Emission Factor Documentation for AP-42
Section 9.5.1

Meat Packing Plants

Final Report

For U. S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Emission Factor and Inventory Group

EPA Contract 68-D2-0159
Work Assignment No. 4-04

MRI Project No. 4604-04

June 1997

MRI

MIDWEST RESEARCH INSTITUTE
Suite 350
401 Harrison Oaks Boulevard
Cary, North Carolina 27513-2412
Telephone (919) 677-0249
FAX (919) 677-0065

June 24, 1997

Mr. Dallas Safriet
Emission Factor and Inventory Group (MD-14)
U. S. Environmental Protection Agency
Research Triangle Park, NC 27711

Re: Review and Update of Food and Agricultural Sections,
Chapter 9, AP-42
EPA Contract No. 68-D2-0159; Work Assignment No. 4-04
MRI Project No. 4604-04

Dear Mr. Safriet:

This letter confirms transmittal of three bound copies and one unbound reproducible master of the Final Report on AP-42 Section 9.5.1 -- Meat Packing Plants. One copy of the Final Report on a 3.5-inch disk is also enclosed.

If you have any questions, please contact me at 677-0249, ext. 5258.

Sincerely,

Tom Lapp
Principal Environmental Scientist

5 Enclosures

cc: E. King, EPA (MD-33)
K. Koeller-Anna, MRI/NC (w/o Enclosures)
Project File

Emission Factor Documentation for AP-42 Section 9.5.1

Meat Packing Plants

Final Report

For U. S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Emission Factor and Inventory Group
Research Triangle Park, NC 27711

Attn: Mr. Dallas Safriet (MD-14)

EPA Contract 68-D2-0159
Work Assignment No. 4-04

MRI Project No. 4604-04

June 1997

NOTICE

The information in this document has been funded wholly or in part by the United States Environmental Protection Agency under Contract No. 68-D2-0159 to Midwest Research Institute. It has been reviewed by the Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency, and has been approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

PREFACE

This report was prepared by Midwest Research Institute (MRI) for the Office of Air Quality Planning and Standards (OAQPS), U. S. Environmental Protection Agency (EPA), under Contract No. 68-D2-0159, Work Assignment No. 4-04. Mr. Dallas Safriet was the requester of the work.

Approved for:

MIDWEST RESEARCH INSTITUTE

Roy Neulicht

Roy Neulicht
Program Manager
Environmental Engineering Department

Rebecca L. Nicholson

for Jeff Shular
Director, Environmental Engineering Department

June 1997

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EMISSION FACTOR DOCUMENTATION FOR AP-42 SECTION 9.5.1
Meat Packing Plants

1. INTRODUCTION

The document *Compilation of Air Pollutant Emission Factors* (AP-42) has been published by the U. S. Environmental Protection Agency (EPA) since 1972. Supplements to AP-42 have been routinely published to add new emission source categories and to update existing emission factors. AP-42 is routinely updated by EPA to respond to new emission factor needs of EPA, State and local air pollution control programs, and industry.

An emission factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. Emission factors usually are expressed as the weight of pollutant divided by the unit weight, volume, distance, or duration of the activity that emits the pollutant. The emission factors presented in AP-42 may be appropriate to use in a number of situations, such as making source-specific emission estimates for area wide inventories for dispersion modeling, developing control strategies, screening sources for compliance purposes, establishing operating permit fees, and making permit applicability determinations. The purpose of this report is to provide background information from test reports and other information to support preparation of AP-42 Section 9.5.1, Meat Packing Plants.

This background report consists of five sections. Section 1 includes the introduction to the report. Section 2 gives a description of the meat packing industry. It includes a characterization of the industry, a description of the different process operations, a characterization of emission sources and pollutants emitted, and a description of the technology used to control emissions resulting from these sources. Section 3 is a review of emission data collection (and emission measurement) procedures. It describes the literature search, the screening of emission data reports, and the quality rating system for both emission data and emission factors. Section 4 describes the results of the literature search. Section 5 presents the AP-42 Section 9.5.1, Meat Packing Plants.

2. INDUSTRY DESCRIPTION

2.1 INDUSTRY CHARACTERIZATION[1,2]

The meat packing industry is made up of establishments primarily engaged in the slaughtering, for their own account or on a contract basis for the trade, of cattle, hogs, sheep, lambs, calves, and vealers for meat to be sold or to be used on the same premises in canning, cooking, curing, and freezing, and in making sausage, lard, and other products. Also included in this industry are establishments primarily engaged in slaughtering horses for human consumption.

The 1992 Census of Manufactures indicated that 122.4 thousand people were employed in the industry, an increase of 7 percent from the 1987 census. The leading States in employment in 1992 were Iowa, Nebraska, Kansas, and Texas, accounting for approximately 45 percent of the industry's employment.

Red meat, which includes beef, pork, veal, and lamb and mutton, production in commercial plants and on farms for the United States during 1995 totaled 19.8 billion kilograms (kg) (43.7 billion pounds [lb]). The leading States in total red meat production were Iowa, Nebraska, Kansas, and Texas, accounting for approximately 52 percent of total production. In 1996, there were 988 Federally inspected slaughter plants in the United States and 2,560 other slaughter plants, for a total of 3,548 livestock slaughter plants. Table 2-1 presents the number of U.S. livestock slaughter plants by State operating in 1996. No data were available on the sizes or capacities of specific plants; however, according to the USDA, of the 836 plants that slaughtered at least 1 head of cattle, 14 plants slaughtered 49 percent of the total head; of the 802 plants that slaughtered at least 1 hog, 11 plants accounted for 45 percent of the total; of the 617 plants that slaughtered at least 1 head of sheep or lambs, 3 plants accounted for 56 percent of the total head; and, of the 343 plants that slaughtered at least one calf or vealer, 10 plants accounted for 48 percent of the total head.

In 1995, there were 35,639,277 cattle slaughtered commercially and 178,000 slaughtered on the farm, for a total of 35,817,277 cattle slaughtered in the United States. These cattle produced 11.4 billion kg (25.2 billion lb) of carcass, averaging 323 kg (711 lb) per animal. Table 2-2 presents 1995 beef production figures by State.

In 1995, there were 96,325,454 hogs slaughtered commercially and 210,000 slaughtered on the farm, for a total of 96,535,454 hogs slaughtered in the United States. These hogs produced 8.1 billion kg (17.8 billion lb) of carcass, averaging 84 kg (186 lb) per hog. Table 2-3 presents 1995 pork production figures by State.

In 1995, there were 4,559,864 sheep and lambs slaughtered commercially and 71,400 slaughtered on the farm, for a total of 4,631,264 sheep and lambs slaughtered in the United States. These sheep and lambs produced 131 million kg (288 million lb) of carcass, averaging 29 kg (63 lb) per head. Table 2-4 presents 1995 lamb and mutton production figures by State.

In 1995, there were 1,430,173 calves and vealers slaughtered commercially and 47,000 slaughtered on the farm, for a total of 1,477,173 calves and vealers slaughtered in the United States. These calves and vealers produced 144 million kg (318 million lb) of carcass, averaging 99 kg (218 lb) per head. Table 2-5 presents 1995 calf and veal production figures by State.

TABLE 2-1. NUMBER OF LIVESTOCK SLAUGHTER PLANTS BY STATE, 1996[a]

State	Number of plants	State	Number of plants
Ohio	209	Virginia	62
Iowa	208	Mississippi	58
Pennsylvania	201	Tennessee	57
Texas	199	Florida	56
Minnesota	189	North Dakota	55
Illinois	163	Montana	54
Kansas	152	Arkansas	53
Wisconsin	148	Idaho	53
Missouri	146	Colorado	52
Nebraska	129	West Virginia	45
Indiana	118	Delaware/Maryland	28
North Carolina	100	Utah	28
South Dakota	99	Wyoming	28
Oklahoma	98	Arizona	26
Georgia	90	Oregon	25
Louisiana	81	South Carolina	24
New York	77	New Mexico	23
California	76	New Jersey	21
Michigan	76	Washington	17
Kentucky	74	Hawaii	12
New England[b]	72	Nevada	4
Alabama	62		
U.S. Total	3,548		

[a]Reference 2. No data are available on the sizes of individual plants, however, according to the USDA, of the 3,548 facilities: 14 account for 49 percent of the cattle slaughtered; 10 account for 48 percent of the calves slaughtered; 11 account for 45 percent of the hogs slaughtered; and 3 account for 56 percent of the sheep and lambs slaughtered.

[b]New England includes Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.

TABLE 2-2. COMMERCIAL CATTLE PROCESSING: LIVE WEIGHT BY STATE, 1995[a]

State	Cattle processed, 1,000 lb	State	Cattle processed, 1,000 lb
Kansas	8,444,480	New York	75,905
Nebraska	8,190,485	Indiana	73,591
Texas	7,170,274	Kentucky	69,946
Colorado	3,099,454	Delaware/Maryland	45,810
Iowa	2,137,115	Oklahoma	42,735
Wisconsin	1,711,240	New England[b]	34,786
Minnesota	1,356,194	New Mexico	33,822
Illinois	1,342,866	Arkansas	28,255
Pennsylvania	1,259,625	New Jersey	24,957
California	1,210,734	Oregon	24,064
Washington	1,119,341	Montana	23,715
Arizona	519,499	Louisiana	21,230
South Dakota	278,796	Virginia	19,084
Missouri	197,083	West Virginia	15,720
Alabama	162,730	Hawaii	15,321
North Carolina	159,843	Wyoming	7,203
Ohio	148,682	Nevada	1,292
U.S. Total[c]	42,172,204		

[a]Reference 2. Includes slaughter in federally inspected and in other slaughter plants, but excludes animals slaughtered on farms.
[b]New England includes Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.
[c]U.S. total includes figures for States not shown to avoid disclosing individual operations.

TABLE 2-3. COMMERCIAL PORK PROCESSING: LIVE WEIGHT BY STATE, 1995[a]

State	Hogs processed, 1,000 lb	State	Hogs processed, 1,000 lb
Iowa	7,770,748	Oklahoma	52,877
Illinois	2,416,832	Alabama	50,826
North Carolina	1,932,536	Oregon	34,891
Minnesota	1,751,481	Florida	23,216
South Dakota	1,562,169	North Dakota	18,073
Nebraska	1,452,047	New York	13,887
Virginia	1,165,227	Colorado	13,151
Indiana	869,463	Louisiana	10,888
Kentucky	794,026	New England[b]	9,070
Pennsylvania	556,525	Hawaii	8,069
California	445,188	Montana	6,899
Ohio	355,407	West Virginia	5,681
Wisconsin	143,266	Arizona	2,781
Texas	114,159	Wyoming	1,693
Arkansas	102,111	New Mexico	775
Delaware/Maryland	63,336	Nevada	446
U.S. Total[c]	24,642,974		

[a]Reference 2. Includes slaughter in federally inspected and in other slaughter plants, but excludes animals slaughtered on farms.

[b]New England includes Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.

[c]U.S. total includes figures for States not shown to avoid disclosing individual operations.

TABLE 2-4. COMMERCIAL SHEEP AND LAMB PROCESSING: LIVE WEIGHT BY STATE, 1995[a]

State	Sheep and lambs processed, 1,000 lb	State	Sheep and lambs processed, 1,000 lb
Colorado	206,624	Oregon	754
South Dakota	29,330	Idaho	551
New Jersey	13,494	Montana	370
Pennsylvania	6,314	Louisiana	352
Utah	4,507	Kansas	308
New York	4,377	Wyoming	229
New Mexico	4,339	North Carolina	209
New England[b]	3,274	Nebraska	164
Virginia	2,337	Oklahoma	127
Ohio	1,542	North Dakota	108
Kentucky	1,265	Florida	61
Wisconsin	1,150		
U.S. Total[c]	571,646		

[a]Reference 2. Includes slaughter in federally inspected and in other slaughter plants, but excludes animals slaughtered on farms.
[b]New England includes Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.
[c]U.S. total includes figures for States not shown to avoid disclosing individual operations.

TABLE 2-5. COMMERCIAL CALF AND VEALER PROCESSING: LIVE WEIGHT BY STATE, 1995[a]

State	Calves and vealers processed, 1,000 lb	State	Calves and vealers processed, 1,000 lb
New York	88,393	New Jersey	15,437
Wisconsin	70,922	Washington	13,834
California	66,070	Louisiana	12,725
Pennsylvania	61,326	Texas	11,646
Illinois	47,795	Delaware/Maryland	3,235
Ohio	33,702	Missouri	754
Michigan	19,067	Oklahoma	577
New England[b]	17,077	North Carolina	526
U.S. Total[c]	532,081		

[a]Reference 2. Includes slaughter in federally inspected and in other slaughter plants, but excludes animals slaughtered on farms.
[b]New England includes Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.
[c]U.S. total includes figures for States not shown to avoid disclosing individual operations.

In 1995, there were 326,600 goats and 109,200 horses slaughtered commercially in the United States.

2.2 PROCESS DESCRIPTION

The following sections describe the operations involved in beef processing, pork processing, and other meat processing. Figure 2-1 provides a generic process flow diagram for meat packing operations.

2.2.1 Beef Processing[3-7]

Animals are delivered from the market or farm to the meat plant and are placed in holding areas. These holding areas should have adequate facilities for the inspection of livestock, including walkways over pens, crushes, and other facilities. Sick animals and those unfit for human consumption are identified and removed from the normal processing flow. Plants should have separate isolation and holding pens for these animals, and may have separate processing facilities. The live beef animals are weighed prior to processing so that yield can be accurately determined.

The animals are led from the holding area to the immobilization, or stunning, area where they are rendered unconscious. Stunning of cattle in the U.S. is usually carried out by means of a penetrating or nonpenetrating captive bolt pistol. Livestock for Kosher markets are not immobilized prior to exsanguination.

The anesthetized animals are then shackled and hoisted, hind quarters up, for exsanguination (sticking), which should be carried out as soon as possible after stunning. In cattle, exsanguination is effected by severing the carotid artery and the jugular vein. Blood is collected through a special floor drain or collected in large funneled vats or barrels and sent to a rendering facility for further processing. More information on rendering operations can be found in AP-42 Section 9.5.3, Meat Rendering Plants. Blood can be used in human food only if it is kept completely sterile by removal from the animals through tubes or syringes.

In some plants, electrical stimulation (ES) is applied to the carcasses to improve lean color, firmness, texture, and marbling score; to improve bleeding of carcasses; and to make removal of the hides easier. Electrical stimulation also permits rapid chilling by hastening the onset of rigor before temperatures drop to the cold shortening range. If muscles reach temperatures below 15° to 16°C (59° to 61°F) before they have attained rigor, a contraction known as cold shortening occurs, which results in much less tender meat. In some cases ES is applied to control the fall of pH value. Meat with a low pH value will be pale, soft, and exudative (PSE meat). Meat with a high pH value may be dark, firm, and dry (DFD meat). It has been claimed that ES enhances tenderness, primarily through the hastening of the onset of rigor and prevention of cold shortening. Both high-voltage (>500 volts) and low-voltage (30 to 90 volts) ES systems can be used.

After exsanguination, the actual "dressing," or cleaning, of the carcasses begins. The first step is to separate the esophagus from the trachea, called "rodding the weasand." Alternatively, this can be done after the chest cavity has been opened. This separation aids in evisceration. After separation, a knot is made in the esophagus, or a band is put around it to prevent the contents of the rumen (first stomach) from spilling and contaminating the carcass.

Next, the skin is removed from the head, and the head is removed from the carcass by cutting through the Adam's apple and the atlas joint (heading). The fore and hind feet are then removed to prevent

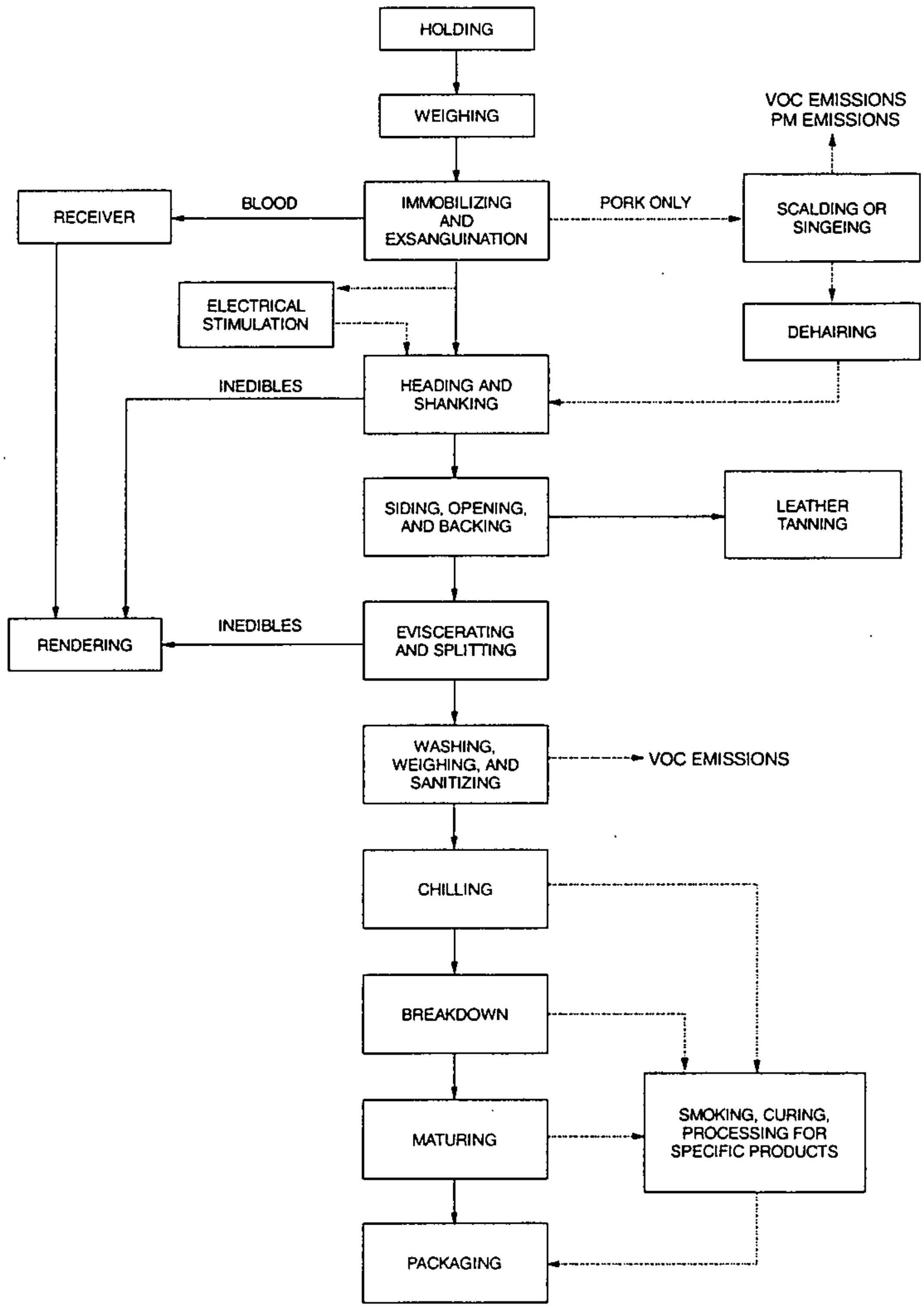


Figure 2-1. Generic meat packing flow diagram.

contamination of the carcass with manure and dirt dropped from the hooves (shanking or legging). Each of the legs is then skinned.

The hide is then opened down the middle of the ventral side over the entire length of the carcass. The hide is removed from the middle down over the sides (siding). Air or electrically powered rotary skinning knives are often used to make skinning easier. Care is taken to avoid cutting or scoring the hide, as this decreases its value for leather.

After siding, the carcass is opened (opening). First, a cut is made through the fat and muscle at the center of the brisket with a knife. Then a saw is used to cut through the sternum. The hind quarters are separated with a saw or knife. The tail is skinned and then removed two joints from the body. After removing the tail, the hide is completely removed (backing). Hides are collected, intermediate preserving operations performed, and the preserved hides sent to tanners for processing into leather. More information on leather tanning processes can be found in AP-42 Section 9.15, Leather Tanning.

After the hide is removed, the carcass is eviscerated. With a knife, the abdomen of the carcass is opened from top to bottom. The fat and membranes that hold the intestines and bladder in place are loosened, and the ureters connecting the bladder and the kidneys are cut. The liver is removed for inspection. The previously loosened esophagus is pulled up through the diaphragm to allow the abdominal organs to fall freely into an inspection cart. The diaphragm membrane is cut and the thoracic organs are removed.

A handsaw or electric saw is used to cut through the exact center of the backbone to split the beef carcass into sides (halving or splitting). Inedible material is collected and sent to a rendering plant for further processing. More information on meat rendering processes can be found in AP-42 Section 9.5.3, Meat Rendering Plants.

After dressing, the carcasses are washed to remove any remaining blood or bone dust. The carcasses may also be physically or chemically decontaminated. The simplest physical decontamination method involves spraying the carcass with high pressure hot water or steam. A variety of chemical decontaminants may be used as well; acetic and lactic acids are the most widely used and appear to be the most effective. In addition, the following may be used: the organic acids, adipic, ascorbic, citric, fumaric, malic, propionic, and sorbic; aqueous solutions of chlorine, hydrogen peroxide, beta-propiolactone, and glutaraldehyde; and inorganic acids, including hydrochloric and phosphoric.

After the carcasses are dressed and washed, they are weighed and chilled. A thorough chilling during the first 24 hours is essential, otherwise the carcasses may sour. Air chillers are most common for beef sides. A desirable temperature for chilling warm beef carcasses is 0°C (32°F). Because a group of warm carcasses will raise the temperature of a chill room considerably, it is good practice to lower the temperature of the room to 5° below freezing (-3°C [27°F]) before the carcasses are moved in. Temperatures more severe than this can cause cold shortening, an intense shortening of muscle fibers, which brings about toughening.

Beef undergoes maturation and should be held for at least a week (preferably longer) at 0°C (32°F) before butchery into retail joints. In the past, sides remained intact up to the point of butchery, but it is now common practice to break down the carcasses into primal joints (wholesale cuts), which are then vacuum packed. Preparation of primal joints in packing plants reduces refrigeration and transport costs, and is a convenient pre-packing operation for retailers.

Some meat products are smoked or cured prior to market. More information on smoking and curing processes can be found in AP-42 Section 9.5.2, Meat Smokehouses.

In the manufacture of frankfurters (hot dogs) and other beef sausages, a mix of ground lean meat and ground fat are blended together; then spices, preservatives, extenders, and other ingredients are blended with the mixture. The mix is transferred to the hopper of the filling machine and fed to a nozzle by a piston pump. The casing, either natural or artificial, is filled from the nozzle on a continuous basis and linked, either manually or mechanically, to form a string of individual frankfurters or sausages.

2.2.2 Pork Processing[3-7]

Animals are delivered from the market or farm to the meat plant and are placed in holding areas. These holding areas should have adequate facilities for the inspection of livestock, including walkways over pens, crushes, and other facilities. Sick animals and those unfit for human consumption are identified and removed from the normal processing flow. Plants should have separate isolation and holding pens for these animals, and may have separate processing facilities. The live animals are weighed prior to processing so that yield can be accurately determined.

Hogs must be rendered completely unconscious in a state of surgical anesthesia, prior to being shackled and hoisted for exsanguination. In large commercial operations, a series of chutes and restrainer conveyers move the hogs into position for stunning. The V restrainer/conveyer, or similar system, is used in most large hog processing operations. Hogs must be stunned with a federally acceptable device (mechanical, chemical, or electrical). Mechanical stunning involves the use of a compression bolt with either a mushroom head or a penetrating head. The force may be provided with compressed air or with a cartridge. Mechanical stunning is largely confined to smaller operations. Chemical stunning involves the use of CO_2, which reduces blood oxygen levels, causing the animals to become anesthetized. Electrical stunning involves the use of an electric current and two electrodes placed on the head. Deep stunning, which was approved by the U.S. Department of Agriculture, Food and Safety Inspection Service in 1985, requires more amperage and voltage and a third electrode attached to the back or a foot. Stunning causes the heart to stop beating (cardiac arrest). The stunned animals undergo exsanguination (sticking) and blood collection in the same manner as described for cattle.

Hog carcasses, unlike cattle carcasses, generally are not skinned after exsanguination. Instead, the carcasses are dropped into scalding water, which loosens the hair for subsequent removal. The carcasses should be kept under water and continually moved and turned for uniform scalding. In large plants, carcasses enter the scalding tub and are carried through the tub by a conveyer moving at the proper speed to allow the proper scalding time. During the hard-hair season (September-November), the water temperature should be 59° to 60°C (139° to 140°F) and the immersion period 4 to 4-1/2 minutes, while in the easy-hair season (February-March), a temperature of 58°C (136°F) for 4 minutes is preferable. In small plants without automation, hair condition is checked periodically during the scalding period. Some plants use an alternative to scalding that involves passing the carcass through gas flames to singe the hair. The hair is then removed by rotating brushes and water sprays, and the carcass is rinsed.

Various dehairing machines, sometimes called "polishers," are manufactured to remove hair from the scalded pork carcasses. The dehairing process is begun with a dehairing machine, which uses one or more cylinders with metal tipped rubber beaters to scour the outside of the carcasses. Hot water (60°C [140°F]) is sprayed on the carcasses as they pass through the dehairer moving toward the discharge end. The carcasses are removed from this machine, hand scraped, then hoisted again, hind quarters up. The carcasses are hand-scraped again from the top (hind quarters) down. Any remaining hairs can be removed by singeing with a propane or similar torch. Once the remaining hairs have been singed, the carcasses are scraped a final time and washed thoroughly from the hind feet to the head. Some plants pass the carcasses through a singeing machine, which singes any remaining hairs from the carcasses.

At one time, it was popular to dip dehaired carcasses into a hot solution (121° to 149°C [250° to 300°F]) of rosin and cottonseed oil for a period of six to eight seconds. When the rosin coating plasticized after cooling, it was stripped by pull-rolling it down the carcass, taking with it the remaining hair, stubble, and roots. However, in recent years, many packers have discontinued its use, turning instead to mechanical brushes and torches to completely clean dehaired pork carcasses.

In some plants, hogs are skinned after exsanguination. The head and belly of the carcass are hand-skinned, and the legs are either hand-skinned or removed. Then the carcass is hoisted, hind quarters up, and placed under tension. A second hoist is connected to the loose head and leg skin and tightened to pull the remaining skin from the carcass. The removed pigskins are trimmed, salted, folded, and stored in 50-gallon drums.

After scalding and dehairing, singeing, or skinning, the head is severed from the backbone at the atlas joint, and the cut is continued through the windpipe and esophagus. The head is inspected, the tongue is dropped, and the head is removed from the carcass. The head is cleaned, washed, and an inspection stamp is applied.

Following heading, the carcass is eviscerated. The hams are separated, the sternum is split, the ventral side is opened down the entire length of the carcass, and the abdominal organs are removed. The thoracic organs are then freed. All of the internal organs are inspected, those intended for human consumption are separated, and the remainder are discarded into a barrel to be shipped to the rendering plant. As mentioned previously, more information on meat rendering can be found in AP-42 Section 9.5.3, Meat Rendering Plants.

After evisceration, the carcass is split precisely in half. Glands and blood clots in the neck region are removed, the leaf fat and kidneys are removed, and the hams are faced (a strip of skin and fat is removed to improve appearance).

The carcass is then washed from the top down to remove any bone dust, blood, or bacterial contamination. A mild salt solution (0.1 M KCl) weakens bacterial attachment to the carcass and makes the bacteria more susceptible to the sanitization procedure, especially if the sanitizing solution is applied promptly. Dilute organic acids (2 percent lactic acid and 3 percent acetic acid) are good sanitizers. In large operations, carcass washing is automated. As the carcass passes through booths on the slaughter line, the proper solutions are applied at the most effective pressure.

After washing and sanitizing, the carcass is inspected one final time, weighed, and the inspection stamp is applied to each wholesale cut. The carcass is then placed in a cooler at 0° to 1°C (32° to 34°F) with air velocity typically 5 to 15 mph, equating to -5°C (23°F) wind chill, for a 24-hour chill period. For thorough chilling, the inside temperature of the ham should reach at least 3°C (37°F). With accelerated (hot) processing, the carcass may be held (tempered) at an intermediate temperature of 16°C (60°F) for several hours, or be boned immediately. When large numbers of warm carcasses are handled, the chill room is normally precooled to a temperature several degrees below freezing -3°C (27°F), bringing the wind chill to -9°C (16°F) to compensate for the heat from the carcasses.

Spray chilling is permitted by the U.S.D.A. to reduce cooler shrink. Spray chilling solutions may contain up to 5 ppm available chlorine, which acts as sanitizer. At least one plant sends carcasses directly from the kill floor through a freezer, to produce a brightly colored pork with reduced carcass shrink. Following cooling, pork carcasses are often divided into deboned primal joints for distribution. The primal joints may be vacuum packed. To manufacture pork sausages, ground lean meat and ground fat are blended together and processed in the same manner as that described for beef sausages in Section 2.2.1.

2.2.3 Other Meat Processing

Other meats undergo processes similar to those described above for beef and pork processing. These other meats include veal, lamb, mutton, goat, horse (generally for export), and farm-raised large game animals.

2.3 EMISSIONS

No emission data quantifying VOC, HAP, or PM emissions from the meat packing industry were identified during the development of this report. However, engineering judgment and comparison of meat packing plant processes with similar processes in other industries may provide an estimation of the types of emissions that might be expected from meat packing plant operations.

Animal holding areas, feed storage, singeing operations, and other heat sources (including boilers) may be sources of PM and PM-10 emissions. Carbon dioxide stunning operations may be sources of CO_2 emissions. Animal holding areas, scalding tanks, singeing operations, rosin dipping (where still used), sanitizing operations, wastewater systems, and heat sources may be sources of VOC, HAP, and other criteria pollutant emissions.

Potential emissions from boilers are addressed in AP-42 Section 1.1 through 1.4 (Combustion). Meat smokehouses, meat rendering operations, and leather tanning may be sources of air pollutant emissions, but these sources are included in other sections of AP-42 and are not addressed in this section.

2.4 EMISSION CONTROL TECHNOLOGY

A number of VOC and particulate emission control techniques are potentially available to the meat packing industry. These options include the traditional approaches of wet scrubbers, dry sorbants, and cyclones. Other options include condensation and chemical reaction. No information is available for the actual controls used at meat packing plants. The controls presented in this section are ones that theoretically could be used. The specific type of control device or combination of devices would vary from facility to facility depending upon the particular nature of the emissions and the pollutant loading in the gas stream. The VOC emissions from meat packing operations are likely to be very low and associated with a high moisture content.

Control of VOC from a gas stream can be accomplished using one of several techniques, but the most common methods are absorption, adsorption, and afterburners. Gas absorption is a diffusion controlled, gas-liquid mass transfer process. Absorptive methods encompass all types of wet scrubbers using aqueous solutions to absorb the VOC. The most common scrubber systems are packed columns or beds, plate columns, spray towers, or other types of towers. Most scrubber systems require a mist eliminator downstream of the scrubber.

Gas adsorption is a relatively expensive technique and may not be applicable to a wide variety of pollutants. Adsorptive methods usually include one of four main adsorbents: activated carbon, activated alumina, silica gel, or molecular sieves. Of these four, activated carbon is the most widely used for VOC control and the remaining three are used for applications other than pollution control. The adsorbent is regenerated by heating or use of steam, which gives rise to new emissions to be controlled.

Afterburners, or thermal incinerators, are add-on combustion control devices in which VOC's are oxidized to CO_2, water, sulfur oxides, and nitrogen oxides. The destruction efficiency of an afterburner is primarily a function of the operating temperature and residence time at that temperature. A temperature above 816°C (1500°F) will destroy most organic vapors and aerosols.

Particulate control commonly employs methods such as venturi scrubbers, dry cyclones, wet or dry electrostatic precipitators (ESP's), or dry filter systems. The most common controls are likely to be the venturi scrubbers or dry cyclones. Wet or dry ESP's are used depending upon the particulate loading of the gas stream. These three systems are commonly used for particulate removal in many types of processing facilities.

Condensation methods and scrubbing by chemical reaction may be applicable techniques depending upon the type of emissions. Condensation methods may be either direct contact or indirect contact. The shell and tube indirect method is the most common technique, and offers heat recovery as a bonus for certain applications. Chemical reactive scrubbing may be used for odor control in selective applications. The major problem with this technique is that it is very specific.

REFERENCES FOR SECTION 2

1. Bureau of the Census, U. S. Department of Commerce, *1992 Census of Manufactures*, Industry Series, MC92-I-20A, Meat Products, Industries 2011, 2013, and 2015, Washington, D.C., U. S. Government Printing Office, June 1995.

2. USDA, National Agricultural Statistics Service, Agricultural Statistics Board, *1995 Livestock Slaughter Annual Summary*, March 14, 1996.

3. J. R. Romans, et al., *The Meat We Eat*, Thirteenth Edition, Interstate Publishers, Inc., Danville, IL, 1994.

4. M. D. Judge, et al., *Principles of Meat Science*, Second Edition, Kendall/Hunt Publishing Company, Dubuque, IA, 1989.

5. A. H. Varnam and J. P. Sutherland, *Meat and Meat Products, Technology, Chemistry, and Microbiology*, Chapman & Hall, New York, NY, 1995.

6. R. A. Lawrie, *Meat Science*, Fifth Edition, Pergamon Press, New York, NY, 1991.

7. N. R. P. Wilson, ed., *Meat and Meat Products, Factors Affecting Quality Control*, Applied Science Publishers, Inc., Englewood, NJ, 1981.

3. GENERAL DATA REVIEW AND ANALYSIS PROCEDURES

3.1 LITERATURE SEARCH AND SCREENING

Data for this investigation were obtained from a number of sources within the Office of Air Quality Planning and Standards (OAQPS) and from outside organizations. The AP-42 background files located in the Emission Factor and Inventory Group (EFIG) were reviewed for information on the industry, processes, and emissions. The Factor Information and Retrieval (FIRE), Crosswalk/Air Toxic Emission Factor Data Base Management System (XATEF), and VOC/PM Speciation Data Base Management System (SPECIATE) data bases were searched by SCC code for identification of the potential pollutants emitted and emission factors for those pollutants. A general search of the Air CHIEF CD-ROM also was conducted to supplement the information from these data bases.

Information on the industry, including number of plants, plant location, and annual production capacities, was obtained from the United States Department of Agriculture and other sources. A search of the Test Method Storage and Retrieval (TSAR) data base was conducted to identify test reports for sources within the meat packing industry. The EPA library was searched for additional test reports. Publications lists from the Office of Research and Development (ORD) and Control Technology Center (CTC) were also searched for reports on emissions from the meat packing industry. In addition, Iowa Beef Packers, Inc. (IBP), and representative trade associations, including the American Meat Institute (AMI), were contacted for assistance in obtaining information about the industry and emissions.

To screen out unusable test reports, documents, and information from which emission factors could not be developed, the following general criteria were used:

1. Emission data must be from a primary reference:

a. Source testing must be from a referenced study that does not reiterate information from previous studies.

b. The document must constitute the original source of test data. For example, a technical paper was not included if the original study was contained in the previous document. If the exact source of the data could not be determined, the document was eliminated.

2. The referenced study should contain test results based on more than one test run. If results from only one run are presented, the emission factors must be down rated.

3. The report must contain sufficient data to evaluate the testing procedures and source operating conditions (e.g., one-page reports were generally rejected).

A final set of reference materials was compiled after a thorough review of the pertinent reports, documents, and information according to these criteria.

3.2 DATA QUALITY RATING SYSTEM[1]

As part of the analysis of the emission data, the quantity and quality of the information contained in the final set of reference documents were evaluated. The following data were excluded from consideration:

1. Test series averages reported in units that cannot be converted to the selected reporting units;

2. Test series of controlled emissions for which the control device is not specified;

3. Test series in which the source process is not clearly identified and described; and

4. Test series in which it is not clear whether the emissions were measured before or after the control device.

Test data sets that were not excluded were assigned a quality rating. The rating system used was that specified by EFIG for preparing AP-42 sections. The data were rated as follows:

A—Multiple test runs that were performed using sound methodology and reported in enough detail for adequate validation. These tests do not necessarily conform to the methodology specified in EPA reference test methods, although these methods were used as a guide for the methodology actually used.

B—Tests that were performed by a generally sound methodology but lack enough detail for adequate validation.

C—Tests that were based on an unproven or new methodology or that lacked a significant amount of background information.

D—Tests that were based on a generally unacceptable method but may provide an order-of-magnitude value for the source.

The following criteria were used to evaluate source test reports for sound methodology and adequate detail:

1. Source operation. The manner in which the source was operated is well documented in the report. The source was operating within typical parameters during the test.

2. Sampling procedures. The sampling procedures conformed to a generally acceptable methodology. If actual procedures deviated from accepted methods, the deviations are well documented. When this occurred, an evaluation was made of the extent to which such alternative procedures could influence the test results.

3. Sampling and process data. Adequate sampling and process data are documented in the report, and any variations in the sampling and process operation are noted. If a large spread between test results cannot be explained by information contained in the test report, the data are suspect and are given a lower rating.

4. Analysis and calculations. The test reports contain original raw data sheets. The nomenclature and equations used were compared to those (if any) specified by EPA to establish equivalency. The depth

of review of the calculations was dictated by the reviewer's confidence in the ability and conscientiousness of the tester, which in turn was based on factors such as consistency of results and completeness of other areas of the test report.

3.3 EMISSION FACTOR QUALITY RATING SYSTEM[1]

The quality of the emission factors developed from analysis of the test data was rated using the following general criteria:

A—Excellent: Developed from A- and B-rated source test data taken from many randomly chosen facilities in the industry population. The source category is specific enough so that variability within the source category population may be minimized.

B—Above average: Developed only from A- or B-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industries. The source category is specific enough so that variability within the source category population may be minimized.

C—Average: Developed only from A-, B- and/or C-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industry. In addition, the source category is specific enough so that variability within the source category population may be minimized.

D—Below average: The emission factor was developed only from A-, B-, and/or C-rated test data from a small number of facilities, and there is reason to suspect that these facilities do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of the emission factor are noted in the emission factor table.

E—Poor: The emission factor was developed from C- and D-rated test data, and there is reason to suspect that the facilities tested do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of these factors are footnoted.

The use of these criteria is somewhat subjective and depends to an extent upon the individual reviewer. Details of the rating of each candidate emission factor are provided in Section 4.

REFERENCE FOR SECTION 3

1. *Procedures For Preparing Emission Factor Documents, Second Revised Draft Version*, Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency, Research Triangle Park, NC, September 1995.

4. AP-42 SECTION DEVELOPMENT

4.1 INTRODUCTION

This section describes the references and test data that were evaluated to determine if pollutant emission factors could be developed for AP-42 Section 9.5.1, Meat Packing Plants.

4.2 REVIEW OF SPECIFIC DATA SETS

No source tests or other documents that could be used to develop emission factors for the AP-42 section were located during the literature search.

4.3 DEVELOPMENT OF CANDIDATE EMISSION FACTORS

No emission factors were developed because no source tests or emissions data were found.

5. AP-42 SECTION

The AP-42, Section 9.5.1, Meat Packing Plants, is presented on the following pages as it will appear in the document.

9.5.1 Meat Packing Plants

9.5.1.1 General[1-2]

The meat packing industry is made up of establishments primarily engaged in the slaughtering, for their own account or on a contract basis for the trade, of cattle, hogs, sheep, lambs, calves, and vealers for meat to be sold or to be used on the same premises in canning, cooking, curing, and freezing, and in making sausage, lard, and other products. Also included in this industry are establishments primarily engaged in slaughtering horses for human consumption.

9.5.1.2 Process Description[3-7]

The following sections describe the operations involved in beef processing, pork processing, and other meat processing. Figure 9.5.1-1 provides a generic process flow diagram for meat packing operations.

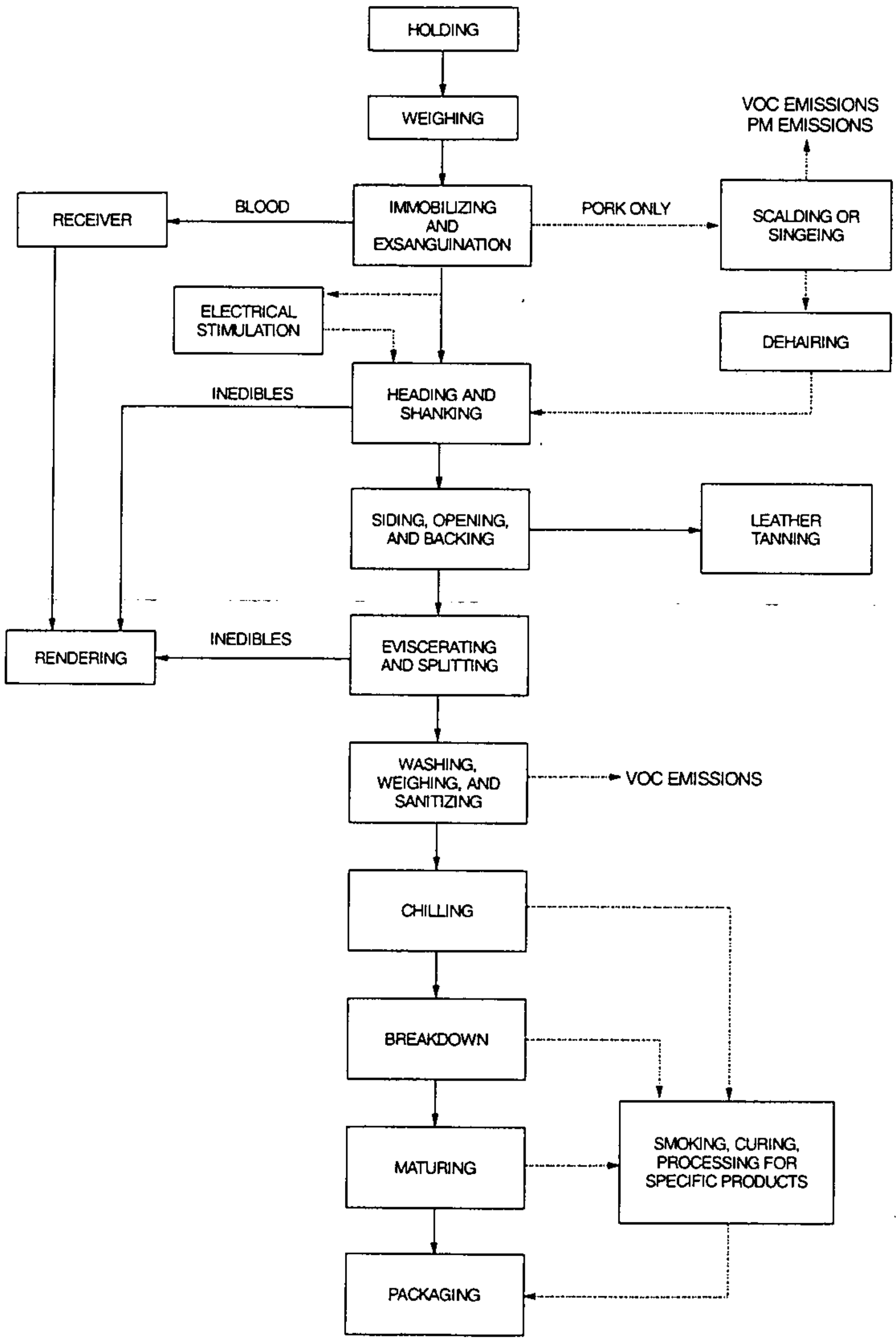
9.5.1.2.1 Beef Processing[3-7] -

Animals are delivered from the market or farm to the meat plant and are placed in holding areas. These holding areas should have adequate facilities for the inspection of livestock, including walkways over pens, crushes, and other facilities. Sick animals and those unfit for human consumption are identified and removed from the normal processing flow. Plants should have separate isolation and holding pens for these animals, and may have separate processing facilities. The live beef animals are weighed prior to processing so that yield can be accurately determined.

The animals are led from the holding area to the immobilization, or stunning, area where they are rendered unconscious. Stunning of cattle in the U.S. is usually carried out by means of a penetrating or nonpenetrating captive bolt pistol. Livestock for Kosher markets are not immobilized prior to exsanguination.

The anesthetized animals are then shackled and hoisted, hind quarters up, for exsanguination (sticking), which should be carried out as soon as possible after stunning. In cattle, exsanguination is effected by severing the carotid artery and the jugular vein. Blood is collected through a special floor drain or collected in large funneled vats or barrels and sent to a rendering facility for further processing. More information on rendering operations can be found in AP-42 Section 9.5.3, Meat Rendering Plants. Blood can be used in human food only if it is kept completely sterile by removal from the animals through tubes or syringes.

In some plants, electrical stimulation (ES) is applied to the carcasses to improve lean color, firmness, texture, and marbling score; to improve bleeding of carcasses; and to make removal of the hides easier. Electrical stimulation also permits rapid chilling by hastening the onset of rigor before temperatures drop to the cold shortening range. If muscles reach temperatures below 15° to 16°C (59° to 61°F) before they have attained rigor, a contraction known as cold shortening occurs, which results in much less tender meat. In some cases ES is applied to control the fall of pH value. Meat with a low pH value will be pale, soft, and exudative (PSE meat). Meat with a high pH value may be dark, firm, and dry (DFD meat). It has been claimed that ES enhances tenderness, primarily through the hastening of the onset of rigor and prevention of cold shortening. Both high-voltage (> 500 volts) and low-voltage (30 to 90 volts) ES systems can be used.


HOLDING
WEIGHING
VOC EMISSIONS
PM EMISSIONS
RECEIVER
BLOOD
IMMOBILIZING AND EXSANGUINATION
PORK ONLY
SCALDING OR SINGEING
ELECTRICAL STIMULATION
DEHAIRING
INEDIBLES
HEADING AND SHANKING
SIDING, OPENING, AND BACKING
LEATHER TANNING
RENDERING
INEDIBLES
EVISCERATING AND SPLITTING
WASHING, WEIGHING, AND SANITIZING
VOC EMISSIONS
CHILLING
BREAKDOWN
MATURING
SMOKING, CURING, PROCESSING FOR SPECIFIC PRODUCTS
PACKAGING

After exsanguination, the actual "dressing", or cleaning, of the carcasses begins. The first step is to separate the esophagus from the trachea, called "rodding the weasand". Alternatively, this can be done after the chest cavity has been opened. This separation aids in evisceration. After separation, a knot is made in the esophagus, or a band is put around it to prevent the contents of the rumen (first stomach) from spilling and contaminating the carcass.

Next, the skin is removed from the head, and the head is removed from the carcass by cutting through the Adam's apple and the atlas joint (heading). The fore and hind feet are then removed to prevent contamination of the carcass with manure and dirt dropped from the hooves (shanking or legging). Each of the legs is then skinned.

The hide is then opened down the middle of the ventral side over the entire length of the carcass. The hide is removed from the middle down over the sides (siding). Air or electrically powered rotary skinning knives are often used to make skinning easier. Care is taken to avoid cutting or scoring the hide, as this decreases its value for leather.

After siding, the carcass is opened (opening). First, a cut is made through the fat and muscle at the center of the brisket with a knife. Then a saw is used to cut through the sternum. The hind quarters are separated with a saw or knife. The tail is skinned and then removed two joints from the body. After removing the tail, the hide is completely removed (backing). Hides are collected, intermediate preserving operations performed, and the preserved hides sent to tanners for processing into leather. More information on leather tanning processes can be found in AP-42 Section 9.15, Leather Tanning.

After the hide is removed, the carcass is eviscerated. With a knife, the abdomen of the carcass is opened from top to bottom. The fat and membranes that hold the intestines and bladder in place are loosened, and the ureters connecting the bladder and the kidneys are cut. The liver is removed for inspection. The previously loosened esophagus is pulled up through the diaphragm to allow the abdominal organs to fall freely into an inspection cart. The diaphragm membrane is cut and the thoracic organs are removed.

A handsaw or electric saw is used to cut through the exact center of the backbone to split the beef carcass into sides (halving or splitting). Inedible material is collected and sent to a rendering plant for further processing. More information on meat rendering processes can be found in AP-42 Section 9.5.3, Meat Rendering Plants.

After dressing, the carcasses are washed to remove any remaining blood or bone dust. The carcasses may also be physically or chemically decontaminated. The simplest physical decontamination method involves spraying the carcass with high pressure hot water or steam. A variety of chemical decontaminants may be used as well; acetic and lactic acids are the most widely used and appear to be the most effective. In addition, the following may be used: the organic acids, adipic, ascorbic, citric, fumaric, malic, propionic, and sorbic; aqueous solutions of chlorine, hydrogen peroxide, beta-propiolactone, and glutaraldehyde; and inorganic acids, including hydrochloric and phosphoric.

After the carcasses are dressed and washed, they are weighed and chilled. A thorough chilling during the first 24 hours is essential, otherwise the carcasses may sour. Air chillers are most common for beef sides. A desirable temperature for chilling warm beef carcasses is 0°C (32°F). Because a group of warm carcasses will raise the temperature of a chill room considerably, it is good practice to lower the temperature of the room to 5° below freezing (-3°C [27°F]) before the carcasses are moved in. Temperatures more severe than this can cause cold shortening, an intense shortening of muscle fibers, which brings about toughening.

Beef undergoes maturation and should be held for at least a week (preferably longer) at 0°C (32°F) before butchery into retail joints. In the past, sides remained intact up to the point of butchery, but it is now common practice to break down the carcasses into primal joints (wholesale cuts), which are then vacuum packed. Preparation of primal joints in packing plants reduces refrigeration and transport costs, and is a convenient pre-packing operation for retailers.

Some meat products are smoked or cured prior to market. More information on smoking and curing processes can be found in AP-42 Section 9.5.2, Meat Smokehouses.

In the manufacture of frankfurters (hot dogs) and other beef sausages, a mix of ground lean meat and ground fat are blended together; then spices, preservatives, extenders, and other ingredients are blended with the mixture. The mix is transferred to the hopper of the filling machine and fed to a nozzle by a piston pump. The casing, either natural or artificial, is filled from the nozzle on a continuous basis and linked, either manually or mechanically, to form a string of individual frankfurters or sausages.

9.5.1.2.2 Pork Processing[3-7] -

Animals are delivered from the market or farm to the meat plant and are placed in holding areas. These holding areas should have adequate facilities for the inspection of livestock, including walkways over pens, crushes, and other facilities. Sick animals and those unfit for human consumption are identified and removed from the normal processing flow. Plants should have separate isolation and holding pens for these animals, and may have separate processing facilities. The live animals are weighed prior to processing so that yield can be accurately determined.

Hogs must be rendered completely unconscious, in a state of surgical anesthesia, prior to being shackled and hoisted for exsanguination. In large commercial operations, a series of chutes and restrainer conveyers move the hogs into position for stunning. The V restrainer/conveyer, or similar system, is used in most large hog processing operations. Hogs must be stunned with a federally acceptable device (mechanical, chemical, or electrical). Mechanical stunning involves the use of a compression bolt with either a mushroom head or a penetrating head. The force may be provided with compressed air or with a cartridge. Mechanical stunning is largely confined to smaller operations. Chemical stunning involves the use of CO_2, which reduces blood oxygen levels, causing the animals to become anesthetized. Electrical stunning involves the use of an electric current and two electrodes placed on the head.

Deep stunning, which was approved by the U.S. Department of Agriculture, Food and Safety Inspection Service in 1985, requires more amperage and voltage and a third electrode attached to the back or a foot. Stunning causes the heart to stop beating (cardiac arrest). The stunned animals undergo exsanguination (sticking) and blood collection in the same manner as described for cattle.

Hog carcasses, unlike cattle carcasses, generally are not skinned after exsanguination. Instead, the carcasses are dropped into scalding water which loosens the hair for subsequent removal. The carcasses should be kept under water and continually moved and turned for uniform scalding. In large plants, carcasses enter the scalding tub and are carried through the tub by a conveyer moving at the proper speed to allow the proper scalding time. During the hard-hair season (September-November), the water temperature should be 59° to 60°C (139° to 140°F) and the immersion period 4 to 4-1/2 minutes, while in the easy-hair season (February-March), a temperature of 58°C (136°F) for 4 minutes is preferable. In small plants without automation, hair condition is checked periodically during the scalding period. Some plants use an alternative to scalding that involves passing the carcass through gas flames to singe the hair. The hair is then removed by rotating brushes and water sprays, and the carcass is rinsed.

Various dehairing machines, sometimes called "polishers", are manufactured to remove hair from the scalded pork carcasses. The dehairing process is begun with a dehairing machine, which uses one or more cylinders with metal tipped rubber beaters to scour the outside of the carcasses. Hot water (60°C [140°F]) is sprayed on the carcasses as they pass through the dehairer moving toward the discharge end. The carcasses are removed from this machine, hand scraped, then hoisted again, hind quarters up. The carcasses are hand-scraped again from the top (hind quarters) down. Any remaining hairs can be removed by singeing with a propane or similar torch. Once the remaining hairs have been singed, the carcasses are scraped a final time and washed thoroughly from the hind feet to the head. Some plants pass the carcasses through a singeing machine, which singes any remaining hairs from the carcasses.

At one time, it was popular to dip dehaired carcasses into a hot solution (121° to 149°C [250° to 300°F]) of rosin and cottonseed oil for a period of six to eight seconds. When the rosin coating plasticized after cooling, it was stripped by pull-rolling it down the carcass, taking with it the remaining hair, stubble, and roots. However, in recent years, many packers have discontinued its use, turning instead to mechanical brushes and torches to completely clean dehaired pork carcasses.

In some plants, hogs are skinned after exsanguination. The head and belly of the carcass are hand-skinned, and the legs are either hand-skinned or removed. Then the carcass is hoisted, hind quarters up, and placed under tension. A second hoist is connected to the loose head and leg skin and tightened to pull the remaining skin from the carcass. The removed pigskins are trimmed, salted, folded, and stored in 50-gallon drums.

After scalding and dehairing, singeing, or skinning, the head is severed from the backbone at the atlas joint, and the cut is continued through the windpipe and esophagus. The head is inspected, the tongue is dropped, and the head is removed from the carcass. The head is cleaned, washed, and an inspection stamp is applied.

Following heading, the carcass is eviscerated. The hams are separated, the sternum is split, the ventral side is opened down the entire length of the carcass, and the abdominal organs are removed. The thoracic organs are then freed. All of the internal organs are inspected, those intended for human consumption are separated, and the remainder are discarded into a barrel to be shipped to the rendering plant. As mentioned previously, more information on meat rendering can be found in AP-42 Section 9.5.3, Meat Rendering Plants.

After evisceration, the carcass is split precisely in half. Glands and blood clots in the neck region are removed, the leaf fat and kidneys are removed, and the hams are faced (a strip of skin and fat is removed to improve appearance).

The carcass is then washed from the top down to remove any bone dust, blood, or bacterial contamination. A mild salt solution (0.1 M KCl) weakens bacterial attachment to the carcass and makes the bacteria more susceptible to the sanitization procedure, especially if the sanitizing solution is applied promptly. Dilute organic acids (2 percent lactic acid and 3 percent acetic acid) are good sanitizers. In large operations, carcass washing is automated. As the carcass passes through booths on the slaughter line, the proper solutions are applied at the most effective pressure.

After washing and sanitizing, the carcass is inspected one final time, weighed, and the inspection stamp is applied to each wholesale cut. The carcass is then placed in a cooler at 0° to 1°C (32° to 34°F) with air velocity typically 5 to 15 mph, equating to -5°C (23°F) wind chill, for a 24-hour chill period. For thorough chilling, the inside temperature of the ham should reach at least 3°C (37°F). With accelerated (hot) processing, the carcass may be held (tempered) at an intermediate temperature of 16°C (60°F) for several hours, or be boned immediately. When large numbers of warm carcasses are handled, the chill room is normally precooled to a temperature several degrees below freezing -3°C (27°F), bringing the wind chill to -9°C (16°F) to compensate for the heat from the carcasses.

Spray chilling is permitted by the U.S.D.A. to reduce cooler shrink. Spray chilling solutions may contain up to 5 ppm available chlorine, which acts a sanitizer. At least one plant sends carcasses directly from the kill floor through a freezer, to produce a brightly colored pork with reduced carcass shrink. Following cooling, pork carcasses are often divided into deboned primal joints for distribution. The primal joints may be vacuum packed. To manufacture pork sausages, ground lean meat and ground fat are blended together and processed in the same manner as that described for beef sausages in Section 9.5.1.2.1.

9.5.1.2.3 Other Meat Processing -

Other meats undergo processes similar to those described above for beef and pork processing. These other meats include veal, lamb, mutton, goat, horse (generally for export), and farm-raised large game animals.

9.5.1.3 Emissions And Controls

No emission data quantifying VOC, HAP, or PM emissions from the meat packing industry were identified during the development of this report. However, engineering judgment and comparison of meat packing plant processes with similar processes in other industries may provide an estimation of the types of emissions that might be expected from meat packing plant operations.

Animal holding areas, feed storage, singeing operations, and other heat sources (including boilers) may be sources of PM and PM-10 emissions. Carbon dioxide stunning operations may be sources of CO_2 emissions. Animal holding areas, scalding tanks, singeing operations, rosin dipping (where still used), sanitizing operations, wastewater systems, and heat sources may be sources of VOC, HAP, and other criteria pollutant emissions.

Potential emissions from boilers are addressed in AP-42 Sections 1.1 through 1.4 (Combustion). Meat smokehouses, meat rendering operations, and leather tanning may be sources of air pollutant emissions, but these sources are included in other sections of AP-42 and are not addressed in this section.

A number of VOC and particulate emission control techniques are potentially available to the meat packing industry. These options include the traditional approaches of wet scrubbers, dry sorbants, and cyclones. Other options include condensation and chemical reaction. No information is available for the actual controls used at meat packing plants. The controls presented in this section are ones that theoretically could be used. The specific type of control device or combination of devices would vary from facility to facility depending upon the particular nature of the emissions and the pollutant loading in the gas stream. The VOC emissions from meat packing operations are likely to be very low and associated with a high moisture content.

Control of VOC from a gas stream can be accomplished using one of several techniques, but the most common methods are absorption, adsorption, and afterburners. Absorptive methods encompass all types of wet scrubbers using aqueous solutions to absorb the VOC. The most common scrubber systems are packed columns or beds, plate columns, spray towers, or other types of towers. Most scrubber systems require a mist eliminator downstream of the scrubber.

Gas adsorption is a relatively expensive technique and may not be applicable to a wide variety of pollutants. Adsorptive methods usually include one of four main adsorbents: activated carbon, activated alumina, silica gel, or molecular sieves. Of these four, activated carbon is the most widely used for VOC control, and the remaining three are used for applications other than pollution control.

Afterburners, or thermal incinerators, are add-on combustion control devices in which VOC's are oxidized to CO_2, water, sulfur oxides, and nitrogen oxides. The destruction efficiency of an afterburner is primarily a function of the operating temperature and residence time at that temperature. A temperature above 816°C (1,500°F) will destroy most organic vapors and aerosols.

Particulate control commonly employs methods such as venturi scrubbers, dry cyclones, wet or dry electrostatic precipitators (ESPs), or dry filter systems. The most common controls are likely to be the venturi scrubbers or dry cyclones. Wet or dry ESPs are used depending upon the particulate loading of the gas stream.

Condensation methods and scrubbing by chemical reaction may be applicable techniques depending upon the type of emissions. Condensation methods may be either direct contact or indirect contact. The shell and tube indirect method is the most common technique. Chemical reactive scrubbing may be used for odor control in selective applications.

References for Section 9.5.1

1. Bureau of the Census, U. S. Department of Commerce, *1992 Census Of Manufactures*, Industry Series, MC92-I-20A, Meat Products, Industries 2011, 2013, and 2015, Washington, D.C., U. S. Government Printing Office, June 1995.

2. USDA, National Agricultural Statistics Service, Agricultural Statistics Board, *1995 Livestock Slaughter Annual Summary*, March 14, 1996.

3. J. R. Romans, et al., *The Meat We Eat*, Thirteenth Edition, Interstate Publishers, Inc., Danville, IL, 1994.

4. M. D. Judge, et al., *Principles Of Meat Science*, Second Edition, Kendall/Hunt Publishing Company, Dubuque, IA, 1989.

5. A. H. Varnam and J. P. Sutherland, *Meat And Meat Products, Technology, Chemistry, And Microbiology*, Chapman & Hall, New York, NY, 1995.

6. R. A. Lawrie, *Meat Science*, Fifth Edition, Pergamon Press, New York, NY, 1991.

7. N. R. P. Wilson, ed., *Meat And Meat Products, Factors Affecting Quality Control*, Applied Science Publishers, Inc., Englewood, NJ, 1981.