Designation: E1333 – 14

# Standard Test Method for Determining Formaldehyde Concentrations in Air and Emission Rates from Wood Products Using a Large Chamber[1]

This standard is issued under the fixed designation E1333; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method measures the formaldehyde concentration in air and emission rate from wood products containing formaldehyde under conditions designed to simulate product use (see 11.5 and Note 9). The concentration in air and emission rate is determined in a large chamber under specific test conditions of temperature and relative humidity. The general procedures are also intended for testing product combinations at product-loading ratios and at air-exchange rates typical of the indoor environment (**1**).[2] The products tested, the loading ratios and the air exchange rates employed are described in the test report.

1.2 This test method determines the average formaldehyde concentration in air and emission rate from a number of large size samples. The average concentration and emission rate reported, thus, will not provide information on higher or lower emitting panels in the test lot.

1.3 This method is primarily used for testing newly manufactured panel products that are shipped for testing either seal-wrapped in polyethylene or with waster sheets, or with both. When this test method is used for evaluating other than newly manufactured panel products (after original application, installation or use), the method of packaging and shipping the product for testing shall be described in the test report.

1.4 The quantity of formaldehyde in the air sample taken from the chamber is determined by an adaptation of the National Institute for Occupational Safety and Health (NIOSH) chromotropic acid test procedure. If another analytical procedure is used to determine the quantity of formaldehyde in the air sample, that procedure shall give results of equivalent or greater accuracy and precision than the adapted chromotropic acid procedure. Detailed procedures based on acetylacetone, pararosaniline (see Test Method D5221), 2,4-dinitrophenylhydrazine (DNPH) (see Test Method D5197) and 3-methyl-2-benzothiazoline (MBTH) (see Test Method D5014) have been found to give results equivalent or greater in accuracy and precision than chromotropic acid. The test report shall note the analytical procedure employed.

NOTE 1—[3] The chromotropic acid analytical procedure described in this test method is applicable for testing urea-formaldehyde bonded wood products. According to NIOSH (4th Edition, 8/15/94), the low end of the working range for the chromotropic acid analytical procedure is 0.02 ppm. A more sensitive analytical procedure is recommended for testing wood panel products where formaldehyde concentrations in air are anticipated to be at or below this level. DNPH is recognized as such a method.

1.5 This test method is used to determine compliance with requirements such as those established for building materials by the U.S. Department of Housing and Urban Development (HUD) Rules and Regulations, HUD 24 CFR 3280, for manufactured housing, by Minnesota Statutes Section 144.495 and California Air Resources Board (CARB), California Code of Regulations sections 93120-93120.12, title 17, Airborne Toxic Control Measure to Reduce Formaldehyde Emissions from Composite Wood Products. Measurement results are also used for comparing concentrations in air and emission rates from different wood products (**2**) and for determining compliance with product standards.

1.6 This test method is not designed for determining general organic emissions from all indoor materials and products.

NOTE 2—ASTM Committee D22 has developed Guide D5116 which describes small-scale environmental equipment and techniques suitable for determining organic emissions and emission rates from materials and products used indoors.

1.7 The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to inch-pound units that are provided for information only and are not considered standard.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the*

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[1] This test method is under the jurisdiction of ASTM Committee D07 on Wood and is the direct responsibility of Subcommittee D07.03 on Panel Products.

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[2] The boldface numbers in parentheses refer to a list of references at the end of this standard.

[3] The notes appearing in this test method are not part of the mandatory sections of this standard, are informative in nature, and appear below that section of the standard to which they pertain.

*responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific hazard statements, see Section 7.

## 2. Referenced Documents

2.1 *ASTM Standards:*[4]

D3195 Practice for Rotameter Calibration

D5014 Test Method for Measurement of Formaldehyde in Indoor Air (Passive Sampler Methodology) (Withdrawn 2006)[5]

D5116 Guide for Small-Scale Environmental Chamber Determinations of Organic Emissions from Indoor Materials/Products

D5197 Test Method for Determination of Formaldehyde and Other Carbonyl Compounds in Air (Active Sampler Methodology)

D5221 Test Method for Continuous Measurement of Formaldehyde in Air (Withdrawn 1997)[5]

E77 Test Method for Inspection and Verification of Thermometers

E220 Test Method for Calibration of Thermocouples By Comparison Techniques

E337 Test Method for Measuring Humidity with a Psychrometer (the Measurement of Wet- and Dry-Bulb Temperatures)

E741 Test Method for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution

2.2 *HUD Document:*[6]

HUD 24 CFR 3280 Manufactured Home Construction and Safety Standards, 24, CFR 3280, Federal Register, Vol 49, No. 155, August 8, 1984

2.3 *NIOSH Document:*[6]

NIOSH Manual of Analytical Methods, Method No. 3500, Fourth Edition, 1994

2.4 *ANSI Standards:*[7]

ANSI/HPVA HP-1-09 Hardwood and Decorative Plywood

ANSI A208.1–2009 Particleboard

ANSI A208.2–2009 Medium Density Fiberboard (MDF) for Interior Applications

2.5 *Other Documents:*

Minnesota Statutes Section 144.495 325F.18 and 325F.181, Formaldehyde Gases in Building Materials, 1986[8]

California Air Resources Board (CARB) California Code of Regulations sections 93120-93120.12, title 17, Airborne Toxic Control Measure to Reduce Formaldehyde Emissions from Composite Wood Products[9]

## 3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *air change rate*—the ratio of hourly conditioned and filtered outside air brought into the chamber, and chamber volume measured in identical volume units (normally expressed in air changes per hour, AC/h).

3.1.2 *emission rate*—formaldehyde emissions per area of exposed surface of tested product in the large chamber per time duration of air sample, normally expressed in mg/($m^2$ ·h).

3.1.3 *loading ratio*—the total exposed surface area (not including panel edges) of each product divided by the test chamber volume.

## 4. Significance and Summary of Test Method

4.1 *Significance and Use:*

4.1.1 Limitations on formaldehyde concentrations in air have been established for some building products permanently installed in manufactured and conventional homes. This test method provides a standard means of testing typical product sizes, such as 1.2 by 2.4 m (4 by 8 ft) sheets, at product loadings consistent with product end use.

4.2 *Summary of Test Method:*

4.2.1 This test method incorporates a chamber of 22 $m^3$ (800 $ft^3$) minimum size to evaluate formaldehyde concentrations in air and emission rates from building products over a specified duration of time. This test method employs a single set of environmental conditions but different product loading ratios to assess formaldehyde concentrations in air and emission rates from certain wood products. Conditions controlled in the procedure are as follows:

4.2.1.1 Conditioning of specimens prior to testing,

4.2.1.2 Exposed surface area of the specimens in the test chamber,

4.2.1.3 Test chamber temperature and relative humidity,

4.2.1.4 Number of air changes per hour, and

4.2.1.5 Air circulation within the chamber.

4.2.1.6 At the end of a 16 to 20-h period in the test chamber, the air is sampled and the concentration of formaldehyde in air and emission rate are determined.

NOTE 3—Care must be exercised in the extension of the results to formaldehyde concentrations in air and emission rates from products under different conditions of air change rate or loading ratio, or both.

## 5. Interferences

5.1 The NIOSH analytical method lists phenols as a negative interference when present at an 8:1 excess over formaldehyde. Modification in the analytical procedure shall be made when relatively high phenol formaldehyde concentrations (8:1) are anticipated (**3, 4**).

## 6. Apparatus

6.1 *Test Chamber:*

6.1.1 The interior volume of the chamber shall be a minimum of 22 $m^3$ (800 $ft^3$). The interior of the test chamber shall

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[4] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[5] The last approved version of this historical standard is referenced on www.astm.org.

[6] Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401, http://www.access.gpo.gov.

[7] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[8] Available from Print Communications, Dept. of Administration, 117 University Ave., St. Paul, MN 55155.

[9] Available from California EPA website: http://www.arb.ca.gov/toxics/compwood/compwood.htm.

be free of refrigeration coils that condense water and items such as humidifiers with water reservoirs as condensate will have the potential of collecting formaldehyde and thus influencing test results. The interior surfaces of the chamber shall be of materials found to minimize adsorption. (Stainless steel, aluminum, and polytetrafluoroethylene (PTFE) have produced recoveries of ≥95 % at a 0.4 ppm formaldehyde challenge concentration in air and have been found appropriate as chamber lining materials.) All joints except for doors used for loading and unloading specimens shall be sealed. Doors shall be self-sealing. The test chamber shall be equipped with metal specimen racks with dividers spaced a minimum of 150 mm (6 in.) to support specimens on edge.

6.1.2 *Make-Up Air:*

6.1.2.1 The make-up air shall come from a filtered dust-free environment and contain not more than 0.02 ppm of formaldehyde using the sampling rate and volume of air as described in 10.2. This shall be accomplished by passing make-up air through a filter bed of activated carbon, activated alumina impregnated with potassium permanganate, or other materials capable of absorbing, adsorbing, or oxidizing formaldehyde.

6.1.2.2 Make-up air for the chamber must pass through a calibrated, totalizing dry gas test meter or other airflow rate measuring device permanently placed in the chamber air intake duct with calibration traceable to the National Institute of Standards and Technology (NIST). It is also acceptable to calibrate the airflow rate measuring device, as installed, using a tracer gas technique described in Test Method E741. Air change rate per hour (AC/h) is calculated as $(V_2 - V_1) \div ((t - 0) \times \text{chamber volume})$; where $V_2$ and $V_1$ are dry-gas test-meter readings in cubic metres at time, $t$ (in hours), and time 0 divided by the chamber volume in cubic metres. The air-intake port and exhaust port shall be on different walls of the chamber and at different elevations. The chamber test shall be operated at a positive pressure of 1 Pa (0.004 in. of water) or greater as determined by a permanently mounted differential pressure device.

6.1.3 *Nonsparking Fan Sizing and Positioning*—A nonsparking fan shall be used to circulate air within the chamber. The air flow shall be directed horizontally in the direction of the chamber length above where the test samples are to be placed in the chamber. The fan shall be sized and positioned to achieve a uniform concentration in air of formaldehyde (within 0.02 ppm) as determined from a minimum of six air sampling locations. These locations shall be at three elevations, 0.3 m (12 in.) from the chamber floor and ceiling, and at a height between 1.3 and 1.5 m (51 and 59 in.); and at two vertical placements, one-third the chamber length from each end of the chamber and at chamber mid-width.

6.1.4 *Air Sampling Ports*—For testing, at least two air-sampling ports shall be used, located at equal distance along the chamber length at an elevation between 1.3 and 1.5 m (51 and 59 in.) and shall be placed at least 0.6 m (24 in.) from any interior wall. The sampling lines shall be of materials found to minimize adsorption such as stainless steel, PTFE and aluminum, securely fixed to supports during the test, and shall be as short as possible. The length of the sampling line outside the chamber shall not exceed 6 m (20 ft).

6.2 Examples of acceptable reagents, materials, and equipment are provided in Appendix X1.

## 7. Hazards

7.1 *Chromotropic Acid Reagent Treatment* (see 10.3.4 and A4.5)—During this hazardous operation, the operator shall wear rubber gloves, apron, and a full face mask or be protected from splashing by a transparent shield such as a hood window. The solution becomes extremely hot during addition of sulfuric acid. Add acid slowly to avoid loss of sample due to splattering.

7.2 *Cleaning Chemicals for Glassware*—Appropriate precautions shall be taken if cleaning chemicals are considered to be hazardous.

## 8. Test Specimens

8.1 *Standard Face and Back Configuration Testing:*

8.1.1 Loading ratio is defined as the total exposed specimen surface area, exclusive of edge area, divided by the chamber volume (on effect of loading refer to Ref (**5**)). If the edge exposure is greater than 5 % of the surface area, include the total edge-exposure area in the calculation of surface-exposure area. Loading ratios used for testing wood panel products containing formaldehyde are as follows:

| Loading Ratios, ±2 % | | |
|---|---|---|
| ($m^2/m^3$) | ($ft^2/ft^3$) | Product |
| 0.95 | 0.29 | Hardwood Plywood Wall Paneling |
| 0.43 | 0.13 | Particleboard Flooring Materials |
| | | Industrial Particleboard Panels |
| | | Industrial Hardwood Plywood Panels |
| 0.26 | 0.08 | Medium Density Fiberboard (MDF) |
| 0.13 | 0.04 | Low Density Particleboard Door Core Grade |

NOTE 4—Panel grades are defined in the ANSI standards referenced in 2.4.

NOTE 5—See Appendix X3 for a discussion of loading ratios.

8.2 *Non-Standard Sample Configuration Testing:*

8.2.1 *Testing Products with Single Surface Exposed*—Some products have significantly different formaldehyde release characteristics for each surface and have only one surface exposed to the indoor living space.[10] In those cases, panels shall be tested back-to-back with edges taped together. The panels shall be identified as tested in the back-to-back mode.

8.2.2 *Testing Cabinets and Furniture*—Some products are made of assembled wood panel products. Such items shall be designated in the test report by the product name and a description of the cabinet or furniture items. (See Appendix X4 for a discussion of shipment of such products for testing.)

8.2.3 *Combination Testing*—Where different products are tested in combination, the test report shall fully describe the purpose of the test and the nature of the products and must note the loading ratios for each of the products tested.

NOTE 6—HUD 24 CFR 3280 does not indicate that panels are tested

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[10] Examples of products exhibiting this characteristic are interior wall and ceiling finish building materials that contain decorative liquid applied finishes that may emit significant quantities of formaldehyde, and laminates not containing emitable formaldehyde from the exposed surfaces that are bonded to a substrate that prevents or significantly restricts emissions from the unexposed back surface of the laminates.

back-to-back (see 8.2.1) or that different products are tested in combination. This test method, however, provides an option of performing tests on components or assembled panels in the back-to-back mode or testing products in combination where appropriate to simulate use in certain structures.

## 9. Sample Material Shipping and Specimen Conditioning

9.1 *Shipping*—Materials selected for testing shall be shipped from the manufacturer, distributor or building site to the laboratory in bundles, seal-wrapped in minimum 0.15-mm (6-mil) thickness polyethylene plastic, or shipped with a top and bottom waster sheet taken from the same population of the sample, or both. Materials selected for testing shall not include the top or bottom panels or pieces in a stack, unit or pallet. All material shall be held intact prior to specimen conditioning. When other than newly manufactured wood products (after original application, installation or use) are tested, the method of packaging and shipping the product for testing shall be fully described. Information known on the age and product history of other than newly manufactured products shall be detailed in the test report.

NOTE 7—See Appendix X4 for additional discussion on shipping materials for testing.

9.2 *Conditioning*—Condition test specimens with a minimum distance of 0.15 m (6 in.) between each specimen for seven days ±3 h at conditions of 24 ± 3°C (75 ± 5°F) and 50 ± 5 % relative humidity. The formaldehyde concentration in the air within 0.3 m (12 in.) of where specimens are conditioned shall not be more than the lesser of 0.10 ppm or the applicable compliance limit when testing for compliance purposes, during the conditioning period as determined by taking air samples in the conditioning area. (See Note 8.) Circulation of the conditioning air shall be achieved by fans that direct air flow horizontally in the direction parallel to the primary surface of the test specimens.

NOTE 8—Test specimens with low levels of formaldehyde may absorb formaldehyde from the air when the air formaldehyde content exceeds that of the test specimen. Consideration should be taken to avoid such air conditions during storage and conditioning. and when conditioning specimens with different emission characteristics.

## 10. Procedure

10.1 *Test Procedure for Materials:*

10.1.1 Purge the chamber by running empty or with the use of filters designed to reduce the formaldehyde background concentration in air, or both. The formaldehyde background concentration in air of the empty operating chamber shall not contain more formaldehyde than is capable of being measured considering the sensitivity of the analytical procedure and the volume of the air samples taken (see 10.2). Clean chamber surfaces periodically with water or solvent to ensure that formaldehyde background concentrations remain at or below the sensitivity of the analytical procedure used.

10.1.2 Locate the specimens in the chamber so that the air stream of the circulating fan is not blocked by any specimen.

10.1.3 Operate the chamber at 25 ± 1°C (77 ± 2°F) and 50 ± 4 % relative humidity (refer to Test Methods E77, E220, and E337). Continuously record the temperature and humidity. Conduct the chamber test at 0.5 ± 0.05 AC/h.

10.1.4 Specimens remain in the operating chamber from 16 to 20 h prior to air sampling for formaldehyde concentration in air and emission rate determinations.

10.2 *Air Sampling*—Purge air sampling lines for 5 min. Take at least two simultaneous air samples. At each sampling station, bubble air through a single impinger containing 20 mL of a 1 % sodium bisulfite ($NaHSO_3$) solution. A filter trap shall be placed between the impinger and the flowmeter. Set a calibrated flowmeter (calibrated using the equipment listed in X1.1.7) to maintain an average airflow of 1 ± 0.05 L/min for a minimum of 60 min with time measured accurately to within 5 s. Following air sampling, analyze the collection solution. Formaldehyde concentrations from simultaneous air samples taken from the two lines shall not vary by more than 0.02 ppm. If the samples differ by more than 0.02 ppm, repeat 10.2.

10.3 *Analysis of Air Samples:*

10.3.1 Pipet 4 mL of the $NaHSO_3$ solution from the impingers into each of two 16 by 150 mm screwcap test tubes for duplicate analysis of each impinger sample.

10.3.2 Pipet 4 mL of 1 % $NaHSO_3$ into a 16- by 150-mm screwcap test tube to act as a reagent blank.

10.3.3 Add 0.1 mL of 1 % chromotropic acid reagent to each test tube. Shake tube after addition.

10.3.4 Slowly and carefully pipet 6.0 mL concentrated sulfuric acid into each test tube (**Warning—**see 7.1) and allow to flow down the side of test tube. Allow the volumetric pipet to drain. DO NOT BLOW OUT. Before placing caps on test tubes, check the condition of the PTFE cap liners to make sure they are clean and not deteriorated.)

10.3.5 Slowly and gently agitate test tubes to effect mixing. Mixing is complete when there is no sign of stratification. (**Warning—**Avoid rapid mixing as heating and pressure will increase and potentially break the test tube.)

10.3.6 If absorbance readings exceed 1.0 or if spectrophotometric analysis is performed within 2 h, heat capped test tubes to 95°C or place capped test tubes in a boiling water bath for 15 ± 2 min to ensure that the chemical reaction is completed. After removal, allow the test tubes to cool to room temperature. Carefully vent test tubes to release pressure.

10.4 *Absorbance Readings:*

10.4.1 Standardize the spectrophotometer using distilled water at 580 nm in accordance with the instrument's operating instructions. The reagent blank (Tube 1) shall be read against distilled water. A high absorbance for the reagent blank indicates contamination of reagent blank or improper solution preparation. If absorbance for the reagent blank compared to distilled water is greater than 0.040 (using a 12-mm cell path length) or above 0.030 (using a 10-mm cell path length), repeat the entire standardization procedure.

10.4.2 Zero the instrument using the reagent blank, or the instrument shall be left zeroed on distilled water, and the absorbance of the reagent blank subtracted from the absorbance of the standard solutions.

10.4.3 Read and record absorbance at 580 nm for each test tube prepared (see 11.2 for calculations). If the absorbance of the specimen solution is found to fall outside the absorbance range (>1.0 or as determined in Annex A4), 10.3.1 – 10.3.4 shall be repeated using an appropriate dilution of each impinger solution.

## 11. Calculation

11.1 Convert the volume of air sampled to the volume of air at standard conditions as follows:

$$V_s = \frac{V \times P \times 298}{101 \times (T + 273)} \tag{1}$$

where:

$V_s$ = volume of air at standard conditions (101 kPa and 298 K), L,
$V$ = volume of air sampled, L,
$P$ = barometric pressure, kPa, and
$T$ = temperature of sample air, °C.

11.2 Calculate total micrograms of formaldehyde collected in each impinger sample as follows:

$$C_t = C_a \times F_a \tag{2}$$

where:

$C_t$ = total formaldehyde in the sample, µg,
$C_a$ = total quantity of formaldehyde in the sample aliquots taken from the impinger (as determined from the calibration curve in Annex A4), µg, and

$$\mathrm{F_a} = \text{aliquot factor} = \frac{\text{sampling solution volume, mL}}{\text{aliquot used, mL}} \tag{3}$$

11.2.1 Calculate the concentration in air of formaldehyde in the large chamber as follows:

$$C_L = \frac{C_t \times 24.47}{V_s \times 30.03} \tag{4}$$

where:

$C_L$ = parts of formaldehyde per million parts air, ppm,
30.03 = molecular weight of formaldehyde, and
24.47 = µL of formaldehyde gas in 1 µmol at 101 kPa and 298 K.

Round calculated formaldehyde concentrations in air to the nearest 0.01 ppm. Round up to the nearest 0.01 ppm all residual values at or in excess of 0.005 ppm (any value or only zeros following the 0.005). Round down all residual values below 0.005 to the nearest 0.01 ppm.

11.3 When the chamber temperature differs from 25 by 0.3°C (77 by 0.5°F) or more, adjust the large-chamber formaldehyde concentrations in air obtained to a standard temperature of 25°C (77°F) using the formula developed by Berge, et al. (**6**). Annex A1 contains a table of conversion factors for use at different observed test temperatures as calculated using this formula. The observed test temperature is the average temperature for the total period of 30 min prior to air sampling plus the time of air sampling.

11.4 The large chamber formaldehyde concentration in air shall be adjusted to a concentration at 50 % relative humidity when the difference in relative humidity from 50 % is greater than or equal to 1 % (see Annex A2).

11.5 The emission rate (ER) shall be calculated from the formaldehyde concentration in air observed in the large chamber at steady-state conditions. The formaldehyde ER shall be calculated as follows:

$$ER = 1.23\, C_s \times N/L = \mathrm{mg/(m^2 \cdot h)} \tag{5}$$

where:

$ER$ = formaldehyde emissions per unit area and unit time, $\mathrm{mg/(m^2 \cdot h)}$,
$C_s$ = formaldehyde concentration in air at steady state conditions, ppm,
$N$ = ventilation rate, air changes per hour, (AC/h), and,
$L$ = loading rate, $\mathrm{m^2/m^3}$.

NOTE 9—Concentration in air and emission rate are only relevant to the specific test air exchange rate and test loading ratio used. Concentration in air and emission rate do not change in direct proportion with changes in air exchange rates or loading ratios. Estimates of formaldehyde exposures in structures can be made by using mathematical models (**7**). Concentration in air or emission rate profile information from large chamber tests can be used as mathematical model inputs. This data is not normally obtained in Test Method E1333 unless testing is extended and chamber concentrations in air and emission rates are obtained for the tested product at multiple chamber air exchange rates or multiple product loading ratios, or both.

## 12. Report

12.1 *Report the Following Information:*

12.1.1 Test number,

12.1.2 Title of report shall state if standard face and back configuration testing (see 8.1) or if nonstandard configuration testing (see 8.2) was performed.

12.1.3 The manner in which materials were shipped or stored, or both; wrapped separately in vapor retarder, wrapped collectively in vapor retarder; waster sheet on top and bottom; or in original box or container. If materials were shipped unwrapped, with no top or bottom waster sheets, or not in the original box or container, it shall be noted on the test report. For other than newly manufactured products, the age and product history, if known, shall be described in the test report.

12.1.4 Name of product manufacturer or name of company submitting material, or both, and date of manufacture.

12.1.5 Description of test material or product to include generic product name, thickness, size, if surface finished or sealed (both surfaces shall be described), and special treatment (if known).

12.1.6 The nature of machining, if the test material is grooved, routed, bored or otherwise machined results in increased emitting area of the test material.

12.1.7 Specimen conditioning details to include temperature (and range), relative humidity (and range), time to nearest hour, approximate distance between specimens, and the air circulation conditions (for example, air velocity or air exchange rate).

12.1.8 Formaldehyde background concentration in air in room or area where specimens are conditioned (see 9.2).

12.1.9 Chamber volume; nominal length, width, and height.

12.1.10 Test material or product loading ratio in chamber.

12.1.11 Description of specimens as loaded into chamber including number of specimens in charge and number of surfaces exposed.

12.1.12 Average temperature during the conduct of the test (see 10.1.3) and temperature range during sampling period.

12.1.13 Chamber formaldehyde concentration in air at test conditions, chamber formaldehyde concentration in air corrected to 25°C (77°F), 50 % relative humidity, rounded to nearest 0.01 ppm.

12.1.14 Formaldehyde emission rate at 25°C (77°F), 50 % relative humidity, rounded to the nearest 0.001 mg/($m^2$·h).

12.1.15 Relative humidity average and range during sampling period and if chamber values have been corrected to 50 % relative humidity using the formula in Annex A2.

12.1.16 The analytical method employed if different than the adapted NIOSH chromotropic acid test procedure.

12.1.17 Average air-change rate during test.

12.1.18 Formaldehyde background concentration in air in chamber prior to test and formaldehyde concentration of make-up air.

12.1.19 Air-sampling rate and time.

12.1.20 Date of test.

## 13. Precision and Bias

13.1 Variation in the formaldehyde emission from products evaluated by this test method is a consequence of both variation in the materials tested and variation in the application of the test method. Limited information does exist to show the kind of variability that is expected between test results when the method is used in one or more laboratories (**8**). The relationship of a basis chamber to four other chambers using the same test method shows good agreement. The correlation coefficient (*r*) is 0.94.

13.1.1 *Repeatability (Within Laboratory)*—Test results indicate a precision of within 0.03 ppm on the same samples.

13.1.2 *Reproducibility (Between Laboratory)*—A test series involving two laboratories on five matched board sets in which conditioning of the panels was tightly controlled showed that measured concentrations in air were within ±6.3 % for panels ranging in formaldehyde chamber concentrations in air from 0.26 to 0.53 ppm.

## 14. Keywords

14.1 chromotropic acid analysis; concentration in air; emission rate; formaldehyde; large chamber; wood products containing formaldehyde

# ANNEXES

### (Mandatory Information)

## A1. TEMPERATURE CONVERSION FACTORS FOR FORMALDEHYDE

A1.1 Table A1.1 is based on the Berge, et al. (**6**) formula to correct formaldehyde concentrations in air for temperature:

$$C = C_o \cdot e^{-R(1/t - 1/t_o)} \qquad \text{(A1.1)}$$

or

$$C_o = C \cdot e^{R(1/t - 1/t_o)} \qquad \text{(A1.2)}$$

where:

$C$ = test formaldehyde concentration in air,
$C_o$ = corrected formaldehyde concentration in air,
$e$ = exponential function,
$R$ = coefficient of temperature (9799),
$t$ = actual temperature K, and
$t_o$ = corrected temperature, K.

**TABLE A1.1 Temperature Conversion Table for Formaldehyde**

Note 1—The Berge, et al. (**6**) equation is an exponential function. The greater the variance between actual and corrected temperature, the greater the potential error. Two horizontal lines within the table delineate the specified test temperature range 25 ± 1°C (77 ± 2°F).

| Actual | | To Convert to 25°C (77°F) Multiply by | Actual | | To Convert to 25°C (77°F) Multiply by |
|---|---|---|---|---|---|
| °C | (°F) | | °C | (°F) | |
| 22.2 | (72) | 1.36 | 25.0 | (77) | 1.00 |
| 22.5 | (72.5) | 1.32 | 25.3 | (77.5) | 0.97 |
| 22.8 | (73) | 1.28 | 25.6 | (78) | 0.94 |
| 23.1 | (73.5) | 1.24 | 25.8 | (78.5) | 0.91 |
| 23.3 | (74) | 1.20 | 26.1 | (79) | 0.89 |
| 23.6 | (74.5) | 1.17 | 26.4 | (79.5) | 0.86 |
| 23.9 | (75) | 1.13 | 26.7 | (80) | 0.83 |
| 24.2 | (75.5) | 1.10 | 26.9 | (80.5) | 0.81 |
| 24.4 | (76) | 1.06 | 27.2 | (81) | 0.78 |
| 24.7 | (76.5) | 1.03 | 27.5 | (81.5) | 0.76 |
| | | | 27.8 | (82) | 0.74 |

## A2. RELATIVE HUMIDITY CONVERSION FACTORS FOR FORMALDEHYDE

A2.1 Table A2.1 is based on the Berge, et al. (**6**) formula to correct formaldehyde concentrations in air for relative humidity:

$$C = C_o\,[1 + A(H - H_o)] \qquad (A2.1)$$

or

$$C_o = \frac{C}{1 + A(H - H_o)} \qquad (A2.2)$$

where:

$C$ = test formaldehyde concentration in air,
$C_o$ = corrected formaldehyde concentration in air,
$A$ = coefficient of humidity (0.0175),
$H$ = actual relative humidity, and
$H_o$ = corrected relative humidity, %.

**TABLE A2.1 Relative Humidity Conversion Table for Formaldehyde**

| Actual RH | To Convert to 50 % RH Multiply by | Actual RH | To Convert to 50 % RH Multiply by |
|---|---|---|---|
| 46 | 1.08 | 51 | 0.98 |
| 47 | 1.06 | 52 | 0.97 |
| 48 | 1.04 | 53 | 0.95 |
| 49 | 1.02 | 54 | 0.93 |
| 50 | 1.00 | ... | ... |

## A3. STANDARD SOLUTIONS A AND B

### A3.1 Standardization of Formaldehyde Standard Solution A (1.0 mg/mL)

A3.1.1 Pipet 2.70 mL of 37.0 % formaldehyde solution into a 1-L volumetric flask. Dilute to mark with freshly distilled water and mix well. This solution is stable for at least one month in a closed container at laboratory conditions.

A3.1.2 Calibrate the pH meter with standard buffer solution of pH 9.0.

A3.1.3 Pipet two 50-mL aliquots of Formaldehyde Standard Solution A into two 150-mL beakers for duplicate analysis and add 20 mL of 1 M sodium sulfite to each beaker.

NOTE A3.1—Sodium sulfite solution can age, thus the 1-M sodium sulfite solution shall be adjusted to a 9.5 pH before adding to Standard Solution A aliquots.

A3.1.4 Place solution on magnetic stirrer. Immerse pH electrodes into the solution and carefully titrate with 0.100 N hydrochloric acid (HCl) to the original pH of the solution. Record volume of HCl and corresponding pH intermittently. Make a graph of pH versus volume of HCl.

A3.1.5 Calculate the concentration, $C_A$, of Formaldehyde Standard Solution A in milligrams per millilitre as follows:

$$C_A = \frac{V \times N \times 30.03\ (\text{mg per milliequivalent})}{50\ (\text{mL})} \qquad (A3.1)$$

where:

$V$ = 0.100 N HCl required at pH of 9.5 from the graph prepared in A3.1.4, mL, and
$N$ = normality of HCl.

A3.1.6 Record the concentration value (mg/ml) of Standard Solution A ($C_A$) which is the average of the two analyses conducted.

### A3.2 Standard Solution B

A3.2.1 Prepare a 1% sodium bisulfite ($NaHSO_3$) solution by dissolving 10 g of $NaHSO_3$ in a 1000 mL volumetric flask and diluting to the mark with distilled water.

A3.2.2 Prepare formaldehyde Standard Solution B in a 1000 mL volumetric flask by adding 5 mL of Standard Solution A diluting to the mark with the 1% sodium bisulfite solution. The target concentration of Solution B is 5 µg/ml. This standard is stable for at least one week in a closed container at laboratory conditions.

$$C_B = (C_A \times 1000 \times 5\ \text{mL})/1000\text{mL} \qquad (A3.2)$$

*where:*

$C_B$ = concentration of Standard Solution B, µg/ml,
$C_A$ = concentration of Standard Solution A, mg/ml,
1000 = constant conversion factor,
5 mL = amount of Standard Solution A added, and
1000 mL = size of flask used to prepare Standard Solution B.

A3.2.3 Record the concentration value (µg/ml) of Standard Solution B ($C_B$).

## A4. CALIBRATION CURVE

A4.1 Prepare a 1 % sodium bisulfite ($NaHSO_3$) solution by dissolving 10 g of $NaHSO_3$ in a 1000-mL volumetric flask and diluting to the mark with distilled water. This solution is stable in a closed container at laboratory room temperature and shall be prepared on a weekly basis.

A4.2 Prepare eight standard solutions in 200 mL volumetric flasks by pipetting the following amounts of Solution B followed by dilution to the mark with 1 % sodium bisulfite ($NaHSO_3$) solution that was prepared in A4.1.

| Flask Number | Solution B (mL) | Target Flask HCHO Concentration (µg/ml) |
|---|---|---|
| 1 | 0.00 | 0.000 |
| 2 | 5.00 | 0.125 |
| 3 | 7.00 | 0.175 |
| 4 | 10.00 | 0.250 |
| 5 | 12.00 | 0.300 |
| 6 | 16.00 | 0.400 |
| 7 | 20.00 | 0.500 |
| 8 | 30.00 | 0.750 |

Concentration of each flask is calculated as follows:

$$\text{flask HCHO concentration } (\mu g/mL) = (C_B\ (\mu g/ml) \times \text{Solution B added } (mL)) / 200\ mL$$

A4.2.1 Record the concentration value for each flask.

A4.3 Pipet a 4 mL aliquot from each flask specified in A4.2 into three test tubes for triplicate analyses.

A4.3.1 Note that no Solution B is added to Flask No. 1. Flask No. 1 will contain the reagent blank.

| Test Tube (TT) Set | Target Test Tube HCHO Content (µg) |
|---|---|
| 1 | 0.000 |
| 2 | 0.500 |
| 3 | 0.700 |
| 4 | 1.000 |
| 5 | 1.200 |
| 6 | 1.600 |
| 7 | 2.000 |
| 8 | 3.000 |

$$\text{test tube HCHO content } (\mu g) = \text{flask concentration } (\mu g/ml) \times 4\ mL$$

Record the content value for each test tube and that value will be used in A4.9.2.

A4.4 Add 0.1 mL of 1 % chromotropic acid reagent to each test tube. Shake tube after addition.

A4.5 Slowly and carefully pipet 6.0 mL concentrated $H_2SO_4$ into each test tube (**Warning—**See 7.1.) and allow to flow down the side of the test tube. Allow the volumetric pipet to drain. DO NOT BLOW OUT. Before placing caps on test tubes, check the condition of the PTFE cap liners to make sure they are clean and not deteriorated.

A4.5.1 Slowly and gently agitate test tubes to effect mixing. Mixing is complete when there is no sign of stratification. Rapid mixing will cause heating and a pressure increase that will increase the potential for breaking the test tube. If absorbance readings exceed 1.0 or if spectrophotometric analysis is performed within 2 h, heat capped test tubes to 95°C or place in a boiling water bath for 15 ± 2 min to ensure that the chemical reaction is completed. After removal, allow the test tubes to cool to room temperature. Carefully vent test tubes to release pressure.

A4.6 Standardize the spectrophotometer using distilled water at 580 nm in accordance with the instrument's operating instructions. The reagent blank (Flask #1 TT 1) shall be read against distilled water. A high absorbance for the reagent blank indicates contamination of reagent blank or improper solution preparation. If absorbance for the reagent blank compared to distilled water is greater than 0.040 (using a 12-mm cell path length) or above 0.030 (using a 10-mm cell path length), repeat the entire standardization procedure.

A4.7 Zero the instrument using the reagent blank (Flask #1 TT 1), or the instrument shall be left zeroed on distilled water, and the absorbance of the reagent blank subtracted from the absorbance of the standard solutions. Recovery shall be within ±5 % of reagent blank.

A4.8 Read and record absorbance at 580 nm for each standard prepared (Solutions from Flask Nos. 2 - 8).

A4.9 Plot absorbance against micrograms of formaldehyde in the color developed solution. Note that the amount of formaldehyde in micrograms is based upon the concentration of formaldehyde in Standard Solution flasks, which is dependent upon the standardization carried out on Standard Solution A in Annex A3.

A4.9.1 The average absorbance shall be plotted against the average total micrograms of formaldehyde from each test tube set.

A4.9.2 The absorbance of each chamber impinger aliquot specimen determined in 10.4.3 shall be compared to this calibration curve, and the total micrograms of formaldehyde in the aliquot shall be represented as $C_a$ in 11.2.

A4.10 Preparation of the calibration curve (A4.3 – A4.9) shall be repeated at least once more and the final calibration line must reflect the composite of the determinations (or the curve shall be calculated using a linear least square fitting technique). If the plot in A4.9 shows the last few points deviating from linearity, omit the points from calculations or repeat the entire procedure. Further, the curve must be frequently checked based on changes in reagent lot numbers, past experience, data scattering, or instrument instability.

NOTE A4.1—The calibration curve as described in this annex is provided as an example of a curve appropriate for products designed to conform with HUD 24 CFR 3280 for manufactured homes, Minnesota Statutes Section 144.495, and CARB CCR 93120. If absorbance readings are outside of this range, the calibration curve shall incorporate appropriate volumes of Standard Solution B (see Annex A3) to reflect that range.

NOTE A4.2—If absorbent readings exceed 1.0 or if spectrophotometric analysis is performed within 2 h, heat capped test tubes to 95°C or place capped test tubes in a boiling water bath for 15 ± 2 min to ensure that the chemical reaction is completed. After removal, allow the test tubes to cool to room temperature. Carefully vent test tubes to release pressure.

# APPENDIXES

## (Nonmandatory Information)

## X1. REAGENTS, MATERIALS, AND EQUIPMENT FOUND SUITABLE FOR USE

### X1.1 Air-Sampling Apparatus

NOTE X1.1—Other apparatus and instruments may be used if equivalent results are anticipated.

X1.1.1 *Midget Impingers,*

X1.1.2 *Rotameters,* 1 L/min,

X1.1.3 *Line Filter,* with desiccant (to dry the air before entering rotameters),

X1.1.4 *Polytetrafluoroethylene (PTFE) tubing*,

X1.1.5 *Buret,* 250 or 500-mL (to calibrate rotameters),

X1.1.6 *Impinger Pumps,*

X1.1.7 *Film-Type Laboratory Calibrators or Bubble Tube,* for calibrating pumps and rotameters, and

X1.1.8 *Differential Pressure Gage,* for determining that the chamber is at positive pressure.

### X1.2 Analytical Apparatus

X1.2.1 *Spectrophotometer,*

X1.2.2 *Spectrocheck,* for calibration of the spectrophotometer,

X1.2.3 *Beaker,* 150-mL, low form,

X1.2.4 *Volumetric Flask,* 1000-mL,

X1.2.5 *Volumetric Flask,* 100-mL,

X1.2.6 *Volumetric Flasks,* two, 10-mL,

X1.2.7 *Buret,* 25-mL, Class A,

X1.2.8 *pH meter,*

X1.2.9 *Magnetic Stirrer,*

X1.2.10 *Pipet,* volumetric, 4-mL,

X1.2.11 *Pipet,* volumetric, 50-mL·10, Class A, and

X1.2.12 *Pipet,* volumetric, 6-mL·10, Class A.

X1.2.13 *Pipet,* long-tip Mohr type, 2 by 0.01-mL,

X1.2.14 *Pipet,* Mohr, 10 by 0.1-mL,

X1.2.15 *Safety Bulb,* for pipeting,

X1.2.16 *Test Tubes,* 16 by 150-mm, with PTFE lined screw caps,

X1.2.17 For repetitive analyses of sample solutions and for added safety, use of automatic pipeting equipment may be desirable. Use of the following have been found suitable.

X1.2.17.1 *Brinkman Dispensers,* volume 0.1 to 0.5 mL (for chromotropic acid) volume 1 to 10 mL (for sulfuric acid), and volume to 25 mL (for distilled water),

X1.2.17.2 *Oxford Macro-Set Pipet,* and

X1.2.17.3 *Tips,* 250, for transferring 4-mL aliquots.

X1.2.18 *Volumetric Flask,* 200 mL.

### X1.3 Reagents

X1.3.1 *Chromotropic Acid Reagent*—Dissolve 0.10 g of chromotropic acid (4,5-dihydroxy-2,7-naphthalene-disulfonic acid disodium salt) in freshly distilled water and dilute to 10 mL. This solution is to be made up daily.

X1.3.2 *Sulfuric Acid,* ACS grade. Nitrate concentration shall be no greater than 0.2 ppm.

X1.3.3 *Buffer Solution,* pH 9.0.

X1.3.4 *Hydrochloric Acid* (HCl) 0.100 *N*, standard.

X1.3.5 *Sodium Sulfite Solution*, 1.0 M—Dissolve 12.67 g anhydrous sodium sulfite (ACS assay 99.5 %) in a 100-mL volumetric flask and dilute to the mark with freshly distilled water. The correct amount to be dissolved should be 12.6/ACS assay of the anhydrous sodium sulfite actually being used (read assay from bottle label).

X1.3.6 *Formaldehyde Solution,* weight 37 %.

X1.3.7 *Sodium Bisulfite,* ($NaHSO_3$) reagent grade.

X1.3.8 *Mild Liquid Soap.*

## X2. CHAMBER FORMALDEHYDE EMISSION MEASUREMENT VERIFICATION

### X2.1 Listing of Variables Used for Calibration Preparation X2.1

$A$ = Aliquot of stock solution necessary to spike chamber, mL.
$AC/h$ = air change rate per hour.
$Cv$ = chamber volume, L.
$F_{0.0}$ = formaldehyde equal to 1.0 ppm at 0.0 AC ⁄h, µg.
$F_{0.5}$ = formaldehyde equal to 1.0 ppm at 0.5 AC ⁄h, µg.
$Fr$ = flow rate of delivery pump, mL/h.
$Gr$ = generation rate of HCHO, µg/h.
$GSc$ = generation solution concentration, µg/mL.
$SSa$ = stock solution aliquot diluted to 250 mL (necessary to prepare generation solution), mL.
$SSc$ = stock solution concentration, µg/mL.

### X2.2 Chamber Validation Procedure X2.2

| | Validation Conditions |
|---|---|
| Air change rate per hour, AC/h | 0.5 ± 0.05 |
| Target concentration in air, ppm | 0.3 ± 0.015 |
| Temperature, of °C (°F) | 25 ± 1 (77 ± 2) |
| Relative humidity, % | 50 ± 4 |

### X2.3 Initial Preparation of Chamber Parameters, Measurements, and Solutions

NOTE X2.1—Variables used throughout the calibration procedure should be listed with their appropriate generated values. These variables are later used for various calculations.

X2.3.1 *Temperature/Relative Humidity*—Maintain a continuous record of the temperature and relative humidity throughout the calibration procedure.

X2.3.2 *Background Formaldehyde Concentrations in Air*—Prior to each generation of formaldehyde, the background concentrations in air should be measured and fall within the limits stated in the standard procedure.

X2.3.3 *Air Sampling Rate Calibration*—Airflow measuring devices should be calibrated in accordance with Practice D3195.

X2.3.4 *Chamber Volume*—Determine the volume ($V$) of the test chamber in litres as follows:

$$V = (\text{cubic feet of chamber}) \times (28.32)$$

X2.3.5 *Delivery Pump Rate Calibration:*[11]

X2.3.5.1 The flow rate ($Fr$), in millilitres per hour, of the formaldehyde generation delivery pump is to be determined by replicate measurements. The actual flow rate required depends on the chamber volume and concentration of the generation solution. The flow rate should not exceed 15 mL ⁄h. This maximum allows for complete evaporation of each drop during the generation process.

X2.3.5.2 It is recommended that the pump rate and subsequent drop rate, together with the pump-evaporation apparatus, be tested for complete evaporation. Each drop should completely evaporate prior to the next drop entering the evaporation cup. Distilled water can be used as a test solvent.

X2.3.6 *Calibration Stock Solution Preparation:*

X2.3.6.1 Weigh about 36 g of 37 % formaldehyde into a 250-mL volumetric flask. Dilute to mark with distilled water and mix well.

X2.3.6.2 Pipet 50.0 mL into a 250-mL volumetric flask, dilute to mark with distilled water, and mix well.

X2.3.6.3 Determine the concentration of the diluted solution in triplicate using the HCl titration method described in the standard procedure. Titrate to a pH end point of 9.5 as follows:

$$\text{mg/mL} = \frac{(\text{mL HCl required}) \times (\text{N of HCl}) \times 30.03}{50\ \text{mL}} \quad (X2.1)$$

X2.3.6.4 Calculate the concentration of the original stock solution SSc in micrograms per millilitre as follows:

$$SSc = (\text{mg/mL of diluted solution}) \quad (X2.2)$$

$$\times (250\ \text{mL}/50\ \text{mL}) \times 1000$$

NOTE X2.2—The SSc concentration should be about 52 000 µg ⁄mL.

X2.3.7 *Calibration Working Solutions:*

X2.3.7.1 Amount of formaldehyde (HCHO), in micrograms, present in the test chamber as follows:

$$F_{0.0} = \mu\text{g HCHO at 0.0 ACH at 1.0 ppm} = 1.2 \times 1.0 \times Cv \quad (X2.3)$$

$$F_{0.5} = \mu\text{g HCHO at 0.5 AC/h} = F_{0.0}/2$$

NOTE X2.3—1.0 ppm HCHO = 1.2 µg/L.

X2.3.7.2 *Initial Spike Solution for 0.3 ppm HCHO Concentration in Air at 0.0 AC/h*—To achieve a chamber HCHO concentration in air of 0.3 ppm at 0.0 AC ⁄h it is necessary to spike the chamber with an equivalent aliquot, $A$, in millilitres, of the HCHO stock solution. Thus:

$$\text{HCHO required}\ (\mu\text{g}) = (0.3\ \text{ppm}) \times F_{0.0} \quad (X2.4)$$

therefore:

$$A\ (\text{mL}) = \frac{\text{HCHO required}\ (\mu\text{g})}{SSc\ (\mu\text{g/mL})} \quad (X2.5)$$

X2.3.7.3 *Generation Solution for 0.3 ppm HCHO Concentration in Air at 0.5 AC/h*—Continuous generation of HCHO necessary to maintain a concentration in air of 0.3 ppm with an air change rate of 0.5 AC ⁄h requires the following calculations:

$$\text{Gr} = (0.3\ \text{ppm}) \times F_{0.5} \quad (X2.6)$$

For *GSc*, dilute an appropriate aliquot of stock solution (*SSa*) to a 250-mL volumetric flask necessary to provide *Gr* in micrograms per hour at a delivery pump rate of *Fr* in millilitres per hour as follows:

$$GSc\ (\text{g/mL}) = \frac{Gr\ (\mu\text{g/h})}{Fr\ (\text{mL/h})} \quad (X2.7)$$

hence:

$$SSa\ (\text{mL}) = \frac{GSc\ (\mu\text{g/mL}) \times 250\ \text{mL}}{SSc\ (\mu\text{g/mL})} \quad (X2.8)$$

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[11] An alternative procedure for generating constant formaldehyde concentrations in air involves the use of purified gas generation devices, one of which is described by Balmat (**9**).

### X2.4 Calibration Test Protocol and Chamber Operating Procedure

X2.4.1 *Testing Protocol:*

X2.4.1.1 The calibration test shall be conducted over a 2-day period with chamber samples taken each day at 2, 4, and 6 h after starting the generation delivery pump.

X2.4.1.2 Upon completion of sampling for a given day, generation of formaldehyde is discontinued and the chamber is purged overnight. The following day the HCHO background concentration in air is checked prior to chamber spiking and initiation of generation delivery pump.

X2.4.1.3 The generation solution (*GSc*) is prepared fresh daily from the HCHO stock solution (*SSc*). The stock solution is standardized daily.

X2.4.1.4 Formaldehyde determinations are made by the adapted NIOSH chromotropic acid method using 1.0 % NaHSO$_3$ as the absorbing solution.

X2.4.2 *Chamber Operating Procedure:*

X2.4.2.1 With the chamber operating under dynamic conditions, determine the background HCHO concentration in air.

X2.4.2.2 Discontinue dynamic conditions, that is, AC/h = 0.0.

X2.4.2.3 Using a syringe, spike the chamber by transferring the calculated aliquot, in millilitres, of stock solution into the evaporation cup. (See Fig. X2.1 for diagram of delivery pump and evaporation apparatus.) Allow for complete evaporation and chamber equilibrium prior to initiation of generation delivery pump. About 10 min is sufficient.

X2.4.2.4 Initiate dynamic conditions (AC/h = 0.5) and, as simultaneously as possible, start generation delivery pump.

X2.4.2.5 Sample the chamber atmosphere, in duplicate, at the time specified.

X2.4.2.6 Following the third sampling, turn off the generation delivery pump. Allow the chamber to purge by continuing dynamic conditions (0.5 AC/h or greater) overnight.

X2.4.2.7 Repeat calibration testing, following the testing protocol, by starting with X2.4.

X2.4.2.8 Collected sample solutions can be stored under refrigeration until testing protocol is complete. They shall be analyzed using chromotropic acid as outlined in this test method.

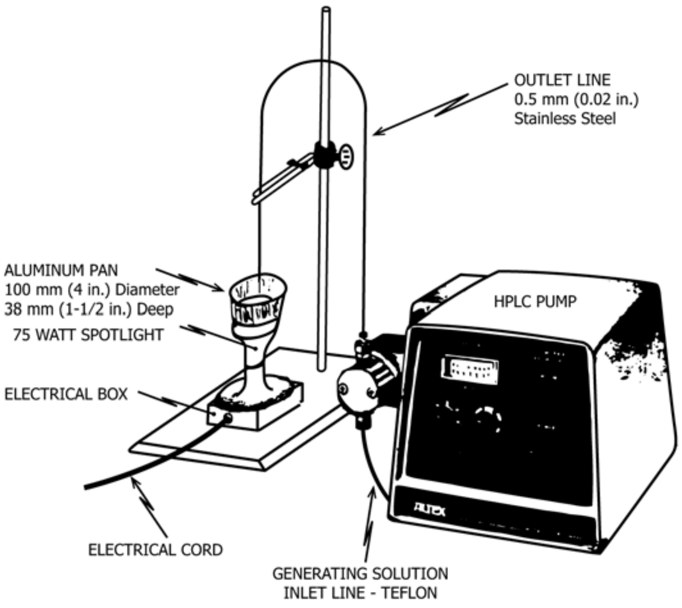

**FIG. X2.1 Equipment Description**

## X3. LARGE CHAMBER TEST LOADING RATIOS

### X3.1 Loading Ratios Referenced in Federal and State Regulations

X3.1.1 *U.S. Department of Housing and Urban Development (HUD)*—HUD 24 CFR 3280 references loading ratios for plywood and particleboard. In a memorandum letter of January 31, 1985, HUD described the test loading ratio for industrial panels made with formaldehyde resins as "unfinished multi-ply composite wood products which consist of various combinations of hardwood veneer faces and pressed wood materials or mineral fiber cores (that is, plywood, particleboard, hardboard, and so forth). These panels are used in making cabinets, furnishings and in other non-structural applications." HUD loading ratios are as follows:

0.95 m$^2$ /m$^3$ (0.29 ft$^2$ /ft$^3$)—Plywood
0.43 m$^2$ /m$^3$ (0.13 ft$^2$ /ft$^3$)—Particleboard
0.43 m$^2$ /m$^3$ (0.13 ft$^2$ /ft$^3$)—Industrial Panels

X3.1.2 Minnesota Statutes Section 144.495, 325F.181, Formaldehyde Product Standard, references HUD 24 CFR 3280, 3280.308 and 3280.406, sections of the HUD Manufactured Home Construction and Safety Standards (1984), but also lists medium density fiberboard (MDF) as a covered product. Minnesota reference loading ratios are as follows:

0.95 m$^2$ /m$^3$ (0.29 ft$^2$ /ft$^3$)—Plywood
0.43 m$^2$ /m$^3$ (0.13 ft$^2$ /ft$^3$)—Particleboard
0.43 m$^2$ /m$^3$ (0.13 ft$^2$ /ft$^3$)—MDF

### X3.2 Loading Rates Referenced in Voluntary Standards for Wood Products

X3.2.1 *ANSI/HPVA HP-1-09*—American National Standard for Hardwood and Decorative Plywood references 0.95 m$^2$ /m$^3$ (0.29 ft $^2$ /ft$^3$) loading ratio for hardwood plywood wall paneling, 0.43 m$^2$/m$^3$ (0.13 ft$^2$/ft$^3$) for industrial hardwood plywood panels and 0.43 m$^2$/m$^3$ (0.13 ft$^2$/ft$^3$) for reconstituted wood wall panels.

X3.2.2 *ANSI A208.1–2009*—American National Standards for Particleboard references 0.425 m$^2$ /m$^3$ (0.13 ft$^2$/ft$^3$) for high and medium density particleboard, manufactured home decking and underlayment particleboard, and 0.13 $m^2/m^3$ (0.04 $ft^2/ft^3$) for low density particleboard.

X3.2.3 *ANSI A208.2–2009*—American National Standard for Medium Density Fiberboard (MDF) references 0.26 $m^2/m^3$ (0.08 $ft^2/ft^3$) for medium density fiberboard (MDF).

X3.3 *Actual or Estimated Loading Rates in Homes Referenced by Federal Agencies*—The Consumer Product Safety Commission, Environmental Protection Agency and U.S. Department of Housing and Urban Development have reviewed or had contractors review reports that describe loading ratios of formaldehyde containing wood products typical of manufactured (mobile) and conventional homes. These loading ratios generally range from 0.016 $m^2/m^3$ (0.005 $ft^2/ft^3$) which describe a loading ratio for an incidental use of a formaldehyde containing wood product (closet shelving, for example) to 0.95 $m^2/m^3$ (0.29 $ft^2/ft^3$) which describes the use of interior wall paneling applied to almost all interior walls of a manufactured home. Large chamber tests can be conducted with products at the same loading ratios as in an actual home.

## X4. SHIPMENT OF TEST MATERIALS TO THE LABORATORY

X4.1 Formaldehyde-containing wood products typically tested by this method are in flat panel form sent to the laboratory for testing either wrapped with 0.15-mm (6-mil) polyethylene plastic or put between a top and a bottom waster sheet, or both.

X4.2 Some products such as kitchen and audio/video cabinets and wood furniture may be made using substantial quantities of wood product components containing formaldehyde. These products are not in flat panel form and are, from time to time, tested in large chambers to determine formaldehyde emission potential. The manner in which the products are prepared for shipment for testing can differ depending on the objectives for the test. Two examples are provided.

X4.2.1 *Example 1*—A kitchen cabinet manufacturer may seek information on the formaldehyde release potential of kitchen cabinets to those who are installing the cabinets in a home. New kitchen cabinets representative of the use of wood product components may be sent to a laboratory in packaging typical of the manufacturer such as corrugated boxes. The shipment of the test cabinets is coordinated with the laboratory. On the day of receipt of the kitchen cabinets by the laboratory, they are placed in conditioning without opening the packaging for a day to ensure temperature equilibrium inside the boxes. On the day of testing, the cabinets are placed in a large chamber, the corrugated boxes are opened and the formaldehyde concentration in air is measured following chamber equilibrium the following day. Using large chamber test data and other inputs will allow the use of mathematical models for estimating formaldehyde concentration in air exposures to home construction workers.

X4.2.2 *Example 2*—A manufacturer, distributor or other party may seek information on the formaldehyde release potential of an audio cabinet system in a home, other living space, or working space. The party requesting the test may wish to deviate from using the typical packaging and shipment technique and send the audio cabinets seal-wrapped and crated to minimize any change in formaldehyde release potential due to shipment. On receipt of the test cabinets the party requesting testing and the laboratory may determine that the cabinets should be conditioned a specified period of time, such as one week, prior to testing to achieve formaldehyde emission rate stabilization. Large chamber test data and other inputs will allow the use of mathematical models for estimating formaldehyde concentration in air exposures to occupants of homes or indoor spaces due to the emission potential of the audio cabinet system.

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