10.6.3 Medium Density Fiberboard Manufacturing

10.6.3.1 General[1-2,8]

The Composite Panel Association defines medium density fiberboard (MDF) as a dry-formed panel product manufactured from lignocellulosic fibers combined with a synthetic resin or other suitable binder. The panels are compressed to a density of from 496 to 801 kilograms per cubic meter (kg/m^3) (31 to 50 pounds per cubic foot [lb/ft^3]) in a hot press. The entire interfiber bond is formed by a synthetic resin or other suitable organic binder.

In contrast to particleboard, MDF has more uniform density throughout the board and has smooth, tight edges that can be machined. It can be finished to a smooth surface and grain printed, eliminating the need for veneers and laminates. Most of the thicker MDF panels (1.27 to 1.91 centimeters [cm]) (1/2 to 3/4 inch [in.]) are used as core material in furniture panels. Medium density fiberboard panels thinner than 1.27 cm (1/2 in.) typically are used for siding.

10.6.3.2 Process Description[2-8]

The general steps used to produce MDF include mechanical pulping of wood chips to fibers (refining), drying, blending fibers with resin and sometimes wax, forming the resinated material into a mat, and hot pressing. Figure 10.6.3-1 presents a process flow diagram for a typical MDF plant.

The furnish for MDF normally consists of wood chips. Wood chips typically are delivered by truck or rail from offsite locations such as sawmills, plywood plants, furniture manufacturing facilities, satellite chip mills, and whole tree chipping operations. If wood chips are prepared onsite, logs are debarked, cut to more manageable lengths, and then sent to chippers. If necessary, the chips are washed to remove dirt and other debris.

Clean chips are softened by steam and then sent to atmospheric or pressurized disk refiners, also known as attrition mills. The refiners use single or double revolving disks to mechanically pulp the chips to obtain fibers in a suitable form for making the board.

From the refiners, the fibers move to the drying and blending area. Tube dryers are typically used to reduce the moisture content of the fibers to desired levels. Heat is usually provided by the direct firing of propane, natural gas, or distillate oil. Two-stage dryers are used when the moisture content of the incoming furnish is highly variable. The first stage equalizes the moisture content in the furnish; the second stage is the main dryer.

The sequence of the drying and blending operations depends on the method by which resins and other additives are blended with the fibers. Some plants inject resins into a short-retention blender, while others inject resin formulations into a blowline system. If resin is added in a separate blender, the fibers are first dried and separated from the gas stream by a primary cyclone, then conveyed to the blender. The fibers then are blended with resin, wax, and any other additives and conveyed to a dry fiber storage bin. Urea-formaldehyde (UF) resins are the most common resins used in the manufacture of MDF. Phenolic resins and melamine resins are also used.

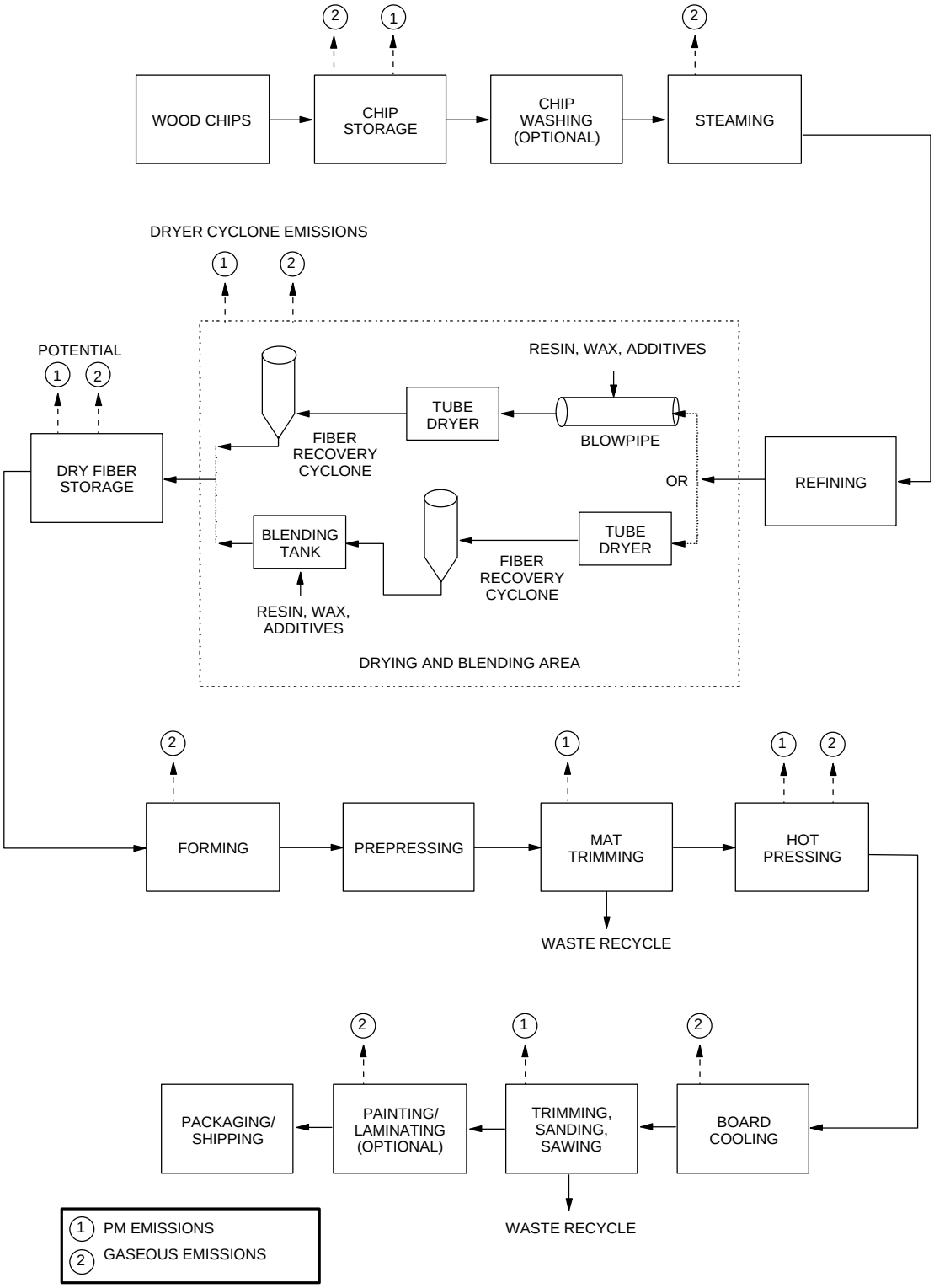

Figure 10.6.3-1. Typical process flow diagram for a medium density fiberboard (MDF) plant.

If a blowline system is used, the fibers are first blended with resin, wax, and other additives in a blowpipe that discharges the resinated fibers to the dryer. After drying, the fibers are separated from the gas stream by a primary cyclone and then conveyed to a dry fiber storage bin.

Air conveys the resinated fibers from the dry storage bin to the forming machine, where they are deposited on a continuously moving screen system. The continuously formed mat must be prepressed before being loaded into the hot press. After prepressing, some pretrimming is done. The trimmed material is collected and recycled to the forming machine.

The prepressed and trimmed mats then are transferred to the hot press. The press applies heat and pressure to activate the resin and bond the fibers into a solid panel. The mat may be pressed in a continuous hot press, or the precompressed mat may be cut by a flying cutoff saw into individual mats that are then loaded into a batch-type hot press. Radio-frequency (RF) heating and steam heating of the press platens are common in domestic MDF plants. After pressing, the boards are cooled, sanded, trimmed to final dimensions, any other finishing operations are done, and the finished product is packaged for shipment.

10.6.3.3 Emissions And Controls[2-8]

The primary emission sources at MDF mills are fiber dryers and press vents. Other emission sources may include boilers, chip production operations, and finishing operations such as sanding, trimming, edge painting, and laminate application.

Although most MDF mills have chips delivered from offsite locations, in mills where chips are generated onsite, operations such as log debarking, sawing, chipping, and grinding generate particulate matter (PM) and PM less than 10 micrometers (PM-10) emissions in the form of sawdust and wood particles.

Emissions from dryers that are exhausted from the primary recovery cyclone include wood dust and other solid PM, volatile organic compounds (VOCs), condensible PM, and products of combustion such as carbon monoxide (CO), carbon dioxide (CO_2), and nitrogen oxides (NO_x), if direct-fired units are used. The condensible PM and a portion of the VOCs leave the dryer stack as vapor but condense at normal atmospheric temperatures to form liquid particles or mist that creates a visible blue haze. Both the VOCs and condensible PM are primarily compounds evaporated from the wood, with a minor constituent being combustion products. Quantities emitted are dependent on wood species, dryer temperature, fuel used, and other factors including season of the year, time between logging and processing, and chip storage time.

Calculating PM-10 emissions from the wood products industries is problematic due to the relationship between PM-10 (or PM) emissions and VOC emissions from these processes. Because the Method 201A train (PM-10) operates with an in-stack cyclone and filter, organic materials that are volatile at stack gas temperatures but that are condensed at back half impinger temperatures (~20°C [~68°F]) are collected as condensible PM-10. However, these materials will also be measured as VOCs via Methods 25 and 25A, which operate with a heated or an in-stack filter. Hence, if PM-10 is calculated as the sum of filterable and condensible material, some pollutants will be measured as both PM-10 and VOC emissions. However, if only filterable material is considered to be PM-10, the PM-10 emission factors will be highly dependent on stack gas temperature. In this AP-42 section, PM-10 is reported as front half catch only (Method 201A results only; condensible PM, based on Method 202 results are not included). However, separate emission factors for condensible PM are presented, and those emission factors can be combined with the PM-10 emission factors as appropriate for a specific application. Measured VOC emissions may be affected by the sampling method and by the quantity of formaldehyde and other aldehydes and ketones in the exhaust; formaldehyde is not quantified using Method 25A, and other low molecular weight oxygenated compounds have reduced responses to Method 25A. Therefore, when VOC emissions are measured using

Method 25A, the emission rates will be biased low if low molecular weight oxygenated compounds are present in significant concentrations in the exhaust stream. A more extensive discussion of these sampling and analysis issues is provided in the background report for this section (Reference 8).

Emissions from board hot presses are dependent on the type and amount of resin used to bind the wood fibers together, as well as wood species, wood moisture content, wax and catalyst application rates, and press conditions. When the press opens, vapors that may include resin ingredients such as formaldehyde, phenol, and other VOCs are released. The rate at which formaldehyde is emitted during pressing and board cooling operations is a function of the amount of excess formaldehyde in the resin, board thickness, press temperature, press cycle time, and catalyst application rates.

Only limited data are available on emissions of the organic constituents included in the exhaust streams from MDF dryers and presses. However, speciated organic emission data for waferboard/oriented strandboard (WB/OSB) and particleboard may provide an indication of the types of organic compounds emitted from MDF dryers and presses. Emission factors for speciated organic emissions from WB/OSB and particleboard dryers and presses are included in AP-42 Sections 10.6.1 and 10.6.2, respectively.

Emissions from finishing operations for MDF are dependent on the type of products being finished. For most MDF products, finishing involves trimming to size and, in some cases, painting or coating the edges. Other products may require sanding or the application of laminate surfaces with spray adhesives. Trimming and sanding operations are sources of PM and PM-10 emissions. No data specific to MDF trimming or sawing are available. However, emission factors for general sawing operations may provide an order of magnitude estimate for similar MDF sawing and trimming operations, bearing in mind that the sawing of dry MDF panels may result in greater PM and PM-10 emissions than the sawing of green lumber. No data specific to MDF panel sanding are available. It is expected that water-based coatings are used to paint MDF edges, and the resultant VOC emissions are relatively small. Emissions from adhesives used in the application of laminate surfaces are likely to include VOCs.

In MDF mills where wood chips are generated onsite, PM and PM-10 emissions from log debarking, sawing, and grinding operations can be controlled through capture in an exhaust system connected to a sized cyclone and/or fabric filter collection system. These wood dust capture and collection systems are used not only to control atmospheric emissions, but also to collect the dust as a by-product fuel for a boiler or dryer.

A VOC control technology gaining popularity in the wood products industry for controlling both dryer and press exhaust gases is regenerative thermal oxidation. Thermal oxidizers destroy VOCs, CO, and condensible organics by burning them at high temperatures. Regenerative thermal oxidizers (RTOs) are designed to preheat the inlet emission stream with heat recovered from the incineration exhaust gases. Up to 98 percent heat recovery is possible, although 95 percent is typically specified. Gases entering an RTO are heated by passing through pre-heated beds packed with a ceramic media. A gas burner brings the preheated emissions up to an incineration temperature between 788° and 871°C (1450° and 1600°F) in a combustion chamber with sufficient gas residence time to complete the combustion. Combustion gases then pass through a cooled ceramic bed where heat is extracted. By reversing the flow through the beds, the heat transferred from the combustion exhaust air preheats the gases to be treated, thereby reducing auxiliary fuel requirements.

Biofiltration systems can be used effectively for control of a variety of pollutants including organic compounds (including formaldehyde and benzene), NO_x, CO, and PM from both dryer and press exhaust streams. Data from pilot plant studies in U.S. OSB mills indicate that biofilters can achieve VOC control efficiencies of 70 to 90 percent, formaldehyde control efficiencies of 85 to 98 percent, CO control efficiencies

of 30 to 50 percent, NO_x control efficiencies of 80 to 95 percent, and resin/fatty acid control efficiencies of 83 to 99 percent.

Other potential control technologies for MDF dryers and presses include regenerative catalytic oxidation (RCO), absorption systems (scrubbers), and adsorption systems.

Fugitive emissions from road dust and uncovered bark and dust storage piles may be controlled in a number of different ways. These methods include enclosure, wet suppression systems, and chemical stabilization. Control techniques for these sources are discussed more fully in AP-42 Chapter 13, Miscellaneous Sources.

Table 10.6.3-1 presents emission factors for dryer emissions of PM, including filterable PM, filterable PM-10, and condensible PM. Table 10.6.3-2 presents emission factors for dryer emissions of SO_2, NO_x, CO, and CO_2. Table 10.6.3-3 presents emission factors for dryer emissions of organic pollutants. Table 10.6.3-4 presents emission factors for press and board cooler emissions of PM, including filterable PM, filterable PM-10, and condensible PM. Table 10.6.3-5 presents emission factors for press emissions of NO_x and CO. Table 10.6.3-6 presents emission factors for press and board cooler emissions of organic pollutants.

Emission factors for specific mixes of wood species may be calculated by combining emission factors for individual wood species in the ratio specific to a given application, as emission data for those species become available. For example, a VOC emission factor for a direct wood-fired tube dryer processing 60 percent pine and 40 percent hardwood may be calculated using the VOC emission factors for unspecified pines (6.6 lb/ODT) and hardwood (6.5 lb/ODT). In this specific example, the pine emission factor is based on only Method 25A data. The hardwood factor is based on Method 25A plus formaldehyde. In order to compare like values, formaldehyde should be subtracted out of the hardwood factor to yield the emission factor for hardwood based on Method 25A only (5.6 lb/ODT). Using the two factors based on Method 25A (6.6 lb/ODT and 5.6 lb/ODT) and the ratio of 60 percent to 40 percent, the resultant emission factor, rounded to two significant figures, would be 6.2 lb/ODT. Corrections for formaldehyde and for non-VOC compounds can be made as emission data for these compounds become available.

Table 10.6.3-1. EMISSION FACTORS FOR MDF DRYERS--PARTICULATE MATTER[a]

Source	Emission Control[b]	Filterable[c]				Condensible[d]	EMISSION FACTOR RATING
		PM	EMISSION FACTOR RATING	PM-10	EMISSION FACTOR RATING		
Tube dryer, direct wood-fired							
Unspecified pines[e] (SCC 3-07-009-21)	None	10	D	1.6	D	0.59	D
Tube dryer, indirect heat							
Unspecified pines[e] (SCC 3-07-009-31)	None	1.4	E	ND		ND	
Mixed species[f] (SCC 3-07-009-39)	None	1.5	E	0.28	E	0.73	E

[a] Emission factor units are pounds per oven-dried ton (lb/ODT) of wood material out of dryer. One lb/ODT = 0.5 kg/Mg (oven-dried). SCC = Source Classification Code. Reference 5. ND = no data available.

[b] Cyclones are used as product recovery devices and are not considered to be emission control equipment.

[c] Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train.

[d] Condensible PM is that PM collected in the impinger portion of a PM sampling train.

[e] Unspecified pines = mixed pine species or the specific pine species processed were not reported.

[f] Mixed species = 50 percent hardwood and 50 percent softwood.

Table 10.6.3-2. EMISSION FACTORS FOR MDF DRYERS--SO_2, NO_x, CO, AND CO_2[a]

Source	SO_2	EMISSION FACTOR RATING	NO_x	EMISSION FACTOR RATING	CO	EMISSION FACTOR RATING	CO_2	EMISSION FACTOR RATING
Tube dryer, direct wood-fired (SCC 3-07-009-21, 3-07-009-25)	ND		ND		4.0	D	ND	

[a] Factors represent uncontrolled emissions. SCC = Source Classification Code. ND = no data available. NR = not reported. All emission factors in units of pounds per oven-dried ton (lb/ODT) of wood material out of dryer. One lb/ODT = 0.5 kg/Mg (oven-dried). Reference 5.

Table 10.6.3-3. EMISSION FACTORS FOR MDF DRYERS--ORGANICS[a]

Source	CASRN[h]	Pollutant	Emission Factor	EMISSION FACTOR RATING
Tube dryer, direct wood-fired				
Unspecified pines[b] (SCC 3-07-009-21)		VOC[c]	6.6[d]	E
Hardwoods (SCC 3-07-009-25)		VOC[c]	6.5[e]	D
	50-00-0	Formaldehyde*	0.86	E
Tube dryer, indirect heat				
Hardwoods (SCC 3-07-009-35)		VOC[c]	4.7[e]	D
	50-00-0	Formaldehyde*	0.20	E
	75-07-0	Acetaldehyde*	0.013	E
Mixed species[f] (SCC 3-07-009-39)		VOC[c]	2.2[g]	E
	50-00-0	Formaldehyde*	1.4	E
	5779-94-2	2,5-Dimethyl benzaldehyde	3.8×10^{-4}	E
	75-07-0	Acetaldehyde*	0.013	E
	67-64-1	Acetone	0.0025	E
	98-86-2	Acetophenone*	2.4×10^{-4}	E
	107-02-8	Acrolein*	0.0022	E
	80-56-8	Alpha pinene	0.0062	E
	10482-56-1	Alpha terpeneol	0.0022	E
	100-52-7	Benzaldehyde	0.0026	E
	117-81-7	Bis-(2-ethylhexyl phthalate)*	2.7×10^{-4}	E
		Butylbenzyl phthalate	2.4×10^{-4}	E
		Butylaldehyde	0.0028	E
	127-91-3	Beta pinene	0.0064	E
	74-87-3	Chloromethane*	0.0015	E
	123-73-9	Crotonaldehyde	0.0019	E
	84-74-2	Di-n-butyl phthalate*	1.8×10^{-4}	E
	66-25-1	Hexaldehyde	0.0026	E
	540-84-1	Isooctane*	6.2×10^{-4}	E
	590-86-3	Isovaleraldehyde	0.0019	E
	78-93-3	Methyl ethyl ketone*	0.0063	E
	75-09-2	Methylene chloride*	0.0029	E
	91-20-3	Naphthalene*	6.6×10^{-4}	E

Table 10.6.3-3. (cont.).

Source	CASRN[h]	Pollutant	Emission Factor	EMISSION FACTOR RATING
Mixed species[f] (cont.)	110-54-3	n-Hexane*	0.0014	E
	529-20-4	o-Tolualdehyde	7.4×10^{-4}	E
	108-95-2	Phenol*	2.0×10^{-4}	E
	123-38-6	Propionaldehyde*	0.0011	E
	99-87-6	p-Cymene	1.9×10^{-4}	E
	104-87-0	p-Tolualdehyde	0.0036	E
	75-69-4	Trichlorofluoromethane	0.0014	E
	110-62-3	Valeraldehyde	0.0021	E

[a] Factors represent uncontrolled emissions. SCC = Source Classification Code. All emission factors in units of pounds per oven-dried ton of wood material out of dryer (lb/ODT). One lb/ODT = 0.5 kg/Mg (oven-dried). Reference 5. * = hazardous air pollutant.

[b] Unspecified pines = mixed pine species or the specific pine species processed were not reported.

[c] Volatile organic compounds as propane. Based on results of EPA Method 25A.

[d] Formaldehyde has not been added, but is suspected to be present, which would increase the VOC value given.

[e] Formaldehyde has been added.

[f] Mixed species = 50 percent hardwood and 50 percent softwood.

[g] Formaldehyde has been added; acetone and methylene chloride have been subtracted.

[h] CASRN = Chemistry Abstracts Service Registry Number.

Table 10.6.3-4. EMISSION FACTORS FOR MDF PRESSES AND BOARD COOLERS--PARTICULATE MATTER[a]

Source	Filterable[b]				Condensible[d]	EMISSION FACTOR RATING
	PM[c]	EMISSION FACTOR RATING	PM-10	EMISSION FACTOR RATING		
Batch hot press , UF resin (SCC 3-07-009-60)	0.18	D	0.075	E	0.26	E
Continuous hot press, UF resin (SCC 3-07-009-50)						
Uncontrolled[e]	0.17	E	ND		0.14	E
RTO-controlled[e]	0.040	E	ND		0.016	E
MDF board cooler, UF resin (SCC 3-07-009-71)	0.054	E	0.0038	E	ND	

[a] Reference 5 unless otherwise noted. Emission factor units are lb/thousand square feet of 3/4-inch thick panel (lb/MSF-3/4). One lb/MSF-3/4 = 0.26 kg/m^3. SCC = Source Classification Code. ND = no data available. Factors represent uncontrolled emissions unless otherwise noted.

[b] Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train.

[c] Filterable PM emissions from process consist primarily of filterable PM-10.

[d] Condensible PM is that PM collected in the impinger portion of a PM sampling train.

[e] Reference 9.

Table 10.6.3-5. EMISSION FACTORS FOR MDF PRESSES--NO_x AND CO[a]

Source	NO_x	EMISSION FACTOR RATING	CO	EMISSION FACTOR RATING
Batch hot press, UF resin (SCC 3-07-009-60)	0.030	E	0.034	E
Continuous hot press, UF resin (SCC 3-07-009-50)				
Uncontrolled[b]	ND		ND	
RTO-controlled[b]	0.51	E	0.085	E

[a] Factors represent uncontrolled emissions unless otherwise noted. SCC = Source Classification Code. Reference 5 unless otherwise noted. ND = no data available. Emission factor units are pounds per thousand square feet of 3/4-inch thick panel (lb/MSF-3/4). One lb/MSF-3/4 = 0.26 kg/m^3. All data for mills using urea-formaldehyde resins.

[b] Reference 9.

Table 10.6.3-6. EMISSION FACTORS FOR MDF PRESSES AND BOARD COOLERS--ORGANICS[a]

Source	CASRN[e]	Pollutant	Emission Factor	EMISSION FACTOR RATING
Batch hot press, UF resin (SCC 3-07-009-60)		VOC[b]	0.69[c]	D
	5779-94-2	2,5-Dimethyl benzaldehyde	0.0025	E
	75-07-0	Acetaldehyde*	0.0051	E
	67-64-1	Acetone	0.0031	E
	107-02-8	Acrolein*	0.0012	E
	100-52-7	Benzaldehyde	0.00055	E
		Butylaldehyde	0.0024	E
	123-73-9	Crotonaldehyde	0.0011	E
	50-00-0	Formaldehyde*	0.30	D
	66-25-1	Hexaldehyde	0.0029	E
	590-86-3	Isovaleraldehyde	0.0014	E
	78-93-3	Methyl ethyl ketone*	0.00059	E
	529-20-4	o-Tolualdehyde	0.00070	E
	123-38-6	Propionaldehyde*	0.00054	E
	104-87-0	p-Tolualdehyde	0.0010	E
	110-62-3	Valeraldehyde	0.0024	E
Continuous hot press, UF resin (SCC 3-07-009-50)				
Uncontrolled[d]		VOC[b]	1.4[c]	E
	50-00-0	Formaldehyde*	1.1	E
RTO-controlled[d]		VOC[b]	0.032[c]	E
	50-00-0	Formaldehyde*	0.0091	E
MDF board cooler, UF resin (SCC 3-07-009-71)		VOC[b]	0.20[c]	E
	5779-94-2	2,5-Dimethyl benzaldehyde	0.00019	E
	75-07-0	Acetaldehyde*	0.0010	E
	67-64-1	Acetone	0.0021	E
	107-02-8	Acrolein*	0.00022	E
	100-52-7	Benzaldehyde	9.9×10^{-5}	E
		Butylaldehyde	0.0014	E
	123-73-9	Crotonaldehyde	0.00026	E
	50-00-0	Formaldehyde*	0.11	E
	66-25-1	Hexaldehyde	0.00065	E
	590-86-3	Isovaleraldehyde	0.00025	E
	78-93-3	Methyl ethyl ketone*	0.00011	E

Table 10.6.3-6. (cont.).

Source	CASRN[e]	Pollutant	Emission Factor	EMISSION FACTOR RATING
Board cooler, UF resin (cont.).	529-20-4	o-Tolualdehyde	6.5×10^{-5}	E
	104-87-0	p-Tolualdehyde	0.00017	E
	110-62-3	Valeraldehyde	0.00048	E

[a] Emission factor units are pounds per thousand square feet of 3/4-inch thick panel (lb/MSF-3/4). One lb/MSF-3/4 = 0.26 kg/m^3. Factors represent uncontrolled emissions unless otherwise noted. Reference 5 unless otherwise noted. SCC = Source Classification Code. All data for mills using urea-formaldehyde resins. * = hazardous air pollutant.

[b] Volatile organic compounds on a propane basis. Factors are based on Method 25A results. For total VOC, add the appropriate formaldehyde emission factors (where available).

[c] Formaldehyde has been added.

[d] Reference 9.

[e] CASRN = Chemistry Abstracts Service Registry Number.

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