Odor Emission Control for the Food Industry

HAROLD J. RAFSON

☐ ODOR OR AROMA in the food industry usually has a positive connotation. However, even a pleasant odor continually emitted into neighboring offices and homes can be objectionable, and possibly a hazard. Therefore, it is irrelevant whether the odor emitted from a food plant is the lovely fragrance of baking bread or the noxious smell of rendering animal fat. Both can be considered to be sources of air pollution and their emissions must be controlled.

SOURCES OF EMISSIONS

Table 1 lists the process sources and descriptions of the odor emissions common to various segments of the food industry.

This or any other list of sources of food plant odors is bound to be incomplete because of the breadth and complexity of the industry. The emissions from each plant must be examined to determine not only the source, but also the type, composition, and characteristics of each of the odors emitted.

CHARACTERISTICS OF ODOROUS MATERIALS

To be odorous, any material must be in the vapor or gaseous state. However, both solid particles and liquid droplets may carry aromas if the solid or liquid materials have high vapor pressures. The higher the vapor pressure of a material, the more likely it is to be perceived as odorous.

In addition to vapor pressure, the following characteristics are also important: solubility in water; solubility in other solvents; boiling point; odor threshold level; ionic nature of the material; surface activity; film forming ability; and the chemical reactions of the material.

EXAMPLES ILLUSTRATE TYPES OF ODORS

To illustrate the different types of odors, we have chosen two examples—the flavor house, and the rendering plant.

• **The Flavor House** emits a wide variety of both vapors and particles. To complicate the problem of emission control even further, composition of the substances being emitted is constantly changing because flavor house production is characterized by short runs.

• **The Rendering Plant** emits high volumes of moist noxious vapors, which are always of the same type. This industry has been recognized in many states as a major source of air pollution, and regulations have been established to limit the odors emitted from these plants.

THE AUTHOR is president of QUAD Corporation 1852 Dale Ave., Highland Park, IL 60035.

DO-IT-YOURSELF SURVEY

Odors from food plants not equipped with emission control systems are simply blown into the atmosphere. Therefore, the first step in solving a food plant odor problem is to determine what, where, and how much is being blown out.

The simplest way to do this is to walk around the roof of your plant and smell the emissions from the various exhausts—such as spray drier stacks, retort vents, and air conditioner blowers.

Walking around the roof also gives you a good view of your neighbors, especially those who are downwind of your plant. You must recognize that stack gases often go down rather than up. This is particularly obvious when the air is moist and there are climate inversions which trap stack emissions at ground level.

If you can also get to a position where you can look down on your roof, you should do so. Such a bird's-eye view will help you locate particulate emissions because of the discoloration of the roof around the stacks. Often, the discoloration is not apparent when the examination is made at close range.

TRADITIONAL APPROACHES

Following are descriptions and evaluations of several traditional approaches to odor control.

• **Scrubbers** are devices which bring odor-emitting gases into intimate contact with water. Types of scrubbers available to food processors include cyclone, impingement, submerged, fog, pebble bed, multidynamic, venturi, crossflow, and jet.

Removal of an odor by a scrubber is based on the solubility of the gas in water, the contact obtained between the gas and the water, and the time of contact. The advantage of the scrubber is that if it works, it is a simple solution to the problem.

Some disadvantages of scrubbers are: large volumes of water are required; water is used inefficiently and this usually gives rise to a waste water disposal problem; many types have high energy and maintenance costs; in general they are not versatile; most are inefficient.

• **Afterburners** are based on either thermal incineration or catalytic combustion. Contaminants are burned in air, oxygen, or in catalytic combustion units. Ordinary afterburners operate at temperatures ranging from 1500 to 2000°F, and the catalytic units from 1000 to 1500°F.

The main disadvantage of afterburners is the high energy requirement. The afterburner also may be a fire hazard, and it removes only combustible pollutants. Catalytic units require frequent replacement of expensive catalysts because the catalysts are frequently poisoned by the many compounds going through the system.

• **Gas Absorption** is a diffusion controlled gas-liquid mass transfer process. As such, it is dependent on diffusion rate, solubility, interfacial area, turbulence, and time of contact. These are, in design, spray towers, packed towers, or fiber cell columns.

This kind of process may have application to a single specific contaminant, or solvent recovery, in a continuous and unchanging process.

• **Gas Adsorption** is an expensive process which also has problems. One selected adsorbent may not work well on a wide variety of chemicals to be adsorbed. Then the adsorbent has to be retained on the adsorbent, and not stripped out by subsequent gas flows. The adsorbing reaction is generally exothermic, raising the temperature of the bed, and decreasing adsorption efficiency. The pores on the surface of the adsorbent rapidly plug up, collection efficiency declines, resulting in fluctuating performance of the unit.

The adsorbent must be regenerated by heating or steam distillation giving rise to new emissions which, too, must be controlled.

OTHER TECHNOLOGIES

Condensation and chemical reaction are used for food plant odor emission control less frequently than are the techniques described above. However, an examination of the characteristics of these two technologies shows that condensation and chemical reaction and a system which combines the two, offer advantages to food processors.

• **Condensation** reduces odors by removing condensible odors from gas streams. Because many food odors are so highly volatile and have such low boiling points, only condensers with refrigerated coils would be effective in removing all odors. High capital costs, high maintenence problems, and other factors preclude the use of refrigerated condensers. Thus, at temperatures of practical operation—the temperature of the available water—condensation is only a partial solution to odor emission.

While it does not end up with odor-free emission, condensation does decrease the quantity and variety of odors in the stack. It has another major advantage—heat recovery. Since food plants usually require considerable amounts of hot water for equipment cleaning, product cooking, and plant heating, condensation offers operation cost reduction through heat recovery.

• **Chemical Reaction** is a technique which transforms odoriferous gases into non-odorous form. All other techniques—with the exception of incineration—merely try to capture the odor. The main disadvantage of this technology is that it is very specific. Its specificity is also its major advantage—if the right reaction and reactants are chosen, odor removal is highly efficient.

Some of the reactions which can be used are oxidation, reduction, saponification, and esterification. Any of these reactions are effective with numerous compounds, and multiple reactions can be performed in series. In addition, chemical reaction also offers options in choosing the reactant—oxidation, e.g., can be performed with potassium permanganate or with sodium hypochlorite.

Table 1—SOME ODOR EMISSIONS *from selected food industries*

Industry	Process Source & Description
All food industry using process	Waste treatment—H_2S, variety
	Furnaces—SO_x
	Incinerators—Variety
	Normal handling—Evaporation, spillage—Variety
	Spray or other driers—Variety
	Chemical syntheses or decomposition reactions—Variety
	Flavor development reactions—Roasting, baking
	Pressing and extraction processes and solvent recovery
	Steam and vacuum distillation—Distillate and venting odors
	Cooking and retorting
	Grinding and blending—Particularly of spices and flavors
	Laboratory—Reactions performed in hoods; Lab animals, etc.
Fruits & vegetables	Retorting—Cooking
	Concentration—Aromas
Dairy & cheese	Fermentation—Cheesy, whey
Brewing & distilling, yeast manufacture	Fermentation—Yeasty, malty, alcohol
Baking	Fermentation, baking
Fresh meat, poultry or fish	Rendering, meat decomposition
Feed lot	Animal, wastes, alfalfa, drying pelletizing
Processed meat	Smoke
Flavor manufacturers	Variety
Thickener	Gum, gelatine—raw materials, cooking
Starches	Starch driers—reaction products
Fruit jams & jellies	Aromas
Beverages—coffee, cocoa	Roasting
Fats & margarine	Deodorization, hydrogenation
Animal food	Rendering, raw materials, cooking
Sugar	Beet mash or cane molasses
Soups	Cooking

CONDENSATION + CHEMICAL REACTION VS. OTHER SYSTEMS

Any system has to be well designed for a particular application. However, for many food plant applications the combination of condensation and chemical reaction has proven to be economical and effective.

The proper design of the condenser must provide for adequate condensation heat transfer surface, effective contact with gas impingement, and ease of cleaning. Many food plant emissions contain particulate entrainment which would rapidly foul a condenser not adequately designed.

The condenser removes condensables, particulates, recovers heat, and greatly reduces the volume of the gas. This decreased gas volume allows a greater reaction time to be achieved in the reaction chamber.

The chemical reaction chamber must provide a great deal of surface, and time for reaction between the gas and properly selected reactant. Other design factors that are important are recycling, pressure drop, avoidance of channeling or short circuiting, limitation of fouling, use of water and creation of a liquid disposal problem.

The spreading of the chemical reactant is performed in the packed tower by a cascading of liquid over packing; in spray chambers by conventional atomization; and in newer designs, by special surface extending techniques.

The surface area that is achieved in a traditional packed tower is 150 ft^2 or less per cubic foot of space; in a conventional design, spray chamber, 400 ft^2/ft^3; and in newer designs, up to 6,000 ft^2/ft^3 (Quad Corp., 1977).

The time available for reaction is a function of the gas flow rate and chamber volume. The gas flow rate is greatly decreased by the condensation stage. Gas flow is also a function of collection methods, which should avoid diluting concentrated odor streams, with large volumes of slightly odorous air. The chamber volume is primarily determined by design and materials of construction. Packed towers, which conventionally use only 40% of their volume for packing, are usually more costly than spray or newer design reaction chambers.

Recycling of reactant is common with low surface area systems, decreasing efficiency further due to recycling spent reactant, and often creating odoriferous by-products. High surface systems can use decreased reactant volume once-through.

The choice of the chemical reaction that eliminates the odors is most important. While single stage reactions are effective, in many cases, where extremely complex and varied odor constituents occur, multiple chemical reactions may be performed. The choice of applicable reactions are primarily oxidation, reduction, saponification and esterification. The specific reactant and concentration chosen allows additional flexibility of the system. For oxidation, for example, potassium permanganate, sodium or calcium hypochlorite, or hydrogen perioxide may be selected.

CASE STUDIES

• **Rendering Odors**—A large beef operation, slaughtering approximately 300 head per hour, was expanding production and rendering capacity, and therefore planned an expanded odor emission control system. Figure 1 illustrates the rendering process, and source of odors. Table 2 summarizes the comparative costs and operating characteristics of alternate systems to

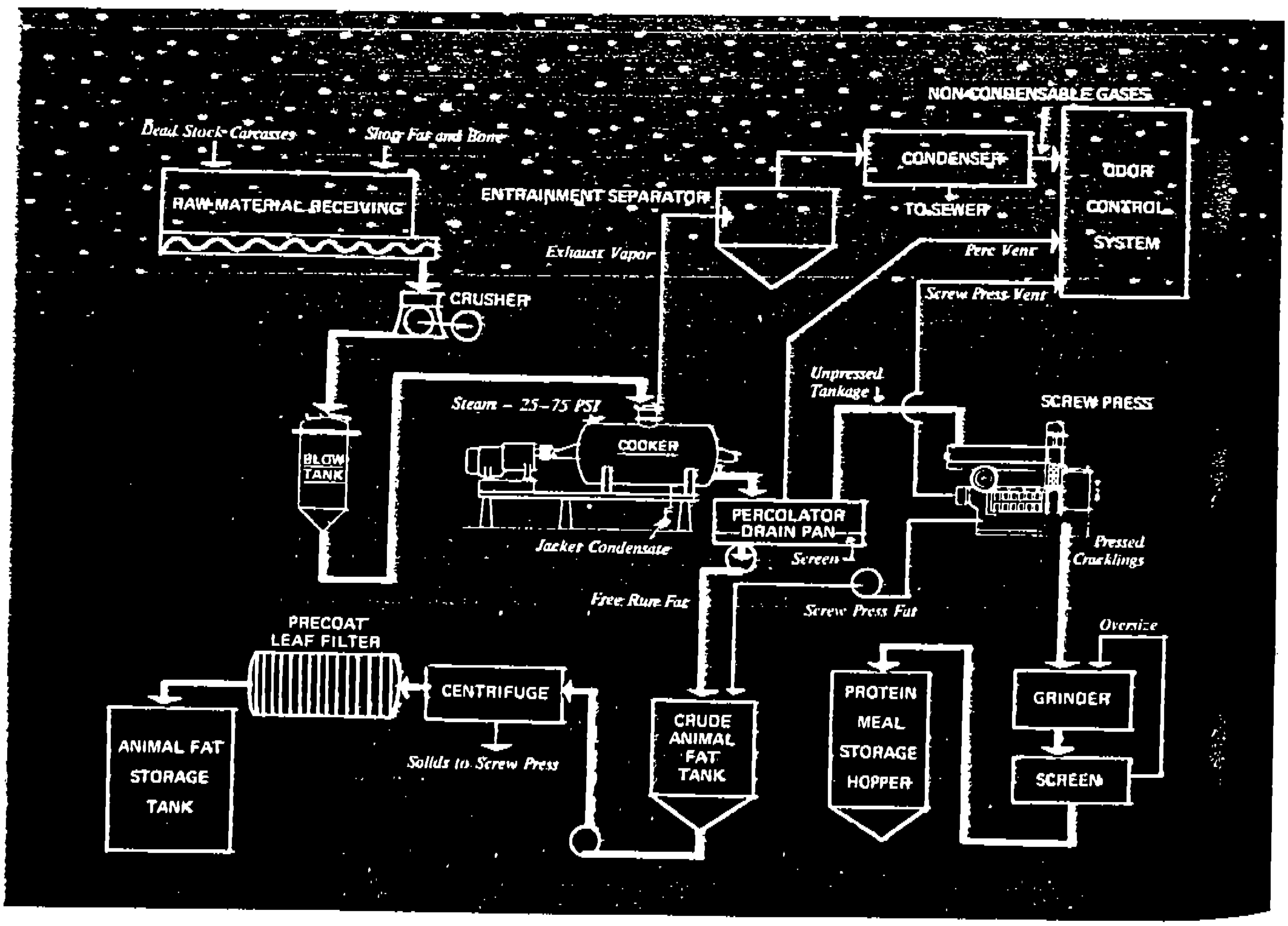

Fig. 1—**FLOW DIAGRAM** *of batch cooker rendering process (Source: Prokop, 1974)*

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Table 2—**RENDERING OPERATION**, *comparative costs and operating characteristics of alternate odor emission control systems*

Item	Venturi Scrubber & Packed Tower	Newer Design Condenser and Reaction Chamber
Capital Cost, installed	$600,000	$100,000
Operating Cost per year[a]	$64,000	$3,300
Recovered Heat Value per year	0	$400,000
Odor Elimination	~95%	> 99%
Surface Area—× 10[a] sq. ft.	17	9
Reaction Time—seconds	1	20
Fan hp	200	10
Water Usage, million gal./yr.	63.4	.4

[a]Basis: 10 hr/day; 300 days/yr; $3/million Btu

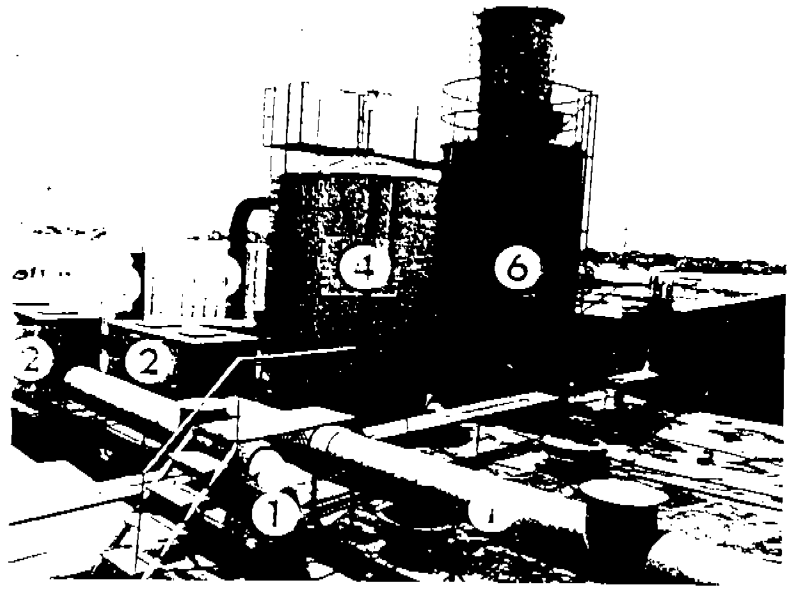

Fig. 2—**EMISSION CONTROL SYSTEM** *installed by Quad Corp. at Monfort Packing Company, Greeley, Colo. This "3-D" system consists of the following: (1) Ducts from rendering cookers which transfer vapors from rendering operation; (2) Chambers which collect vapors for conduction to heat transfer units mounted on lower roof; (3) Pipe which conducts heat from heat transfer unit; (4) Chemical reaction chamber; and (5) Exhaust for deodorized gases. Unit (6) is an obsolete scrubber which formerly served one rendering cooker.*

fulfill the expansion requirements obtained from competitive quotations and operating performance estimates. Figure 2 illustrates the newer design chemical reaction chamber, serving three cookers, adjacent to the obsolete water scrubber which served one cooker. Among the design differences between the traditional and newer techniques are: a greatly decreased gas volume as a result of condensation and thereby longer reaction time, heat recovery, elimination of odors through chemical reaction, decreased water and fan horsepower usage.

• **Flavor House Spray Drier**—This rather small spray drier, with an airflow of approximately 3,000 cfm, and a drying capacity of approximately 300 lbs. per hour of water, was used to dry a wide variety of flavors. Table 3 summarizes the comparative costs with competitive bids, on an equal installed basis, of incineration, a two-stage chemical reaction, and a Venturi and single packed tower combination. It is apparent how the energy cost of the afterburner eliminates it from consideration, even though it is effective in eliminating all odors. The Venturi-packed tower combination was rejected because it did not remove odors adequately. It was necessary to design a two-stage chemical reaction system to eliminate all of the varied odors. The use of heat recovery was uneconomic due to the small quantity of heat in the exhaust.

Table 3.—**FLAVOR HOUSE SPRAY DRYING OPERATION**, *comparative costs and operating characteristics of alternate odor emission control systems*

	After-burner	Venturi Scrubber & Packed Tower	Newer Design Condenser and Reaction Chamber
Capital Cost, installed	$50,000	$80,000	$30,000
Operating Cost per year[a]	$32,000	$13,000	$1,000
Recovered Heat Value per year	—	—	—
Odor Elimination	>99%	~95%	>99%
Surface Area—× 10[a] sq. ft.	—	.3	6
Reaction Time—seconds	—	1	20
Fan, hp	—	7.5	0
Water Usage, million gal./yr.	—	5.3	.4

[a]Basis: 10 hr/day; 300 days/year; $3/million Btu

CONCLUSIONS

Most food companies have odor emission problems from their plants, even where it has not yet been recognized as a nuisance. Odor emission problems can be eliminated, and in many cases, at an operating cost saving. Each odor emission problem has to be evaluated, and each solution designed for the particular application.

The buyer should be cautious in evaluating design alternatives, and compare effectiveness in odor elimination, operating costs, water usage and disposal, as well as initial capital costs.

REFERENCES

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