9.5.2 Meat Smokehouses

9.5.2.1 General[1-3,7-9]

Meat smokehouses are used to add flavor, color, and aroma to various meats, including pork, beef, poultry, and fish. Smokehouses were at one time used to smoke food for preservation, but refrigeration systems have effectively eliminated this use.

Four operations are typically involved in the production of smoked meat: (1) tempering or drying, (2) smoking, (3) cooking, and (4) chilling. However, not all smoked foods are cooked, thus eliminating the cooking and chilling processes from some operations. Important process parameters include cooking/smoking time, smoke generation temperature, humidity, smoke density, type of wood or liquid smoke, and product type.

The two types of smokehouses that are almost exclusively used are batch and continuous smokehouses. Figures 9.5.2-1 and 9.5.2-2 show typical batch and continuous smokehouses, respectively. Both types of systems circulate air at the desired process conditions (temperature, humidity, and smoke density) over the surface of the meat. In batch smokehouses, the meat is placed on stationary racks for the entire smoking process. In continuous smokehouses, the meat is hung on sticks or hangers and then conveyed through the various zones (smoking, heating, and chilling) within the smokehouse. Following processing in the smokehouse, the product is packaged and stored for shipment.

Several methods are used to produce the smoke used in smokehouses. The most common method is to pyrolyze hardwood chips or sawdust using smoke generators. In a typical smoke generator, hardwood chips or sawdust are fed onto a gas- or electrically-heated metal surface at 350° to 400°C (662° to 752°F). Smoke is then ducted by a smoke tube into the air recirculation system in the smokehouse. Smoke produced by this process is called natural smoke.

Liquid smoke (or artificial smoke), which is a washed and concentrated natural smoke, is also used in smokehouses. This type of smoke (as a fine aerosol) can be introduced into a smokehouse through the air recirculation system, can be mixed or injected into the meat, or can be applied by drenching, spraying, or dipping.

9.5.2.2 Emissions And Controls[1-2,4]

Particulate matter (PM), carbon monoxide (CO), volatile organic compounds (VOC), polycyclic aromatic hydrocarbons (PAH), organic acids, acrolein, acetaldehyde, formaldehyde, and nitrogen oxides have been identified as pollutants associated with meat smokehouses. The primary source of these pollutants is the smoke used in the smokehouses. Studies cited in Reference 1 show that almost all PM from smoke has an aerodynamic diameter of less than 2.0 micrometers (µm). Acetic acid has been identified as the most prevalent organic acid present in smoke, followed by formic, propionic, butyric, and other acids. Also, acetaldehyde concentrations have been shown to be about five times greater than formaldehyde concentrations in smoke. Heating zones in continuous smokehouses (and the cooking cycle in batch smokehouses) are a source of odor that includes small amounts of VOC. The VOC are a result of the volatilization of organic compounds contained in the meat or the smoke previously applied to the meat. Heating zones are typically heated with ambient air that is passed over electrically-heated or steam-heated coils (steam from boilers used elsewhere at the facility). Therefore, heating zones are not a source of combustion products. Factors that may effect

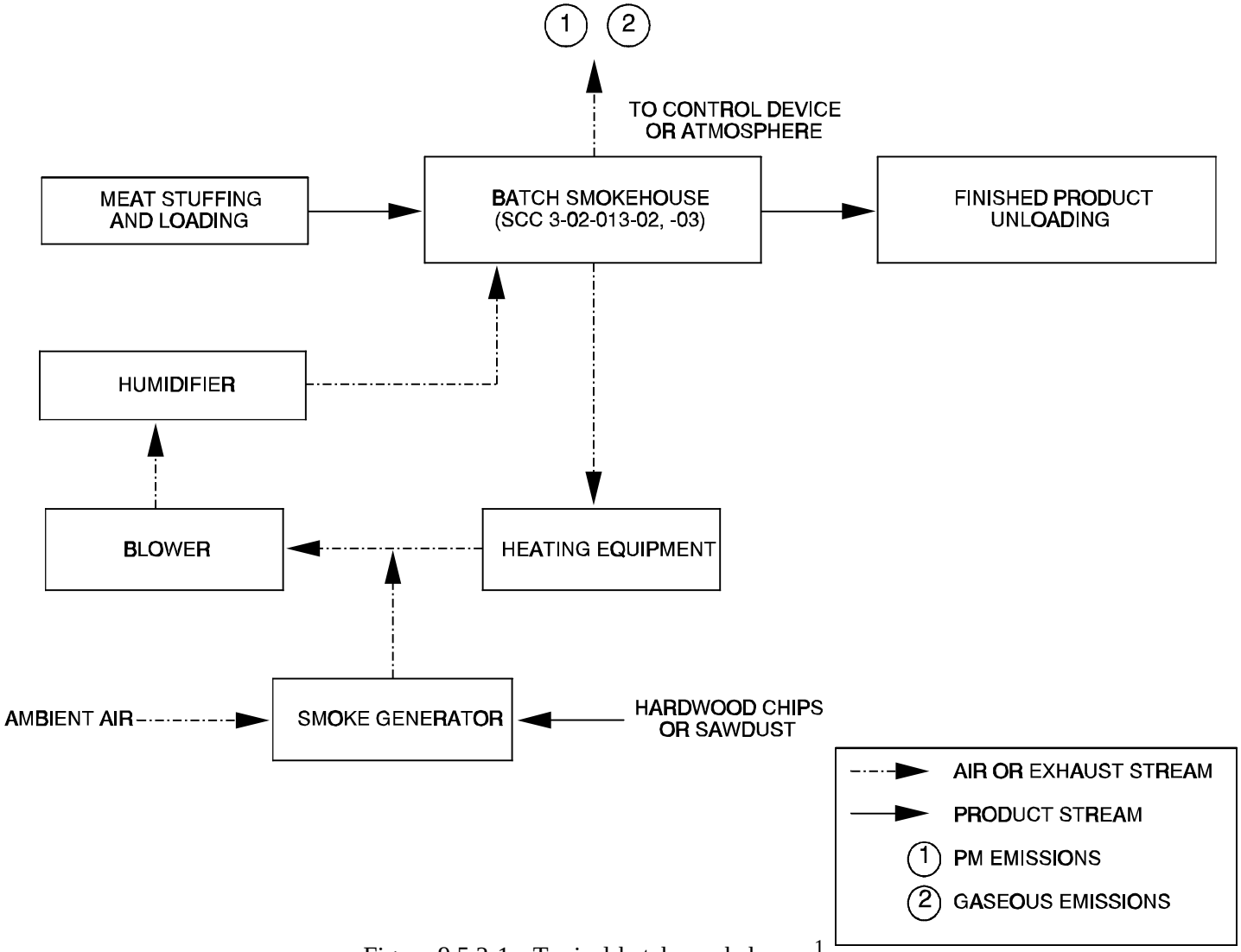

Figure 9.5.2-1. Typical batch smokehouse.[1]
(Source Classification Code in parentheses.)

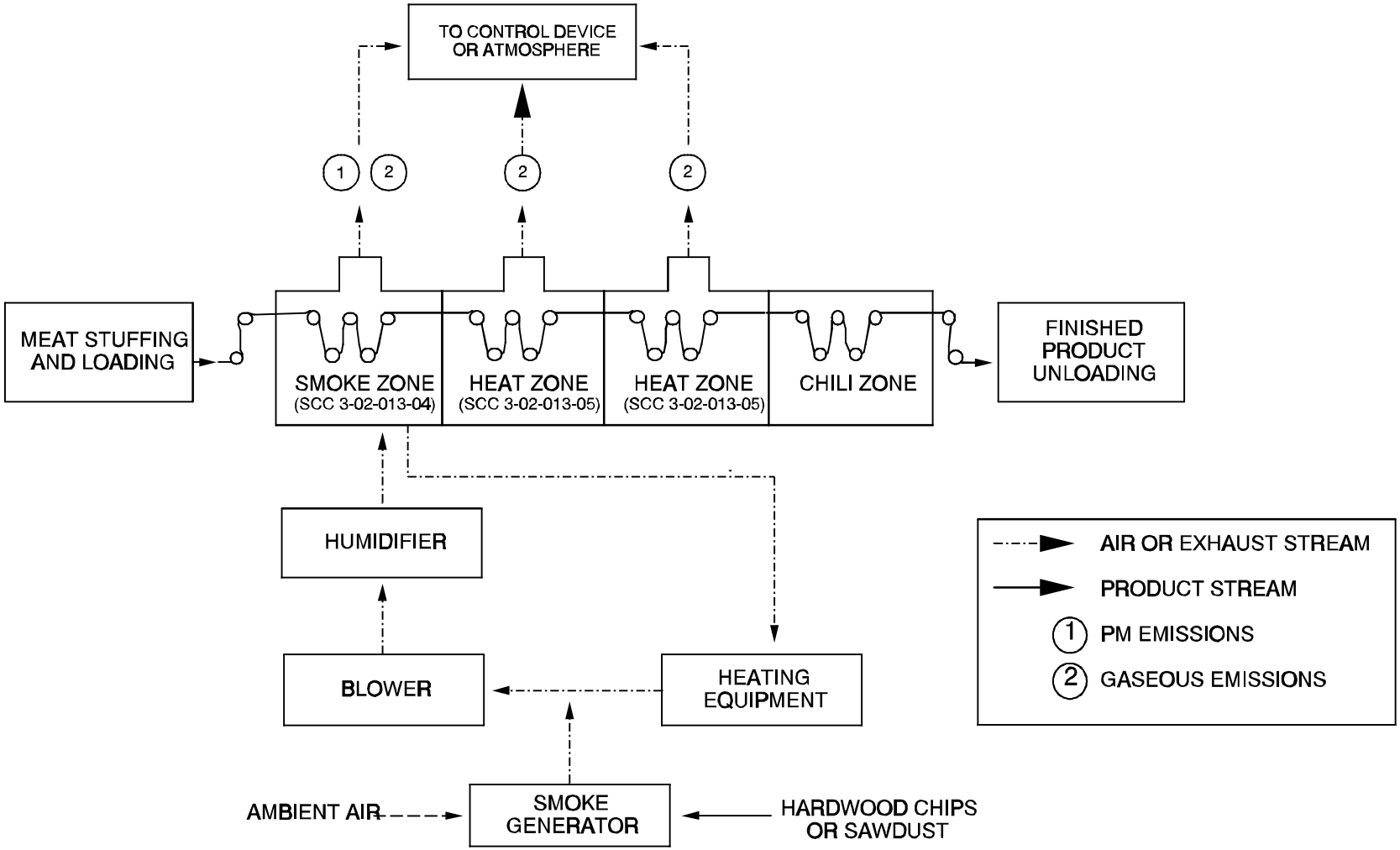

Figure 9.5.2-2. Typical continuous smokehouse.[1]
(Source Classification Code in parentheses.)

smokehouse emissions include the amount and type of wood or liquid smoke used, the type of meat processed, the processing time, humidity, and the temperature maintained in the smoke generators.

Control technologies used at meat smokehouses include afterburners, wet scrubbers, and modular electrostatic precipitators (ESP). Emissions can also be reduced by controlling important process parameters. An example of this type of process control is maintaining a temperature not higher than about 400°C (752°F) in the smoke generator, to minimize the formation of PAH.

Afterburners are an effective control technology for PM, organic gases, and CO from smokehouses, but energy requirements may be costly for continuous smokehouse operations. Also, the additional air pollution resulting from afterburner fuel combustion makes afterburners a less desirable option for controlling smokehouse emissions.

Wet scrubbers are another effective control technology for both PM and gaseous emissions. Different types of scrubbers used include mist scrubbers, packed bed scrubbers, and vortex scrubbers. Mist scrubbers introduce a water fog into a chamber, and exhaust gases are then fed into the chamber and are absorbed. Packed bed scrubbers introduce the exhaust gases into a wetted column containing an inert packing material in which liquid/gas contact occurs. Vortex scrubbers use a whirling flow pattern to shear water into droplets, which then contact the exhaust gases. Limited test data (from Reference 4) show a vortex scrubber (followed by a demister) achieving about 51 percent formaldehyde removal, 85 percent total organic compound removal, 39 percent acetic acid removal, and 69 percent PM removal. Particulate matter removal efficiencies for scrubbers can be increased through the use of surfactants, which may enhance the capture of smoke particles that do not combine with the scrubber water.

Elecrostatic precipitators are effective for controlling PM emissions. Combined control technologies, such as a wet scrubber for gaseous emission control followed by an ESP for PM removal, may also be used to control emissions from smokehouses.

Smokehouse control devices are operated during the smoking cycle and are sometimes bypassed during the cooking and cooling cycles. Continuous smokehouses may include separate vents for exhaust streams from the different zones, thus minimizing the air flow through the control device.

The average emission factors for meat smokehouses are shown in Tables 9.5.2-1 and 9.5.2-2. These emission factors are presented in units of mass of pollutant emitted per mass of wood used to generate smoke. Normally, emission factors are based on either units of raw material or units of product. In this industry, the amount of smoke flavor applied to the meats varies; consequently the emissions are dependent on the quantity of wood (or liquid smoke) used, rather than the quantity of meat processed. The emission factors presented in Tables 9.5.2-1 and 9.5.2-2 were developed using data from only two facilities and, consequently, may not be representative of the entire industry.

Table 9.5.2-1. EMISSION FACTORS FOR BATCH AND CONTINUOUS MEAT SMOKEHOUSES[a]

EMISSION FACTOR RATING: D

Process	Filterable PM		Condensible PM			Total PM	
	PM	PM-10	Inorganic	Organic	Total	PM	PM-10
Batch smokehouse, smoking cycle[b] (SCC 3-02-013-02)	23	ND[c]	11	19	30	53	ND[c]
Continuous smokehouse, smoke zone[d] (SCC 3-02-013-04)	66	ND[c]	36	39	75	140	ND[c]
Continuous smokehouse, smoke zone, with vortex wet scrubber and demister[d] (SCC 3-02-013-04)	13	ND[c]	9.8	6.0	16	29	ND[c]

[a] Emission factor units are lb/ton of wood or sawdust used. ND = no data available. SCC = Source Classification Code.
[b] Reference 5.
[c] Although data are not directly available, Reference 1 states that all PM from smoke is less than 2 micrometers in aerodynamic diameter.
[d] References 4-6.

Table 9.5.2-2. EMISSION FACTORS FOR BATCH AND CONTINUOUS MEAT SMOKEHOUSES[a]

Process	VOC	EMISSION FACTOR RATING	Formaldehyde	EMISSION FACTOR RATING	Acetic Acid	EMISSION FACTOR RATING
Batch smokehouse, smoking cycle[b] (SCC 3-02-013-02)	44	D	ND	NA	ND	NA
Batch smokehouse, cooking cycle (SCC 3-02-013-03)	ND	NA	ND	NA	ND	NA
Continuous smokehouse, smoke zone[c] (SCC 3-02-013-04)	17	D	1.3	E	4.5	E
Continuous smokehouse, smoke zone, with vortex wet scrubber and demister[d] (SCC 3-02-013-04)	4.4	E	0.62	E	2.8	E
Continuous smokehouse, heat zone (SCC 3-02-013-05)	ND	NA	ND	NA	ND	NA

[a] Emission factor units are lb/ton of wood or sawdust used, unless noted. ND = no data available. NA = not applicable. SCC = Source Classification Code.
[b] Reference 5. VOC, measured as methane.
[c] References 5-6. VOC, measured as methane.
[d] Reference 4. VOC, measured as methane. VOCs were measured on a gas chromatograph calibrated against acetaldehyde, and the results were converted to a methane basis.

References For Section 9.5.2

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5. *Report On Diagnostic Testing*, Oscar Mayer Foods Corporation, Madison, WI, January 13, 1994.

6. Written correspondence from D. Sellers, Wisconsin Department of Natural Resources, Madison, WI, to Wisconsin Department of Natural Resources Files, Madison, WI, June 17, 1994.

7. Written communication from J. M. Jaeckels, BT^2, Inc., Madison, WI, to D. Safriet, U. S. Environmental Protection Agency, Research Triangle Park, NC, December 15, 1994.

8. Telephone communication between B. L. Shrager, Midwest Research Institute, Cary, NC, and J.M. Jaeckels, BT^2, Inc., Madison, WI, March 16 and 17, 1995.

9. Emission Factor Documentation, AP-42 Section 9.5.2, Meat Smokehouses, EPA Contract No. 68-D2-0159, Midwest Research Institute, Cary, NC, September 1995.