Appendix D

Basis for Formaldehyde Emission Factors:

To calculate the HCHO emission rates for uncoated hardwood plywood (HWPW), particleboard (PB), and medium density fiberboard (MDF) in the proposed ATCM, a linear relationship was assumed between the product's ASTM E1333 value and surface HCHO emission rate using two correlations on p. 100 of Battelle (1996):

- PB and MDF: E1333 = 0.30 ppm ≈ 440 µg HCHO/m^2-hr; and
- HWPW: E1333 = 0.20 ppm ≈ 290 µg HCHO/m^2-hr.

The resulting emission rates are consistent with measured or estimated values in Battelle (1996) and other reports. Using these relationships, the following average emission rates were calculated for 2002 production-weighted products reported in the CARB 2003 Survey:

- HWPW (2002 average E1333 = 0.09 ppm) = 131 µg HCHO/m^2-hr;
- PB (2002 average E1333 = 0.18 ppm) = 264 µg HCHO/m^2-hr; and
- MDF (2002 average E1333 = 0.25 ppm) = 367 µg/m^2-hr.

For HWPW, 131 µg/m^2-hr is about 75% of the maximum rate measured in Battelle (1996) (Table D-1). For PB, 264 µg/m^2-hr is about 52% of the Battelle maximum value, and slightly lower than the calculated mean value from the Battelle data. For MDF, 367 µg/m^2-hr is about 95% of the Battelle maximum value, and 68% of the Battelle maximum for MDF cabinet doors.

Table D-1. Reported Formaldehyde Emission Rates[1]

Emission Source	---------- Emission Rate (µg/m^2-hr) ----------			
	Max	Mean	Median	Min
Interior Door – PB Core	15	11	-----	7
MDF Cabinet Doors	535	450	-----	364
Uncoated HWPW	170	87	74	6.8
Uncoated MDF	385	293	288	210
Uncoated PB	508	189	161	104
Uncoated ¼" PB	1,580	1,375	-----	1,170

(1) Sources: Battelle (1996); CARB (2005).

For the proposed Phase 1 and Phase 2 standards, % reductions from the 2002 production-weighted average E1333 values were calculated and applied to the above emission factors as follows:

% reduction for Phase 1 HWPW = {[(0.08 ppm x 0.85) ÷ 0.09 ppm] – 1} x 100%
= {[(0.068) ÷ 0.09 ppm] – 1} x 100%
= {[(0.755) – 1] x 100%
= -24%

% reduction for Phase 1 PB = {[(0.18 ppm x 0.85) ÷ 0.18 ppm] – 1} x 100%
= {[(0.153) ÷ 0.18 ppm] – 1} x 100%
= {[(0.85) – 1] x 100%
= -15%

% reduction for Phase 1 MDF = {[(0.21 ppm x 0.85) ÷ 0.25 ppm] – 1} x 100%
= {[(0.178) ÷ 0.25 ppm] – 1} x 100%
= {[(0.71) – 1] x 100%
= -29%

% reduction for Phase 2 HWPW = {[(0.05 ppm x 0.85) ÷ 0.09 ppm] – 1} x 100%
= {[(0.042) ÷ 0.09 ppm] – 1} x 100%
= {[(0.47) – 1] x 100%
= -53%

% reduction for Phase 2 PB = {[(0.09 ppm x 0.85) ÷ 0.18 ppm] – 1} x 100%
= {[(0.076) ÷ 0.18 ppm] – 1} x 100%
= {[(0.42) – 1] x 100%
= -58%

% reduction for Phase 2 MDF = {[(0.11 ppm x 0.85) ÷ 0.25 ppm] – 1} x 100%
= {[(0.093) ÷ 0.25 ppm] – 1} x 100%
= {[(0.37) – 1] x 100%
= -63%

Values for the proposed Phase 1 or Phase 2 standards were multiplied by 0.85 to account for the establishment of a “cap” vs. an “average” standard. For a cap, it was assumed that a target E1333 level would be about 15% lower than the numerical value of the standard. The value of the “average” was not adjusted as the average was assumed to be the target E1333 level.

To calculate the HCHO emission rates, the percentage reductions were applied to the emission rates determined for 2002 production-weighted average products listed on page 1. Table D-2 contains the ASTM E1333 values, calculated % reductions, emission factors for 2002 production-weighted, Phase 1, and Phase 2 HWPW, PB, and MDF:

Table D-2. Comparison of ASTM E1333 Values, % Reduction in ASTM E1333 Value, and Resulting HCHO Emission Rates for the Proposed Phase 1 and Phase 2 Emission Standards

A. ASTM E1333 Values			
	ASTM E1333 Value (ppm)		
Standard or Mean	HWPW	PB	MDF
2002 Mean	0.09	0.18	0.25
Phase 1 Standard	0.08	0.18	0.21
Phase 2 Standard	0.05	0.09	0.11
B. % Reduction in ASTM E1333 Value			
% Reduction	HWPW	PB	MDF
Phase 1 vs. 2002 Mean	-24	-15	-29
Phase 2 vs. 2002 Mean	-53	-58	-63
C. Resulting HCHO Emission Rate			
Standard or Mean	Emission Rate (µg HCHO/m^2-hr)		
	HWPW	PB	MDF
2002 Mean	131	264	367
Phase 1 Standard	99	224	262
Phase 2 Standard	62	112	137

The Phase 1 and Phase 2 emission factors were used to estimate decreases in maximum potential HCHO emissions in site-built homes (Appendix E), which were used to calculate changes in indoor HCHO concentration resulting from the implementation of the ATCM.

Overview of the Emission Data in Battelle (1996) and CARB (2005)

General Information

- Typical and Elevated tests differed in terms of air temperature (70 vs. 80 F) and air change rate (1 vs. 0.3 hr^{-1}), while relative humidity was 50% for both test conditions.

Meters to Feet			Feet to Meters	
Metric	English		English	Metric
1 meter	3.28 feet		1 foot	0.304 meter
1 m^2	10.76 ft^2		1 ft^2	0.092 m^2
1 m^3	35.29 ft^3		1 ft^3	0.028 m^3
1 m^2/m^3	0.304 ft^2/ft^3		1 ft^2/ft^3	3.28 m^2/m^3

Hardwood Plywood (Battelle, 1996)

- Data from tests no. 9, 16, 17, 18, and 19 (n = 12)
- Data from typical (T) and elevated (E) test conditions were combined since there did not appear to be a substantive or consistent difference in emission rates under the two test conditions (19: T > E, 18(1): T > E, 18(2): E > T, 17: T > E, 16: E > T, and 9: T > E) – same for all other products
- Tests conducted on ¼”-¾” stock HWPW and ½” HWPW-VC
- Maximum emission rate (µg/m^2-hr) = 170 (#9-typical)
- Minimum emission rate (µg/m^2-hr) = 6.8 (#19-elevated)
- Median emission rate (µg/m^2-hr) = 74 ([#17-elevated + #18-typical] ÷ 2)
- Mean emission rate (µg/m^2-hr) = 87
- Mean of highest 33% (µg/m^2-hr) = 144 (n = 4); mean of middle 33% (µg/m^2-hr) = 80 (n = 4); mean of lowest (µg/m^2-hr) = 37 (n = 4)

Medium Density Fiberboard (Battelle, 1996)

- Data from tests 4, 6, and 7 (n = 6)
- Tests conducted on ⅝”-¾” MDF
- Maximum emission rate (µg/m^2-hr) = 385 (#7-elevated)
- Minimum emission rate (µg/m^2-hr) = 210 (#6-typical)
- Median emission rate (µg/m^2-hr) = 288 ([#4-typical + #6-elevated] ÷ 2)
- Mean emission rate (µg/m^2-hr) = 293 (for MDF)
- Mean of highest 33% (µg/m^2-hr) = 360 (n = 2); mean of middle 33% (µg/m^2-hr) = 288 (n = 2); mean of lowest (µg/m^2-hr) = 232 (n = 2)

MDF Cabinet Doors (Battelle, 1996)

- Data from test 3 (n = 2)
- Maximum emission rate (µg/m^2-hr) = 535 (#3-elevated)

- Minimum emission rate (µg/m^2-hr) = 364 (#3-typical)
- Mean emission rate (µg/m^2-hr) = 450 (for MDF cabinet door, n = 2)
- Mean emission rate for (MDF + MDF cabinet doors) = 314 (n = 8)

Particleboard (Battelle, 1996)
- Data from tests 2, 5, 8, 10, 11, 12, 13, 14, and 15 (n = 22)
- Tests conducted on ⅝'-¾" industrial PB, ⅝" PB underlayment, and ⅝" mobile home decking
- Maximum emission rate (µg/m^2-hr) = 508 (#2-typical)
- Minimum emission rate (µg/m^2-hr) = 104 (#15-typical)
- Median emission rate (µg/m^2-hr) = 161 ([#11-typical + #11-elevated] ÷ 2)
- Mean emission rate (µg/m^2-hr) = 189 (n = 22)
- Mean of highest 33% (µg/m^2-hr) = 119 (n = 7); mean of middle 33% (µg/m^2-hr) = 159 (n = 8); mean of lowest (µg/m^2-hr) = 293 (n = 7)

¼" Particleboard (Battelle, 1996)
- Data from test 1 (n = 2)
- Maximum emission rate (µg/m^2-hr) = 1,580 (#1-typical)
- Minimum emission rate (µg/m^2-hr) = 1,170 (#1-elevated)
- Mean emission rate (µg/m^2-hr) = 1,375 (n = 2)
- Mean emission rate (PB + ¼" PB) = 288 (n = 24)

Adhesives (CARB, 2005)
- Maximum emission rate (µg/m^2-hr) = 88
- Minimum emission rate (µg/m^2-hr) = 72
- Mean emission rate (µg/m^2-hr) = 80

Carpet Cushion (CARB, 2005)
- Reported emission rate (µg/m^2-hr) = 8

Paints (Battelle, 1996; CARB, 2005)
- Data from 6-tests by Battelle and 1 test reported in CARB
- Maximum emission rate (µg/m^2-hr) = 10
- Minimum emission rate (µg/m^2-hr) = 5.3
- Median emission rate (µg/m^2-hr) = 9.8
- Mean emission rate (µg/m^2-hr) = 8.7 (n = 7)

Seam Tape (CARB, 2005)
- Reported emission rate (µg/m^2-hr) = 5

Sheet Vinyl Flooring (CARB, 2005)
- Reported emission rate (µg/m^2-hr) = 4

Wallpaper (Battelle, 1996 – Table 2, p. 10)
- Reported emission rate (µg/m^2-hr) = 27

Coated MDF Cabinet Doors (Battelle, 1996)

- Data from test 20 (n = 2)
- Maximum Emission Rate (µg/m^2-hr) = 1,300 (#20-elevated)
- Minimum emission rate (µg/m^2-hr) = 460 (#20-typical)
- Mean emission rate (µg/m^2-hr) = 880 (n = 2)

Coated PB – Paper Laminated (Battelle, 1996)

- Data from tests 21, 22, and 25 (n = 6)
- Maximum emission rate (µg/m^2-hr) = 120 (#21-elevated)
- Minimum emission rate (µg/m^2-hr) = 26 (#25-typical)
- Median emission rate (µg/m^2-hr) = 52
- Mean emission rate (µg/m^2-hr) = 60 (n = 6)

Coated PB – Mobile Home Decking (Battelle, 1996)

- Data from test 23 (n = 2)
- Maximum Emission Rate (µg/m^2-hr) = 52 (#23-elevated)
- Minimum emission rate (µg/m^2-hr) = 35 (#23-typical)
- Mean emission rate (µg/m^2-hr) = 44 (n = 2)

Coated PB – Melamine Laminated (Battelle, 1996)

- Data from tests 24, 26, 31, and 33 (n = 12)
- Maximum emission rate (µg/m^2-hr) = 86 (#24-elevated)
- Minimum emission rate (µg/m^2-hr) = 2.2 (#31-elevated)
- Median emission rate (µg/m^2-hr) = 11
- Mean emission rate (µg/m^2-hr) = 20 (n = 12)

Coated PB – Rigid Vinyl (Battelle, 1996)

- Data from test 27 (n = 2)
- Maximum Emission Rate (µg/m^2-hr) = 31 (#27-elevated)
- Minimum emission rate (µg/m^2-hr) = 16 (#27-typical)
- Mean emission rate (µg/m^2-hr) = 24 (n = 2)

Coated PB – Vinyl or Acrylic (Battelle, 1996)

- Data from tests 28, 30, and 32 (n = 8)
- Maximum emission rate (µg/m^2-hr) = 8.6 (#28-typical)
- Minimum emission rate (µg/m^2-hr) = 1.3 (#30-elevated)
- Median emission rate (µg/m^2-hr) = 2.7
- Mean emission rate (µg/m^2-hr) = 4.0 (n = 8)

Interior Door – PB Core (Battelle, 1996)

- Data from test 29 (n = 2)
- Maximum Emission Rate (µg/m^2-hr) = 15 (#29-elevated)
- Minimum emission rate (µg/m^2-hr) = 7 (#29-typical)
- Mean emission rate (µg/m^2-hr) = 11 (n = 2)

Literature Cited

Battelle. 1996. Determination of Formaldehyde and Toluene Diisocyanate Emissions from Indoor Residential Sources. Final Report, CARB Contract No. 93-315, Research Division, Sacramento, CA.

CARB. 2005. Indoor Air Pollution in California. Report to the Legislature, Pursuant to Health & Safety Code §39930. Research Division, Sacramento, CA.