

i. Flame Spread: "Acceptable" for use in all areas if it is installed on a noncombustible substrate. "Acceptable" for use over cellulosic substrates except in hazardous areas such as furnace areas.

ii. Smoke Generated: "Acceptable" for use when installed on noncombustible substrates. "Potentially hazardous" when installed on cellulosic substrates.

iii. Toxic Combustion Products: "Potentially hazardous". The toxic combustion products produced by the covering should be weighed against those produced by furnishings and other combustible materials found in a residence to determine their importance.

iv. Flash Point: The adhesive is relatively safe using normal precautions.

c. Supported Impact: "Acceptable" for all test conditions.

d. Unsupported Impact: "Good" for all test conditions.

e. Abrasion Resistance: "Acceptable" for all test conditions.

f. Scratch Resistance: "Acceptable" for all test conditions.

g. Washability: "Good" washability with a sponge.

h. Water Vapor Permeance: "Acceptable" for use in all interior application.

i. Colorfastness: "Acceptable" for all use conditions except where exposure to sunlight is likely ("potentially unacceptable" under this condition).

III. Recommendations for Field Evaluation:

Recommended for use in normally dry areas on walls, doors, and wood trim (when thermoformed) as suggested by the manufacturer. A solid substrate in good repair is required for adhesive attachment. Minor voids can be bridged. The product is not recommended for use in areas where contact with moisture is likely. Since health and safety problems are not anticipated during installation, the product can be used in both occupied and vacant dwellings. Because of its fire hazard properties, the product should not be used over large areas of cellulosic materials in hazardous areas. The use of mechanically fastened trim strips on exposed edges would improve the peel resistance of the covering system.

6.3.2. Gypsum Impregnated Jute Fabric

I. Observations:

a. Ease of Application: There should be no problem when the covering is installed in a manner similar to that used with vinyl wall coverings.

b. Stability During Accelerated Aging: The jute fabric appeared to discolor and darken when subjected to moisture aging.

c. Toxicity of Volatile Solvents: No problem; the adhesive contains an aqueous solvent.

d. Maintainability: A damaged area could be cut out and replaced with another piece of covering; however the color and pattern match would not be perfect. The surface can be coated with ordinary paints.

II. Test Results:

a. Adhesion: "Satisfactory" at 73°F, 50% rh and at 160°F, 4% rh. "Unsatisfactory" at 160°F, 95% rh and when water soaked at 73°F.

b. Fire Hazard:

i. Flame Spread: "Acceptable" for use in all areas if it is installed on a noncombustible substrate. "Acceptable" for use over cellulosic substrates except in exit areas, kitchens and hazardous areas.

ii. Smoke Generated: "Acceptable" for use when installed on noncombustible substrates; on the borderline between "acceptable" and "potentially hazardous" when installed on cellulosic substrates.

iii. Toxic Combustion Products: "Acceptable" for use in all areas when installed on substrates similar to those tested.

iv. Flash Point: Adhesive is "relatively safe" using normal precautions.

c. Supported Impact: "Acceptable" for all test conditions.

d. Unsupported Impact: "Acceptable" for all test conditions.

e. Abrasion Resistance: The weight loss would normally cause this material to be classified as a "potential problem" for all test conditions; however, in view of the textured nature of this material which tends to conceal abrasive wear, the covering is "probably acceptable".

f. Scratch Resistance: The scratch width could not be measured because of the nature of the material; however, since there was only minor fiber damage for all test conditions, the material is "probably acceptable".

g. Washability: "Potentially unacceptable".

h. Water Vapor Permeance: "Acceptable" for use in areas where direct contact with water is unlikely and where adequate ventilation is provided for the escape of water vapor.

i. Colorfastness: "Potentially unacceptable" when exposed to moisture or sunlight on a continual basis.

III. Recommendations for Field Evaluation:

Recommended for use, in normally dry areas, on walls, as suggested by the manufacturer. A solid substrate in good repair is required for adhesive attachment. Minor voids can be bridged. The product is not recommended for use in areas where contact with moisture is likely. Since health and safety problems are not anticipated during installation, the product can be used in both occupied and vacant dwellings. Because of its fire hazard properties the product should not be used over large areas of cellulosic materials in exit areas, kitchens and hazardous areas. The use of mechanically fastened trim strips on exposed edges would improve the peel resistance of the covering system.

6.3.3. Urethane Varnish

I. Observations:

a. Ease of Application: This product can be applied with either a brush or a spray gun with no difficulty. An annoying odor was given off during application.

b. Stability During Accelerated Aging: No visible deterioration.

c. Toxicity of Volatile Solvents: The product contains a mineral spirits solvent. Adequate ventilation should be provided and prolonged contact with skin and breathing of vapor or spray mist should be avoided. The container should be closed after use. According to Levinson [23], mineral spirits has a TLV of 500 ppm.

d. Maintainability: Damaged areas can be readily repaired by recoating with the varnish and blending in with the surrounding areas.

II. Test Results:

a. Adhesion: "Satisfactory" for all test conditions.

b. Fire Hazard:

i. Flame Spread: "Acceptable" for use in all areas if it is installed on a noncombustible substrate. "Not acceptable" for use over cellulosic surfaces.

ii. Smoke Generated: "Acceptable" for use in all areas when installed on substrates similar to those tested.

iii. Toxic Combustion Products: "Acceptable" for use in all areas when installed on substrates similar to those tested.

iv. Flash Point: "Relatively safe", but should not be used in the presence of heat or an open flame and adequate ventilation should be provided.

c. Supported Impact: "Acceptable" for use on plywood and similar materials for all test conditions. "Not acceptable" for use on gypsum board and similar materials for any test conditions.

d. Unsupported Impact: "Probably not acceptable" for all test conditions.

e. Abrasion Resistance: "Acceptable" for all test conditions.

f. Scratch Resistance: "Acceptable" for all test conditions.

g. Washability: "Good" with a sponge at room temperature. "Potentially unacceptable" in conditions where high temperature and humidity are present.

h. Water Vapor Permeance: "Acceptable" for use only in normally dry areas.

i. Colorfastness: "Potentially unacceptable" when exposed to either moisture or sunlight on a continual basis.

III. Recommendations for Field Evaluation:

The product is possibly acceptable for use on sound woodwork. The product will not perform effectively as a barrier if the lead bearing paint beneath it becomes delaminated from the woodwork. Application on exterior doors, windows and associated trim would not be recommended since the moisture problems that commonly occur in these areas can cause the leaded paint beneath the covering to delaminate. Because of its fire hazard properties, the product should not be used over large areas of cellulosic materials.

In addition, the product should not be applied in the presence of heat or an open flame and adequate ventilation should be provided.

In summary, this product is of limited value as a solution to the problem caused by lead bearing paints in housing.

6.3.4. One Component Epoxy Paint

I. Observations:

a. Ease of Application: The coating could not be applied smoothly by means of a brush or roller, although these methods are specified by the materials supplier. Airless spray coating is probably the only acceptable application method that can be used. The use of airless spraying is not very desirable in occupied dwellings.

b. Stability During Accelerated Aging: No visible deterioration.

c. Toxicity of Volatile Solvents: The coating is a water emulsion, and there should be no toxicity problems.

d. Maintainability: Since brush and roller application do not give a satisfactory finish, it is difficult to touch up small areas. Repainting of the surface by airless spraying may be required.

II. Test Results:

a. Adhesion: "Satisfactory" for all test conditions.

b. Fire Hazard:

i. Flame Spread: "Acceptable" for use in all areas if it is installed on a noncombustible substrate. Acceptable for use over cellulosic substrates except in exit areas, kitchens, and hazardous areas.

ii. Smoke Generated: "Acceptable" for use when installed on noncombustible substrates. "Hazardous" for use when installed on cellulosic substrates.

iii. Toxic Combustion Products: "Acceptable" for use when installed on substrates similar to those tested.

iv. Flash Point: "Relatively safe" using normal precautions.

c. Supported Impact: Acceptable for use on plywood and similar materials for all test conditions. Not acceptable for use on gypsum board and similar materials for any test conditions.

d. Unsupported Impact: "Probably not acceptable" for any test conditions.

e. Abrasion Resistance: "Acceptable" for all test conditions.

f. Sctatch Resistance: "Acceptable" for all test conditions.

g. Washability: "Acceptable" removal of soil, but noticeable changes in the appearance of the surface as a result of washing were measured.

h. Water Vapor Permeance: "Acceptable" for use in all areas.

i.. Colorfastness: "Potentially unacceptable" for use in areas where exposure to moisture is likely. "Acceptable" for use in areas where exposure to sunlight is likely.

III. Recommendation for Field Evaluation:

The product is possibly acceptable for use on sound woodwork; however it will not perform effectively as a barrier if the lead bearing paint beneath it becomes delaminated from the woodwork. Application on exterior doors, windows and associated trim would not be recommended since the moisture problems that commonly occur in these areas can cause the leaded paint beneath the covering to delaminate.

In summary, this product is of limited value as a solution to the problem caused by lead bearing paints in housing.

6.3.5. Vinyl Counter Top Material

I. Observations:

a. Ease of Application: No problem when the covering is applied on walls or other surfaces. Support should be provided when it is applied on ceilings until the adhesive cures. A contact type adhesive may be more desirable than the adhesive recommended by the manufacturer.

b. Stability During Accelerated Aging: The product appeared to yellow during aging at 160°F and 95% rh and is softened by 160° heat. Specimens delaminated when being dried after moist heat aging (160°F, 95% rh).

c. Toxicity of Volatile Solvents: The adhesive appears to contain an aqueous solvent and is not labelled as hazardous.

d. Maintainability: A damaged area could be cut out and replaced with another piece of the same covering; however, the color and pattern match may not be perfect. The covering can be painted with special paints intended for vinyls; however, ordinary alkyd and latex paints would probably not be acceptable.

II. Test Results:

a. Adhesion: "Satisfactory" at 73°F, 50% rh, and at 160°F, 4% rh. However, it was "unsatisfactory" when dried after moist conditioning and therefore would not be satisfactory in moist environments.

b. Fire Hazard:

i. Flame Spread: "Acceptable" for use in all areas if it is installed on a noncombustible substrate. Acceptable for use over cellulosic substrates except in exit areas, kitchens and hazardous areas.

ii. Smoke Generated: "Acceptable" for use when installed on all substrates.

iii. Toxic Combusion Products: "Potentially hazardous" [It may not pose a significant life safety problem to occupants because of the low flame spread of this material; however, it can pose a problem

if there is significant room involvement in a fire.]

iv. Flash Point: "Relatively safe" using normal precautions.

c. Supported Impact: "Acceptable" for use in dry areas on substrates similar to those tested. "Not acceptable" for use in moist areas (the covering delaminated from the substrate on which it was applied).

d. Unsupported Impact: "Good" for all test conditions.

e. Abrasion Resistance: "Acceptable" for all test conditions except moist heat aging where specimens delaminated prior to testing.

f. Scratch Resistance: "Acceptable" for all test conditions except moist heat aging where specimens delaminated prior to testing.

g. Washability: "Godd" washability.

h. Water Vapor Permeance: "Acceptable" for use in all areas.

i. Colorfastness: "Acceptable" for use where exposure to moisture and sunlight is likely.

III. Recommendations for Field Evaluation:

Recommended for use in normally dry areas on walls, doors, and wood trim (when thermoformed). A solid substrate in good repair is required for adhesive attachment. Minor voids can be bridged. The product is not recommended for use in areas where contact with moisture is likely. Since health and safety problems are not anticipated during installation, the product can be used in both occupied and vacant dwellings. Because of its fire hazard properties, the product should not be used over large areas of cellulosic materials in exit areas, kitchens and hazardous areas. The use of mechanically fastened trim strips on exposed edges would improve the peel resistance of the covering system.

6.3.6. Vinyl Wall Covering - Light Duty

I. Observations:

a. Ease of Application: The product can be readily applied using vinyl wall covering application techniques.

b. Stability During Accelerated Aging: The covering delaminated when subjected to moisture aging.

c. Toxicity of Volatile Solvents: The adhesive contains an aqueous solvent so there should be no toxicity problem.

d. Maintainability: A damaged area could be cut out and replaced with another piece of the same covering, however the color and pattern match may not be perfect. The covering can be painted with special paints intended for vinyls; however, ordinary alkyd and latex paints are not satisfactory for this purpose.

II. Test Results:

a. Adhesion: "Unsatisfactory" for all conditions.

b. Fire Hazard:

i. Flame Spread: "Acceptable" for use in all areas if it is installed on a noncombustible substrate. "Acceptable" for use over cellulosic substrates except in exit areas, kitchens and hazardous areas.

ii. Smoke Generated: "Acceptable" for use when installed on noncombustible substrates. On the borderline between "acceptable" and "potentially hazardous" when installed on cellulosic surfaces.

iii. Toxic Combustion Products: "Acceptable" for use on substrates similar to those tested.

iv. Flash Point" "Relatively safe" using normal precautions.

c. Supported Impact: "Acceptable" for use in dry and moist areas on all solid substrates. "Not acceptable" for use in areas where direct contact with water is likely (the covering delaminated).

d. Unsupported Impact: "Probably not acceptable" for all test conditions.

e. Abrasion Resistance: A "potential problem" when tested after curing at 73°F, 50% rh and aging at 160°F, 4% rh. Specimens delaminated during aging in moist heat (160°F, 95% rh) and soaking in water at 73°F and therefore were considered to fail the test.

f. Scratch Resistance: "Acceptable" for all test conditions except soaking in water at 73°F where coverings delaminated.

g. Washability: "Potentially unacceptable."

h. Water Vapor Permeance: "Acceptable" for use only in normally dry areas.

i. Colorfastness: "Potentially unacceptable" for use where contact with moisture and sunlight is likely.

III. Recommendations for Field Evaluation:

Not recommended for use since the wheat paste-type adhesive specified by the manufacturer has inadequate bond strength. The light duty vinyl wall covering might be satisfactory as a barrier covering if a stronger bond strength adhesive was used. The use of mechanically fastened trim strips on exposed edges would improve the peel resistance of the covering system.

6.3.7. Veneer Plaster with Bonding Agent

I. Observations:

a. Ease of Application: No problems are anticipated when properly trained personnel are used. The bonding agent can be applied by means of a brush or roller. Standard plastering procedures are used to apply the veneer plaster finish coat.

b. Stability During Accelerated Aging: Delamination of the plaster veneer was observed when specimens were subjected to moisture aging.

c. Toxicity of Volatile Solvents: According to the manufacturer, the product contains a non-toxic aqueous solvent.

d. Maintainability: Damaged areas can be readily patched and repainted.

II. Test Results*:

a. Adhesion: "Satisfactory" at 73°F, 50% rh and at 160°F, 4% rh. "Unsatisfactory" at 160°F, 95% rh and when water soaked.

b. Fire Hazard:

i. Flame Spread: "Acceptable" for use in all areas when installed on substrates similar to those tested.

ii. Smoke Generated: "Acceptable" for use in all areas when installed on substrates similar to those tested.

iii. Toxic Combustion Products: "Acceptable" for use in all areas when installed on substrates similar to those tested.

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* An unpainted veneer plaster surface was used to evaluate the properties listed below. Since properties 'e' to 'i' are a function of the surface finish, they can be improved considerably if a high quality paint coat is applied.

iv. Flash Point: The bonding agent is "relatively safe" when normal precautions are used.

c. Supported Impact: "Acceptable" for use in dry areas on walls. (Since plaster is not used on woodwork, the product was not evaluated on a plywood substrate.) "Unacceptable: for use in areas where contact with moisture is likely.

d. Unsupported Impact: "Potentially unacceptable" for use in all applications.

e. Abrasion Resistance: A "potential problem" unless painted.

f. Scratch Resistance: A "potential problem" unless painted.

g. Washability: "Potentially unacceptable" (easily stained and difficult to clean) unless painted.

h. Water Vapor Permeance: "Acceptable" for use in dry areas and in areas where direct contact with water is unlikely.

i. Colorfastness: "Acceptable".

III. Recommendations for Field Evaluation:

The product is recommended for use on walls and ceilings in areas where exposure to moisture is not likely. The product is not recommended for use on doors, baseboards and similar items nor should it be used in areas where exposure to moisture is likely.

A good quality paint top coat and primer should be provided on wall areas to improve the functional properties of the surface.

The system should only be applied on a sound substrate where delamination is unlikely since it will not perform adequately as a barrier if delamination occurs.

6.3.8. Vinyl Wall Covering-Medium Duty

I. Observations:

a. Ease of Application: The product can be readily applied using standard vinyl wall covering application techniques.

b. Stability During Accelerated Aging: The covering delaminated when subjected to moisture aging.

c. Toxicity of Volatile Solvents: The adhesive formulation uses water as a solvent, so there should be no toxicity problem.

d. Maintainability: A damaged area could be cut out and replaced with another piece of the same covering; however, the color and pattern match may not be perfect. The covering cannot be painted.

II. Test Results:

a. Adhesion: "Satisfactory" at 73°F, 50% rh and at 160°F, 4% rh. "Unsatisfactory" at 160°F, 95% rh and when water soaked.

b. Fire Hazard:

i. Flame Spread: "Acceptable" for use in all areas if it is installed on a noncombustible substrate. "Acceptable" for use over cellulosic substrates except in kitchens, exit areas and hazardous areas such as furnace rooms.

ii. Smoke Generated: "Acceptable" for use when installed on noncombustible substrates. "Potentially hazardous" when installed on cellulosic substrates.

iii. Toxic Combustion Products: "Acceptable" for use in all areas when installed on substrates similar to those tested.

iv. Flash Point: The adhesive had a flash point greater than 212°F; no problems are anticipated.

c. Supported Impact: "Acceptable" for use in dry areas on substrates similar to those tested. Not acceptable for use in moist areas (the covering delaminated from the substrate on which it was applied).

d. Unsupported Impact: "Good" for all test conditions.

e. Abrasion Resistance: "Acceptable" for use in areas where exposure to moisture is not likely (the coverings came off during conditioning with moisture).

f. Scratch Resistance: "Acceptable" for use in areas where exposure to moisture is not likely (the covering delaminated during moisture conditioning).

g. Washability: "Good" with a sponge; "acceptable" with a brush.

h. Water Vapor Permeance: "Potentially unacceptable" for use in areas where contact with moisture is likely.

i. Colorfastness: "Potentially unacceptable" for use in areas where prolonged contact with ultraviolet radiation or moisture is likely.

III. Recommendations for Field Evaluation:

Recommended for use in normally dry areas on walls, as suggested by the manufacturer. The product should not be used to cover large expanses of cellulosic materials in kitchens, exit areas and hazardous areas such as furnace rooms because of its fire hazard properties; however, it is satisfactory for use on plaster walls in these areas.

A solid substrate in good repair is required for adhesive attachment. The product is not recommended for use in areas where contact with moisture is likely. Since health and safety problems are not anticipated during installation, the product can be used in both occupied and vacant dwellings. The use of mechanically fastened trim strips on exposed edges would improve the peel resistance of the covering system.

6.3.9. Nylon Formulated One Component Paint

I. Observations:

a. Ease of Application: An inexperienced painter would have difficulty in applying this coating without leaving brush marks. Roller application is somewhat more desirable.

b. Stability During Accelerated Aging: No visible deterioration.

c. Toxicity of Volatile Solvents: The coating is a water-based emulsion and there should be no toxicity problems.

d. Maintainability: It may be difficult to match the texture of surrounding areas when small areas are repaired.

II. Test Results:

a. Adhesion: "Satisfactory" for all test conditions.

b. Fire Hazard:

i. Flame Spread: "Acceptable" for use in all areas if it is installed on a noncombustible substrate. "Acceptable" for use over cellulosic substrates except in kitchens, exit areas and hazardous areas such as furnace rooms.

ii. Smoke Generated: "Acceptable" for use in all areas when installed on substrates similar to those tested.

iii. Toxic Combustion Products: "Acceptable" for use in all areas when installed on substrates similar to those tested.

iv. Flash Point: The paint was a water based emulsion and had a flash point greater than 212°F. No problems are anticipated.

c. Supported Impact: "Acceptable" for use on plywood and similar substrates for all test conditions. "Unacceptable" for use on gypsum board and similar materials for any test conditions.

d. Unsupported Impact: "Probably not acceptable" for any test conditions.

e. Abrasion Resistance: A "potential problem" for all test conditions. The abrasion weight loss was slightly avove the level that was considered to be adequate.

f. Scratch Resistance: "Acceptable" for all test conditions.

g. Washability: "Acceptable" with a sponge after aging at 73°F, 50% rh, but marginal after aging. Inconsistent test results were obtained.

h. Water Vapor Permeance: "Acceptable" for use in areas where contact with water vapor is likely, but not in areas where there can be direct contact with water.

i. Colorfastness: "Potentially unacceptable" for use in areas where exposure to moisture is likely. "Acceptable" for use in areas where exposure to sunlight is likely.

III. Recommendations for Field Evaluation:

The product is possibly acceptable for use on sound woodwork in normal living areas; however, it has several limitations. Its fire hazard properties make it undesirable for use on woodwork in kitchens, exit areas and hazardous areas such as furnace rooms. In addition, its poor abrasion makes it somewhat undesirable for use in high wear applications, and it will not perform adequately as a barrier if the lead bearing paint beneath it becomes delaminated. For the latter reason, application on exterior doors, windows and associated trim would not be recommended because of the moisture problems that commonly occur in these areas.

In summary, this product is of limited value as a solution to the problem caused by lead bearing paints in housing.

6.3.10. Nylon Formulated Two Component Paint

I. Observations:

a. Ease of Application: The coating was relatively easy to apply smoothly with a brush and a roller.

b. Stability During Accelerated Aging: No visible deterioration.

c. Toxicity of Volatile Solvents: The product is labeled as a "skin sensitizer". Prolonged contact with the skin or inhalation of the solvent vapors should be avoided.

d. Maintainability: Should be no problem.

II. Test Results:

a. Adhesion: "Satisfactory" for all test conditions.

b. Fire Hazard:

i. Flame Spread: "Acceptable" for use in all areas if it is installed on a noncombustible substrate. "Not acceptable" for use over cellulosic substrates.

ii. Smoke Generated: "Acceptable" for use over noncombustible substrates. A "potential problem" when used over cellulosic substrates.

iii. Toxic Combustion Products: "Acceptable" for use over noncombustible substrates. "Potentially hazardous" when installed on cellulosic substrates; its performance was marginal.

iv. Flash Point: Should be safe for use if normal precautions, as directed on the label are followed.

c. Supported Impact: "Acceptable" for use on plywood and similar substrates after dry conditioning; marginal after exposure to moisture. "Unacceptable" for use on gypsum board and similar materials for any test conditions.

d. Unsupported Impact: "Probably not acceptable" for any test conditions.

e. Abrasion Resistance: "Acceptable" for all test conditions.

f. Scratch Resistance: "Acceptable" for all test conditions.

g. Washability: "Good" with a sponge, marginal with a brush.

h. Water Vapor Permeance: "Acceptable" for use in areas where exposure to moisture is not likely. "Potentially unacceptable" for use in moist areas.

i. Colorfastness: "Potentially unacceptable" for use in areas where exposure to moisture is likely. "Acceptable" for use in areas where exposure to sunlight is likely.

III. Recommendations for Field Evaluation:

The product is possibly acceptable for use on sound woodwork: however, it will not perform effectively as a barrier if the lead bearing paint beneath it becomes delaminated from the woodwork. The smoke and toxic combustion product levels measured on a plywood substrate indicate that a possible hazard will be created if the product is used to cover large expanses of cellulosic materials. Application on exterior doors, windows and associated trim would not be recommended because of the delamination problems that can be caused by moisture in these areas.

In summary, the product is of limited value as a solution to the problem caused by lead bearing paints in housing.

6.3.11. Nylon Formulated Two Component Paint with Flexible Primer

I. Observations:

a. Ease of Application: The coatings were relatively easy to apply smoothly with a brush and a roller. The primer coat had to be allowed to get tacky prior to applying the cover coat.

b. Stability During Accelerated Aging: No visible deterioration.

c. Toxicity of Volatile Solvents: The products are labelled as "skin sensitizers". Prolonged contact with the skin, or inhalation of the solvent vapors should be avoided.

d. Maintainability: Should be no problem.

II. Test Results:

a. Adhesion: "Satisfactory" for all test conditions.

b. Fire Hazard:

i. Flame Spread: "Acceptable" for use in all areas if it is installed on a noncombustible substrate. "Not acceptable" for use over cellulosic substrates.

ii. Smoke Generated: "Acceptable" for use over noncombustible substrates. A "potential problem" when used over cellulosic substrates.

iii. Toxic Combustion Products: "Acceptable" for use when installed on substrates similar to those tested.

iv. Flash Point: Should be safe for use if normal precautions, as directed on the label, are followed.

c. Supported Impact: "Probably not acceptable" when installed on plywood and similar substrates after dry curing. "Unacceptable" for use on gypsum board and similar materials.

d. Unsupported Impact: "Probably not acceptable" for any test conditions.

e. Abrasion Resistance: "Acceptable" after curing.

f. Scratch Resistance: "Acceptable" after curing.

g. Washability: "Good" with a sponge, "acceptable" with a brush.

h. Water Vapor Permeance: "Acceptable" for use in all areas.

i. Colorfastness: "Potentially unacceptable" for use in areas where exposure to moisture is likely. "Acceptable" for use in areas where exposure to sunlight is likely.

III. Recommendations for Field Evaluation:

The product would not be recommended since its fire hazard properties preclude its use on large areas of woodwork, and its low supported impact resistance on gypsum board makes it undesirable for use on substrates such as painted plaster walls.

6.3.12. High Build Textured Spray Coating-Fine Texture

I. Observations:

a. Ease of Application: The product can only be applied by spraying with equipment designed to handle aggregate filled, viscous, liquids. Relatively inexpensive hopper spray guns, in combination with a source of compressed air, can be used for small jobs.

b. Stability During Accelerated Aging: No visible deterioration.

c. Toxicity of Volatile Solvents: According to the manufacturer, the product solvent system is primarily water-based and its use complies with existing air pollution control regulations regarding hydrocarbon emissions.

d. Maintainability: It would be difficult to match the texture of surrounding areas, when small areas are patched, unless spray equipment was used.

II. Test Results:

a. Adhesion: "Satisfactory" for all test conditions.

b. Fire Hazard:

i. Flame Spread: "Acceptable" for use in all areas if it is installed on a noncombustible substrate. "Not acceptable" for use over cellulosic substrates.

ii. Smoke Generated: "Acceptable for use over noncombustible substrates. A "potential problem" when used over cellulosic substrates.

iii. Toxic Combustion Products: "Acceptable" for use when installed on substrates similar to those tested.

iv. Flash Point: The flash point was greater than 212°F; should be no problem.

c. Supported Impact: "Acceptable" for use when installed on plywood and similar substrates. "Unacceptable" when installed on gypsum board and similar substrates.

d. Unsupported Impact: "Probably not acceptable" for any test conditions.

e. Abrasion Resistance: A "potential problem" for all test conditions.

f. Scratch Resistance: Probably "acceptable"; the scratch resistance was acceptable after aging, but not before.

g. Washability: "Potentially unacceptable."

h. Water Vapor Permenance: "Acceptable" for use only in areas where direct contact with water is not likely.

i. Colorfastness: "Potentially unacceptable" for use in areas where exposure to moisture is likely. "Acceptable" for use in areas where exposure to sunlight is likely.

III. Recommendations for Field Evaluation:

The product would not be recommended for use since its fire hazard properties preclude its use on large areas of woodwork, and its low supported impact resistance on gypsum board makes it undesireable for use on substrates such as painted plaster walls.

6.3.13. High Build Textured Spray Coating-Medium Texture

I. Observations:

a. Ease of Application: The product can only be applied by spraying with equipment designed to handle aggregate filled, viscous liquids. Relatively inexpensive hopper spray guns, in combination with a source of compressed air, can be used for small jobs.

b. Stability During Accelerated Aging: No visible deterioration.

c. Toxicity of Volatile Solvents: According to the manufacturer, the product solvent system is primarily water-based and its use complies with existing air pollution control regulations regarding hydrocarbon emissions.

d. Maintainability: It would be difficult to match the texture of surrounding areas, when small areas are patched, unless spray equipment was used.

II. Test Results:

a. Adhesion: "Satisfactory" for all test conditions.

b. Fire Hazard:

i. Flame Spread: "Acceptable" for use in all areas if it is installed on a noncombustible substrate. "Not acceptable" for use over cellulosic substrates.

ii. Smoke Generated: "Acceptable" for use over noncombustible substrates. A "potential problem" when used over cellulosic substrates.

iii. Toxic Combustion Products: "Acceptable" for use when installed on substrates similar to those tested.

iv. Flash Point: The flash point was greater than 212°F; should be no problem.

c. Supported Impact: "Acceptable" for use when installed on plywood, and similar substrates. "Probably not acceptable" after room temperature curing and "unacceptable" after moisture aging, when applied to gypsum board and similar substrates.

d. Unsupported Impact: "Probably not acceptable" for any test conditions.

e. Abrasion Resistance: A "potential problem" for all test conditions.

f. Scratch Resistance: "Acceptable" for all test conditions.

g. Washability: "Potentially unacceptable."

h. Water Vapor Permeance: "Acceptable" for use only in areas where direct contact with water is not likely.

i. Colorfastness: "Acceptable" for use in areas where exposure to moisture and/or sunlight is likely.

III. Recommendations for Field Evaluation:

Although the product's fire hazard properties preclude its use on large areas of woodwork, it has possible application as a protective covering on sound, painted plaster walls in dry areas. A solid backing is required for adequate performance. Its borderline supported impact resistance on painted gypsum board, and the low cost potential of this type of product make it worthy of further investigation. Field trials in occupied housing should be used as a basis for making a final decision as to whether or not the product is satisfactory. A good quality paint top coat should be applied over the textured coating to improve its abrasion resistance and washability. The coating can be applied over a wire mesh if improved impact resistance is desired and if application over deteriorated surfaces is desired. Application in a vacant dwelling would be desirable since the coating is spray applied.

6.3.14. Two Component Epoxy Paint

I. Observations:

a. Ease of Application: The product is somewhat difficult to apply without leaving brush marks. The manufacturer recommends smoothing out the brush marks with a water soaked nylon brush after the paint is applied.

b. Stability During Accelerated Aging: No visible deterioration.

c. Toxicity of Volatile Solvents: Both components of the paint formulation were dispersed in water; no problems are anticipated.

d. Maintainability: No problems are anticipated.

II. Test Results:

a. Adhesion: "Satisfactory" for all test conditions.

b. Fire Hazard:

i. Flame Spread: "Acceptable" for use in all areas if it is installed on a noncombustible substrate. "Not acceptable" for use over cellulosic substrates.

ii. Smoke Generated: "Acceptable" for use over noncombustible substrates. A "potential problem" when used over cellulosic substrates.

iii. Toxic Combustion Products: "Acceptable" for use when installed on substrates similar to those tested.

iv. Flash Point: Both components were water emulsions and had flash points greater than 212°F; should be no problem.

c. Supported Impact: "Probably not acceptable" for any test conditions.

e. Abrasion Resistance: "Acceptable" for all test conditions.

f. Scratch Resistance: "Acceptable" for all test conditions.

g. Washability: "Good" when tested with a sponge; acceptable with a brush.

h. Water Vapor Permeance: "Acceptable" for use only in areas where contact with moisture is not likely.

i. Colorfastness: "Acceptable" for use in areas where exposure to moisture and/or sunlight is likely.

III. Recommendations for Field Evaluation:

The product would not be recommended for use since its fire hazard properties preclude its use on large areas of woodwork and its low supported impact resistance on gypsum board makes it undesirable for use on substrates such as painted plaster walls.

6.3.15. Cementitious Coating-"Orange Peel" Texture

I. Observations:

a. Ease of Application: The coating can be spray or trowel applied. Spray equipment capable of handling textured, viscous liquids would be required. Some shrinkage cracking was observed during the curing process; but the performance of the covering did not appear to be affected.

b. Stability During Accelerated Aging: The coating delaminated from the substrate that it was applied on when test specimens were exposed to moist aging conditions.

c. Toxicity of Volatile Solvents: Water is used; no problem is anticipated.

d. Maintainability: It may be difficult to match the texture of surrounding areas when small areas are repaired.

II. Test Results:

a. Adhesion: "Satisfactory" at 73°F, 50% rh and at 160°F, 4% rh. "Unsatisfactory" at 160°F, 95% rh and when water soaked.

b. Fire Hazard:

i. Flame Spread: "Acceptable" when installed on substrates similar to those tested.

ii. Smoke Generated: "Acceptable" when installed on substrates similar to those tested.

iii. Toxic Combustion Products: "Acceptable" when installed on substrates similar to those tested.

iv. Flash Point: Should be no problem; water is used as a solvent.

c. Supported Impact: "Acceptable" for use, when installed on plywood and similar substrates, under dry conditions; specimens delaminated during moisture aging. "Probably not acceptable" on gypsum board after 73°F, 50% rh curing; delaminated after moisture aging.

d. Unsupported Impact: "Probably not acceptable" for any test conditions.

e. Abrasion Resistance: A "potential problem" for all test conditions.

f. Scratch Resistance: "Acceptable" for all test conditions.

g. Washability: "Potentially unacceptable."

h. Water Vapor Permeance: "Acceptable" for use only in areas where direct contact with water is not likely.

i. Colorfastness: "Potentially unacceptable" for use in areas where exposure to moisture is likely. "Acceptable" for use in areas where exposure to sunlight is likely.

III. Recommendations for Field Evaluation:

The product is acceptable for use as a barrier over tightly adhered lead bearing paints on wood surfaces in all dry areas. It is also possibly acceptable for use on painted plaster and gypsum board in dry areas. The loss of bonding that occurs when the covering, applied over a smooth paint surface, is exposed to moisture precludes its use in areas where moisture problems are common, such as bathrooms and exterior doors, windows, and associated trim. Since the covering requires a solid supportive substrate for adequate performance, it should only be applied on sound backings. The bond can probably be improved considerably by scoring the painted surface, or attaching a wire mesh to it, prior to spraying on the coating. A quality paint topcoat should be provided to improve the poor abrasion resistance and washability of the cementitious coating. Spray application in vacant dwellings is most desirable.

Since the covering had borderline impact resistance when it was tested on a gypsum board substrate, it should be field evaluated under controlled conditions in housing where children are present before final approval is given.

6.3.16. Cementitious Coating-Medium Texture

I. Observations:

a. Ease of Application: The coating can be spray or trowel applied. Spray equipment capable of handling textured, viscous liquids would be required.

b. Stability During Accelerated Aging: The coating delaminated from the substrate that it was applied on when test specimens were exposed to moist aging conditions.

c. Toxicity of Volatile Solvents: Water is used; no problem is anticipated.

d. Maintainability: It may be difficult to match the texture of surrounding areas when small areas are repaired.

II. Test Results:

a. Adhesion: "Satisfactory" at 73°F, 50% rh and at 160°F, 4% rh. "Unsatisfactory at 160°F, 95% rh and when water soaked; the plywood delaminated.

b. Fire Hazard:

i. Flame Spread: "Acceptable" for use, over substrates similar to those tested, in normal living areas. "Not acceptable" for use in kitchens, exit areas, and hazardous areas such as furnace rooms.

ii. Smoke Generated: A "potential problem" when installed on plywood and similar substrates. "Acceptable" for use when installed on noncombustible substrates.

iii. Toxic Combustion Products: "Acceptable" for use in all areas when installed on substrates similar to those tested.

iv. Flash Point: Not tested.

c. Supported Impact: "Acceptable" for use on plywood, gypsum board, and similar substrates, except where exposure to moisture is likely (moist heat aging caused the plywood to delaminate).

d. Unsupported Impact: "Acceptable" for use in all areas except where exposure to moisture is likely (delamination occurred under this test condition).

e. Abrasion Resistance: "Acceptable" for use in all areas except those where exposure to moisture is likely.

f. Scratch Resistance: A "potential problem" for all test conditions.

g. Washability: "Good" cleaning with both brush and sponge applicators; however the surface finish is caused to darken considerably.

h. Water Vapor Permeance: "Acceptable" for use in all areas where direct contact with water is not likely.

i. Colorfastness: "Acceptable" colorfastness in the presence of sunlight and/or moisture; however, the gloss of the surface finish was significantly reduced.

III. Recommendations for Field Evaluation:

Recommended for use as a barrier over leaded paints on walls in dry areas other than kitchens, exit areas, and hazardous areas such as furnace rooms. The covering can be applied over voids. Adequate ventilation should be provided to prevent the buildup of harmful vapors from the adhesive. Since the product delaminated when it was exposed to moist heat aging, it is not recommended for use in wet areas.

6.3.17. Plywood Paneling-Prefinished

I. Observations:

a. Ease of Application: The product can be applied, with adhesives and mechanical fasteners, by commonly accepted procedures.

b. Stability During Accelerated Aging: Moist aging conditions caused the plywood layers to delaminated.

c. Toxicity of Volatile Solvents: According to Gleason, et al [29] the recommended adhesive contains methylethylketone, toluol and naphtha, all of which are fairly toxic. Since the adhesive is in a paste form, the amounts of solvent that will be encountered are much less than would be found in a liquid suspension.

d. Maintainability: It would be very difficult to repair damaged surfaces without painting the entire paneling surface.

II. Test Results:

a. Adhesion: "Satisfactory" at 73°F, 50% rh and at 160°F, 4% rh. "Unsatisfactory" at 160°F, 95% rh and when water soaked; the plywood delaminated.

b. Fire Hazard:

i. Flame Spread: "Acceptable" for use, over usbstrates similar to those tested, in normal living areas. "Not acceptable" for use in kitchens, exit areas, and hazardous areas such as furnace rooms.

ii. Smoke Generated: A "potential problem" when installed on plywood and similar substrates. "Acceptable" for use when installed on noncombustible substrates.

iii. Toxic Combustion Products: "Acceptable" for use in all substrates similar to those tested.

iv. Flash Point: Not tested; the recommended adhesive was not in a liquid form.

c. Supported Impact: "Acceptable" for use on plywood, gypsum board, and similar substrates, except where exposure to moisture is likely (moist heat aging caused the plywood to delaminate).

d. Unsupported Impact : "Acceptable" for use in all areas except where exposure to moisture is likely (delamination occurred under this test condition).

e. Abrasion Resistance: "Acceptable" for use in all areas except those where exposure to moisture is likely.

f. Scratch Resistance: A "potential problem" for all test conditions.

g. Washability: "Good" cleaning with both brush and sponge applicators; however the surface finish is caused to darken considerably.

h. Water Vapor Permeance: "Acceptable" for use in all areas where direct contact with water is not likely.

i. Colorfastness: "Acceptable" colorfastness in the presence of sunlight and/or moisture; however, the gloss of the surface finish was significantly reduced.

III. Recommendations for Field Evaluation:

Recommended for use as a barrier over leaded paints on walls in dry areas other than kitchens, exit areas, and hazardous areas such as furnace rooms. The covering can be applied over voids. Adequate ventilation should be provided to prevent the buildup of harmful vapors from the adhesive. Since the product delaminated when it was exposed to moist heat aging, it is not recommended for use in wet areas.

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Appendix A

A. Test Procedures*

A.1. General Comments

Test methods and procedures were chosen, modified or designed to simulate the service conditions that are likely to be encountered in actual use in housing. For example, glossy painted surfaces that could cause adhesion problems were simulated by the use of test panels painted with glossy alkyd paint and by phenolic board substrates. The accelerated aging procedures described in section 2.3.1. were used to simulate the effects of moisture attack and normal dry aging over extended periods of time.

For the purpose of this investigation, pre-test treatment is defined as the environmental treatment to which a test specimen is exposed from the moment that a covering is applied on a substrate to the moment that the specimen is tested. It shall consist of three separate stages, as defined below:

Curing period or cure: The time period stated by the supplier as required for development of the properties of the system. However, in no case was the period less than 7 days.

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* The test procedures and recommended performance levels discussed in this publication are preliminary in nature and subject to revision as more information becomes available.

Aging: Exposure for a period of time to an environmental condition intended to simulate the effects of long-term in-service exposure, following the curing period.

Conditioning: The equilibration of test specimens to prescribed conditions immediately prior to testing.

A.2. Adhesion (Tensile Bond)

A. Objective: To determine the effectiveness and the durability of the bond between the proposed covering systems and the surfaces that occur in buildings.

B. Scope: The proposed systems are applied on substrates simulating the well cured paint surfaces found in existing dwellings. The strength of the bond between the covering and the substrate is determined after exposure to standard laboratory conditions and after exposure to aging.

C. Test Specimens: Test specimens shall be prepared for each of the pre-test treatments described in section C.1. A set of 5 specimens shall be prepared for each test listed. Bond test specimens shall be prepared by applying coverings to 1/4 inch thick phenolic board substrates meeting the requirements for Type I, Grade XX, Federal Specification L-P-509a [1]*. The covering shall be applied to the substrate using the procedure recommended by the supplier. The phenolic board shall be cut into 2 in x 2 in squares prior to application of the barrier when there is a possibility that cutting the test specimen afterwards

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* Underlined numerals in brackets indicate references given on page A-49.

will disrupt the bond or covering. (Cutting up large boards after the application of coverings is generally more convenient when large numbers of small specimens are required.)

C.1. Pre-Test Treatment:* Specimens shall be subjected to the 4 types of pre-test treatments shown in figure A-1. The first shall be curing at standard laboratory conditions (73±3°F, 50±5% rh). The second shall be for 7 days at 160±5°F, 95±3% rh, the third shall be for 7 days at 160±5°F, 4% rh, and the fourth shall be for 7 days in water at 73°F.

Note: Test specimens shall be cured for a minimum of 7 days prior to initiating the aging procedures. This "cure" time, which will vary from 7 to 28 days, should be long enough to permit bond development.

D. Tensile Test Procedure: The test method shall be as described in ASTM C-297 [2]. The rate of loading shall be adjusted so that failure will occur in 2 to 6 min. after starting load applications.

Note: The basic feature of the ASTM X-297 test method is the application of a tensile load through two heavy steel plates which are bonded to opposite faces of the test specimen. The tensile load induces failure in the weakest of the materials in the composite specimen.

Figures A-2 and A-3 show a typical test specimen mounted in the tensile tester used to measure bond strength.

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* Initial tests were performed on specimens soaked in water at 160°F in addition to the aging conditions shown in figure A-1. This procedure was later discontinued since it was believed to be overly severe.

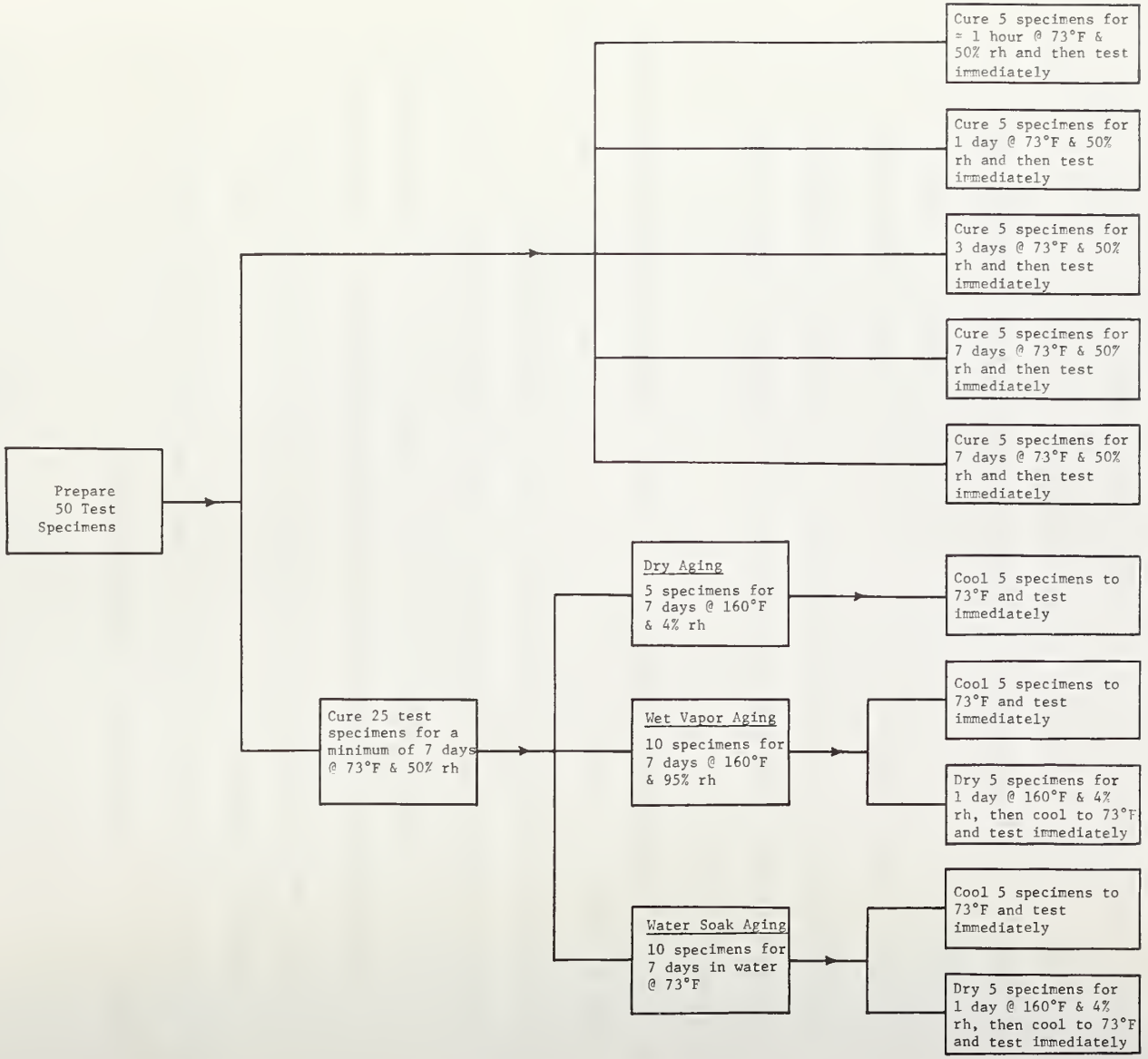

Figure A-1. Tensile bond adhesion pre-test treatment schedule.

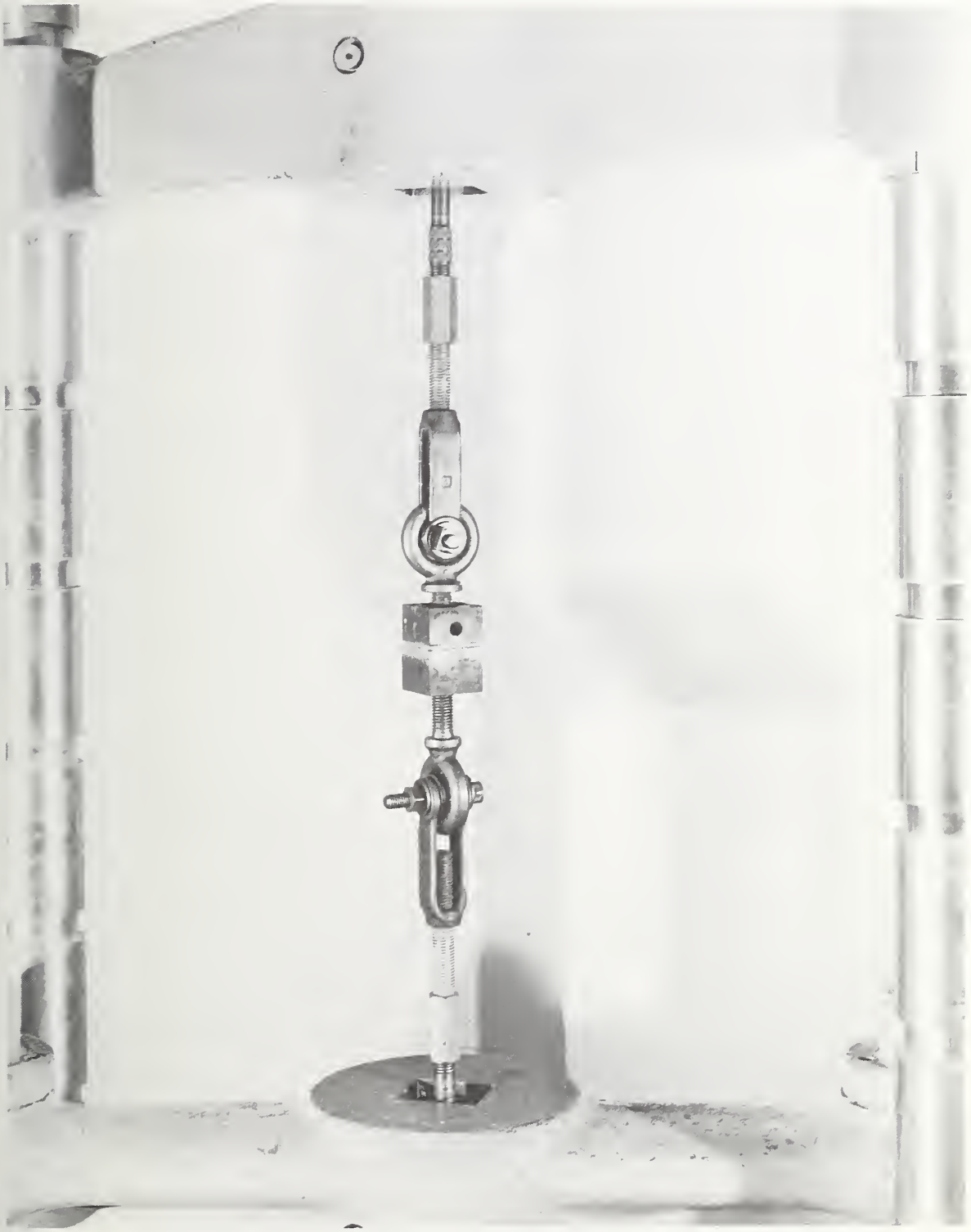

Figure A-2. Tensile bond adhesion test apparatus.

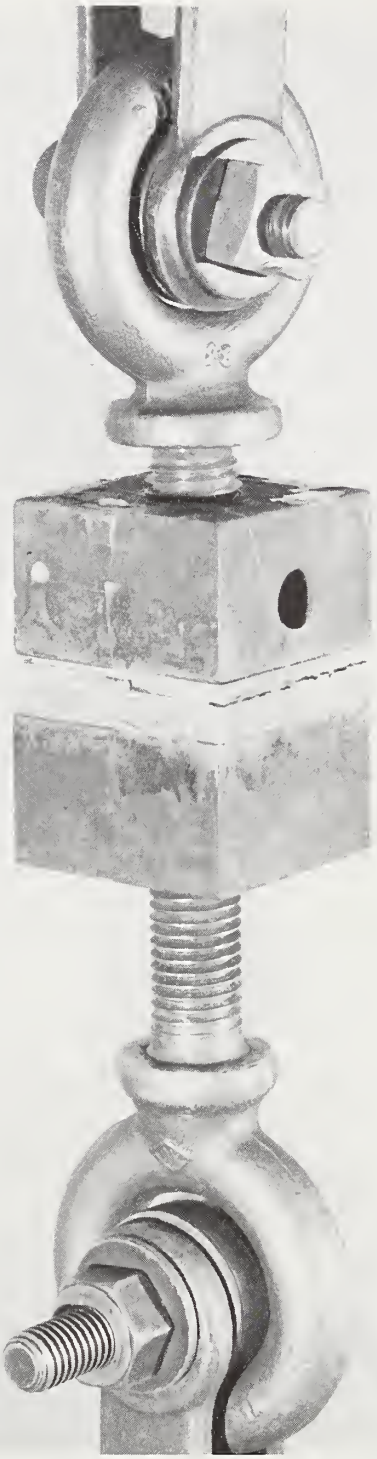

Figure A-3. Tensile bond adhesion test specimen assembly.

For these tests 2 in x 2 in x 1 in thick steel plates shall be bonded to the substrate and to the barrier materials with a high tensile strength adhesive. The tensile load shall be applied to the steel plates by means of a universal joint to ensure a uniform loading.

All tests shall be made with the test specimen at a standard laboratory temperature of 73±3°F. The moisture content of the specimen at the time of test will vary with the pre-test treatment.

A.3. Fire Hazard Evaluation

A.3.1. Flame Spread

A. Objective: To determine the surface burning characteristics of the proposed covering systems applied on surfaces that occur in housing.

B. Scope: The proposed systems are subjected to flame spread tests to determine a flame spread index number which reflects the rate of flame propagation over the surface of a material.

C. Test Specimens and Pre-test Treatment: Two substrate materials, 1/4 in asbestos cement board (ACB) conforming to Federal Specification SS-B-755a, Type U [3], and 3/4 in plywood, conforming to Product Standard 1-66, Type A-D, Interior [4], shall be used. The ACB represents essentially noncombustible surfaces such as plaster or gypsum board, and the plywood represents combustible surfaces. Each substrate shall be primed and then coated with 2 coats of semi-gloss enamel conforming to Federal Specification TT-E-508b [5]. Covering systems shall be applied to each of the painted substrates in accordance with the supplier's instructions. Three 6 in x 18 in specimens shall be prepared for each system-substrate combination. Following curing for a minimum of 7 days at standard laboratory conditions, two of the three specimens shall be subjected to

the following pre-test treatment procedures; aging for 24 hours at 140°F and then conditioning at 73±5°F and 50±5% rh until the specimen reaches equilibrium. One specimen of the three shall be subjected to more severe treatment by grooving to promote delamination, and aging for 5 days, rather than 24 hours, at 140°F prior to conditioning. Preparation of the grooved specimen from each set of three shall be in accordance with paragraph 4.9.3. of ASTM E 162 [6].

Note: If on the first test on a set of specimens the covering becomes completely delaminated, mechanical fastening shall be used to prevent the covering from falling off the substrate during subsequent tests.

D. Test Procedures: The procedures of ASTM E 162 shall be used with the following exceptions: (1) paragraph 4.9.2. shall not be followed and (2) three specimens shall be substituted for the four specified in paragraph 6.1.

The method involves employing a radiant heat source (12 by 18 inch panel) in front of which an inclined 6 x 18 inch specimen of the material is mounted, as is shown in figures A-4 and A-5. The specimen shall be oriented so that ignition is induced near the upper edge and the flame front progresses downward. A factor derived from the rate of progress of the flame front (ignition properties) and another relating to the rate of heat liberation by the material under test shall be combined to provide a flame spread index.

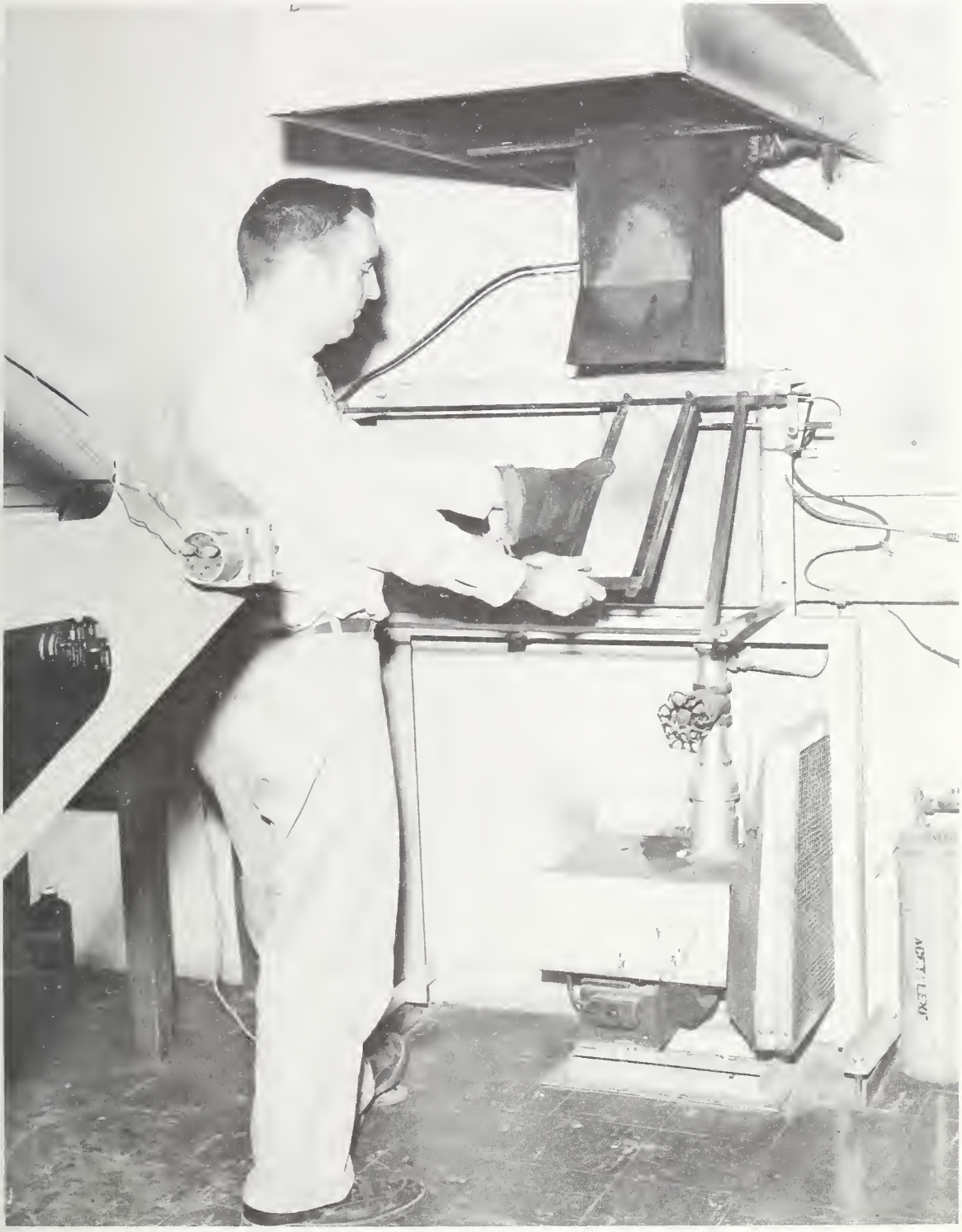

Figure A-4. Radiant panel flame spread test apparatus.

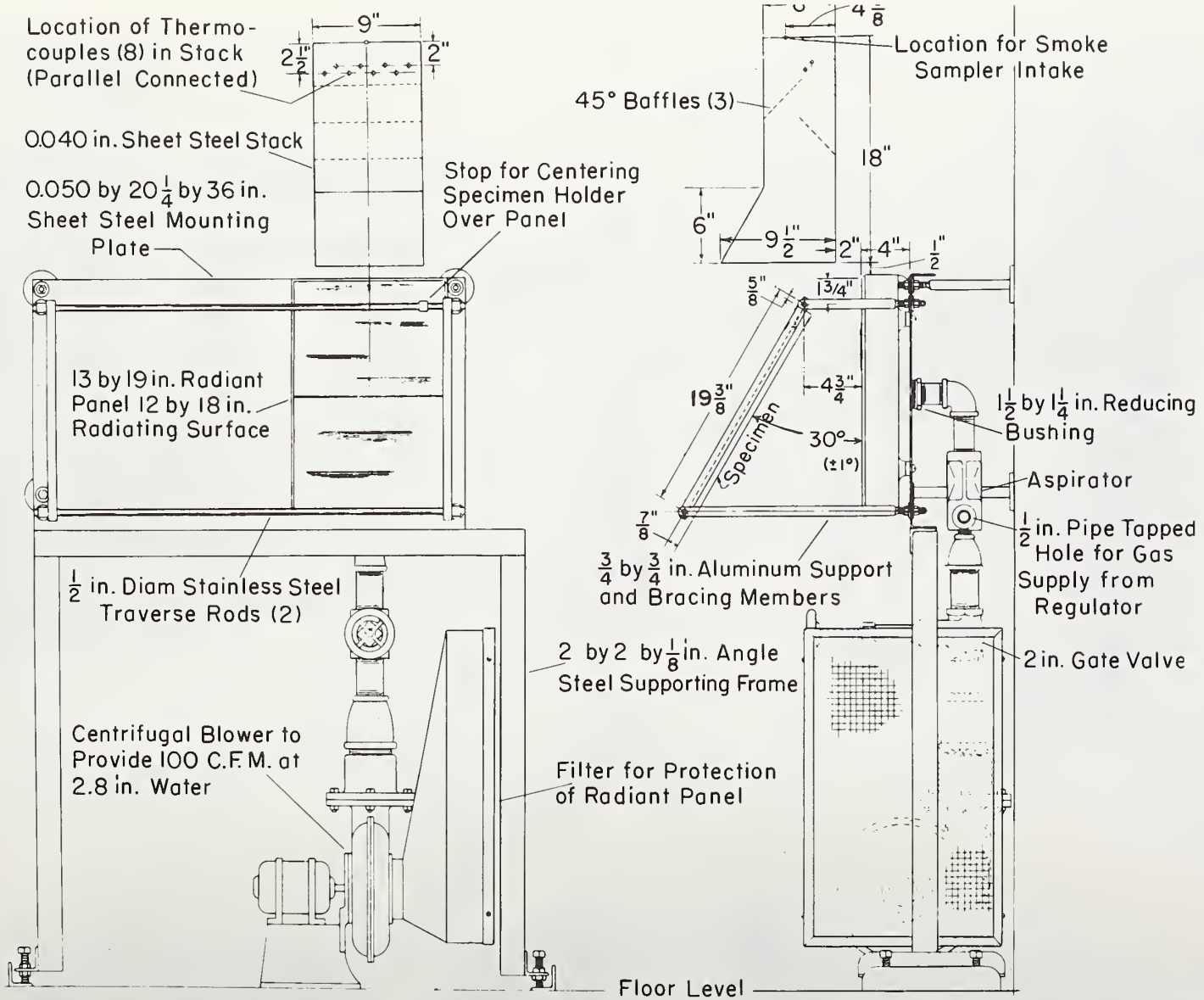

Figure A-5. Radiant panel test apparatus - Construction details.

A.3.2. Smoke Generated

A. Objective: To measure the relative smoke levels generated by combustion of the proposed covering systems when they are used over surfaces in housing. Smoke generated in accidental fires is generally considered to be a major factor in the life safety of building occupants.

B. Scope: The proposed systems are evaluated for smoke generation by measuring the maximum attenuation of a light beam passed through the smoke aerosol generated by the test specimen within an enclosed smoke chamber. The smoke level is "reported in terms of specific optical density, a dimensionless attenuation coefficient which defines the maximum amount of smoke accumulated from a specimen of unit surface area in terms of its photometric obscuration over unit path length within a chamber of unit volume" [7].

C. Test Specimens and Pre-test Treatment: Two substrate materials shall be used for each surface material tested. The substrate materials shall be painted 1/4 in asbestos cement board (ACB) and painted 3/4 in plywood, as specified in section A.3.1. The ACB represents essentially noncombustible surfaces. Six 3 in x 3 in specimens shall be prepared for each covering material on each of the substrates. For each covering evaluated, there shall be three tests in the flaming mode and three tests in the nonflaming mode for each of the two substrates.

Following curing for a minimum of 7 days at standard laboratory conditions, two of the three specimens shall be subjected to the following pre-test treatment procedures; aging for 24 hours at 140°F and then conditioning to equilibrium at 73±5°F and 50±5% rh. The third specimen shall be subjected to aging for 5 days at 140°F instead of 24 hours prior to conditioning.

D. Test Procedure: The test method described by T. G. Lee [8,9] shall be followed.

The basic test apparatus used is shown in figures A-6 and A-7. Changes in the transmitted light flux caused by the smoke generated by test specimens when they are exposed to a heat flux of 2.5 W/cm^2* shall be measured by means of a photometer. Tests shall be performed under both flaming and non-flaming (smoldering) test modes. The flaming test mode shall be induced by means of a small pilot natural gas flame applied at the base of the specimen. This flame shall be absent in the non-flaming mode.

The specific optical density of the smoke generated, D_s, is a property of a specimen of a given thickness, and represents the optical density (D) measured over unit path length (L), within a chamber of unit volume (V), produced from a specimen of unit surface area (A). Thus,

$$D_s = D\left[\frac{V}{AL}\right] = \left[\frac{V}{AL}\right] \log_{10}\left[\frac{F_o}{F}\right]$$

where F = the transmitted flux, and F_o = the incident flux. For the specified test chamber, V = 18 $ft.^3$, A = 0.0456 $ft.^2$, and L = 3 ft. The change in D_s for a specific material with time should depend only on its thickness, its chemical and physical composition, and the conditions to which it is exposed. The maximum measured value for F shall be used in determining D_s for each specimen.

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* Watts per square centimeter area.

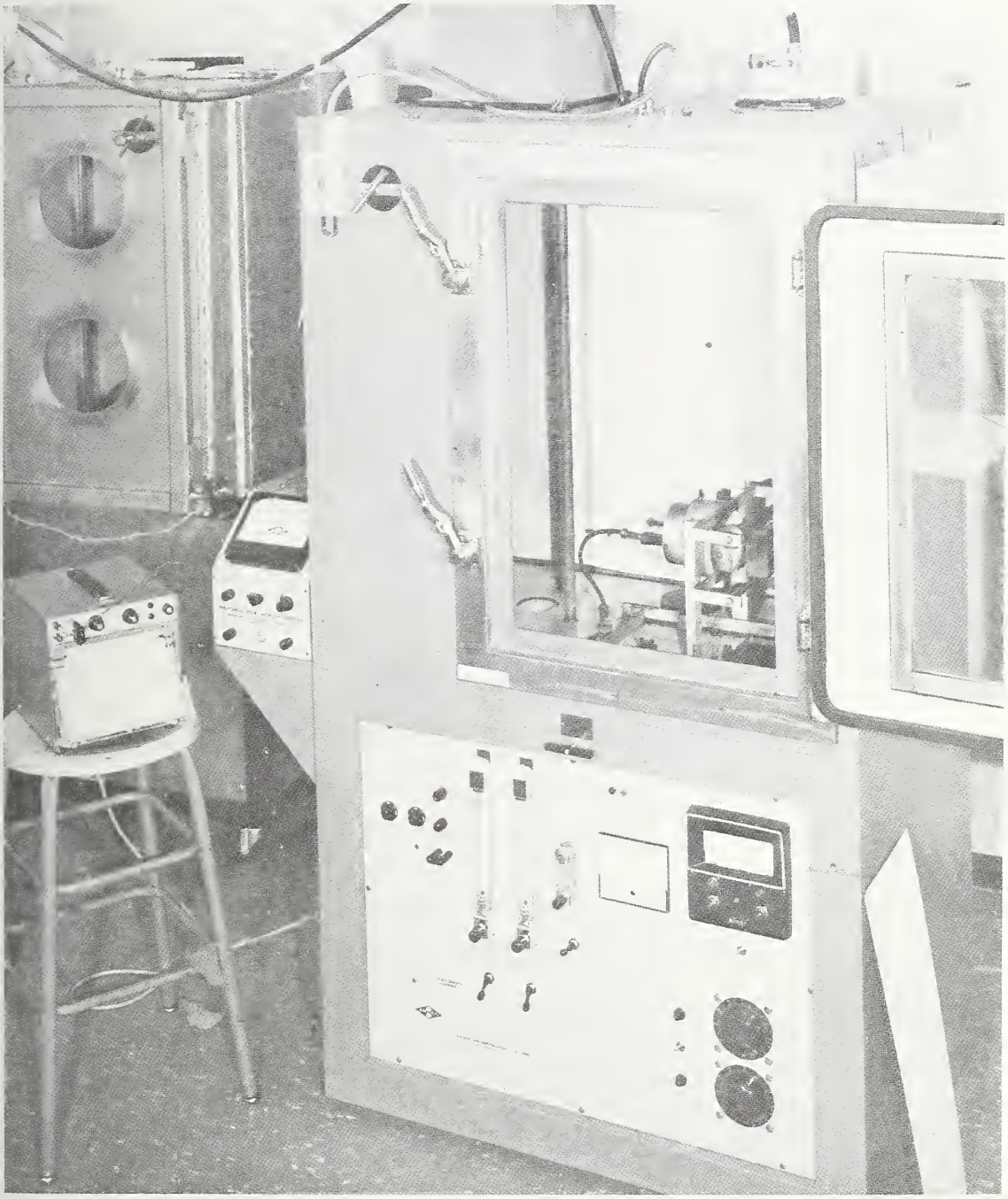
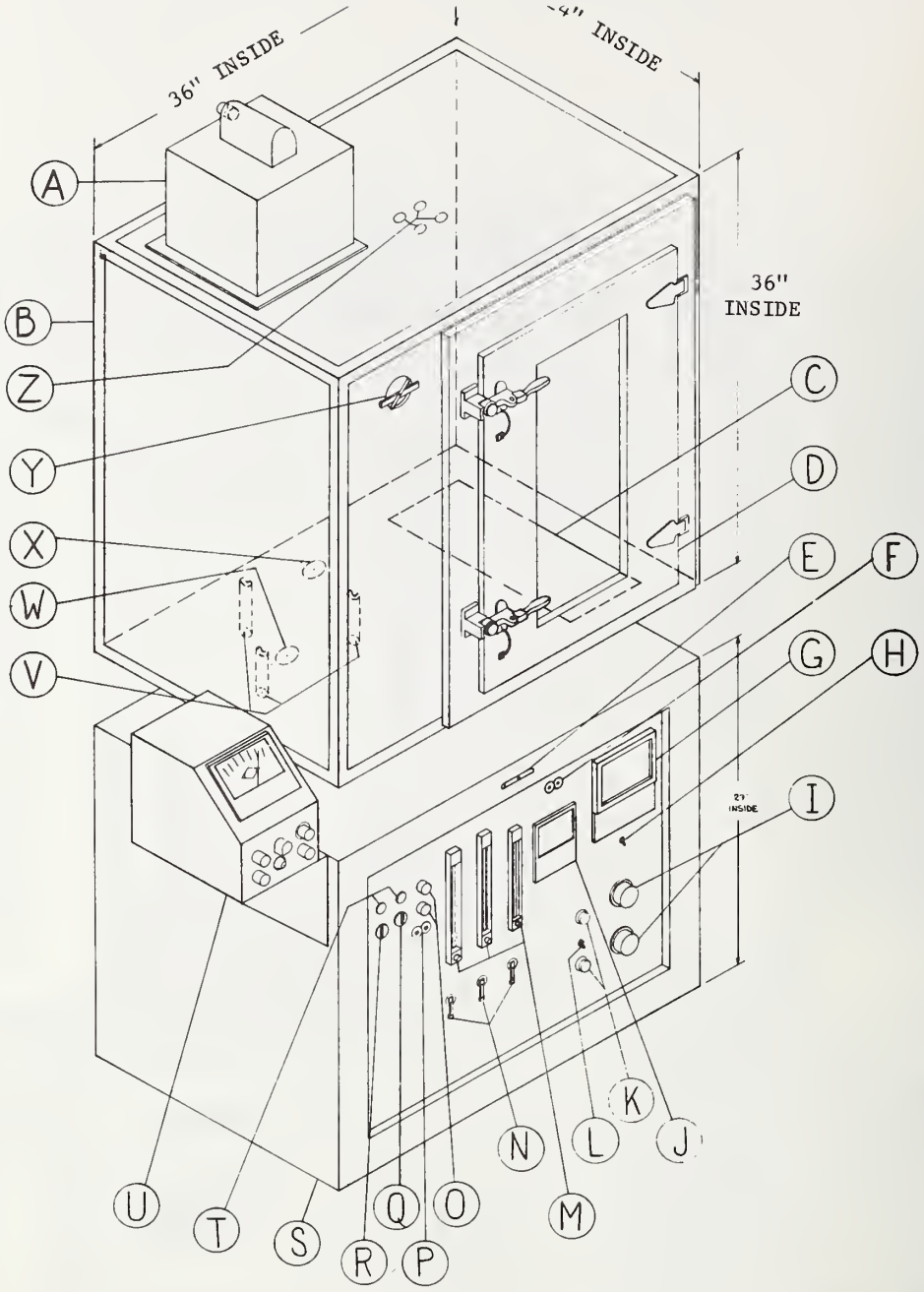


Figure A-6. Smoke test chamber.



A - Phototube Enclosure
B - Chamber
C - Blowout Panel
D - Hinged Door with Window
E - Exhaust Vent Control
F - Radiometer Output Jack
G - Temperature Controller
H - Temperature Controller Switch
I - Autotransformers
J - Voltmeter (furnace)
K - Fuse Holders
L - Furnace Heater Switch
M - Gas & Air Flowmeters
N - Gas & Air Shutoff Valves
O - Light Intensity Controls
P - Light Voltage Measuring Jack
Q - Light Source Switch
R - Line Switch
S - Support Frame
T - Indicating Lamps
U - Photometer Readout
V - Rods
W - Glass Window
X - Exhaust Vent
Y - Inlet Vent
Z - Access Ports

Figure A-7. Smoke chamber assembly - Consturction details.

A.3.3. Toxic Combustion Products

A. Objective: To determine the concentration of potentially hazardous gases generated in the combustion of covering materials when exposed to a standard method of test for smoke generation.

B. Scope: The proposed surface covering systems are subjected to smoke generation tests in both the flaming and nonflaming modes. During the test for smoke generation (section A.3.2.), the gases inside the smoke chamber are analyzed for HCN, NO and NO_2, HCl and CO.

C. Test Specimens and Pre-test Treatment: The test specimens and their preparation shall be exactly the same as for the smoke generation tests (see section A.3.2.). Toxic combustion product concentration test measurements shall be taken during the smoke generation tests.

D. Test Procedure*: Concentrations of gaseous products in parts per million (ppm), shall be determined by drawing samples of the gas mixture created by the combustion of test specimens in the NBS Smoke Density Chamber through commercial colorimetric gas detector tubes. Results shall be reported on the basis of comparison with the manufacturer's calibrations for the length of the color stains which are obtained when fixed volumes of combustion products are drawn through the colorimetric tubes. Colorimetric tubes that are specific for the toxic gas whose concentration is desired shall be used. Gas concentrations of HCl, HCN, NO + NO_2, and CO, shall be simultaneously determined at the time of peak smoke accumulation during the first smoke generation test conducted for each material-substrate, test-mode combination. Based

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* See references [8,9].

upon the results of the first gas sampling the gases that are critical to life safety shall be determined. Critical gases shall be determined at least three times during the second smoke generation test, unless the length of test is so short as to preclude three repetitions. For instance, if it is found as a result of the first test that the CO or HCl gas concentrations are at levels that are considered to be critical to life safety, at least 2 indicator tubes for each gas shall be used at one time, with this same combination repeated during the test at approximately five minute intervals.

If the concentration of HCl is found to be above 1000 ppm, the normal upper limit of the colorimetric tubes, a method based on a Chloride Selective Ion Electrode [7] shall be utilized. In this procedure, the highly soluble HCl gas and vapor in the sample (100cc) is absorbed by a water-wetted glass filter as the sample flows through it at a constant flow rate. The wetted filter with absorbed HCl shall be subsequently transferred to a container, and diluted and analyzed for chloride ion concentration by means of a standard test method using chloride ion reference electrodes. A potentiometer shall be used to measure the EMF between the electrodes. (The specific ion electrode should have a sensitivity limit in the order of 1×10^{-5} mole/liter for chloride ions in solution and a equilibrium response time of about 1 min.) A calibration curve shall be used to determine the relationship between EMF output and chloride ion concentration.

A.3.4. Flash Point

A. Objective: To determine the relative fire hazards caused by the vapors created when solvent-based liquid coatings, paint removers and adhesives are used.

B. Scope: The lowest temperature required to cause solvent vapors to ignite is determined by means of an open cup test procedure.

C. Test Method: The procedures described in ASTM D 1310 [10] for the Tag Open Cup Tester shall be used. This procedure is specified in the Federal Hazardous Substances Labeling Act [11] for the determination of hazardous flash points.

A.4. Supported Impact Resistance

A. Objective: To determine the resistance of supported covering systems to impact forces such as might occur during normal use.

B. Scope: This method covers a procedure for determining the impact resistance of coverings applied on gypsum board and plywood substrates that simulate those used in service. Specimens are tested on a falling-weight, impact apparatus after being subjected to various pre-test environmental treatments intended to simulate normal in-use aging.

C. Test Specimens: These shall consist of covering materials applied on representative substrates.

Both 3/8 in thick gypsum wallboard conforming to ASTM C 36 [12] (any type except the insulating product) and 1/2 in thick plywood (Exterior AC grade, Species Group 1) as in Product Standard PS 1-66 [4] shall be used as substrates. If tapered-edge gypsum wallboard is used, a portion 12 inches from each edge of the sheet shall be discarded.

For each substrate, 48 4 in x 4 in specimens shall be prepared and tested, 12 for each of the 4 pre-test treatments specified in section D. Six of the 12 specimens shall be tested over a die support and six on a steel plate support (as described in sections E and F).

Before the covering material is applied, each substrate shall be primed and then coated with a semi-gloss enamel conforming to the requirements of Federal Specification TT-E-508b [5]. The undercoat shall be as recommended by the manufacturer of the enamel used. The enamel surface shall be sanded lightly prior to the application of the covering material. The covering material shall be applied in accordance with instructions provided by the respective materials supplier.

For aging with moist heat, as in D.2. below, the edges of the specimens shall be coated with a water-resistant coating, such as a marine epoxy paint, which will adhere to the edges and withstand the aging conditions.

D. Pre-test Treatment: All specimens shall be tested at and after conditioning to 73±3°F and 50±3% rh. Conditioning shall be as in D.5. below.

D.1. Curing. Specimens shall be cured for a minimum of 7 days at 73±3°F and 50±3% rh following their preparation. Longer cure periods shall be used when recommended by the materials supplier.

D.2. Moist heat aging. Specimens shall be cured as specified in D.1., then placed in an environmental chamber at 160±3°F and 95% nominal rh in the presence of liquid water for 7 days.

D.3. Dry heat aging. Specimens shall be cured under ambient conditions as in D.1., then placed in a ventilated oven at 160±3°F for 7 days.

D.4. Water soak aging. Specimens shall be cured under ambient conditions as in D.1., then soaked in water at 73°F for 7 days.

D.5. Conditioning. Specimens cured as in D.1. under ambient conditions may be tested immediately. Specimens aged as in D.3. with dry heat shall be further conditioned for 7 days at 73±3°F and 50±3% rh. Specimens aged as in D.2. (moist heat) or D.4. (soaking in water) shall be further conditioned as follows:

2 days at 73±3°F, 50% rh,

1 day in an oven at 160±3°F, 4% rh, and finally

4 days at 73±3°F, 50% rh.

E. Apparatus: The apparatus shall be as described in ASTM D 2794 [13], with a 2 lb cylindrical impact weight, a 0.625 in diameter indenter with a rounded nose, and a support die having an inner diameter of 0.640 inches, as is shown in figure A-8. A steel plate support shall be used for some of the tests, as described in section F. The plate shall be flat and smooth, with parallel faces, and shall be approximately 1/2 inch in thickness and 4 to 6 inches square. The scale of the apparatus shall read in inch-pounds force (in-lbf) and its zero setting shall be adjusted to compensate for variations in the specimen thickness and also for alternate use of the die and the steel plate.

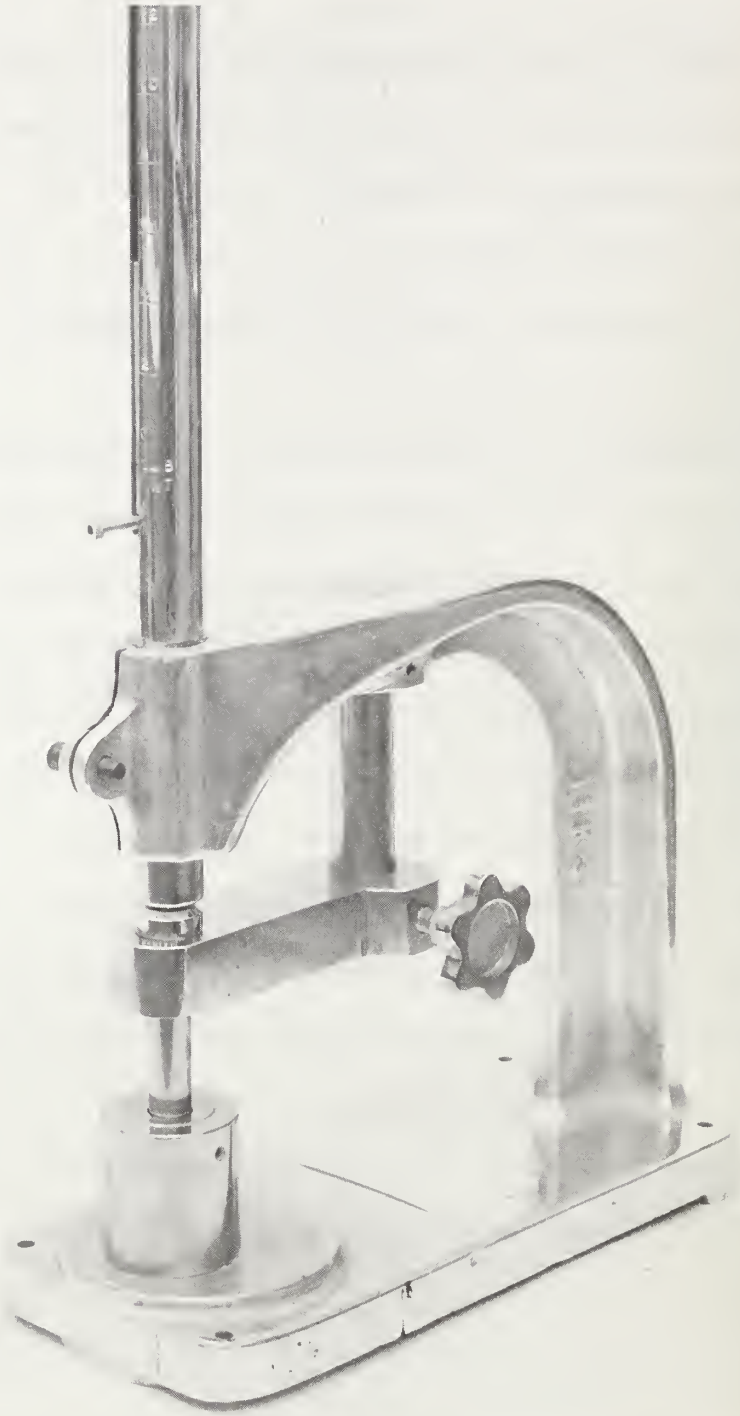

Figure A-8. Basic impact test apparatus with female die installed on base.

F. Test Procedure: Impact tests shall be performed on 12 specimens, 6 using the die and 6 using the steel plate, for each covering, on each of the 2 substrates, for each of the 4 pre-test treatments.

Center the specimen on the die or on the steel plate, which is center on the die. Adjust the scale zero setting for the proper reading as in section E. Raise the cylindrical weight to the height corresponding to the desired force to be applied to the specimen, and drop the weight. If the specimen fails, as descrived in section G, test at a lower force. If the specimen passes the test, repeat the impact at a higher force.

Tests shall be performed at 5 positions on each specimen, one at each corner and one in the center. The point of impact for tests at the corners shall be approximately 1 inch from each edge. If impact at the corner damages the specimen more than impact at the center (edge effect), further tests shall be run nearer to the center of each specimen.

The approximate force causing failure shall be established from prior experience or by performing tests on one specimen at 2, 10, 40, 60, 80 in-lbf or until the specimen fails. The failure point shall then be determined within 2 in-lbf by means of the criteria given in G. There shall be six tests (drops) at each impact force immediately above and below the failure point. For example, if a specimen fails at an impact between 60 and 62 in-lbf, six drops shall be performed at 60 and 6 drops at 62 in-lbf. Specimens that show no evidence of failure at 80 in-lbf (the maximum impact force obtainable with the apparatus) shall be reported to pass 80+ in-lbf impact. In cases where the thickness of

the test specimen prevents testing at 80 in-lbf, the highest obtainable impact force shall be used.

G. Criteria for Failure:

1. Failure of more than 1 of 6 specimens of a set at a given impact load shall be reported as a failure for the set of 6 specimens.

2. Coverings shall be considered to fail the test if:

a. there is visible tearing in the impact area through the covering that exposes the substrate. (This is applicable to non-reinforced coverings and should be observed without the use of magnification.)

b. there is any evidence of cracking or delamination outside the area of impact. (This is applicable to all covering materials.)

c. there is any evidence of tearing through reinforcement fibers.

Note: when reinforcement fibers are widely spaced (i.e., leaving an open mesh greater than 1/4" x 1/4", criteria (a) and (b) should be used.

3. Any cracking or tearing through the bottom of the substrate shall be considered as a substrate failure.

A.5. Unsupported Impact Resistance

A. Objective: To determine the resistance of unsupported coverings to the tearing and puncture forces to which they can be exposed when they are applied over voids in a surface or when they delaminate from the solid substrates to which they were originally applied.

B. Scope: This method covers an impact test procedure performed on rigidly clamped, unsupported coverings. Test specimens are exposed to several pre-test environmental conditions to simulate the deterioration that could be expected as a result of actual in-use service.

C. Test Specimens: Unsupported films of the various covering materials selected for evaluation shall be used as test specimens. Factory manufactured coverings such as those of the rigid board and flexible wall covering types shall be tested as supplied by their respective manufacturers. Adhesives furnished for application of the covering shall not be applied prior to testing. Free films of liquid-applied coverings shall be prepared by applying said coatings on sheets of either photographic paper (emulsion side up), or on polyethylene as an alternate method, using a doctor blade to control spreading rates to those recommended by the respective manufacturers. The coatings shall be allowed to cure as specified and the films shall then be either floated off the photographic paper in water or peeled from the polyethylene.

Following pre-test aging, as specified below, specimens shall be allowed to equilibrate at room conditions (73±3°F and 50% rh) prior to testing. A minimum undamaged film area of 2 in long by 2 in wide shall be used as a test specimen.

D. Pre-test Treatment: Sufficient quantities of the various materials shall be prepared so that specimens can be subjected to all 3 of the aging conditions listed below (approximately 2 square feet per condition). Aging cycle 1 shall consist of curing the test specimens

at 73±3°F and 50±3% rh for a period of at least 7 days prior to testing. Aging cycle 2 shall consist of cycle 1 followed by aging the test specimens at 160±3°F and approximately 4% rh (the rh of room temperature air heated to 160°F) for 14 days and then allowing the specimens to equilibrate at 73±3°F and 50±3% rh prior to testing. Aging cycle 3 shall consist of cycle 1 followed by aging the test specimens at 160±3°F and 95% rh for 14 days and then allowing the specimens to equilibrate at 73±3°F and 50±3% rh prior to testing.

E. Test Procedure: Each specimen shall be mounted in a clamping fixture, figure A-9, so that an unsupported test area having a 1 in diameter is provided. The clamped border of the specimen surrounding the test area shall be a minimum of 1/2 in wide.

The clamping fixture, and specimen, shall be placed on the die of the impact tester as shown on figure A-10. The basic impact tester shall be as described in section A.4., part E (Apparatus). A separate specimen shall be used for each impact. Testing shall continue for specimens treated with each of the aging conditions until the failure point (as defined in F.) is determined to within 2 in-lbf (e.g., pass 60 in-lbf, fail 62 in-lbf).

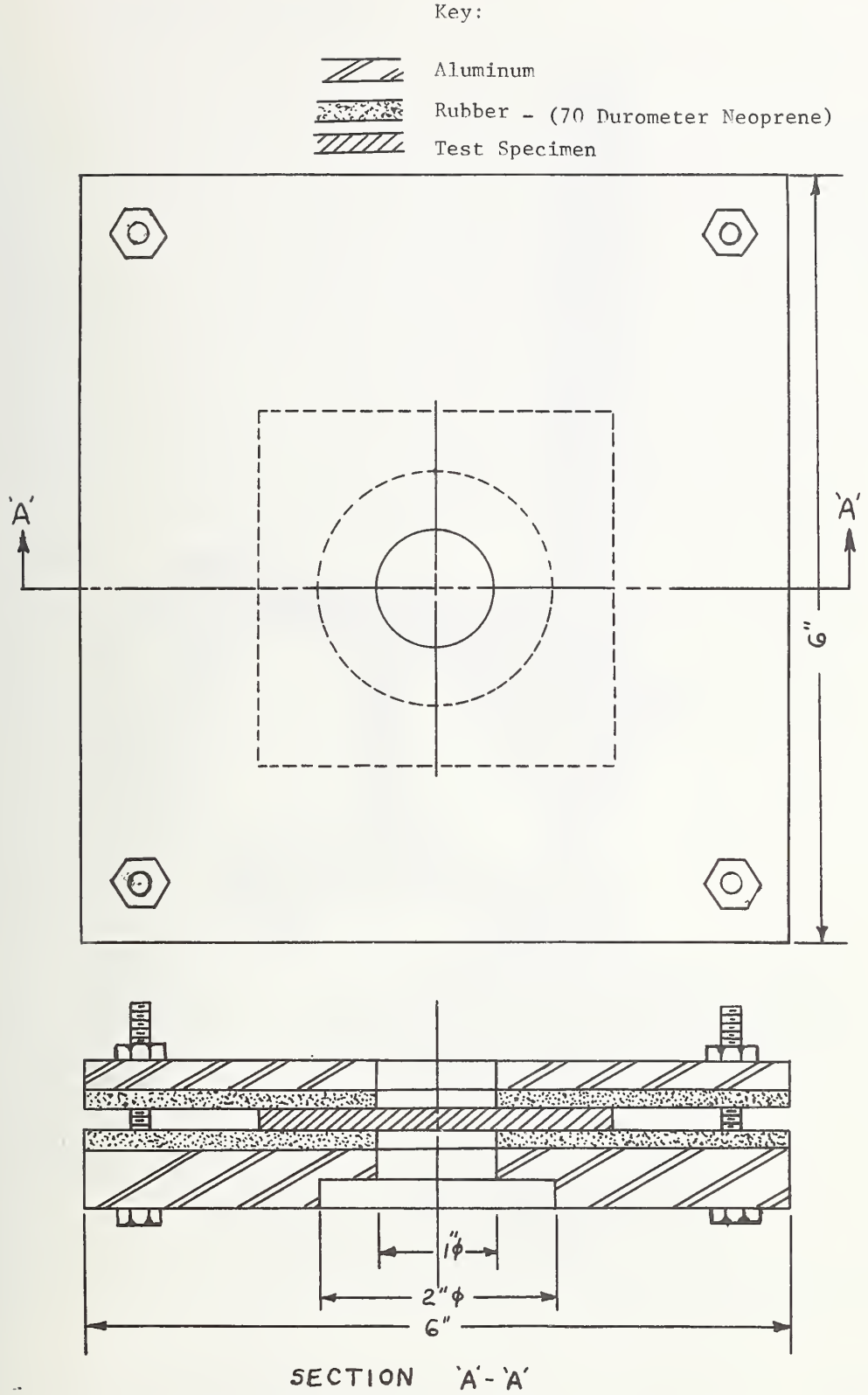

Figure A-9. Unsupported Impact Attachment

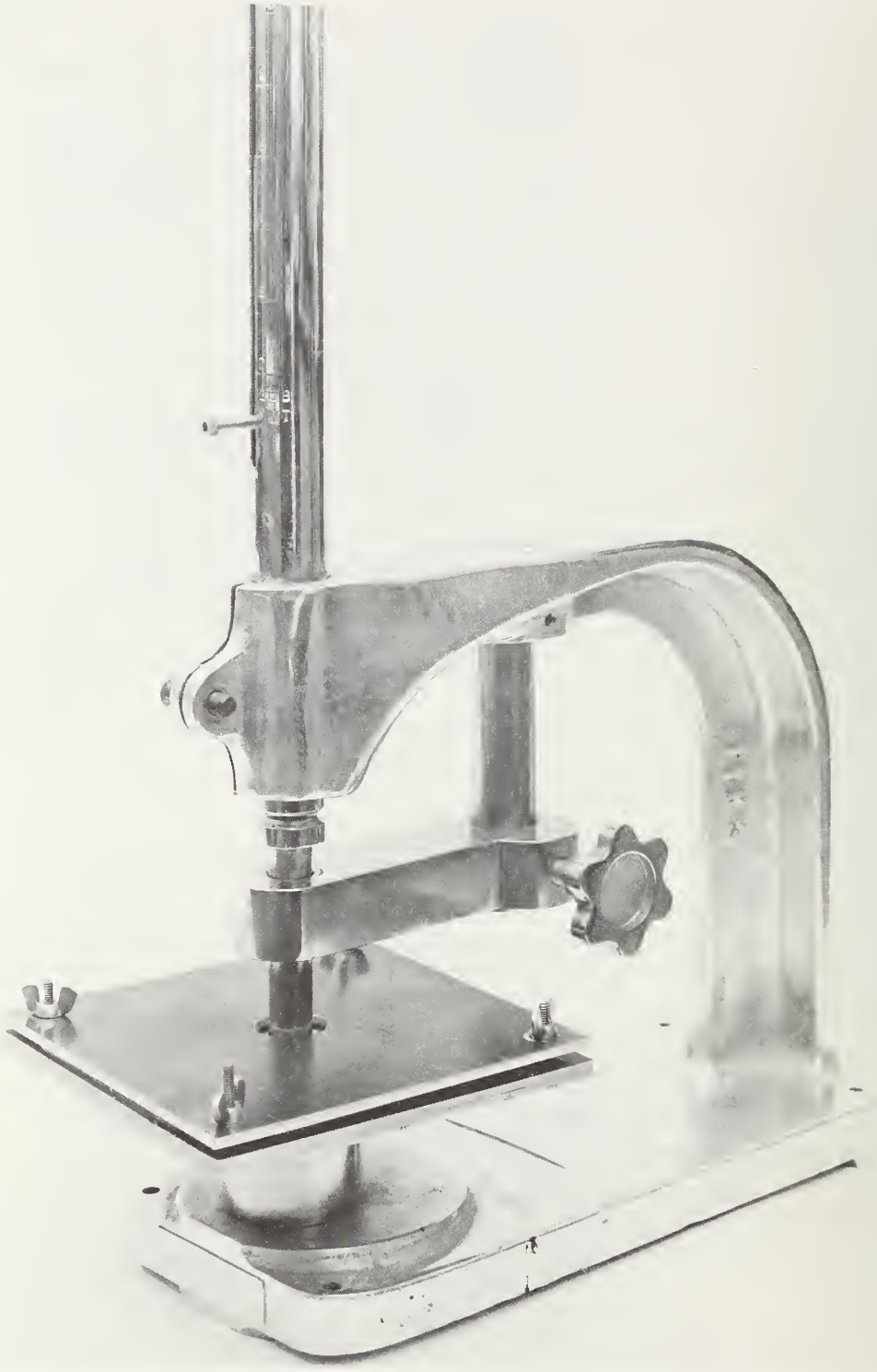

Figure A-10. Basic impact test apparatus with unsupported impact clamping fixture installed.

F. Criteria for Failure:

1. Failure of more than 1 of 6 specimens of a set at a given impact load shall be reported as a failure for the set of 6.

2. Coverings shall be considered to fail at a given impact if:

a. there is visible tearing in the impact area through the covering. (This is applicable to non-reinforced coverings and should be observed without the use of magnification.),

b. there is any evidence of cracking or delamination outside the area of impact. (This is applicable to all covering materials.),

c. there is any evidence of tearing through reinforcement fibers.

Note: when reinforcement fibers are widely spaced (i.e., leaving an open mesh greater than 1/4 in x 1/4 in) criteria (a) and (b) should be used.

A.6. Abrasion Resistance

A. Objective: To determine the resistance of coverings to abrasion such as might occur during normal use.

B. Scope: This method covers a procedure for determining the abrasion resistance of surface covering materials in terms of loss in weight after 500 cycles of abrasion, using the abraser described in Method 6192, Federal Test Method Standard No. 141a [14]. Aging procedures are used to simulate the deterioration that could occur during normal use.

C. Test Specimens: These shall consist of comparison standards and covering material test specimens. All coverings shall be applied on substrate plates of 1/4 inch thick phenolic board, natural color, Type I, Grade XX, Federal Specification L-P-509a [1]. The substrate plates shall be cut 4 inches square. In addition, they shall have slightly rounded corners and a 1/4 in diameter hole shall be drilled and reamed in the center of each plate to accommodate a shaft 1/4 inch in diameter. The plates shall have uniform, plane, and parallel surfaces and one surface shall be sanded lightly to assure good adhesion of coatings or adhesives to the surface.

C.1. Comparison standards. For calibration purposes, a reference organic coating shall be applied to six specimen plates. The coating shall be selected to give an average loss in weight of 50 to 60 milligrams after 500 cycles of abrasion. A suitable reference coating is two coats (brushed or sprayed) of a synthetic resin latex paint, conforming to Federal Specification TT-P-29g [15], allowing one day drying time between coats and at least three days drying time after the second coat before testing. Six comparison standard specimens shall be prepared and tested and the average weight loss recorded. If the computed standard deviation of the test results is more than 10 milligrams (standard error more than 4), additional specimens shall be tested until the error is within these limits.

Note: The comparison standards are intended to provide a basis for the comparison of measurements made on different pieces of equipment, or by different operators. If readings on the comparison standards are not in the 50 to 60 milligram range, the readings obtained for

test specimens of covering systems shall be multiplied by a factor of 55 divided by the reading obtained for the comparison standard.

C.2. Test specimens of covering systems. For evaluation of the abrasion resistance of coverings, 24 specimens shall be prepared and tested, six each for treatments D.1. to D.4. Coverings shall be applied on the substrate in accordance with the manufacturer's directions for application to a flat surface. For specimens aged with moist heat, as in D.2., the edges of the specimens shall be coated with a water resistant coating, such as a marine epoxy paint, which will adhere to the edges and withstand the aging conditions.

D. Pretest Treatment: All test specimens shall be tested at and after conditioning to 73±3°F and 50±3% rh. Conditioning shall be as in D.5.

D.1. Curing. Specimens shall be cured for a minimum of 7 days at 73±3°F and 50±3% rh. Longer cure periods shall be used when specified by the materials supplier.

D.2. Moist heat aging. Specimens shall be cured under ambient conditions as in D.1., then placed in an environmental chamber at 160±3°F and 95% rh, in the presence of liquid water, for 7 days.

D.3. Dry heat aging. Specimens shall be cured under ambient conditions as in D.1., then placed in a ventilated oven at 160±3°F for 7 days.

D.4. Water soak aging. Specimens shall be cured under ambient conditions as in D.1., then soaked in water at 73°F for 7 days.

D.5. Conditioning. Specimens cured under ambient conditions as in D.1. may be tested immediately after said treatment. Specimens

aged as in D.3. with dry heat shall be further conditioned for 7 days at 73±3°F and 50±3% rh. Specimens aged as in D.2. (moist heat) or D.4. (soaking in water) shall be further conditioned as follows:

2 days at 73±3°F, 50% rh, then for

1 day in an oven at 160±3°F, 4% rh, and then for

4 days at 73±3°F, 50% rh.

E. Apparatus: The apparatus shall consist of an abraser and accessories as is shown in figure A-11 and shall be maintained as described in section 2. of Method 6192, with the following modifications:

E.1. The CS-10 abraser wheels specified in Method 6192 shall be used. Wheels shall be used within one year of the date of manufacture.

E.2. New wheels shall be faced for 100 cycles with two fresh S-11 abrasive discs as specified in Method 6192, 50 cycles on each disc. Wheels shall be refaced for 50 cycles, with a fresh S-11 abrasive disc before testing each specimen.

E.3. Wheels shall not be operated when worn to or below a minimum diameter of 1 3/4 in. If a minimum diameter mark is not supplied with the wheels, a mark shall be made. Wheels should be measured with calipers as they approach the minimum diameter.

F. Test Procedure: Determine and record the initial weight of each test specimen to the nearest milligram. Mount the pair of abrasive

Figure A-11. Abrasion test apparatus with abraser wheels being refaced on an abrasive disc.

wheels on their respective flange holders, taking care not to handle them by their abrasive surfaces. Use a load of 500 grams on each wheel. Mount a new S-11 refacing disc on the turntable and reface the wheels for 50 cycles, brushing the residue from the disc during the process and using the vacuum pickup as with the test specimens. Mount the specimen on the turntable and lower the abrading heads carefully until the wheels rest squarely on the specimen. Place the vacuum pickup nozzle in position and adjust it to 1/32 to 1/16 inch (approximately 1 mm) above the specimen surface. Clear the counter reading to zero, start the vacuum pickup, and then the meter of the abraser. Abrade each specimen for 500 cycles of the abraser. Remove the specimen and determine and record its weight loss. Repeat the operation on each of the five remaining specimens and average their weight losses. Test six specimens for each covering material under each of the four pre-test treatments.

A.7. Scratch Resistance

A. Objective: To determine the resistance of covering materials to scratches, from sharp objects, such as might occur in normal service.

B. Scope: This method covers a procedure for determining resistance to scratching and tearing of covering materials by means of a weighted diamond tool. Aging procedures are used to simulate the deterioration that could occur during normal use.

C. Test Specimens: These shall consist of comparison standards and test specimens of covering materials applied on specimen plates

of 1/4 inch phenolic board, natural color, Type I, Grade XX, Federal Specification L-P-409a [1]. Plates shall be cut 4 inches square. The plates shall have uniform, plane, and parallel surfaces and one surface shall be sanded lightly to ensure good adhesion of coatings or adhesives to the surface.

C.1. Comparison standards. For the purpose of standardizing the diamond tool, two brands of vinyl asbestos tile which conform to Type IV, Federal Specification SS-T-312 [16] shall be used. Two pieces of each brand of tile, each 4 inches square, shall be used as comparison standards.

C.2. Covering system test specimens. Eight specimens shall be prepared and tested for each covering system evaluated; two for each of four conditionings or pretreatments as in section D. The coverings shall be applied in accordance with the manufacturer's directions for application to a flat surface. For pretreatment with moist heat, as in D.2., the edges of the specimens shall be coated with a water-resistant coating, such as a marine epoxy paint, which will adhere to the edges and withstand pretreatment conditions.

D. Pre-test Treatment: All specimens shall be tested at and after conditioning to 73±3°F and 50±3% rh. Conditioning shall be as in D.5.

D.1. Curing. Specimens shall be cured for a minimum of 7 days at 73±3°F and 50±3% rh. Longer cure periods shall be used when specified by the materials supplier.

D.2. Moist heat aging. Specimens shall be cured under ambient conditions as in D.1., then placed in an environmental chamber at 160±3°F and 95% rh in the presence of liquid water, for 7 days.

D.3. Dry heat aging. Specimens shall be cured under ambient conditions as in D.1., then placed in an oven at 160±3°F, 4% rh.

D.4. Water soak aging. Specimens shall be cured under ambient conditions as in D.1., then soaked in water at 73°F for 7 days.

D.5. Conditioning. Specimens pretreated as in D.1. under ambient conditions may be tested immediately after pretreatment. Specimens pretreated as in D.3. with dry heat shall be further conditioned for 7 days at 73±3°F and 50±3% rh. Specimens pretreated as in D.2. (moist heat) or D.4. (soaking in water) shall be further conditioned, prior to testing, as follows:

2 days at 73±3°F, 50% rh, then for

1 day in an oven at 160±3°F, 4% rh and then for

4 days at 73±3°F, 50 % rh.

E. Apparatus: The apparatus, which is shown in figure A-12, shall be as described in Method 7711, Federal Test Method Standard No. 501a [17] but with a conical diamond tool, having a 90 degree included angle and a radius at the point of 3 mils (0.003 in). The sliding weight shall be adjusted to provide a load of 500±1 grams on the tool.

Figure A-12. Scratch test apparatus

Diamond tools shall be replaced when they do not meet the requirements of Procedure F-6, which is described below.

F. Test Procedure: The test procedure shall be as in Method 7711, with the following deviations:

1. The scratch tool shall be a conical diamond tool as in section E above.

2. Instructions in Method 7711, paragraphs 3.1.3 and 4.2, shall be disregarded.

3. The length of the scratch required by Method 7711, paragraph 4.3 shall be the length of the chord of the arc scribed by the scratch tool.

4. The width of the scratch for each specimen shall be measured at three places, approximately one inch apart.

5. The scratch width shall be measured to the nearest 0.5 mil (0.005 in)

6. The condition of the diamond tool shall be evaluated prior to the tests on each covering. This evaluation is made by making one scratch on each comparison standard and measuring the width of scratch. The average width for the four comparison standards shall be between 4 and 20 mils (0.004 and 0.020 in). The standard deviation of the six measurements on each brand shall not exceed 2 mils (0.002 in). If the average width or the standard deviation is outside these limits the tool shall be discarded.

7. The scratch width shall not be measured on surface coverings with uneven surfaces, such as coverings having textile or other fibers protruding above the surface. On such finishes, results shall be judged by visual observation of damage to the finish.

8. One scratch shall be made on each specimen and two specimens used

for each covering material. The average of six measurements, 3 on each scratch, shall be recorded as the width of the scratch for the material.

A.8. Washability

A. Objective: To determine the relative ease with which soil can be removed from surface finishes and the effects of the removal action on the finishes.

B. Scope: Coverings, applied on or bonded to, a flat uniform surface are soiled and then subjected to the cleaning action of a standard washability procedure (referred to in section E below). Both sponge and brush applicators are used in conjunction with a cleaning medium to determine ease of soil removal, resistance to staining and the resistance to abrasion and/or polishing. The basic test apparatus is shown in figure A-13.

C. Test Specimens: Liquid coverings shall be applied to 6 x 17 x 1/4 in plate glass panels using a doctor blade to control the film thickness and to obtain a smooth surface finish. Manufactured coverings shall be bonded to the plate glass panels following the recommendations of the respective material suppliers.

D. Pre-Test Treatment: Specimens shall be cured, aged and conditioned as specified below prior to testing.

D.1. Curing. Specimens shall be cured for a minimum of 7 days at 73±3°F and 50±3% rh prior to aging. Longer cure periods shall be used when specified by the respective material suppliers.

D.2. Aging and conditioning. After being allowed to cure properly, specimens shall either be (1) tested immediately, (2) aged for 7 days at 160±5°F and 95±3% rh and allowed to equilibrate at 73±3°F and 50±5% rh

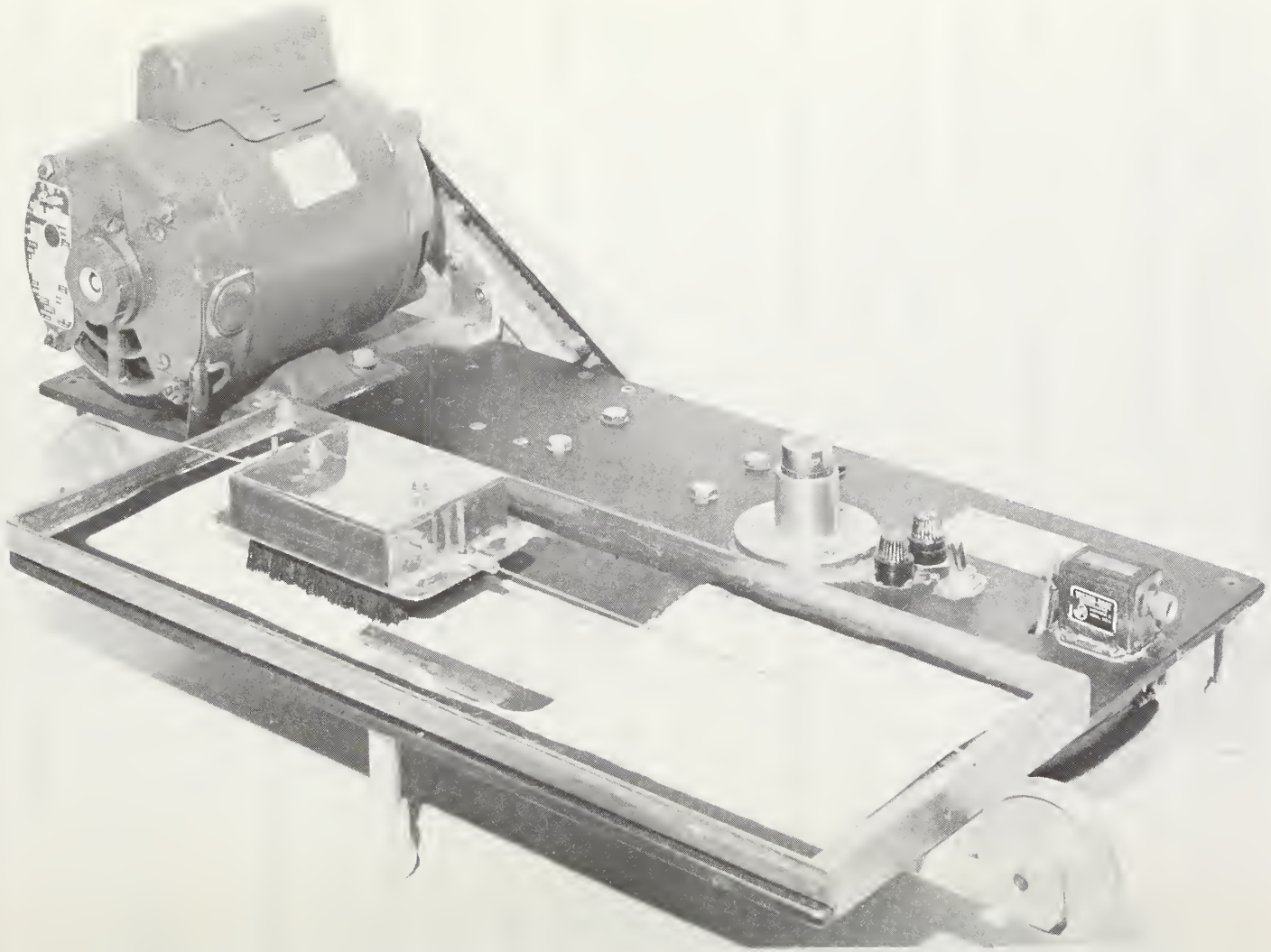

Figure A-13. Washability test assembly with a brush applicator being used to clean the standard soiling medium from a fine texture high build spray coating test specimen.

prior to testing or (3) aged for 7 days at 160±5°F and 4±1% rh and allowed to equilibrate at 73±3°F and 50±5% rh prior to testing. Three specimens shall be aged and tested for each of the above aging conditions.

E. Washability Procedure: The basic test procedure described in Method 6141 of Federal Test Method Standard No. 141a [18] shall be used.

A.9. Water Vapor Permeance

A. Objective: To measure the resistance of covering systems to the passage of moisture when a water vapor pressure gradient is established between the two surfaces of the covering.

B. Scope: Test specimens prepared by applying covering materials onto a standard substrate are exposed to a water vapor gradient. The amount of moisture transmitted, which is a function of the water vapor pressure difference between the two sides of the specimen, is expressed in terms of perms*.

C. Test Specimens: Nine test specimens for each covering system shall be prepared by application of the covering to the unsealed portion of nine standard HK forms**. Liquid coverings shall be applied at the spreading rates recommended by the suppliers and by use of a doctor blade. Sheet coverings shall be applied to the HK forms using the supplier's recommendations for application to wall surfaces.

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* A perm is defined as the water vapor transmission rate of one grain of water vapor per square foot per inch of mercury difference in water pressure.

** As referenced in Federal Specification TT-P-29g [15].

After the curing period (see D.1 below) a 4 inch disk shall be cut from the center of each coated form, sealed in a permeability cup and tested in accordance with section D. (below).

D. Test Method: The basic test method shall be as described in ASTM E 96 [19].

D.1. Curing. Specimens shall be cured for a minimum of 7 days at 73±3°F and 50±3% rh prior to aging. Longer cure periods shall be used when specified by the respective material supplier.

D.2. Aging and conditioning. Following the curing period (D.1 above) specimens shall either be (1) tested immediately, (2) aged for 7 days at 160±5°F and 95±3% rh and allowed to equilibrate at 73±3°F and 50±5% rh prior to testing or (3) aged for 7 days at 160±5°F and 4±1% rh and allowed to equilibrate at 73±3°F and 50±5% rh prior to testing. Three specimens of each covering system shall be aged and tested for each of the above aging conditions.

D.3. Summary of method. A film or sheet of the material under test shall be sealed over the mouth of a permeability cup containing a desiccant and the assembly placed in an atmosphere of 73±2°F and 50±2% relative humidity. The assembly, which is shown in figure A-14, shall be weighed at intervals and for the period in which the gain in weight is linear with time, the results shall be used to calculate the rate, in perms, of water vapor movement through the membrane.

Figure A-14. Water permeability test cup assembly.

A.10. Colorfastness

A.10.1. Condensed Moisture Aging

A. Objective: To determine the color stability of covering systems when they are exposed to conditions which cause moisture condensation on the surface of the covering.

B. Scope: This method is concerned with procedures for determining the detrimental effects of condensed moisture by measuring changes that occur in the gloss, reflectance, and color of coverings when their surfaces are exposed to continuous condensation at 100±5°F and 95±5% rh.

C. Test Specimens: Liquid coatings shall be applied on 4 x 8 x 1/4 in plate glass panels using a doctor blade to control film thickness and to obtain a smooth finish; sheet materials shall be bonded to the glass panels. The respective material supplier's directions for liquid coating spreading rates and adhesive application rates shall be used. Four specimens shall be prepared and tested for each covering system.

D. Pre-test Treatment: Specimens shall be cured for a minimum of 7 days at 73±3°F and 50±3% rh prior to testing. Longer cure periods shall be used when specified by the respective material suppliers.

E. Test Procedure: Directional reflectance, yellowness index and 85 degree specular gloss shall be measured on properly cured test specimens before and after exposure to a humidity chamber. These measurements shall be used to calculate gloss retention, lightness index difference and yellowness index difference (for white coverings only).

The 85 degree specular gloss shall be determined as specified in Method 6103 of Federal Test Method Standard 141a [20].

Directional reflectance shall be measured as specified in Method 6121 of Standard 141a [21]. Yellowness index shall be measured as specified in Method 6131 of Standard 141a [22].

After initial measurements are made on the specimens, they shall be exposed on the humidity cabinet described in ASTM D 2247 [23], for 700 hours at 100±5°F and 95±5% rh. After exposure on the humidity cabinet, which is shown in figure A-15, specimens shall be allowed to equilibrate for 7 days at 73±3°F and 50±5% rh to eliminate the effects of entrapped moisture.

Directional reflectance, yellowness index and 85 degree specular gloss shall then be remeasured on these specimens. Percent gloss retention, lightness index difference and yellowness index difference shall then be calculated as specified below:

Percent gloss retention shall be calculated by dividing the gloss measured after humidity aging by the gloss measured immediately after curing and multiplying by 100.

Lightness index difference shall be calculated from the directional reflectance as specified in Method 6122 of Standard 141a [24].

Yellowness index difference shall be calculated as described in Method 6131.

Figure A-15. Condensed moisture aging test humidity cabinet assembly with test specimens installed face down on the upper surfaces of the humidity cabinet.

A.10.2. Water Vapor Aging

A. Objective: To determine the resistance of surface covering materials to exposure to continuous heat and high humidity.

B. Scope: This method covers a procedure for determining the changes in the appearance of surface finishes caused by exposure to heat and high humidity aging. Minute changes in gloss, reflectance and color are determined by measuring these properties on test specimens before and after they are exposed for 7 days at 120±2°F and 95±5% rh.

C. Test Specimens: Liquid coatings shall be applied on 4 x 8 x 1/4 in plate glass panels using a doctor blade to control film thickness and obtain a smooth finish; sheet materials shall be bonded to the glass panels. The respective material supplier's directions for liquid coating spreading rates and adhesive application rates shall be used. Four specimens shall be prepared and tested for each covering system.

D. Pre-test Treatment: Specimens shall be cured for a minimum of 7 days at 73±3°F and 50±3% rh prior to testing. Longer cure periods shall be used when specified by the respective material suppliers.

E. Test Procedure: The basic test procedure shall consist of measuring directional reflectance, yellowness index, and 85 degree specular gloss on properly cured test specimens before and after they are subjected to aging in a closed cabinet for 7 days at 120±2°F and 95±5% rh. These measurements shall be used to calculate percent gloss retention, lightness index difference and yellowness index difference (for white coverings only).

The 85 degree specular gloss shall be determined as specified in Method 6103 of Federal Test Method Standard 141a [20].

Directional reflectance shall be measured as specified in Method 6121 of Standard 141a [21].

Yellowness index shall be measured as specified in Method 6131 of Standard 141a [22].

After measurements are made on cured specimens, they shall be exposed for 7 days in a closed cabinet at 120±2°F and 95±5% rh. Following this exposure, specimens shall be allowed to equilibrate for 7 days at 73±3°F and 50±5% rh to eliminate the effects of entrapped moisture.

Directional reflectance, yellowness index and 85 degree specular gloss shall then be remeasured on these specimens. Percent gloss retention, lightness index difference and yellowness index difference shall then be calculated as specified below:

Percent gloss retention shall be calculated by dividing the gloss measured after humidity aging by the gloss measured immediately after curing and multiplying by 100.

Lightness index difference shall be calculated as specified in Method 6122 of Standard 141a [24].

Yellowness index difference shall be calculated as described in Method 6131.

A.10.3. Ultraviolet Radiation Aging

A. Objective: To determine the effects of solar ultraviolet (UV) radiation and heat aging on the surface properties of covering systems.

B. Scope: This method covers a procedure for determining the detrimental effects of UV light and heat aging on surface finishes by exposing test specimens to radiation from a carbon arc lamp. Changes that occur in the gloss, reflectance and color of covering materials are determined by measuring these properties before and after exposure to the carbon arc.

C. Test Specimens: Liquid coatings shall be applied on 4 x 10 x 1/4 in plate glass panels using a doctor blade to control film thickness and obtain a smooth finish; sheet materials shall be bonded to the glass panels. The respective material supplier's directions for liquid coating spreading rates and adhesive application rates shall be used. Four specimens shall be prepared and tested for each covering system.

D. Pre-test Treatment: Specimens shall be cured for a minimum of 7 days at 73±3°F and 50±3% rh prior to testing. Longer cure periods shall be used when specified by the respective material suppliers.

E. Test Procedure: The basic test procedure shall consist of measuring directional reflectance, yellowness index, and 85 degree specular gloss on properly cured test specimens before and after they are placed in a weathering machine. (The weathering machine and its operation are described in Method 6152 of Federal Test Method Standard 141a [25]). The measurements shall be used to calculate percent gloss retention, lightness index difference and yellowness index difference (for white coverings only).

The 85 degree specular gloss shall be determined as specified in Method 6103 of Standard 141a [20].

Directional reflectance shall be measured as specified in Method 6121 of Standard 141a [21].

Yellowness index shall be measured as specified in Method 6131 of Standard 141a [22].

After measurements are made on the cured specimens, they shall be placed in the accelerated weathering machine. The machine shall be operated without a water spray. Test specimens shall be exposed to a temperature of 145±5°F and the radiation of a carbon arc for 500 hours.

After exposure in the accelerated weathering machine, specimens shall be allowed to equilibrate at 73±3°F and 50±5% rh.

Directional reflectance, yellowness index and 85 degree specular gloss shall then be remeasured on these specimens. Percent gloss retention, lightness index difference and yellowness index difference shall then be calculated as specified below:

Percent gloss retention shall be calculated by dividing the gloss measured after humidity aging by the gloss measured immediately after curing and multiplying by 100.

Lightness index difference shall be calculated as specified in Method 6122 of Federal Test Method Standard 141a [24].

Yellowness index difference shall be calculated as described in Method 6131.

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The National Bureau of Standards is providing technical support to the Department of Housing and Urban Development which is required by Public Law 91-695 (the Lead Paint Poisoning Prevention Act) to carry out a research program to evaluate and make recommendations regarding technology for the removal of the lead based paint hazard from the Nation's housing.

Potential hazard elimination methods have been identified by means of a survey of available technology. This report describes testing and evaluation methodologies used to determine (1) the suitability for use of a series of removal and lead barrier systems, (2) the results of this evaluation, and (3) recommendations concerning the use of said systems.

Paint removal systems were evaluated in terms of the hazards that they present in the course of their use. Both the flammability and the toxicity of the solvents found in removers were considered. Covering systems were evaluated for their suitability for use as barrier layers over lead bearing paints in housing. The effectiveness of covering systems in protecting children from leaded paint, their fire hazard properties and functional properties which are related to their serviceability were considered in making this evaluation. The properties of the systems were assessed in terms of minimum acceptable performance levels and recommendations are given for their use in a field evaluation program.

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