

Meeting the Requirements of the California Composite Wood ATCM Using Chambers of Different Sizes

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Introduction: The California Air Resources Board (CARB) has promulgated a new Airborne Toxics Control Measure (ATCM) to reduce formaldehyde emissions from composite wood products that are manufactured, imported, distributed, sold, and fabricated in the state of California. The ATCM sets ceiling limits for the emission of formaldehyde from these products that will go into effect beginning with Phase 1 requirements on January 1, 2009. CARB specifies the use of a large chamber test method (ASTM E 1333) as the reference method for demonstrating compliance. This paper describes an alternate testing approach using small-scale chambers.

Background: ASTM Standard Test Method E 1333 (2002a) is used by the composite wood industry for establishing compliance of their products with U.S. Dept. of Housing and Urban Development (HUD) and ANSI standards for formaldehyde emissions (see E 1333, Annex X3 for a list of these standards). The new California Air Resources Board, Airborne Toxic Control Measure (ACTM) (2007) for composite wood specifies E 1333 as the reference method. E 1333 requires test specimens to be conditioned for seven days followed by a 16 to 20 hour exposure period in a large-scale chamber with a volume $\geq 22 \text{ m}^3$ operated at 0.5 air changes per hour (h^{-1}). E 1333 also requires the use of product loading ratios that are specific to three different product categories: hardwood plywood wall paneling, particleboard (PB), and medium density fiberboard (MDF). Hardwood plywood wall paneling is a small industry segment. Industrial hardwood plywood (HWPW) with either a veneer core (VC) or a composite core (CC), such as used in the manufacturing of cabinetry and case goods, has the same required loading ratio as PB. The E 1333 loading ratios for the three product categories covered by the ATCM are reproduced in Table 1.

Table 1. Loading ratios used for testing wood panel products emitting formaldehyde

Product Category	Loading Ratio $\pm 2\%$	
	(ft ² /ft ³)	(m ² /m ³)
Hardwood Plywood* (HWPW)	0.13	0.43
Particleboard (PB)	0.13	0.43
Medium Density Fiberboard (MDF)	0.08	0.26

*Industrial hardwood plywood panels, HWPW-VC and HWPW-CC

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For the required routine monitoring of their production lines, manufacturers may use methods producing results that correlate with E 1333 results. One viable approach is to use small-scale chambers as described in ASTM Standard Test Method D 6007 (2002b), in which chamber sizes ranging from 0.02 to 1 m³ are specified. The intent of D 6007 is, by application of mass-balance principles, to produce a chamber concentration for a given product specimen that correspond to the concentration that is generated when the product is tested according to E 1333, *i.e.*, the D 6007 method should produce nearly the same results as E 1333.

Principles: The use of chambers to measure emissions of volatile chemicals, such as formaldehyde, from products, is based on mass balance determined by measuring the mass flow rates of a substance entering and leaving a system. In E 1333 and D 6007, the mass balance is calculated assuming steady-state conditions, *i.e.*, the emission rate of formaldehyde from a product is not changing rapidly with time at the time point of interest.

First, it is convenient to convert formaldehyde concentrations in parts-per-million (ppm) to mass volume concentrations with units of µg/m³. Formaldehyde has a molecular weight of 30 g/mol. The molar volume at standard conditions of 25 °C (the specified chamber temperature) and one atmosphere pressure for any gas is 24.45 liters per mole. The procedure for converting, for example, 0.1 ppm of formaldehyde to concentration in µg/m³ is:

$$0.1 \text{ ppm} = 100 \text{ parts-per-billion (ppb)} = \frac{30 \text{ g/mol}}{24.45 \text{ l/mol}} = 123 \text{ } \mu\text{g/m}^3 \quad (1)$$

(yielding a ppb to µg/m³ conversion factor of 1,227). The steady-state mass-balance equation used to calculate an area-specific emission rate of a VOC (*i.e.*, the mass of a VOC emitted per unit area of a material per time; often described as an emission factor, EF) in µg/m²-h is:

$$EF = V n C/A \quad (2)$$

where V is the chamber volume (m³), n is the chamber air change rate (h⁻¹), C is the net formaldehyde chamber concentration (*i.e.*, concentration after subtracting any background chamber concentration) in µg/m³, and A is the area of the product specimen's emitting surface (m²).

The loading factors (*i.e.*, the emitting surface area divided by the chamber volume) in m²/m³ specified by E 1333 are calculated as:

$$L = A/V \quad (3)$$

The area-specific air flow rate (m³/m²-h, or m/h) for a test is the air flow rate entering the chamber (Q, m³/h) calculated as the product of the chamber volume and the air change rate divided by the product surface area, A (m²). This often is expressed as the quotient n/L.

$$V n/A = Q/A = n/L \quad (4)$$

So, for a given chamber size one can adjust the inlet air flow rate and/or the area of the specimen to achieve a desired area-specific air flow rate. E 1333 establishes area-specific air flow rates by requiring a ventilation rate of 0.5 h⁻¹ and an exact loading ratio for both product categories (Table 2).

Parameters for Small-Scale Chamber Tests: Examples of two small chambers are given: a Berkeley Analytical Associates (BAA) 0.067-m³ chamber operating at 1 h⁻¹; and a commercial micro-chamber, the Field and Laboratory Emission Cell (FLEC). The FLEC is essentially a transportable chamber, or lid, in which a smooth planar product forms one of the surfaces; thus, the product surface area is fixed by the device. In Table 2, the operating parameters for these chambers are compared to the parameters for a large-scale chamber operated according to E 1333. For both product categories (PB and HWPW combined and MDF), the parameters are adjusted to achieve the same area-specific air flow rate.

Since the 0.067-m³ chamber is operating at 1 h⁻¹, the product loading ratios are twice the values for the E 1333 large chamber. The areas of the emitting surfaces are selected to achieve these loading ratios and the target area-specific air flow rates. The required sizes of the specimens, assuming squares with two primary emitting surfaces and sealed edges, are shown for the BAA chamber and the large chamber. For the FLEC, which has a fixed product surface area of 0.0177 m², the inlet air flow rate is varied to achieve the target area-specific air flow rates.

For comparison, the chamber operating parameters for tests used to determine compliance with the European E1 panel product formaldehyde emission requirement can be >12 m³, 1 m³ or 0.225 m³ (CEN, 2004). These chambers are operated at 1 h⁻¹ with a 1 m²/m³ loading ratio to achieve an area-specific air flow rate of 1.0 m/h versus a value of 1.173 m/h for tests of PB and HWPW conducted according to E 1333.

The operating parameters for the BAA chamber and the FLEC easily can be adjusted to achieve the target area-specific air flow rates. Everything else being equal including pre-test conditioning, the formaldehyde concentrations in the large, small and micro chambers should be nearly the same at a given specimen age and there should be a one-to-one correspondence among results obtained with the three chambers. The only obvious difference is that the conditions for the FLEC do not exactly match those for the other chambers since only one side of the specimen is exposed to air in the FLEC.

The ability to switch between test environments was demonstrated in one research study (Risholm-Sundman, 1999). This investigation compared formaldehyde emission factors for one PB and five MDF samples measured in a small-scale chamber tests conducted using Standard EN 717-1 (CEN, 2004) with those measured in FLEC tests. The specimens were conditioned for seven days, tested in a 1-m³ chamber for six days and then transferred to the FLEC for a 24-h test. For the MDF samples, the average relative difference in emission factors between the two test environments was 16% (range 0% to 29%). For the PB sample, the FLEC yielded results that were about 40% lower than the chamber results. Thus, for the MDF samples, there was good correspondence between the two test environments.

Impact of ATCM on Formaldehyde Emissions from Composite Wood Products: The ATCM will be implemented in two phases beginning on January 1, 2009. Phase 1 is requiring modest improvements over average industry results assessed by a CARB survey of 2002 E 1333 test data supplied by U.S. manufacturers. Phase 2, which starts in January 2011 with the final limits in place by July 2012, will require substantial reductions in emissions. The impacts of the ATCM on formaldehyde emission factors for HWPW, PB and MDF are summarized in Table 3. Notably, the Phase two emission factor for PB and HWPW of 129 µg/m²-h is equivalent to the current European E1 requirement.

In practice, the ATCM will force formaldehyde emissions lower for both Phase 1 and 2 because the emission limits are set as values that cannot be exceeded, *i.e.*, they are production run

“ceiling” limits, not running averages for a production facility. Consequently, if the test result for a production run exceeds the limit, the product from that run will need to be treated in some manner to reduce its formaldehyde emissions or the product will need to be diverted to another market. This could result in substantial disruption and each manufacturer will need to decide where to set the target operating limit (TOL) to minimize the chance of this disruption, and potential financial loss, occurring at their facilities. The TOL must take into account both the variability in the manufacturing process and the variability associated with the laboratory measurement of formaldehyde emissions. The latter may be relatively high at manufacturing sites due to use of less sophisticated methods. We have assumed the TOLs are set at two-thirds of the emission limits, which is not an unrealistic value. In Table 3, the impacts of incorporating the TOL on the Phase 1 and 2 emission limits are shown. This analysis suggests that Phase 2 formaldehyde emission factors may have to be about three-fold lower than their 2002 values.

Conclusion: ASTM D 6007 is an established ASTM test method that has been crafted to produce results that are equivalent to ASTM E 1333. Based on practical considerations, it is our opinion that ASTM D 6007 should be considered as an alternate method to demonstrate compliance with the CA Composite Wood ATCM. Implementation of the ATCM is anticipated to create a significant demand for testing services that likely cannot be met by the existing inventory of large-scale E 1333 chambers. It will be logistically easier, less costly and quicker for the testing industry to develop small chamber facilities to address the demand. Ultimately there should be cost savings to the composite wood industry due to lower costs for shipping of samples, lower costs for conditioning of small test specimens and lower costs for operating small-scale chambers.

References

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Table 2. Operating parameters for a large-scale chamber specified by ASTM Method E 1333, for Berkeley Analytical Associates (BAA) small-scale chambers as specified by ASTM Method D 6007, and the Field and Laboratory Emission Cell (FLEC). Values are show for each of two product categories: particleboard (**PB**) and hardwood plywood (**HWPW**) combined, and medium density fiberboard (**MDF**)

Parameter	Units	PB & HWPW			MDF		
		E 1333	BAA	FLEC	E 1333	BAA	FLEC
Chamber vol (V)	m ³	22	0.067	35 cm ³	22	0.067	35 cm ³
ACH (n)	h ⁻¹	0.5^a	1.0	593	0.5	1.0	963
Inlet air flow (Q)	m ³ /h	11	0.067	346 cm ³ /min	11	0.067	562 cm ³ /min
Loading (L)	m ² /m ³	0.43	0.85	Na ^b	0.26	0.52	Na
Q/A or n/L	m/h	1.173	1.173	1.173	1.905	1.905	1.905
Emitting area ^c (A)	m ²	9.46	0.057	0.0177	5.72	0.035	0.0177
X & Y Dimen ^d	m	2.17	0.169	Na	1.69	0.132	Na

^aValues highlighted in bold text are fixed by the method or, for the FLEC emitting area, by the chamber

^bNa = Not applicable

^cAssumes edges are <5% of total area, sealed, or not included (FLEC)

^dFace dimensions (X and Y axes) of a square product specimen with both primary faces exposed in chamber

Table 3. Industry average concentration and emission factor (EF) results for **PB** and **HWPW** combined, and **MDF** in 2002 and concentration and emission factor limits required by Phase 1 (Jan 2009) and Phase 2 (Jan 2011 – Jul 2012) of the ATCM. Also shown are Phase 1 and 2 target operating limits (TOL) arbitrarily set at two-thirds of the ATCM limits

Parameter	Units	PB & HWPW			MDF		
		2002	Phase 1	Phase 2	2002	Phase 1	Phase 2
Concentration	ppm	0.18	0.18	0.09	0.25	0.21	0.11
Concentration	µg/m ³	221	221	110	307	258	135
EF	µg/m ² -h	259	259	129	585	492	257
TOL EF	µg/m ² -h	Na*	173	86.0	Na	328	172

*Na = Not applicable