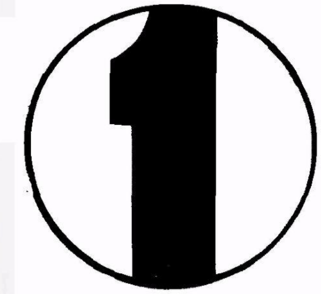
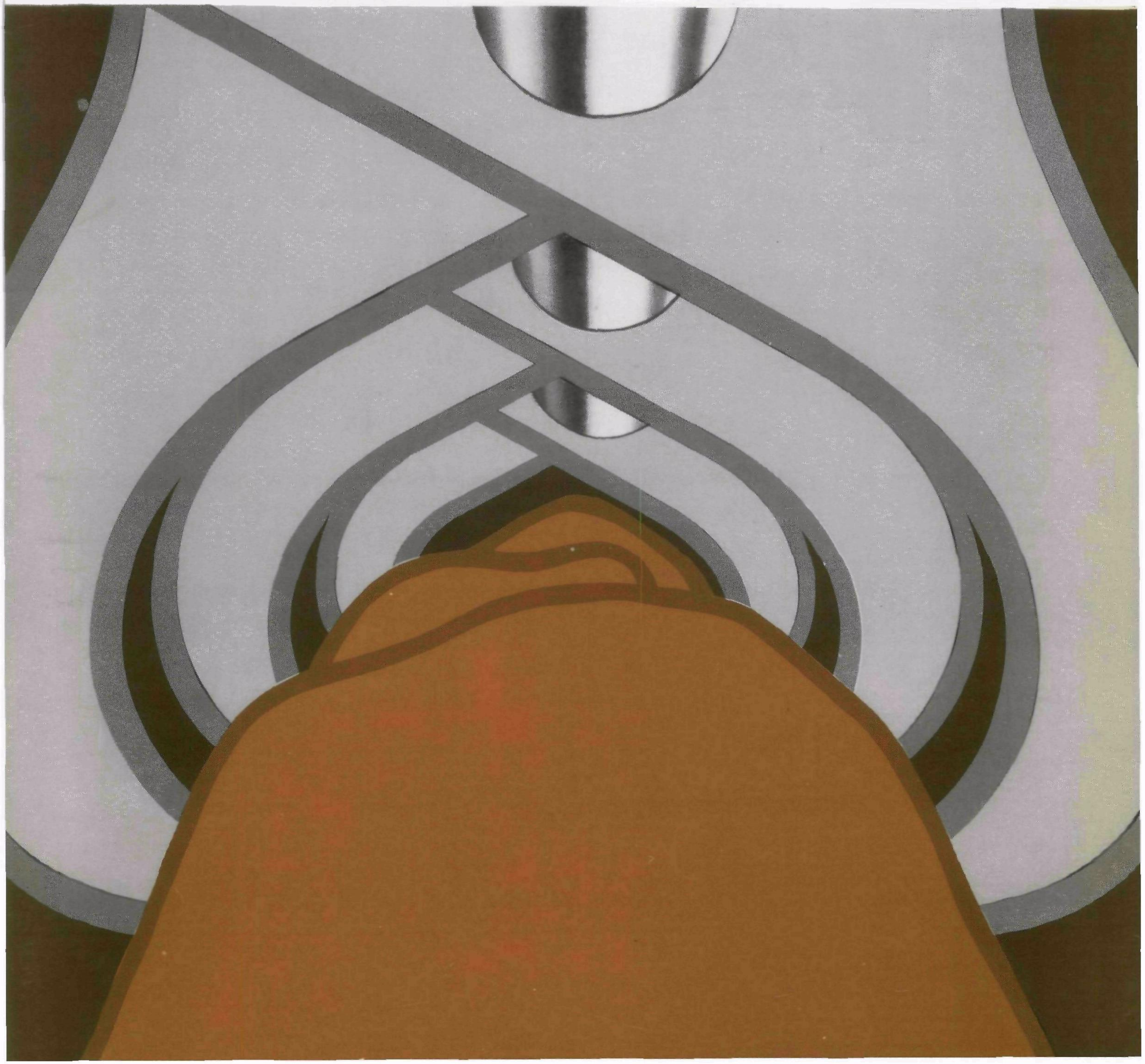


In-Process Modifications and Pretreatment

Upgrading Meat Packing Facilities to Reduce Pollution

EPA Technology Transfer Seminar Publication



IN-PLANT MODIFICATIONS AND PRETREATMENT

Upgrading Meat Packing Facilities to Reduce Pollution

ENVIRONMENTAL PROTECTION AGENCY • Technology Transfer

October 1973

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PREFACE

This presentation is particularly oriented toward owners, managers, superintendents, and engineering and operating staffs of meat packing facilities. No attempt is made to include meat processing at locations apart from killing plants (e.g., dogfood manufacturing, sausage plants), although much of the information can be applied to such facilities.

While it is recognized that many pretreatment systems include biological systems to condition meat packing wastewaters for discharge to municipal systems under municipal regulations, these treatment methods are not covered in this study since they are discussed in "Waste Treatment."

Disposal of solids—such as recovered hog hair, screenings, paunch manure, and floatables and settled solids from grease basins—is beyond the scope of this study, but prevention of discharge of some types of solids and removal of other materials from waste streams are included.

At each seminar a special panel discussion on odor control was held. One of these sessions was taped and the proceedings are included as chapter VI of this publication.

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CONTENTS

Chapter I
INTRODUCTION

BACKGROUND

The importance of in-plant modification to reduce pollution (ch. II) needs no emphasis. It is a simple economic fact that conservation and in-plant waste saving, along with water recycle and reuse, must be considered before any plant undertakes to build pretreatment facilities for discharge to a public sewer, pays a municipal charge for wastewater treatment, or builds a complete treatment plant for discharge to a watercourse.

The importance of chapter III, "Pretreatment of Meat Packing Wastewaters for Discharge to Municipal Systems," becomes evident in the light of a 1967 survey showing that 70 percent of the wastewater from the meat packing industry was discharged to municipal facilities.[1] Although recent data are lacking, it seems likely that this percentage may now be slightly lower with the continuing trend toward decentralization into small plants discharging into independent lagoon systems in semirural areas.

Where possible, this study deals with waste conservation in existing plants. It will be evident, however, that many of the methods discussed are applicable largely to new plants and could not readily be retrofitted into existing plants because of space limitations and layout. Thus, each manager and engineer can use the study as a guide and checklist, evaluating each waste conservation concept as it applies to his particular plant.

Chapter III discusses the elements of equipment that make up a pretreatment plant, whether it be an expansion of existing pretreatment facilities or an entirely new system.

The meat plant owner, operator, or engineer needs neither a preliminary discussion of the processes in the industry nor a separate set of recommendations for beef kill and hog kill. Accordingly, it is assumed that the reader is conversant with industry practices. Figure I-1, however, presents a packinghouse flow chart for reference.

REGULATORY CONSIDERATIONS

Federal

This discussion is limited to Federal regulations relating to the subject matter of this study, and thus does not include a discussion of permits for discharge to watercourses.

Public Law 92-500, amending the Federal Pollution Control Act, was passed by Congress on October 18, 1972, and contains several points of direct interest to industry. In providing grants for new or expanded municipal treatment plants (now amounting to 75 percent of the construction cost), the Federal Government requires that the municipality "has made provision for the payment . . . by the industrial user of the treatment works, of that portion of the cost . . . allocable to the treatment of such industrial wastes . . ." for which he is responsible (sec. 204(b)(1)).

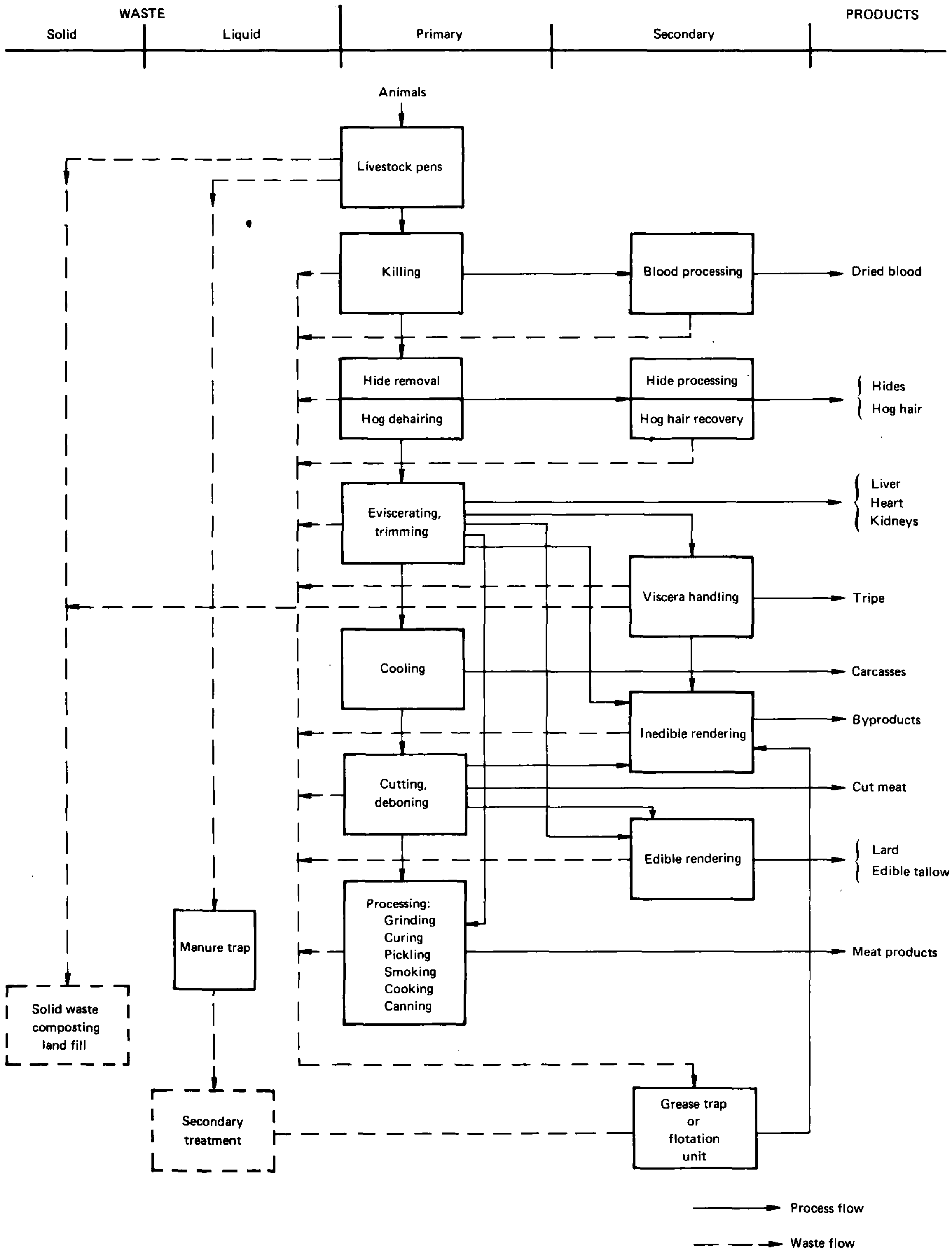

Figure I-1. Flow chart for packinghouse. (From North Star Research and Development Institute, "Final Report, Industrial Waste Study of the Meat Products Industry," EPA (Contract No. 68-01-0031.)

The law also provides that, by April 16, 1973, the EPA shall

> "issue guidelines applicable to payment of waste treatment cost by industrial and nonindustrial recipients of waste treatment services which shall establish (A) classes of users of such services, including categories of industrial users; (B) criteria against which to determine the adequacy of charges imposed on classes and categories of users reflecting factors that influence the cost of waste treatment, including strength, volume, and delivery flow rate characteristics (surges and maximum flows) of wastes; and (C) model systems and rates of user charges typical of various treatment works serving municipal-industrial communities."

Thus the EPA will be involved in the rate structure or formula developed for sewage charges for all municipalities (including sanitary districts) where grant funds are allocated, in order to insure repayment of the Government's cost in proportion to the cost of the treatment works attributable to the industry's wastewater discharged to the municipal sewer. The following is excerpted from *Federal Guidelines—Equitable Recovery of Industrial Waste Treatment Costs in Municipal Systems:*[2]

Quantity or quality formulas based on total cost or average unit costs: This method of cost allocation or derivation of industrial charge is computed by several forms of the generalized formula:

$$C_i = v_o V_i + b_o B_i + s_o S_i$$

where C_i = charge to industrial users, dollars per year

v_o = average unit cost of transport and treatment chargeable to volume, dollars per gallon

b_o = average unit cost of treatment, chargeable to BOD, dollars per pound

s_o = average unit cost of treatment (including sludge treatment) chargeable to suspended solids, dollars per pound

V_i = volume oi wastewater from industrial users, gallons per year

B_i = weight of BOD from industrial users, pounds per year

S_i = weight of suspended solids from industrial users, pounds per year

Note: The principle applies equally well with additional terms (e.g., chlorine feed rates) or fewer terms (e.g., $v_o V_i$ only).

The terms b_o and s_o may include charges (surcharges) for concentrated wastes above an established minimum based on normal load criteria.

Inasmuch as it is an objective of the Guidelines to encourage the initiation and use of user charges, this general method of allocation is both preferable and acceptable.

Since this guideline was published before enactment of the act, it serves only as an indication of possible procedures. No guidelines pursuant to the act have been developed at this time.

Pretreatment before discharge to publicly owned (municipality, sanitary district, county, etc.) treatment works also is regulated under the act. Section 307(b)(1) requires that the EPA, by April 16, 1973,

> "publish proposed regulations establishing pretreatment standards for introduction of pollutants into treatment works . . . , which are publicly owned, for those pollutants which are determined

not to be susceptible to treatment by such treatment works or which would interfere with the operation of such treatment works. Not later than 90 days after such publication, and after opportunity for public hearing, the Administrator shall promulgate such pretreatment standards."

The act allows a maximum of 3 years for compliance by industry, and also provides for revision of these standards as new technology warrants.

The limits may be anticipated to be in two general categories.

- Prohibited items (such as ashes, hair, whole blood, paunch manure, and similar materials untreatable in municipal plants)

- Maximum concentrations of such items as biochemical oxygen demand (BOD), suspended solids, and other constituents that, *in excess*, could interfere with the operation of the municipal plant

Many municipalities will use such maximums in their structure of charges, figuring a volume cost per 1,000 gallons per month (perhaps on a sliding scale similar to water billing or, more conveniently, a definite multiplier of the municipal water bill). To this volume cost, surcharges are added for BOD, suspended solids, grease, and possibly other pollutional ingredients at a determined rate in cents per pound of each such pollutional ingredient beyond a certain basic concentration, the base being representative of the concentration of domestic sewage.

State

This discussion will be limited to the State's role in in-plant conservation and pretreatment before discharge to public sewers. Recycling and reuse of water, and any other major in-plant changes, should be reviewed with the State meat inspection agency if the plant is under State, rather than Federal, inspection.

Approval of plans for pretreatment of wastewaters before discharge to public sewers may be a requirement under the State regulations for approval of plans for sewage treatment. States differ on this point.

In some States, the plant may also be required to have a State-licensed wastewater-treatment-plant operator for such pretreatment facilities.

Municipal ordinances relating to wastewater generally are reviewed by the State stream-pollution-control authority. Thus, ordinances and regulations regarding industrial wastewater and charges and surcharges most likely will be reviewed by the State before passage.

If the city has not passed the legislation required by the EPA for a Federal grant for sewage-treatment construction, the State (which allocates these funds) may advise EPA to withhold a portion of the grant until all requirements are met.

When a new plant is planned for connection to a public sewer, and such connection substantially will increase the flow or pollutional characteristics of wastewaters reaching the municipal wastewater-treatment plant, the agency owning the sewer is required by Federal law to advise the State of such change.

Municipal

Municipal ordinances and regulations that are less stringent than those set up under the Federal act, discussed earlier, will require alteration to conform; but if they exceed the Federal standards, they need not be reduced unless the city elects to do so.

Existing municipal ordinances and regulations covering discharge to the public sewers vary widely. A large number of cities use, as a guide, the so-called Model Ordinance, published as part of *Manual of Practice No. 3* of the Water Pollution Control Federation. Article V of the Model Ordinance contains an extensive list of limiting characteristics applicable to meat packing wastewaters discharged to public sewers.[a]

Municipal ordinances generally cover the subject under two headings, limitations and surcharges.

Limitations. *Prohibition of objectionable matter:* Various minerals, toxic materials, and waste characteristics and materials that are difficult to treat are excluded. The following examples are typical:

- The Metropolitan Sanitary District of Greater Chicago includes the following exclusions on ingredients that may affect packing plant effluents:
  - Noxious or malodorous liquids, gases, or substances that either singly or by interaction with other wastes are sufficient to create a public nuisance or hazard to life, or are sufficient to prevent entry into the sewers for their maintenance and repair
  - Solid or viscous wastes that cause obstruction to the flow in sewers or other interference with the proper operation of the sewerage system or sewage treatment works, such as grease, uncomminuted garbage, animal guts or tissues, paunch manure, bone, hair, hides, and fleshings
  - Waters or waste containing substances that are not amenable to treatment or reduction by the sewage treatment process employed, or are amenable to treatment only to such degree that the sewage treatment plant effluent cannot meet the requirements of other agencies having jurisdiction over discharge to the receiving waters
  - Excessive discoloration
- Other cities use similar limiting clauses in their ordinances, often copied from the *Manual of Practice No. 3*, from which the above wording was adapted in part.

Concentration of pollutional characteristics: The Ordinance of the Metropolitan Sanitary District of Greater Chicago provides no top limits for BOD or suspended solids, but does include surcharges for these items (see "Surcharges"). It does, however, limit temperature to a maximum of 150° F (65° C) and fats, oils, or greases (hexane solubles) to a maximum of 100 mg/l. These limits are included in many municipal ordinances. Other cities may limit BOD to possibly 300 mg/l and suspended solids to 350 mg/l, more or less. Catchall clauses also are common; for example, "The Town Board of Trustees is authorized to prohibit the dumping of wastes into the Town's sewage system which, in its discretion, are deemed harmful to the operation of the sewage works of said Town."

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[a]The "Regulation of Sewer Use," *Manual of Practice No. 3*, is available at $1.50 ($1 to Federation members) from the Water Pollution Control Federation, 3900 Wisconsin Avenue, N.W., Washington, D.C. 20016. A 15-percent quantity discount is available in lots of 12 or more copies.

Surcharges. The Metropolitan Sanitary District of Greater Chicago charges 2.1 cents per 1,000 gallons, 1.4 cents per pound of BOD, and 2.4 cents per pound of suspended solids, after deducting the first 10,000 gal/day (and the BOD and suspended solids it would contain). Also deducted are the sewer district tax (a property-type tax) plus 4 mills per day per employee, an allowance for sanitary sewage discharged during the working day.

Most of the simpler sewage billing systems are based on the water use, ranging from about 50 percent to as high as 125 percent of the water billing, with maximums for BOD, suspended solids, grease, and sometimes other ingredients. These are basic sewer charges applicable to all users—domestic, commercial, and industrial—and are not classified as surcharges unless they include escalation for BOD, suspended solids, grease, and so forth, and possibly flows, in excess of a "domestic" base. Thus the surcharge portion of the ordinance might be similar in structure to the Chicago ordinance, but with a charge for flow in *excess* of a base, and a charge per pound of ingredients *above* a base represented by discharge from a single residence.

Also see the Federal guidelines discussed earlier.

In general, the new Federal act may radically modify existing municipal ordinances and regulations. It should also be noted that recycle and reuse of used water must be checked by the U.S. Department of Agriculture and by any other agency having jurisdiction over product sanitation.

Chapter II

IN-PLANT MODIFICATIONS TO REDUCE POLLUTION

WASTE-CONSERVATION PRACTICES IN THE MEAT PACKING INDUSTRY

Except for very small slaughtering plants, most plants recover blood, screenable solids, and grease by various in-plant systems and devices. Many small packers without blood-drying facilities or inedible-rendering departments recover such materials for local tank truck pickup operated by specialized byproducts plants in the area.

The quantity of water used varies widely, based on waste-conservation practices, blood- and solids-handling methods, and the amount of processing done in the plant. This quantity may range from about 0.5 to 2 gal/lb live weight killed (LWK).

The degree of wastewater conservation, recycle and reuse, and solids and blood recovery in each individual plant depends on many factors:

- Age of the plant
- Views of management
- Whether markets or final disposal facilities for recovered blood, solids, and grease are readily available
- Market prices of the recoverable materials
- Local regulations regarding effluent quality and surcharge costs for plants discharging to public sewers
- The first cost, and operating costs of independent treatment if the packer discharges to a watercourse

The low market price for recovered inedible grease in some localities has forced many packers to dispose of it as feed-grade grease. If the meat packing plant is located conveniently near a soap plant, the possibilities of an improved price will provide special incentives for grease recovery. Variations in economics in disposing of the solids and concentrates such as paunch manure, blood, hair, casing slimes, and concentrated stick (in wet rendering) inevitably affect the diligence with which these pollutional solids are kept out of the sewer.

The limitations and surcharge regulations for wastes discharged to city sewers, however, or the cost of complete treatment if the plant discharges to a watercourse, must be evaluated carefully to establish the level of waste conservation appropriate to the packing plant. For example, a plant discharging to its own anaerobic-aerobic pond system may find that some floatable inert solids, such as stockpen bedding, can improve the insulating scum blanket on the anaerobic lagoon. In this case neglect in recovery of such materials would not be important. On the other hand, a packing plant in Springfield, Mo., faced with a municipal waste-treatment charge of $1,400 a month, modified its production processes (including solids recovery) so that the monthly payment dropped to $225.

In processing and in quality control, the meat industry finds water an essential tool to help cleanse the product and to convey and remove unwanted materials. But in wastewater handling, water becomes a problem—a *diluter* that flushes and dissolves organic matter and carries it to the sewer. Wastewater treatment is basically nothing more than a processing system to separate the organic and inorganic matter from the water that collected it.

The goal of every wastewater engineer is to remove organic solids "dry," without discharging to the sewer, and then use an absolute minimum of water for the essentials of sanitation. The nearer this goal, the simpler becomes the wastewater problem. This goal provides the pattern in waste conservation in the plant, and can be summarized briefly in the following axioms:

- Use water wisely—only enough to get the job done.
- Keep waste solids in bulk whenever possible, for disposal as a solid or as a concentrated sludge, without discharging to the sewer.
- Clean with high pressure and minimum water volume (small hoses). Use the right detergents in the right proportions to clean well with minimum rinsing.
- Recycle water as much as possible, within the limits of U.S. Department of Agriculture regulations. Some reconditioning, such as cooling or screening, may be necessary for recycling in some instances.
- Use the minimum pressure and volume for washing product, consistent with quality control. High pressure in washing product may drive soil into the product and also wash away valuable edible protein and fat.
- Control volume, temperature, and pressure automatically. Dependence upon manual regulation can lead to waste.
- Use valves that shut off automatically when the water is not needed. For example, photoelectric cells are used in Japan to turn water on when product is in a washing position.
- Study each process independently. General rules alone will not do the job.

SEGREGATION OF WASTE STREAMS

In meat packing, it has been common practice to provide separate sewer systems for grease wastes, nongrease (variously termed "manure" sewer or "red" sewer), clear waters from chilling, condensing, and cooling operations, surface and roof water (surface drainage), stockpen wastes, and sanitary wastes. For new plants, however, further segregation often is desirable in order to permit removal of pollutional ingredients before the wastewaters mingle with other plant waters. Screening equipment can be smaller and can be designed for the special solids present. In some cases, such segregated waters may be sufficiently dilute to use for recycling.

In the interests of dry or semidry manure separation, a separate manure sewer should be provided in new plants for all sources of manure. This waste can be pretreated by screening, followed by dissolved air flotation. The floated solids can be analyzed for fats and wet rendered if warranted.

The grease sewer should receive only those wastes that contain grease. If the color of the rendered tallow is a factor, special diligence must be exercised that all manure-bearing wastes be kept out of the sewer. The settled solids should be discharged over a screen, dried, and used in feeds, if possible. These solids contain a significant amount of grease. Basically, the grease sewer should receive wastes from boning, cutting, edible and inedible rendering, casing washing (after manure and slime have been removed), canning, sausage manufacturing, slicing, prepackaging, smoking and smoked meats hanging, cooking, tank car loading and washing, carcass coolers, lard and grease storage areas, equipment washrooms, pickling areas, and the like.

The conventional nongrease sewer receives wastes from hog scalding, dehairing, tripe washing, chitterling washing, and kill drains up to and including the polisher. It also receives the flow from manure recovery systems when a *separate* manure screen is not provided.

Hide-processing waters commonly are recirculated with or without screening for solids reduction. If these waters must be dumped, they should be screened separately and then discharged to the nongrease sewer.

Vapors from cooking and rendering operations can be cooled and condensed through heat exchangers and recycled to driers, or sent to the grease sewer.

All clear water (jacket-cooling water, air conditioner water, steam condensate, and chill water) should be separated carefully for reuse.

Curing pickle (undiluted) has a very high BOD and should be reused whenever possible. Runoff pickle from processing should be caught in recycling pan systems as part of the injection equipment. In a recent study, it was found that only 25 percent of the pickle produced was retained in the product, the rest was lost by general leakage and spilled from the injection machines. The BOD of pickle varies, but the dextrose alone has a BOD of about 660,000 mg/l.

Sanitary wastes are, of course, discharged directly to the city sewer or to a separate treatment system, and should not enter any pretreatment elements.

PLANT WASTE-CONSERVATION SURVEY

The first step in waste conservation is a well-organized and well-executed waste-conservation survey, backed by management. The following elements would be part of the basic survey.

First the engineer should collect data on the volume, nature, and general facilities of the business. If he is a company employee, he already has this information. In addition, he should know all plans for future construction. He should attempt to develop a 10-year forecast of business. If the wastewaters discharge to a city sewer, he should know something about population trends in the area, the possibilities of industrial growth, and whether such growth will add load to the municipal plant. Whether the wastewaters discharge to a public sewer system or to the packer's private treatment plant, the engineer should be familiar with the system and the sewage treatment plant and with the requirements for the receiving stream.

The approach to wastewater control need not be complicated or expensive. The principal effort should be applied toward preventing product (and contaminants) from entering the waste stream and reducing water use to a minimum. High waste-load areas should be probed first. Accurate sampling, chemical analysis, and flow measurements need not be performed initially, but can be deferred until after the gross problems have been solved.

Since most suspended solids in meat wastewaters are organic, their removal results in a reduction of BOD. Suspended solids concentrations (after screening) are a rough measure of BOD and can be measured easily and quickly. Dissolved solids can be measured with a conductivity meter. Red color indicates the presence of blood, a very large contributor of BOD. A simple jar test will give some information. During the initial phase of in-plant waste control, approximate figures are sufficient. Flows must be measured at the time of sampling. Flows can be estimated, or it is simple to catch the flow in a pail or 50-gallon drum for a period of time. The gallons per minute can be calculated. In some instances it may be necessary to break into a sewer line or disconnect a pipe to obtain a sample or flow measurement.

Solids per unit volume, with associated water consumption, will give a measure of the pounds of organic wastes generated. Problem areas then can be studied for methods of control. In many cases, a small outlay of money will effect substantial waste control. Records should be kept to follow progress.

Table II-1 lists waste-load ranges to provide a rough guideline. These ranges are broad because they include small and large operations—some small plants with no inedible rendering and no blood recovery, and others with a broad line of meat processing, with inedible rendering and blood recovery.

Table II-1.—*Typical plant waste generated per 1,000 pounds live weight kill, all species*

BOD	4 to 18 pounds
Suspended solids	3 to 17 pounds
Grease	1.5 to 12 pounds
Flow	600 to 2,000 gallons of water

The following equation can be used to convert laboratory analyses and flow to pounds per 1,000 pounds LWK:

$$\text{Pounds pollutant per 1,000 pounds LWK} = \frac{\text{flow in gallons} \times 8.34 \times \text{mg/l}}{\text{1,000 lb LWK} \times 1{,}000{,}000}$$

where mg/l = milligrams per liter from laboratory data.

Anyone interested in typical flow, BOD, suspended solids, and grease from various processing operations will find useful data in *Industrial Wastewater Control.*[3] These values vary widely from plant to plant; thus, it will be most useful to cite methods of correction without attaching specific values to each process or process change. The order of priorities for in-plant waste conservation will vary depending on the results of the waste-conservation survey in each individual plant.

RECOVERY OF SOLIDS AND BYPRODUCTS

Blood

Blood has the highest BOD of any liquid material emanating from meat processing. It has an *ultimate* BOD (approximately 20-day) of 405,000 mg/l.[4] Customary analytical methods for 5-day BOD (BOD_5) are not sufficiently accurate in these high ranges, but are estimated to average from 150,000 to 200,000 mg/l. Considering that one head of cattle contains approximately 49 pounds of blood, the BOD_5 of blood from a single animal is about 10 pounds, as against about 0.2 pound BOD_5 discharged per person per day.

Thus, if the blood from a single animal killed in a day is discharged to the sewer, its pollutional load would be equivalent to that of 50 people. Clotted blood (about 70 percent of the total) has a BOD (ultimate) of about 470,000 mg/l, while the liquid portion is about 200,000 mg/l.[4] Comparing these figures with the ultimate BOD of domestic sewage, about 300 mg/l, it is evident that blood conservation pays.

The curbed bleeding area that discharges to the blood tank should be as long as possible, and the blood should be squeegeed to the blood tank before the valves are switched to drain to the sewer for the cleanup operation. The floor and walls then should be cleaned with a minimum of water by use of small-diameter hoses. If the water used in the first rinse is held down to 30-50 gallons, it can be discharged to the blood tank as an added conservation measure. The additional cost of evaporating this quantity of water will, in most cases, be far less than the cost of treating it as wastewater.

Water is sometimes mixed with blood to facilitate transportation in pipes. The evaporation of this added water in the drier adds expense and often can be eliminated if the drain from the bleeding area to the blood tank is large enough and the blood tank is located to permit a straight drop into it. If the blood is pumped to the tank, the piping layout should be checked. If sewer alinement cannot be improved to prevent drains from clogging, decoagulating electrodes can be installed to prevent coagulation (see app. A). Troughs to catch and convey blood should be pitched and curved to facilitate squeegeeing before washing.

Blood-processing methods are important in waste conservation. For lowest losses to the sewer, continuous driers are most common, using a jacketed vessel with rotating blades to prevent burn-on. Continuous ring driers are also popular. They produce a relatively small amount of bloodwater that, in small plants, usually is discharged to the sewers. The bloodwater can be clarified further by discharging it through a small settling tank. This waste-conservation problem warrants further study. The older steam coagulation systems are more serious problems in waste conservation, because a substantial amount of fines can be lost when the coagulated blood is screened. A combination of paunch manure solids and bloodwater can be cooked to produce a hydrolyzed hair stick, but the process economics should be explored before a packer embarks on such a project.[5] Casing slimes can be added to the blood drier if desired, or can be dried with other product in conventional inedible dry rendering.

Paunch Manure

Paunch manure is either wet or dry dumped for recovery of tripe. Wet dumping consists of cutting the paunch open in a water flow, discharging to a mechanical screen, and thence to the manure sewer. This washing action carries a large fraction of the BOD from the paunch waste solids into the water phase. Paunch solids are about 75 percent water, weigh about 50 to 60 pounds per animal, and have a "dry dump" first-stage BOD of over 100,000 mg/l (BOD_5 slightly less). Eighty percent of this BOD is soluble.

Dry dumping consists of dry discharge of the manure solids down a chute to an inedible area for ultimate disposal as a waste solid or for blending to produce a marketable solid. After dry dumping, fines are removed by washing and are discharged into the manure sewer.

Stomach and peck contents may contain undigested grains that contain proteins and fats. An investigation may disclose that these materials can be routed directly to a drier, unopened, if the resulting product is acceptable as an ingredient in the end product (see also discussion in "Hasher-Washer Screen").

Casing Saving

Casing-saving operations contribute substantially to pollution. Waste from the deslimer should be passed directly to cookers in inedible rendering or dried with the blood. A small catch basin in the immediate casing area will recover sizable amounts of good-quality fats. Water should be kept at a minimum. Sprays should be checked for efficiency in volume of water used, proper design, proper direction, and maximum spacing.

Stockpen Wastes

Stockpen wastes are high in nutrients and should be segregated in a manner to allow alternative methods of disposal. Pens should be dry cleaned and the waste should be hauled away for land disposal.

Usually runways and pens are hosed down periodically. Consideration should be given to segregation of this strong liquid waste for disposal by trucking or piping for disposal directly on farmland, within the limits of regulations regarding land disposal.

Scraps and Bone Dust

Plant operations in cutting and trimming should be examined carefully for opportunities to intercept waste solids before they enter the sewer. Scraps and liquids from the hog-neck washer should be caught in a container directly beneath the washer. Some form of grease trap can suffice. Collected contents should be routed direct to rendering. Bone dust from sawing operations is an important source of pollution and contains a high concentration of phosphorus. Bone dust is of fine texture and when diluted with water is difficult to recover. It should be recovered intact by catching directly in containers, or by sweeping up and hauling to the inedible rendering department.

Hide Curing

Hide-curing operations are becoming increasingly involved as segments of tanning operations are transferred from tanneries to beef-slaughtering plants. During winter months, a single hide can contain 60 pounds of attached lumps of manure, mud, and ice. In addition, salt, caustic, acids, and fleshing waste enter the sewage stream. The wash water should be recycled, or retained for separate treatment (usually screening) if considerable volumes are involved.

Disposal of Tank Water

If lard is wet rendered, or if any inedible wet rendering is in service at the plant, the disposal of tank water may be a problem (BOD about 22,000 mg/l). In processing lard by low- or medium-temperature continuous rendering, one process uses about 150 pounds of water (as steam) per 230 pounds wet-rendered product. There is, however, a market in some areas for 50- to 60-percent edible stickwater produced by evaporating this tank water. In another process, less water is used and it goes out with the cracklings. In contrast, inedible tank water is evaporated and is commonly blended with animal feed as inedible stickwater. Under no circumstances can this high-BOD waste be discharged to the sewer. In some cases, the tank water can be trucked to a central processing plant for evaporation. It can also be dried with inedible solids.

WATER AND PRODUCT CONSERVATION

Water conservation is an essential part of an in-plant wastewater-control program. It has been shown that packing plants using the most water per animal generate the most waste per animal. Excessive washing, especially with hot water, removes juices and tissues from product and flushes them into the sewers. Water use can be reduced at many locations.

The viscera-pan sterilizer and the final carcass washer are large water users. These washing operations should be modified so that when the carcass chain stops the water automatically shuts off. This modification can be made using solenoid-operated valves under control of the conveyor-chain motor starter. The viscera-pan sterilizer uses large amounts of 180° (F) water. The sterilizer often runs continuously during the workday (and during the cleanup period). Thought should be given to engaging the services of those skilled in spraying techniques—not only to design the sterilizer for economy in water use but also to design cleaned-in-place (CIP) cleaning systems for the viscera pans (see "Automatic CIP Cleaning"). The sprays on the final carcass washer should be checked for proper spacing, direction, shape of spray, pressure, and water consumption.

SELECTION AND MODIFICATION OF PROCESS EQUIPMENT FOR WASTE CONSERVATION

Chitterling Washers

Chitterling washers can be improved by fitting them with limiting orifices and spray nozzles rather than drilled pipes. Water consumption can be reduced from 130 to 70 gal/min by proper design of sprays and control of water and pressure on these units.[3]

Hog-Casing Cleaning Machines

These machines can be modified to recover the slime from the stripper, which amounts to 0.2 pound of dry solids per hog.[3]

Scalding Tub

A means of slow drainage of the scalding tub and separate removal of the sludge will reduce the waste concentration materially. It is reported that 100 hogs, at maximum slaughter rate, produce 11.2 pounds of BOD and 23.5 pounds of suspended solids.[3] It may be expected that as much as 30 percent of the BOD and 80 percent of the suspended solids will settle in the tub. The scalding tub can be fitted with a perforated riser pipe in the drain, extending about 6 inches above the floor of the tub. The residual sludge can then be squeegeed through a 12-inch-square sluice gate at tank-floor level and discharged to a truck for disposal as waste solids.

Edible Rendering

Low- or medium-temperature continuous edible rendering can be accomplished with a limited amount of water discharged to the sewers. This factor should enter the cost analysis when a new system is purchased. See "Disposal of Tank Water," discussed earlier.

Hasher-Washer Screen

It is not uncommon to eliminate the hasher-washer screen. The entire product can be dry rendered if the quality of the rendered product is not a sensitive consideration. The added bulk in dry rendering is small when balanced against increased yield and the elimination of the hasher-washer screen drainage (see discussion of "Paunch Manure").

Automated CIP Cleaning

For daily cleaning, consideration should be given to automated cleaning of viscera pans, tank trucks, continuous rendering systems, conveyor tables, piping, cookers, and driers. Systems that will conserve water and labor are available from detergent manufacturers.

Heart Washers

A considerable amount of raw water is used to chill hearts in modern heart washers. A study of this operation may prove that the use of refrigerated chill water will conserve water and result in a better shelf-life product.

Offal Areas

In the offal areas, continuous streams of water sometimes are used to aid in moving product down chutes. Special sprays or redesign of chutes will reduce water use at these points. Any sprays made up of a pipe with drilled orifices are usually inefficient and should be replaced with engineered sprays, designed for minimum water consumption, proper pressure, and maximum effective coverage. Master shutoff valves can be used to shut groups of sprays during rest periods. Ball-type valves are effective for this service.

Knife and Sterilizing Boxes

Knife and sterilizing boxes often are operated with excessive amounts of water and temperature. The use of electric temperature-controlled knife boxes should be considered—particularly in coolers where steam causes condensation problems and refrigeration losses.

Sanitary Facilities for Personnel

Press-to-open valves (foot or knee operated) should be used on all lavatories. Drinking fountains should not run continuously. Refrigerated water fountains will conserve water.

Animal Drinking Water

Animal drinking water should be minimal, but consistent with satisfactory yields. In the past, it was believed that abundant drinking water was necessary for good yields; consequently, drinking troughs flowed continuously. Recent information indicates that animals can go 1 or 2 days without water and show negligible yield reduction. Timeclock control of the master valve for drinking water supply, programed for 1 minute on and 4 minutes off, will reduce water use by 80 percent.

Raw Water Recycle and Blowdown Water

Once-through raw water in refrigeration condensers and compressor cooling jacket water are expensive. Such water should be either reused in plant processes or recycled through heat-exchanging devices—cooling towers or evaporative condensers. Evaporative condensers are usually the most feasible.

If possible, blowdown water should be returned to the soil because of its high mineral content. Generally, regulated quantities can be discharged to the city sewer directly without violating limiting regulations. Boiler blowdown water is "soft water" and can be reused in cleanup operations or in fabric wash machines. Some experimentation is required to develop a proper blend of plant water supply with the blowdown water, particularly relating to temperature.

Manual Washing

Manual washing of meat and offal products can be improved. Washing operations requiring under-the-spray time of less than 50 percent should have press-to-open sprays. On-site observations have disclosed many hand-washing operations (particularly offal) with time under the spray of not more than 10 percent. Sprays should not flow unattended at work tables. In addition to press-to-open spray valves, efficient redesign of spray heads will improve product cleaning and conserve water. Pressures and volume of flow should be controlled with pipe restrictions or locked valves to establish a minimum consistent with quality results. Photoelectric cells could serve well as automatic control.

Dry Rendering

In dry-rendering systems, many plants mix raw cold water with cooking vapors from rendering driers to condense vapors and reduce odors. This mixture is discharged to the sewer.

A recent study of a typical operation disclosed that each drier used 120 to 130 gal/min of water, and the mixture contained 118 mg/l of BOD and 27 mg/l of grease. It is likely that the BOD and grease were carried over from overloaded driers. The water consumption represented 40 percent of the entire plant water. A heat exchanger was recommended for direct water condensing to eliminate the cooling-water loss. Heat extracted from the vapors can be removed by means of a cooling tower or returned to the plant hot water system. Commonly, cooking operations closely follow killing operations; thus the recovered heat can be reused.

In some instances a portion of dissolved-air-flotation cell effluent is routed to the inedible cooker vapor condensers. Details on dissolved air flotation are given in chapter III, "Static Screens" and "Vibrating Screens."

Condensed cooking vapors from dry-rendering operations should be routed to the fat-bearing stream if they contain a significant amount of recoverable solids.

WATER AND WASTE CONSERVATION IN CLEANUP OPERATIONS

Old-fashioned cleanup operations usually use excessive amounts of water, hot and cold. Many cleanup hoses discharge 10 to 20 gal/min of high-velocity, 140°-180° hot water. Some operators believe that a flood of hot water for cleaning floors and equipment is necessary. Not only is indiscriminate use of hot water undesirable from a wastewater-control standpoint, but such practice erodes floors and walls, removes lubrication from equipment, and can cause electrical failures.

It is altogether too common for cleanup men to remove floor-drain grates and flush meat scraps down the drain, believing that a screen or catch basin will trap all solids. By the time the scraps are recovered, they have been broken up in the flow and much of the organic matter has been dissolved or suspended in the wastewater to the extent that it cannot be removed without complete treatment—by the packer or by the city. What started as a removable scrap has become a part of a wastewater-treatment load.

Floors and equipment should be dry cleaned before hosing and scraps taken to the inedible rendering. This first step in cleanup requires rigid surveillance.

Smaller nozzles on smaller hoses and application of modern cleaning methods will reduce water. For example, a kink-type valve, which is inserted in the hose and opens only when the hose is bent, will automatically stop the water when the operator drops the hose. Water should be controlled automatically to maintain the lowest temperature, lowest volume, and highest pressure consistent with each cleaning job. Effective detergents to emulsify fats and lift proteins and soil will reduce the quantity of rinse water required. Well-qualified cleaning consultants are available for guidance.

As discussed earlier, the use of automated CIP systems will reduce and control water use.

Chapter III

PRETREATMENT OF MEAT PACKING WASTEWATERS FOR DISCHARGE TO MUNICIPAL SYSTEMS

INTRODUCTION

Advantages and Disadvantages of Pretreatment

Although compliance with municipal regulations regarding the quality of a meat packer's wastewater for discharge to the city's sewer usually will determine the degree of pretreatment, there are some factors that may encourage pretreatment beyond the levels required by ordinance.

- A higher quality of pretreatment may be justified economically if the city's charges and surcharges are at a level where some additional pretreatment becomes economically advantageous.

- The meat packer may prefer to assume treatment responsibilities to avoid complaints from the municipality.

- There may be indications that the future will bring increases in the city's rate structure.

- Grease and solids may have a good market in the area. Proximity of a soap plant or similar grease market may produce economic advantages for grease recovery, or may warrant some expense in improving quality of the finished inedible grease or tallow. Such improvements will also improve the wastewater effluent.

Following are some disadvantages in pretreatment:

- The pretreatment will be placed on the property tax rolls, unless State regulations permit tax-free waste treatment for industry.

- The maintenance, operation, and record keeping may be expensive or burdensome.

- The burden of good operation increases as the treatment becomes more complex and extensive.

Evaluating Needs

After the plant has been surveyed completely, and all possible waste conservation and water reuse systems have been cataloged, the necessary pretreatment system must be designed and the cost estimated. Those parts of the treatment attributable to flow (such as grease basins and dissolved air flotation) should be totaled and reduced to a cost per 1,000 gallons. Similar breakouts in costs per pound can be carried out for grease, suspended solids, and BOD.

Then each major in-plant expense for waste conservation and water recycle and reuse can be evaluated, based on the estimated reduction in flow, BOD, suspended solids, and grease. From such data, priorities can be established for each in-plant waste-conservation measure suggested in the survey.

The future planning for the meat packing plant should serve as a guide to determine piping arrangements and suitable locations (and sizes) for projected facilities.

Costs

Waste-saving and treatment costs should be charged back to the department from which the flow, BOD, suspended solids, and grease emanated. Selected costs of some of the equipment common to pretreatment will be discussed later.

FLOW EQUALIZATION

Equalization facilities consist of a holding tank and pumping equipment designed to reduce the fluctuations of waste streams. These facilities can be economically advantageous whether the industry is treating its own wastes or discharging into a city sewer after some pretreatment. The equalizing tank will store wastewater for recycle or reuse, or to feed the flow uniformly to treatment facilities throughout the 24-hour day. The tank is characterized by a varying flow into the tank and a constant flow out. Lagoons may serve as equalizing tanks or the tank may be a simple steel or concrete tank, often without a cover.

Advantages of equalization for the meat packer discharging to a city sewer are

- In-plant pretreatment can be smaller, since it can be designed for the 24-hour average, rather than the peak flows.
- The city may have penalties for high peaks that can be avoided by equalization.

The disadvantages are few.

- More equipment to maintain and operate
- Additional fixed costs

SCREENING AND CENTRIFUGING

Introduction

Because so much of the pollutional matter in meat wastes is originally solid (meat particles and fat) or sludge (manure solids), interception of the waste material by various types of screens and centrifuges is a natural step.

Unfortunately, when these pollutional materials enter the sewage flow and are subjected to turbulence, pumping, and mechanical screening, they break down and release soluble BOD to the flow, along with colloidal and suspended and grease solids. Waste treatment—that is, the removal of soluble, colloidal, and suspended organic matter—is expensive. It is far simpler and less expensive to keep the solids out of the sewer entirely.

But, because in-plant conservation is at best imperfect and people are fallible, final organic solids separation in the main effluent sewer generally is employed. Various combinations of facilities for pretreatment may be selected, including screening, gravity grease and solids separation, dissolved air flotation, and biological treatment of various types.[6]

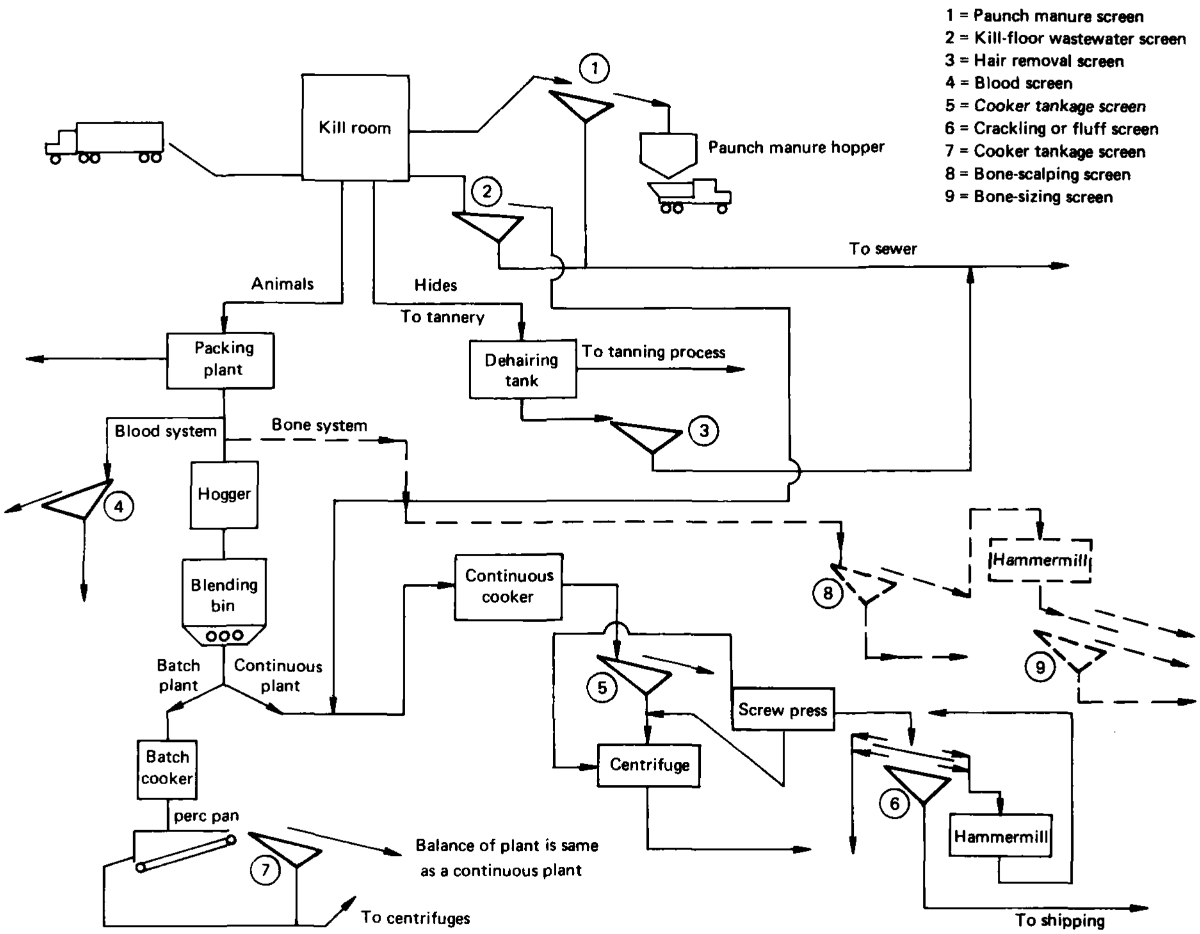


Figure III-1. Complete meat-processing plant.

The information in this discussion of screening and centrifuging can be applied both for in-plant waste conservation and waste treatment.

Figure III-1 shows where screens might be used throughout the plant. While vibrating screens are shown, other types of screens could be suitable for service in the locations cited. Whenever feasible, pilot-scale studies are warranted before selecting a screen, unless specific operating data are available for the specific use intended, in the same solids-concentration range and under the same operating conditions.

Static Screens

During the past several years, a substantial number of so-called static screens have been installed in many process industries to recover suspended matter from plant effluents or liquid flows within a plant. Highly successful screening operations have been achieved in the meat packing, tanning, canning, textile, and paper and board products industries, as well as in domestic sewage-treatment operations. Interesting new developments are underway, such as the treatment of wastes from animal-producing farms and poultry-processing plants.

In most instances, the installed equipment represents new functions or concepts in recovery and generally involves recycling or some other use of the recovered solids. In many cases, stationary screens are installed as replacements for screens that require moving parts to make a suitable separation of solids from a process stream.

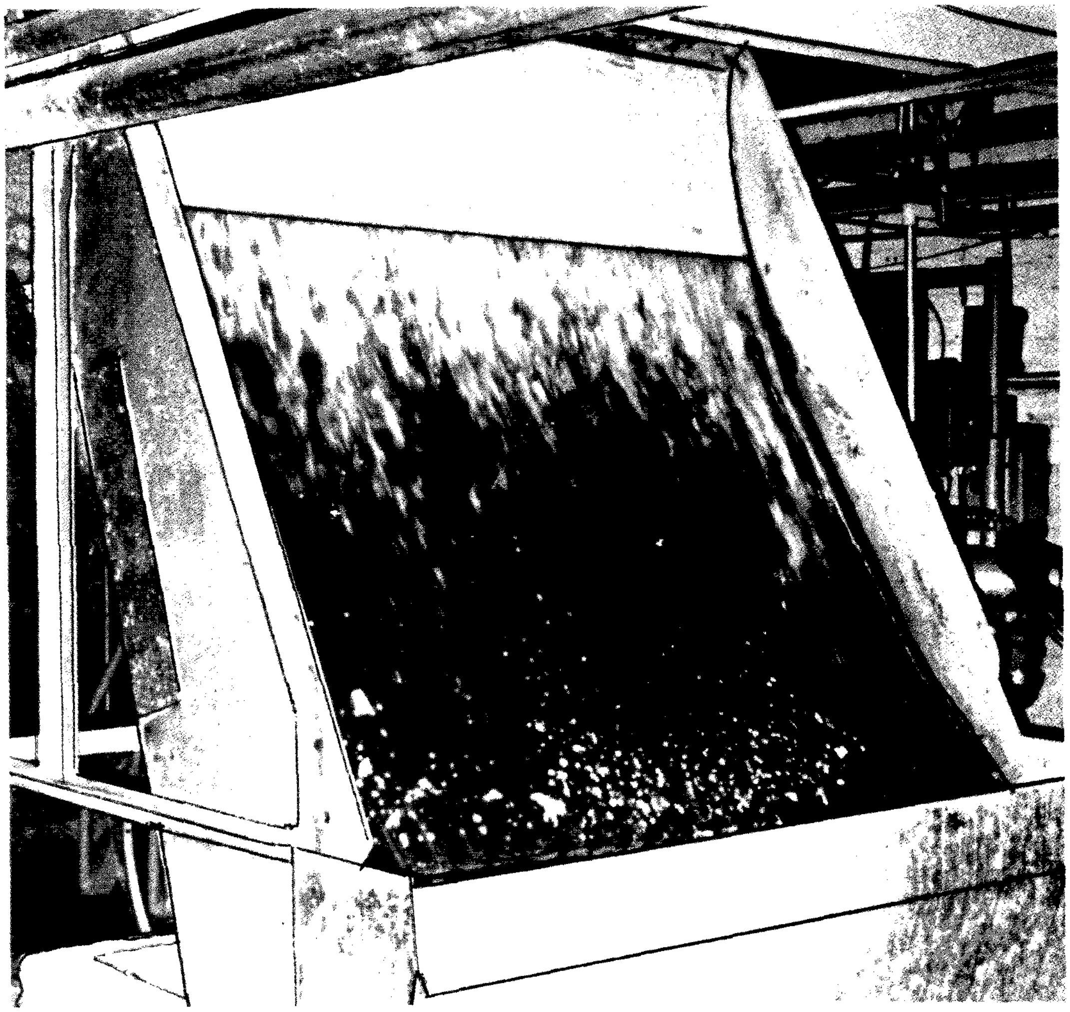


Figure III-2. Single Hydrasieve screen operating on industrial wastewater.

Basic Design Concepts. The primary function of a static screen is to remove "free" or transporting fluids. These fluids can be removed by several means and, in most older concepts, only gravity drainage is involved. A concave screen design using high-velocity pressure feeding was developed and patented in the 1950's for mineral classification, and has been adapted to other uses in the process industries. This design employs bar interference to the slurry, which knifes off thin layers of the flow over the curved surface.

Beginning in 1969, U.S. and foreign patents were allowed on a three-slope static screen made of specially coined curved wires. This concept used the Coanda or wall attachment phenomenon to withdraw the fluid from the under layer of a slurry stratified by controlled velocity over the screen. This method of operation has been found to be highly effective in handling slurries containing fatty or sticky fibrous suspended matter.

Since the field tests to be reported were conducted on the later design of stationary screen, details of this unit are presented here. The device is known commercially as a Hydrasieve. A typical installation of a single screen operating on industrial wastewater is illustrated in figure III-2.

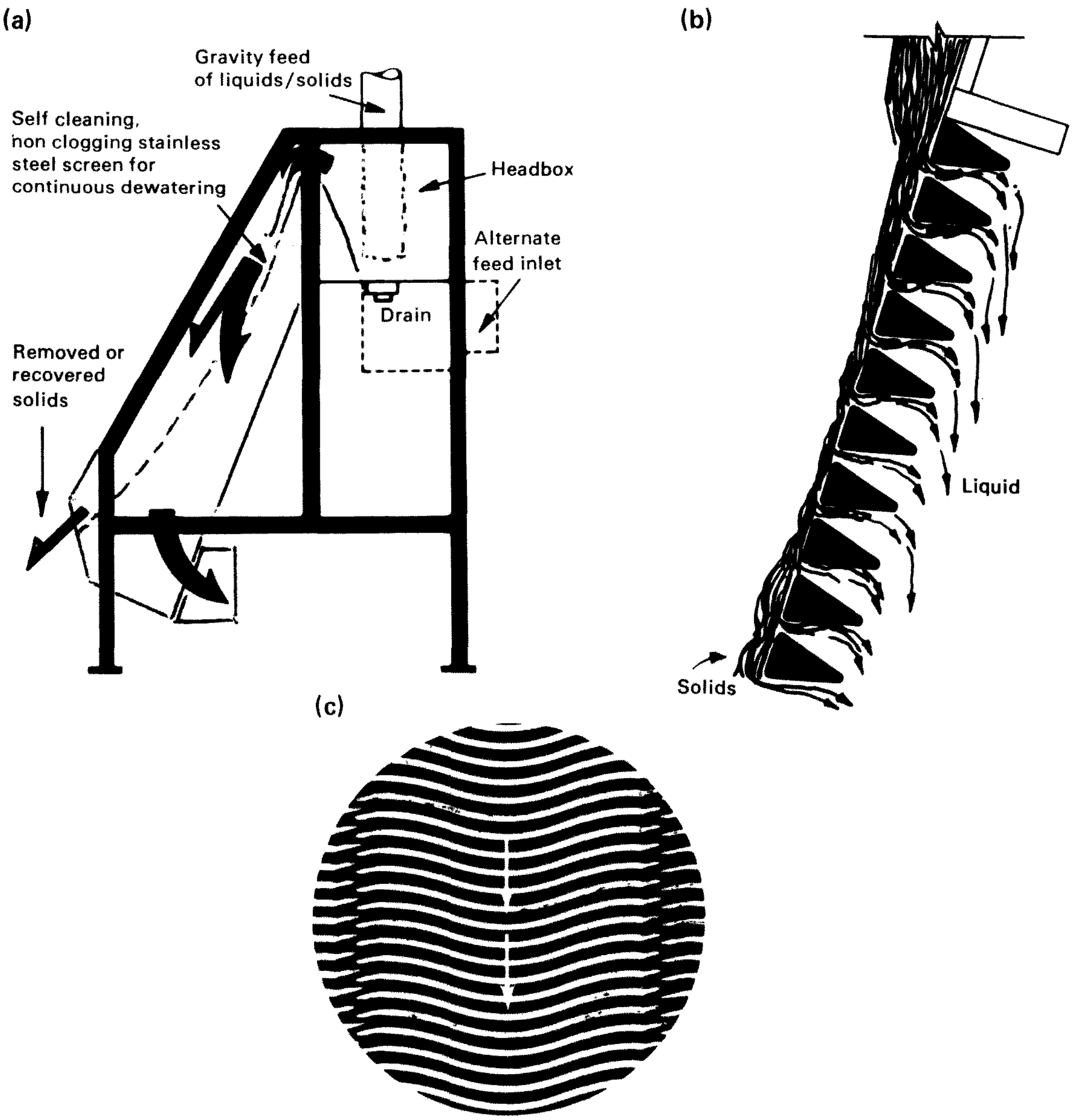


Figure III-3. (a) Diagram showing path of slurry screened by Hydrasieve. (b) Segmented section of screen wires with slurry in contact with upper end of Hydrasieve. (c) Screen design of Marvel' Hydrasieve.

Method of Operation. The slurry to be screened or thickened is pumped or may flow by gravity into the headbox of the machine. As shown in figure III-3(a), the incoming fluid overflows the weir above the screen area and is accelerated in velocity and thinned in depth as it approaches the screen. A lightweight hinged baffle is incorporated into the assembly in such a position that it reduces turbulence in the flow. Turbulence is reduced by the shape of the foil, which causes the fluid to respond to Bernoulli's theorem through the wedge-shaped entrance. The increasing velocity of fluid draws the baffle toward the surface of the screen.

Suspended solids tend to stratify in the thin stream, and fibrous materials aline themselves lengthwise with the direction of flow. Figure III-3(b) shows a segmental section of the screen wires and the slurry as it comes in contact with the upper end of the Hydrasieve screen. Note that the wall attachment of the fluid to the metal bars or wires draws or bends an under portion of the flow through the openings. Part of the underflow also moves along the arcuate surfaces of the wires, and is concentrated primarily at the apex of the downward curve. Here this flow falls by gravity from the screen back or flows in streams attached to the underside of the wire assembly in a central path between the supports. The screen pattern permits a maximum of fluid extraction based on the limit of flow rate and screen area. Figure III-3(c) illustrates the screen design which is registered under the trademark Mar-Vel'.

On the first (top) slope of the screen, most of the fluid is extracted from the bottom of the stream traveling at 25° from the vertical. When the angle of the screen changes to 35°, some additional fluid is withdrawn, and usually the massing solids begin to roll on the surface owing to the residual kinetic energy. This action compacts the solids very slightly. On the final slope of the screen, the solids tend to hesitate for simple drainage action, but are always moved off the flat surface by displacement with oncoming material. The effluent is aerated as it passes through the screen in ultrathin ribbons completely exposed to a natural or controlled atmosphere.

Unique Features. The arrangement of transverse wires with unique singular curves in the sense of flow provides a relatively nonclogging surface for dewatering or screening. The screens are made precisely in No. 316 stainless steel and are extremely rugged. Harder, wear-resisting stainless alloys also may be used for special purposes.

Openings of 0.010 to 0.060 inch meet normal screening needs. The essential features of the Hydrasieve are covered in U.S. Letters Patents No. 3,452,876 and No. 3,751,555. Other U.S. patents are pending. Patents are also issued and pending in foreign countries. Figure III-4 shows a diagram of one Hydrasieve model.

Use in Meat-Processing Industry Installations. A broad range of use for Hydrasieve screens has been developed for meat processors and related operations, including the feed lots and stockyards as well as the tanning and hide-processing industries. In these fields of service the Hydrasieve may be modified to provide a "waterfall" (patent applied for) feed concept that can cope more effectively with high loadings of fat or grease in the slurry being screened. This development resulted from research work done on commercial equipment by the Institute of Leather Technology, Milwaukee, Wis., and has been used widely by the processors of animal hides.

Paunch manure—the residue from cattle stomachs—consists of fluids plus straw, corn, and minor miscellaneous solids. The Hydrasieve is an excellent device for screening this slurry, and usually a 0.040-inch opening screen is used. The solids are separated readily from the carrying stream, and a 72-inch Hydrasieve normally will handle a flow of 600 gal/min. Solids are usually above 5 percent.

Hog stomach contents consist essentially of whole and split corn, with some hair and the possibility of fat. Usually, a 0.040-inch opening screen is employed, and flow rates of about 500 gal/min are obtained on a 72-inch-wide unit.

Hog-hair recovery is the operation in hog processing in which the animals are scalded and dehaired in a beater-scraper type of machine. Material coming from this operation is hair and scurf, a dandruff-type flake. Also present in this operation is foam, which is self-generating because of the gelatin that is cooked out of the skins.

Seventy-two-inch units with 0.020-inch openings are presently in use on the hog-hair recovery application. Flow is 400-500 gal/min, with loads to 1,000 gal/min when the scalding tub is dumped. Some problems existed in the operation due to foaming, but these are solved with proper cold water sprays over the screen and/or antifoam at 10-20-gal/min concentration ahead of the screen.

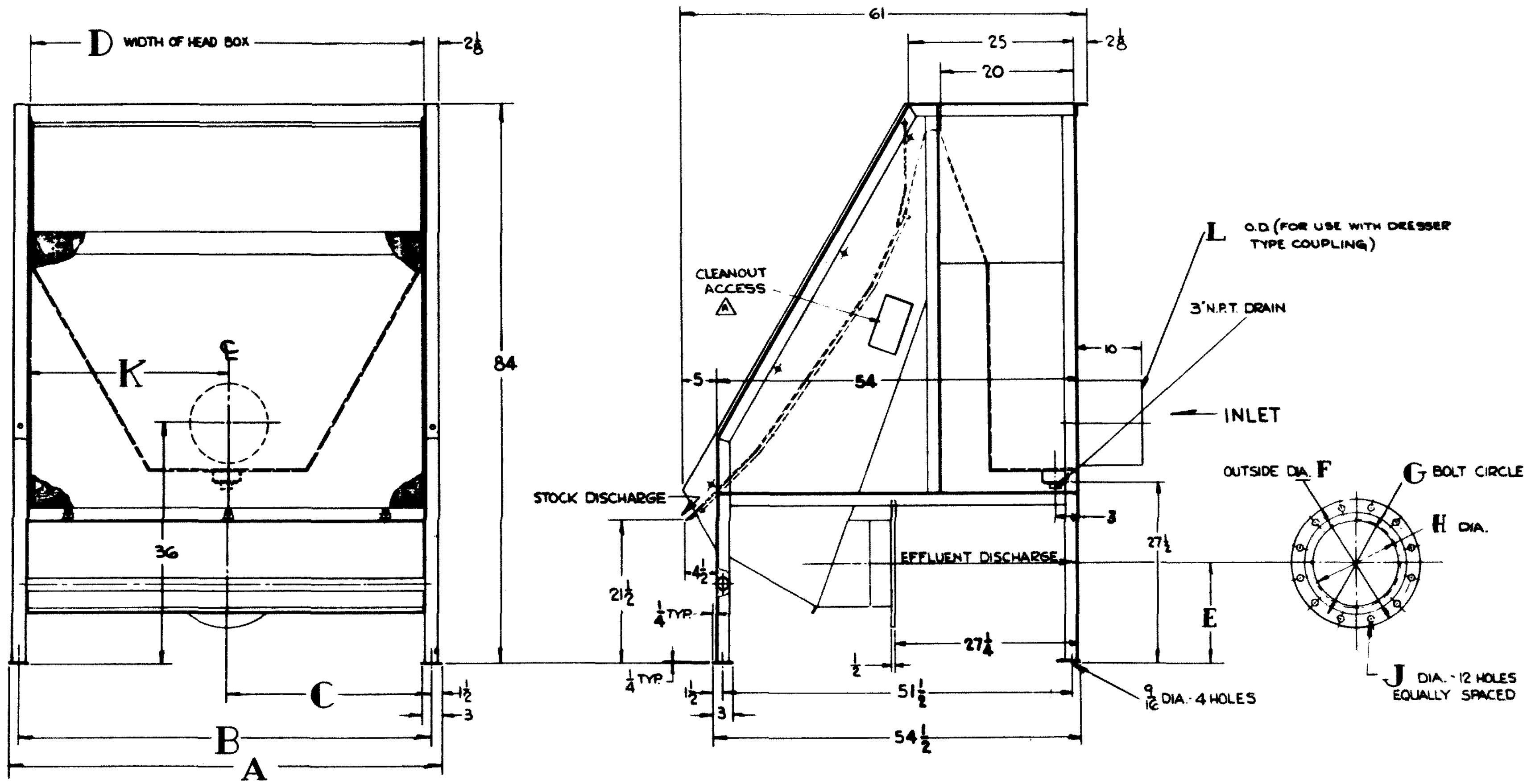


Figure III-4. Diagram for Model 552-36. (Courtesy of the Bauer Bros. Co.)

Hair screening is improved with the stockyard, paunch manure, or stomach contents added to the flow.

Ash from smokemakers results when, in smoking sausage and other meat products, sawdust is burned to produce smoke. The ash is washed from the smokemakers and should be removed before going into grease recovery systems, as this product is unwanted in the rendering. Hydrasieves offer a satisfactory means of screening the wash water.

The normal total waste flow from a packing plant is quite heavy with respect to flow, solids, and fat. Normally, when a packer screens his total flow it is a safety measure used as primary settling, ahead of additional treatment, such as pressurized air flotation. The material from the screen may be rendered.

At present a 72-inch unit with 0.040-inch screen operates on total waste flow of 500-700 gal/min. Sprays are being used and the application is quite successful.

A typical operation on a waste stream from an operation where cattle, hogs, and sheep were processed is indicated by the test data for a No. 552-2, 72-inch by 54-inch Hydrasieve with 0.040 Marvel′ screen, as follows:

- Flow rate, 550 gal/min
- Solids removed, 10,000 lb/day (dry)
- Solids passed, 6,076 lb/day (dry)
- Effluent solids (80 minus 30 mesh), 920 ppm
- Solids removal, 62.5 percent

Solids are removed from stickwater, which is product water and condensation water evolved in the process of wet or steam rendering of lard and tallow. Normally, stickwater is evaporated to produce a high-protein feed additive. Solids in stickwater are coarse and fibrous in inedible rendering, and soft and stringy in edible renderings. Normally, stickwater is hot (130°-160° F) as it goes over the screen, eliminating grease blinding.

Expeller grease solids removal is performed after meat scraps are rendered in melters. Grease is drained from the solids. The solids then are pressed in screw presses, and the additional grease is expelled. This grease contains solids that normally are settled out before the grease is filtered. This grease is sent over a 0.020-inch test screen, and solids are removed to the extent that settling can be eliminated. Flow is low, but separation is also slow. About 5-10 gal/min can be sent over an 18-inch unit with 0.020-inch screen, with adequate results. Modifications need to be made so that the flow will start at the overflow weir, rather than in a headbox.

In hide processing, green (untreated) hides are delivered from the meat packer and are either processed immediately or cured in brine. The first process is to wash the hide in a drum washer, where manure and dirt are removed. Some hair and manure balls are also removed and sent to the sewer. The Hydrasieve is used here to permit recycling of the wash water and for preliminary solids removal. A 72-inch unit with 0.060-inch screen permitted one processor to reduce his flow from this operation by at least half. Seventy-two-inch units are handling 700 gal/min effectively.

A fleshing machine is then used to remove tissue particles and tails. Handling this flow, due to its high fat content (5-14 percent), may be done with a Hydrasieve with the waterfall adapter and periodic cleaning.

Table III-1.—*Typical design information for stockyard effluent based on use of 0.040-inch slot opening*

Hydrasieve	Overall dimensions, feet			Weight, pounds	Capacity, gallons per minute	Price for estimating, dollars
	Width	Depth	Height			
No. 552-18"	2	3.5	5	350	75	2,600
No. 552-36"	3.5	4	5	550	150	3,200
No. 552-48"	4.5	5	7	650	300	4,000
No. 552-60"	5.5	5	7	800	400	5,000
No. 552-72"	6.5	5	7	1,000	500	6,000
No. 552-72-2	7	9.5	7.3	1,800	1,000	10,000
No. 552-72-4	14	9.5	7.3	3,600	2,000	20,000
No. 552-72-6	21	9.5	7.3	5,400	3,000	30,000
No. 552-72-8	28	9.5	7.3	7,200	4,000	40,000
No. 552-72-10	35	9.5	7.3	9,000	5,000	50,000

The hides are cured by saturation in brine solution. The brine is regenerated continuously. Brine should be screened on a Hydrasieve to insure proper operation by removing the hair and manure that accumulate in the brine raceway, or merry-go-round. A 0.030-inch screen in a 72-inch unit will handle 450 gal/min of this solution.

Summary. Almost every static screen application problem has its own, slightly different, design parameters to be met, and in-plant evaluations are sometimes required. Usually experience can be relied upon, however, for an adequate background to engineer a new installation. As a guide, table III-1 gives brief specifications suitable for preliminary planning of an installation of effluent screen.

Vibrating Screens

Vibrating screens have many uses in a meat packing plant. Figure III-1 illustrates the various areas where they can be used in waste conservation.

This discussion is intended to acquaint the meat packer with the design criteria and the basic theory of vibrating screens.

Vibrating screens are designed to

- Convey material retained on the screen surface to uncover the opening, so that the cloth can pass the undersize material or liquid.
- Agitate the bed of material on the screen surface. Agitation and stratification are required to open the bed so that the fine particles or liquids can work their way down through the large particles and pass the openings.
- Dislodge particles that stick or wedge in the opening. Particles of nearly the same dimension as the opening will clog. Motion of the screen must dislodge the particles.
- Distribute the material in order to make most efficient use of the entire screening area. The motion of the deck should distribute the material over the deck evenly.
- Retain material before discharge. For high efficiency, sizing, or removing water from the solids, it is desirable to retain the oversize as long as possible. The material must be moved

faster at the feed end to obtain quick distribution and a shallow bed where the volume is greatest. At the discharge end where the volume is least, the rate of travel should be slowed to allow the remaining fines or liquids to be removed.

Vibrating screens are economical. They vary in size from 2 feet by 4 feet to 8 feet by 20 feet, and are made up of three major parts.

- The vibrating frame—or, as some may call it, the box—which is either the welded structure or the bolted assembly that supports the vibrating mechanism and the screening medium, mounted horizontally or declined on isolation springs

- The screening medium—cloth, perforated plate, or panels

- The vibrating mechanism—the heart of the vibrating screen—which imparts the motion into the vibrating frame

The effectiveness of a vibrating screen depends on a rapid motion. Vibrating screens operate between 900 and 1,800 rpm; the motion can either be circular or straight line, varying from 1/32- to 1/2-inch total travel. The speed and motion are selected by the screen manufacturer for the particular application.

The vibrating screen is driven by a shaft turning in a pair of bearings. The shaft carries unbalanced weights, either machined into or keyed to the shaft. This assembly is normally driven by a V-belt drive.

When the unbalanced weights are rotated the screen follows the weights through a path. When a vibrator is placed on the top of the box, a slight rocking action will take place, resulting in elliptical motion with the ellipse leaning toward the vibrator. This motion tends to move the material away from the feed and retard it at the discharge end. The screen box is mounted on springs to keep vibration from being transmitted to the supports.

On most vibrating screens the cloth is pulled tightly across longitudinal steel members equipped with rubber caps. The cloth may be changed easily by loosening the tension bolts and sliding the screen cloth out at either end.

Of prime importance in the selection of a proper vibrating screen is the application of the proper cloth. The capacities on liquid vibrating screens are based on the percent open area of the cloth. With this factor in mind, cloth should be selected with the proper combination of strength of wire and percent of open area. If the waste solids to be handled are heavy and abrasive, wire of a greater thickness and diameter should be used to insure long life. If the material is light or sticky in nature, however, the durability of the screening surface may be the smallest consideration. In such a case, a light wire may be necessary to provide an increased percent of open area.

Screen cloth is woven in a variety of materials, such as black steel, spring steel, all types of stainless steel, Monel, and brass wire. Normally, on liquid waste applications, a type No. 304 stainless steel wire is used. When conditions require other types of metal, however, special wire cloths can be supplied.

In the discussion of various installations, the term "mesh" will be used frequently to designate the opening. Where mesh is referred to as a number, the reference is to the number of openings to the linear inch. The mesh is counted by starting from the center of one wire and counting the number of openings to a 1-inch distance. If the count does not work out to an even number, the fractional part of the opening should be specified.

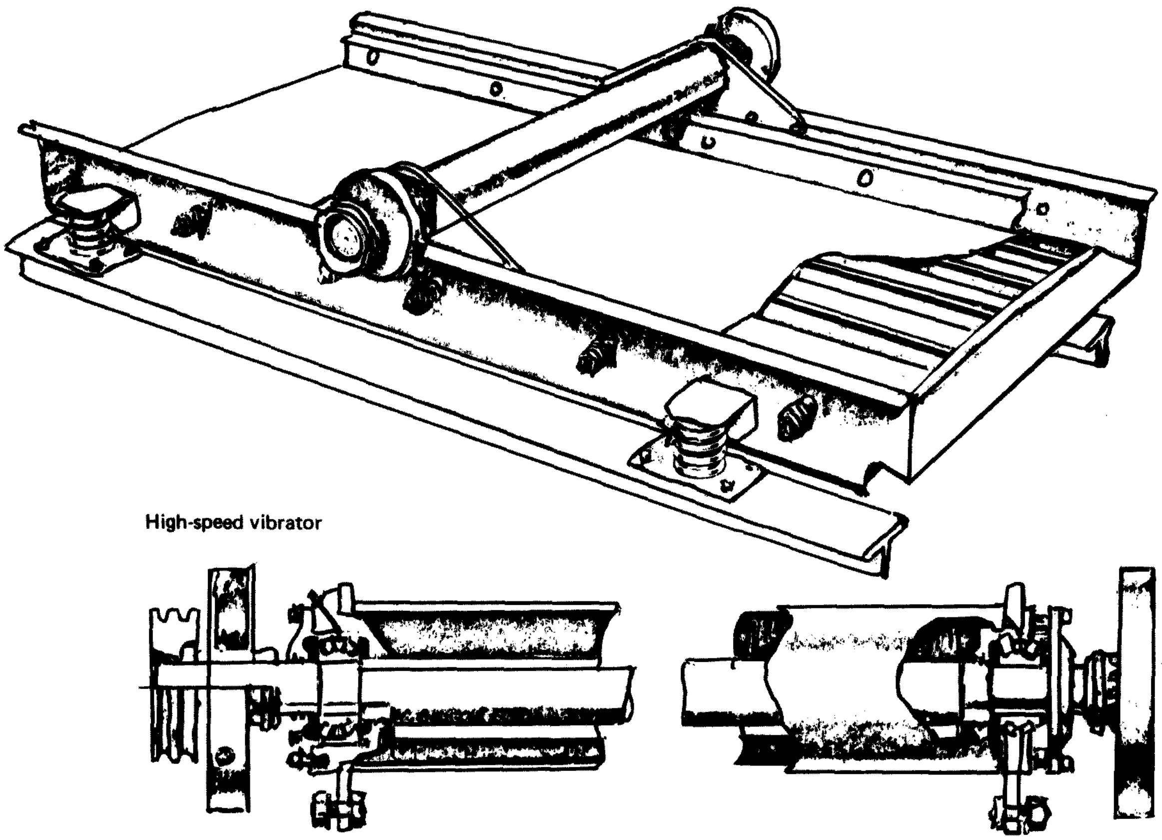


Figure III-5. NRM-148 liquid dewatering screen.

The NRM (fig. III-5) is used in liquid separation extensively; the 4-foot by 8-foot unit costs slightly more than $3,000, with feed flume and tank in black steel. Prices vary with feeding arrangements, surface sprays (if any), and other details, such as special metals and coatings.

Other Solids Removal Systems

Screening Devices. Vibrating, rotary, and static screens are the most popular screens for separating solids from meat packing plant wastewaters.

One type of barrel or rotary screen (fig. III-6(a)), driven by external rollers, receives the wastewater at one open end and discharges the solids at the other open end. The liquid passes outward through the screen, usually stainless steel screen cloth or perforated metal, to a receiving box and effluent sewer mounted below the screen. Usually the screen is sprayed continuously by means of a line of external spray nozzles, and is inclined toward the solids exit end. This type is popular as an offal screen but has not been used to any great extent in secondary polishing—that is, in removing solids from waste streams containing low solids concentrations. A screen of this type has been developed for recycle of hide-brining waters.

Another rotary screen commonly used in the meat industry (figs. III-6(b) and III-6(c)) is driven by an external pinion gear. The raw flow is discharged into the interior of the screen below center, and solids are removed in a trough and screw conveyor mounted lengthwise at the centerline of the barrel. The liquid exits outward through the screen into a box in which the screen is partially submerged. The screen is usually 40 $\times$ 40 mesh, with 1/64-inch openings. Perforated lift paddles

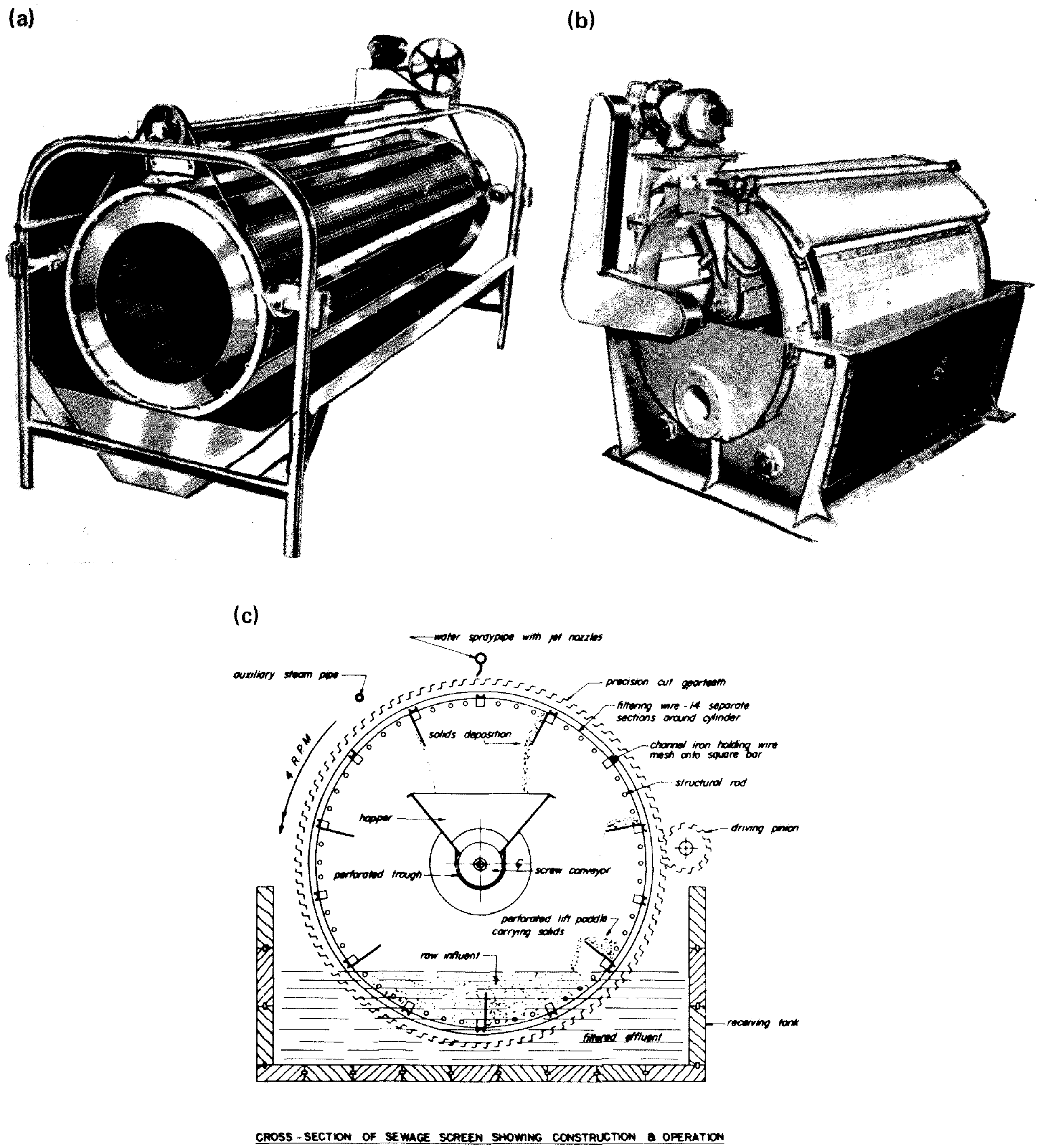


Figure III-6. Rotary screens for wastewater processing: (a) rotary screen driven by external rollers; (b) rotary screen driven by external pinion gear; (c) cross section of rotary screen driven by pinion gear.

mounted lengthwise on the inside surface of the screen assist in lifting the solids to the conveyor trough. This type is also generally sprayed externally to reduce blinding. Grease clogging can be reduced by coating the wire cloth with Teflon. Solids removals up to 82 percent are reported.

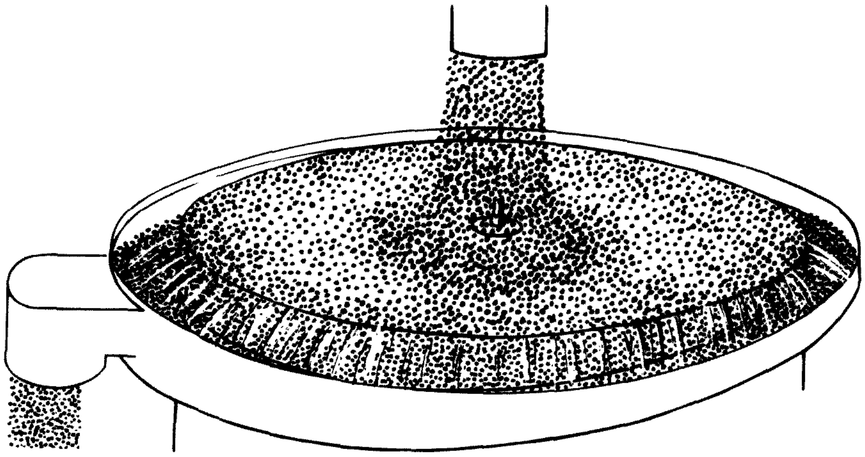


Figure III-7. Influx and discharge from spring-mounted motor-driven screen.

Several other types of mechanical screens have had some application in this field.

One is a rotating disk that is submerged partially in the wastewater flow. As it rotates, particles partially adhere and are scalped off above the flow. The screen disk is placed vertically or at a slight angle. Some problems arise in maintaining the seal between the rotating disk and the flowthrough box or sewer.

Another type is a circular spring-mounted horizontal screen, driven by a motor located under the screen and equipped with variable eccentric weights. As the motor rotates, the eccentric weights impart multiplaned vibrations to the spring-mounted screen. These units are normally centrally fed at the top, the liquid discharging through the screen to a pan above the motor and the sludge discharging from a port at the periphery (see fig. III-7). Pilot units (18 inches diameter) are available on loan. These screens are used in a number of meat packing plants, principally for paunch manure removal, for removing solids from the entire manure sewer flow, and for removing solids from the main sewer leaving the plant. Mesh sizes range from 10 mesh for paunch manure to 80 mesh for the main plant sewer. One plant uses three 48-inch-diameter separators with 80-mesh screening to handle a total main plant flow of 800 to 1,100 gal/min.

A horizontal rotary slowly revolving screen has been developed using wedge bars and the Coanda effect (as in the static screen described earlier), but with the wastewater flowing vertically downward through the screen. Some advantages claimed for rotary design are that the screen is cleaned in its rotation by means of a doctor blade, that it can be rinsed with a stationary spray system, and that the vertical downward flow helps backwash the screen as it flows through into the receiving box under the screen drum. Several meat packing applications are reported, but no operating data are available to date.

There are many other ingenious mechanical screens. Some, such as a vertical spinning drum, successfully have screened meat waste solids. Other screen systems have been tested and are in limited use. Under the impetus of need to improve effluents, testing such devices may be accelerated.

Centrifuges. Centrifuges have found use in processing meat packing wastewater, principally in improving the quality and concentration of grease from grease recovery catch basins and dissolved air flotation.

At one plant, tallow recovery from a catch basin was enhanced by running the skimmings through two centrifuges. At this plant, each centrifuge is of the three-stage type (having separate streams of oil, liquid, and solids), has a capacity of 55 gal/min, is driven by a 25-hp motor, and cost $36,000 plus about $4,000 for installation. The yield amounts to 80 percent of the recoverable tallow, with 0.92 percent moisture and a color of 13 to 15. The temperature is raised to 180° F and is discharged through an 80-mesh, eccentric-weighted-type 60-inch circular vibrating screen, then heated to 195° F and centrifuged. The fat is classified as inedible fancy bleachable tallow and brings top market prices. Flow rate is about 30,000 to 40,000 gal/day, and recovered fats run about 5,000 lb/day.

One system of blood concentration incorporates a centrifuge to separate the water after coagulation, using a chemical aid. The centrifuge is reported to remove about 80 percent of the water. The coagulated blood is then dried. This system, however, still produces BOD in the effluent. Drying of whole blood is better for waste conservation.

First cost and power requirements tend to limit the use of centrifuges for waste solids recovery. As requirements for effluent quality become more stringent, however, the centrifuge may be used more frequently to remove residual grease and fine solids from waste streams.

GREASE AND SUSPENDED SOLIDS SEPARATION BY GRAVITY AND FLOTATION

General

The catch basin for the separation of grease and solids from meat packing wastewaters was developed originally to recover marketable grease. Because the primary object was grease recovery, all improvements were centered on skimming. Many catch basins were not equipped with automatic bottom-sludge-removal equipment. These basins could often be drained completely to the sewer, and were sludged out weekly or at frequencies such that septic conditions would not cause the sludge to rise. Rising sludge was undesirable because it could affect the color and reduce the market value of the grease.

In the past 20 years, with waste treatment gradually becoming an added economic incentive, catch basin design has been improved in the solids removal area as well. In fact, the low market value of inedible grease and tallow has reduced concern about quality of the skimmings, and now the concern is shifting toward overall effluent-quality improvement.

As might be expected, the combinations of screening, catch basins, and dissolved air flotation in pretreatment vary widely. For example, the Beardstown, Ill., plant of Oscar Mayer & Co. discharges the grease sewer to a flotation tank with 30-minute detention at 30 percent recycle (no chemicals), and the manure-carrying (nongrease) sewer to a 3-foot by 8-foot, 4-mesh vibrating screen followed by a gravity basin with 50-minute detention prior to lagoon treatment. Overall operating results show 49 percent BOD removal, 66 percent suspended solids removal, and 76 percent grease removal.[7]

Other pretreatment systems start with screening the individual waste streams followed by a gravity catch basin, and then may be followed by a dissolved air flotation unit.

Gravity grease recovery systems will remove 20-30 percent of the BOD, 40-50 percent of the suspended solids, and 50-60 percent of the grease (hexane solubles).

General removals for dissolved air flotation systems without chemical treatment are about 30-35 percent in BOD, about 60 percent in suspended solids, and 80 percent (some as high as 90 percent) in grease (hexane solubles). Combinations of gravity catch basins (about 25-30 minutes detention) followed by dissolved air flotation produce somewhat better results, because the catch basin removes the larger solids and thereby reduces the requirements imposed upon the flotation unit (see discussion of "Dissolved Air Flotation").

Chemical treatment will improve recovery when installed directly ahead of dissolved air flotation systems. Chemical treatment also can improve *gravity* separation of greases and solids, but as much as 20 minutes of flocculation may be necessary to effect significant improvements.

The use of chemicals to enhance coagulation and flotation varies widely. Generally, flotation is accomplished without chemicals, unless effluent quality must be improved. Alum, as a coagulant with or without a polymer, is used but tends to cause an emulsion problem in the cook tank. Ferric chloride, with or without a polymer, is also used; however, U.S. Department of Agriculture limitations on iron content in feeds should be checked before selecting this coagulant if significant amounts are to be used, and if the end product will be a feed ingredient. As knowledge of polymers improves and their use becomes more general, proper polymers at proper pH and under controlled mixing conditions may be effective alone, and thus may eliminate the problems incident to iron and alum treatment. Zinc chloride has had some success as a coagulant and may be effective in combination with a polymer. The proper pH—an important factor—should be determined by coagulation tests.

Manure-carrying sewers commonly are pretreated by means of screens, gravity basins, and sometimes dissolved air flotation before discharge to the public sewers. If the wastewaters are treated in a separate system for discharge to a watercourse, the type of biological waste treatment may not require the degree of solids removal necessary for discharge to the public sewer.

Simple settling tanks are useful for stockpen flows. They generally consist of shallow concrete trenches, about 3 feet deep, designed for cleaning with a bulldozer.[8] A simple baffle at the outlet end prevents escape of floatables. One head of cattle in a feed lot will discharge 10 to 15 times as much BOD as one person in the same period of time.

Gravity Grease Separation and Suspended Solids Recovery in Rectangular Basins

Design Elements. Engineers are sharply divided as to the merits of rectangular versus circular separators for various purposes. Many prefer rectangular to circular gravity grease recovery tanks because they believe that, in the circular tank, the grease loses its cohesiveness as the flow proceeds outward in a radial direction, with the scum covering an ever-increasing surface area, and thereby becomes thinner as it approaches the scum-removal device at the outer periphery. Others claim that the gradually reducing velocity of the flow as it moves radially outward improves grease separation as well as solids separation (a majority of engineers prefer circular tanks for settling flocculent solids). It is safe to say, however, that the majority favor rectangular basins for gravity recovery of grease. Accordingly, this section will concentrate on this type. In dissolved air flotation systems (discussed later) the two factions are about even. In clarification following biological treatment systems, the circular clarifiers have a decided majority.

Following are size criteria based largely on experience. If individual State standards normally applied to clarifier design are imposed on the meat packer for catch basin design, the regulations of course must be followed.

Rate of flow is the most important criterion for design of a gravity unit. About 30 to 40 minutes' detention time at 1-hour peak flow is a common sizing factor. A shallow basin, 5 to 6 feet liquid depth, generally is preferred. This depth produces about 1 gal/min per square foot area. The daily flow has little relationship to the design of grease recovery systems.

Length-to-width ratio should be at least 3 to 1. Maximum widths are about 20 feet, but heavy sludges may cause an excessive stress on the scrapers at that width. Widths to 12 feet are safe. Beyond this width stresses should be checked, particularly if the system is operated intermittently.

Temperature variations can develop nonuniform density currents, reducing the efficiency of grease and solids separation. Overnight icing can occur in northern climates. Accordingly, protection against wide variations in temperature should be considered.

The design of inlet and outlet arrangements, as well as scum removal, will materially affect the basin efficiency.

The bottom (invert) of the influent sewer should be above the liquid level in the basin. The inlet, however, can enter the basin below the liquid surface. Properly baffled, multiple inlets will reduce inlet velocities but can cause backup in the influent sewer or in an upstream receiving box where scum can collect. Design of such a receiving box to overflow at high-flow periods could prevent scum accumulation in the box. Surface discharge into the basin, on the other hand, can develop velocity currents in the basin. However, multiple surface inlet openings with adjustable baffles will reduce entrance velocities, permit manual adjustments of distribution of the flow across the basin width, and prevent upstream scum accumulations.

The effluent should be conducted over a weir extending the full width of the basin. Weir overflow rates should not exceed 1,500 gallons per lineal foot per hour of maximum flow. A weir trough at the outlet will provide double weir length if necessary.

Scum removal equipment is available in several styles.

The slotted "swing-pipe" scum trough (see fig. III-8) is popular in rectangular municipal clarifiers. In operation, it is periodically rotated manually to a point where the slot meets the liquid level, allowing scum to enter the pipe and flow out one end to a receiving box. It is inadequate generally for the quantities of scum encountered in treating meat packing wastewaters.

A powered helical scum collector (fig. III-9) that mechanizes scum pickup is also available. Its dewatering efficiency and its capacity do not usually satisfy the requirements for scum removal in meat packing wastewater systems, but it is a slight improvement over the swing pipe.

A more positive pickup, but using the same four-sprocket sludge and scum scraper system, consists of a scum trough and "beach" with a short flight-type skimmer (fig. III-10). The skimmings trough extends the full width of the basin and should be sloped to discharge to a receiving box where the grease can be decanted from the residual water. In large installations, a screw conveyor in the trough will be useful. In cold climates, the shaft of the screw can be hollow and can be connected to a steam line to keep the scum from freezing in the trough. The scum trough should be several inches above the liquid level. The metal beach provided on the upstream side for scum pickup permits some dewatering of the scum on that part of the beach above the water level. A short baffle fastened to the underside of the trough and extending downward will reduce scum loss caused by effluent flow moving toward the effluent weir downstream from the trough.

All of the foregoing skimming arrangements permit some grease to escape to the effluent because the grease adheres to the flights as they pass downward under the skimming device. To eliminate this defect, two sets of scraper flights can be provided, as shown in figure III-11. In this system, the sludge is moved independently of scum removal by a three-sprocket collector. A *separate* two-sprocket scraper system, operating above the liquid level, moves the scum toward the scum trough and up the beach into the trough. In this arrangement, septic action can be prevented

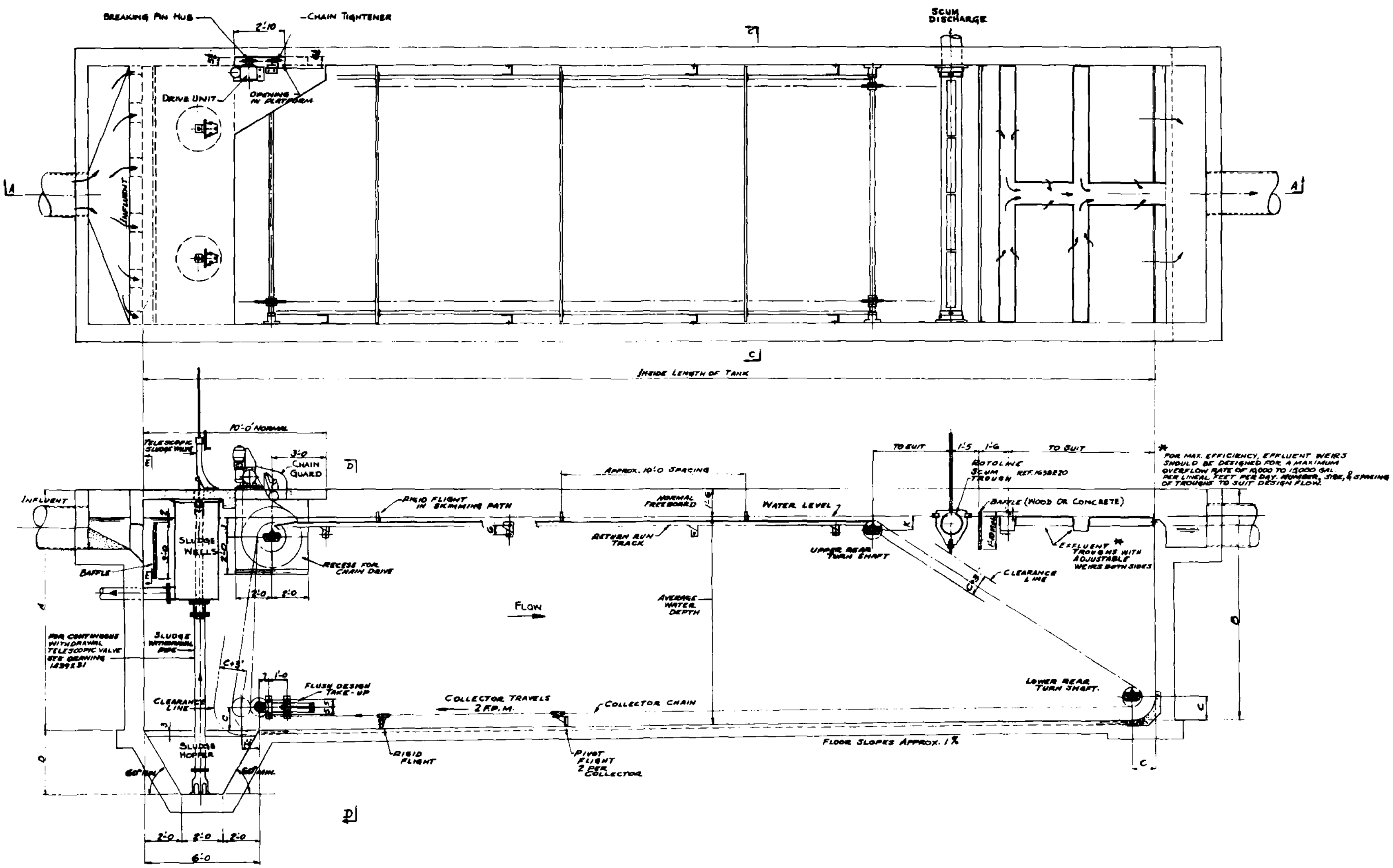


Figure III-8. Four-sprocket collector with scum pipe for grease recovery. (Courtesy of the Link-Belt Company.)

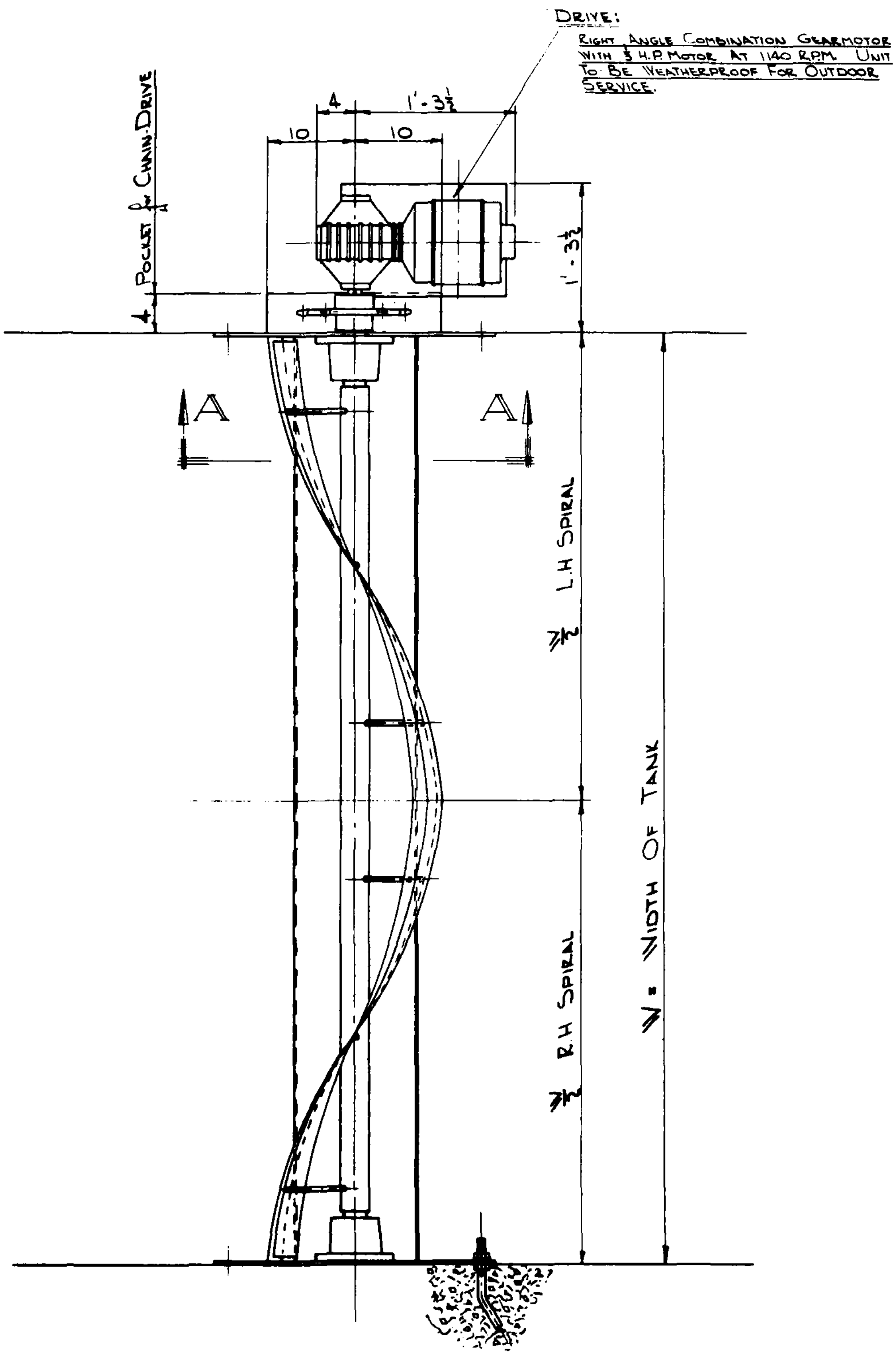


Figure III-9. Helical scum skimmer. (Courtesy of the Link-Belt Company.)

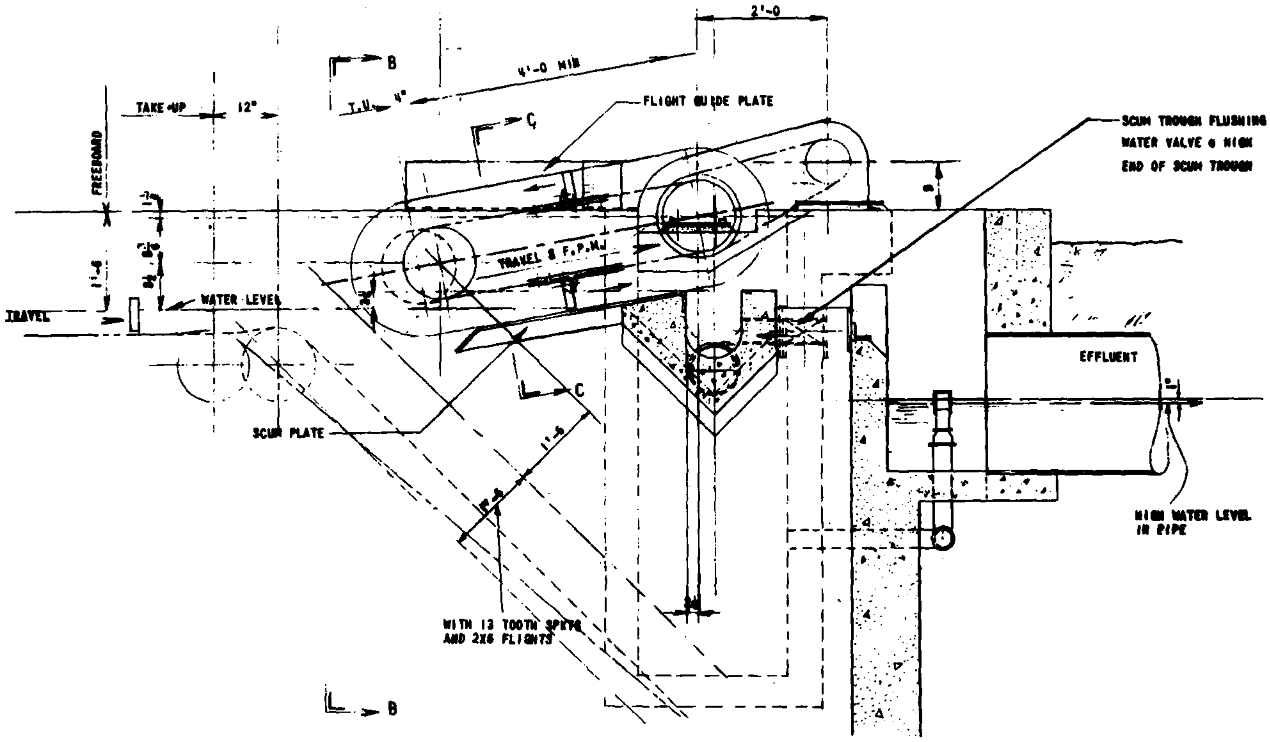


Figure III-10. Four-sprocket collector with flight-type skimmer. (Courtesy of the Link-Belt Company.)

by operating the bottom scrapers continuously. The scum scrapers also can be operated separately on a timer to hold the scum and develop a cohesive dense layer, thereby reducing the liquid content of the skimmings. Normally, about 70 percent of the scum picked up is water. The two-flight system can reduce the water content about 15 to 20 percent.

A new pork plant using this type of arrangement has a production day's flow of 620,000 gal/day and 860 gal/min in a maximum hour. This plant is large, and has complete smoking and sausage manufacturing. Pretreatment consists of a gravity basin (equipped for adding dissolved air flotation when necessary) designed for 28 minutes' detention (12 feet wide, 45 feet long, and 6 feet side-water depth). Estimated raw waste concentrations are 450 mg/l BOD, 400 mg/l suspended solids, and 350 mg/l grease. No raw waste operating data are available to date, but effluent samples taken on January 17, 1973, show BOD 250 mg/l, suspended solids 70 mg/l, and grease 26 mg/l. Sanitary wastes are included in these figures.

Scraper mechanism for sludge removal may scrape the sludge to one or several submerged hoppers, generally at the inlet end of the basin. The need for several hoppers arises from two design limitations. First, the side slopes for the sludge hoppers should be at least 60° with the horizontal. Second, the flat bottom of the hopper should be no greater than 2 feet by 2 feet in size.

In one innovation that eliminates the hoppers and sludge pumps, the effluent end of the basin is built in an incline and the sludge is scraped up the incline into a receiving trough at the top. The sludge is partially dewatered on that portion of the incline that extends above the liquid level. The incline can be as long as necessary to accomplish the desired dewatering before the sludge discharges into the trough. A screw conveyor in the sludge trough is an added convenience to carry the sludge to a truck or receiving box alongside the basin. The effluent weirs and scum removal trough are, of course, upstream from the incline.

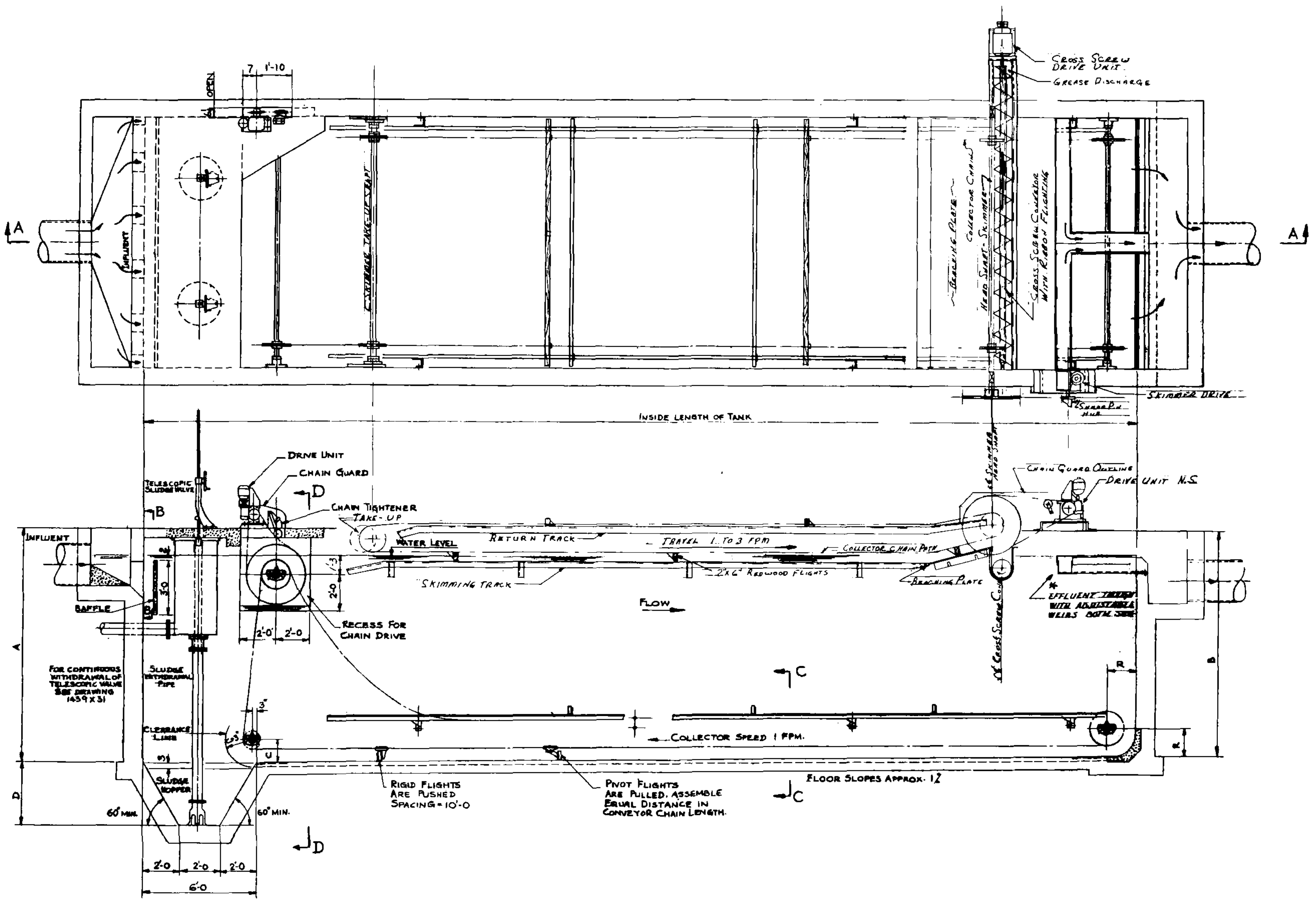


Figure III-11. Three-sprocket collector with flight skimmer full length and cross screw conveyor. (Courtesy of the Link-Belt Company).

Basin Arrangement and Materials of Construction. Usually two identical catch basins, with a common wall, are desirable to permit one to operate whenever the other is down for maintenance or repair. Note that the "Design Example" (following) is based on this arrangement.

Concrete tanks have the inherent advantages of lower overall maintenance and more permanence of structure. Some owners, however, prefer to be able to modify their operation for future expansion or alterations, or even for relocation.

All-steel tanks have the advantage of being semiportable, more easily field erected, and more easily modified than concrete tanks. The all-steel tanks, however, require additional maintenance as a result of wear in areas of abrasion.

A tank equipped with all-steel walls and concrete bottom is probably the best compromise between the all-steel tank and the all-concrete tank. The advantages are the same as for steel. The all-steel tank, however, requires a footing underneath the supporting members; with the steel-wall tank the concrete bottom forms the floor and supporting footings for the tank.

Design Example. Given a peak-hour flow of 1,300 gal/min, design a rectangular catch basin.

- At a selected 40-minute detention, the volume = 52,000 gallons = 6,950 ft^3.
- Select 6 feet average water depth; area = 1,160 ft^2.
- Select two basins, with a common wall, each 10 feet wide, 58 feet long, and 6 feet average water depth.

Cost Estimates for Design Example. All costs are for *two* basins, with a common wall between them. Table III-2 gives cost estimates that are order-of-magnitude prices, and thus should not be used for other than rough approximations. In each particular application, equipment prices and construction costs should be developed for the area where the plant is located and for the specific situation.

Table III-2.—*Cost estimates for design example, rectangular catch basin*
[Dollars]

Basin	Cost installed	Equipment			Total
		Type[1]	Base cost	Installation cost	
Concrete	25,000	I	12,500	3,000	40,500
		II	23,000	3,500	51,500
		III	32,400	5,600	63,000
Steel	29,000	I	12,500	3,000	44,500
		II	23,000	3,500	55,500
		III	32,500	5,500	67,000
Steel with concrete floor	32,000	I	12,500	3,000	47,500
		II	23,000	3,500	58,500
		III	32,500	5,500	70,000

[1]Type I, four-sprocket collector with rotatable scum pipe; type II, four-sprocket collector with short flight skimmer *without* screw conveyor in trough (slightly less with helical scum skimmer); type III, three-sprocket sludge collector with full-length, separate, two-sprocket scum-scraper system, and *with* screw conveyor in trough.

Maintenance and Operation. Most gravity grease recovery units use no chemicals, flocculants, or polymers to achieve the grease separation. There is no requirement, therefore, for design or maintenance of a chemical-feeding system. The gravity grease recovery unit is quite simple in construction and operation, alleviating the need for sophisticated or highly trained operators.

In gravity grease recovery and separation, as with any system of wastewater treatment, the overall system must be considered in addition to the individual elements. Particular attention should be given to maintaining low turbulence in the flow, and minimizing frequency of pumping.

Each gravity grease recovery system requires a certain amount of housekeeping. After being in operation for a few months, the equipment becomes coated with grease. It is difficult, if not impossible, to maintain the equipment when the parts are not visible. Hence, there is a need for scraping, scrubbing, steam cleaning, and in some cases high-pressure hosing, to assist the people responsible for maintenance in keeping the units operational. Cleanliness also helps in the control of odors and elimination of odor-producing bacteria.

Day-to-day observation and periodic checking of alinement, grease levels in speed reducers, and greasing of bearings are natural requirements for mechanical maintenance of any wastewater equipment. Eventually the chains will wear and require replacement. This equipment has a wear life proportional to the hours of use; hence, operation on timers is recommended. A high percentage of grit in the wastewater may accelerate the wearing of the components, because the grease will tend to hold the grit into the wearing part of the unit, acting as a lapping compound and accelerating the wear.

Pilot Plants. The use of pilot plants for grease recovery and other wastewater treatment design cannot be overemphasized. The most important information obtained from pilot plant studies is that the plant can be operated with a relative flow rate and waste characteristics representative of those for which the ultimate plant will be designed. One of the most frequent errors in the use of pilot plants for design purposes is the application of pilot plant data from one meat packing plant to another with different flow pattern, production processes, and production equipment.

Most major manufacturers have pilot plant equipment available on rental terms.

Dissolved Air Flotation

Dissolved air flotation is a waste-treatment process in which oil, grease, and other suspended matter are removed from a waste stream. This treatment process has been in use for over 15 years, and has been most successful in removing oil from waste streams. Its principal early use was, as it still is, the removal of oil from petroleum refinery wastewaters. Another natural area for application of this treatment system has been the removal of contaminants from food-processing plant waste streams. One of the very first applications of this treatment system was for meat processing.

Basically, dissolved air flotation is a process for removing suspended matter from wastewater that uses minute air bubbles, which upon attachment to a discrete particle reduce the effective specific gravity of the aggregate particle to less than that of water. Reduction of the specific gravity for the aggregate particle causes separation from the carrying liquid in an upward direction. As figure III-12 suggests, the particle to be removed may have a natural tendency either to rise or to settle. Attachment of the air bubble to the particle induces a vertical rate of rise noted as V_T.

Figure III-13 illustrates the basic design considerations of the flotation unit. The measurement of the parameter V_T will be discussed later. Since the waste flow must pass through a treatment unit, the particle to be removed will have a horizontal velocity. Certain criteria have been established for limits of the parameter V_H, which sets the width and depth of the treatment unit.

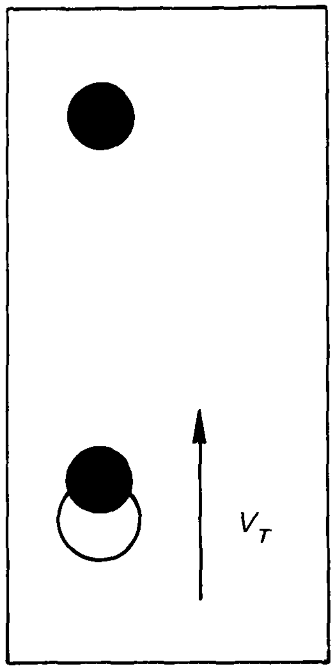


Figure III-12. Separation of particle from wastewater by dissolved air flotation. (V_T = vertical rate of rise.)

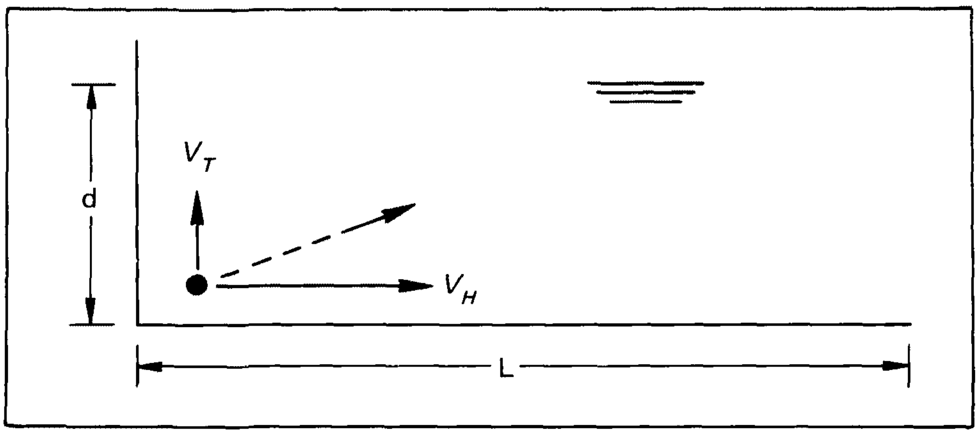


Figure III-13. Basic design concept of flotation unit. (V_T = vertical rate of rise; V_H = horizontal velocity; L = length of treatment unit.)

Therefore, as figure III-13 suggests, the effective length of the treatment unit is directly proportional to the horizontal velocity and depth and inversely proportional to the vertical rate of rise of the particle to be removed.

The mechanics of operation for a dissolved air flotation unit are illustrated in figure III-14. It can be noted that a portion of the clarified effluent is pressurized by a recycle pump. This recycled flow is pumped to a pressure tank into which air is injected. In the pressure tank at approximately 40 psig, the recycle flow is almost completely saturated with air. The pressurized recycle flow, containing the dissolved air, leaves the air saturation tank and flows through a pressure reduction valve.

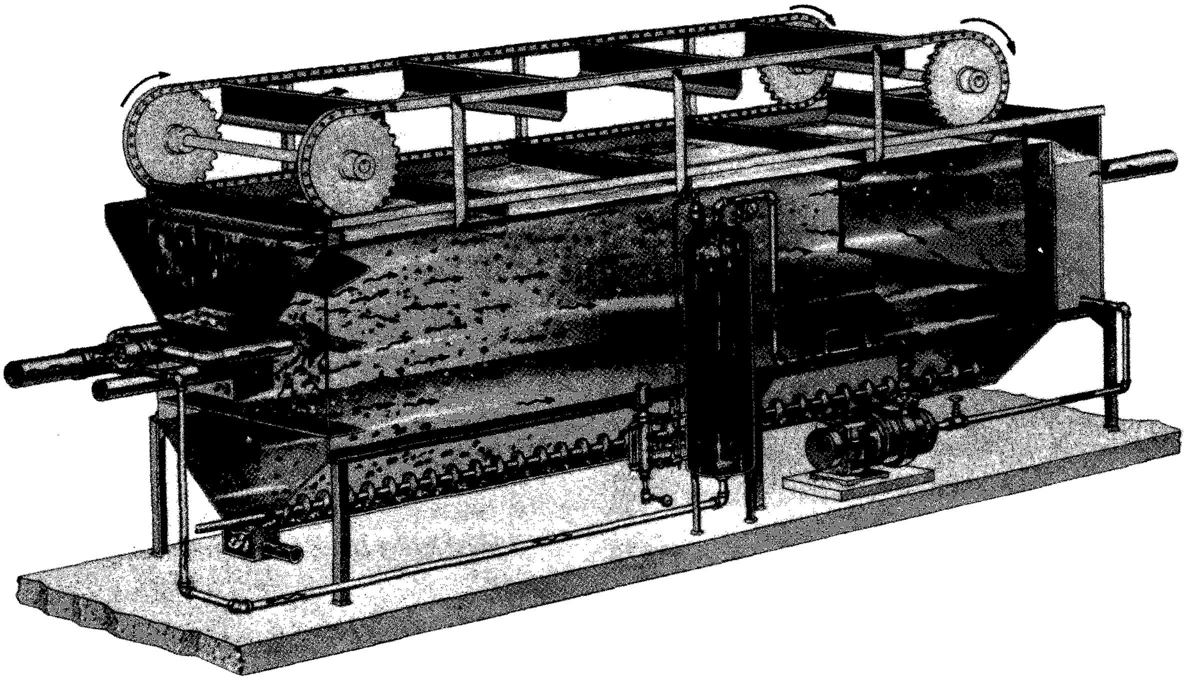


Figure III-14. Dissolved air flotation unit: mechanism of operation.

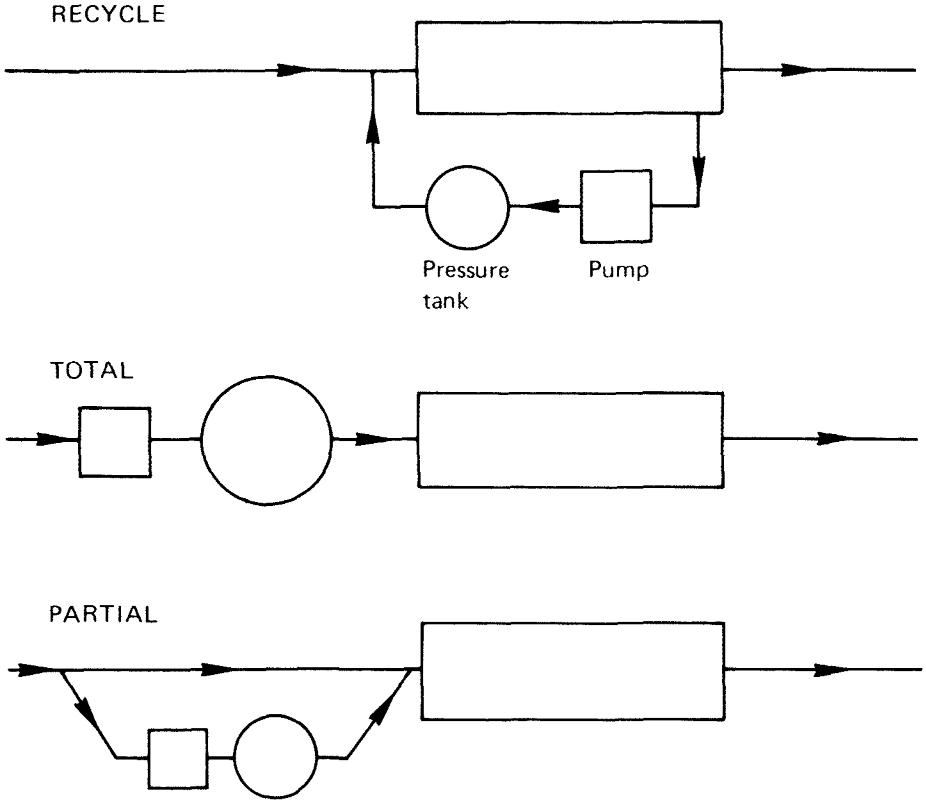


Figure III-15. Injecting air bubbles into the waste stream: recycling, total pressurization, and partial pressurization.

A 40-psig pressure drop occurs at the pressure reduction valve and causes the pressurized flow stream to relinquish its dissolved air in the form of tiny air bubbles. This air-charged recycle flow is then blended with the raw process flow to effect attachment of the air bubbles to the oil and other suspended solids to be removed. The combined flow stream (raw flow plus recycle flow containing the air bubbles) is mixed and uniformly distributed over the cross section of the basin.

As the incoming flow travels to the effluent end of the basin, separation of the oil and solids from the associated liquid occurs. Solids accumulate at the water surface and form an oily sludge blanket. Clarified liquid flows over the effluent weir and into a wet well. From the effluent wet well, a portion of the effluent is recirculated. The remainder of the effluent is removed from the basin for subsequent treatment or discharge. The floated scum blanket of separated solids can be removed from the basin by skimmer flights traveling between two endless strands of chain. Since the influent stream may also contain small amounts of heavy solids, such as grit, which are not amenable to flotation, provision must also be made for solids removal from the bottom of the unit.

The foregoing discussion illustrates the recycle method of injecting the air bubbles into the waste stream. Figure III-15 shows all three methods of dissolved air injection currently used. Total pressurization, as the name implies, occurs where the total waste flow is pressurized before entering the treatment unit. Partial pressurization is a method whereby a portion of the waste flow is pressurized and mixed with the remaining raw flow before entering the treatment unit.

To obtain optimum treatment with some wastes, it has been necessary to use chemical pretreatment before dissolved air flotation. The necessity for use of chemical conditioning is normally associated with a high degree of emulsification of the oil or grease matter in waste stream flow. It is, therefore, a requirement to break the emulsion and form a floc to absorb the oil or grease. It has been shown (fig. III-16) that increasing the particle size increases the rate of separation. Flocculation as a means of promoting particle growth preceding flotation contributes to the effectiveness of the flotation process where chemical conditioning is used. The points of chemical injection and the possible use of flocculation associated with the three methods of air injection are shown in figure III-17.

The use of steel-package dissolved air flotation units lends itself to application in the meat-processing industry. This arrangement provides an economical, flexible design that requires minimal construction cost and area investment. Most manufacturers of dissolved air flotation units have a complete line of steel tank units to meet a wide variety of flow conditions. Rex Nord Model No. 9550A (fig. III-18) would handle a raw waste flow of approximately 800 gal/min. Model No. 8032 handles a raw flow of about 300 gal/min, and Model No. 6020 would handle a raw flow of about 200 gal/min. These raw flow figures were based on a vertical particle rise rate of 0.5 ft/min and a recycle rate of 33 percent.

The use of steel-package units lends itself equally well to those applications requiring flash mixing and flocculation as a part of chemical pretreatment.

In the following discussion, a steel-package Model No. 6020 with flash mix and flocculation compartments has been used to illustrate the costs associated with this type of unit. The capital cost of this unit would be approximately $37,500, which would include the following equipment:

- Flash mixer and drive
- Flocculator and drive
- Two-shaft surface skimmer and drive
- Screw conveyor, sludge collector, and drive

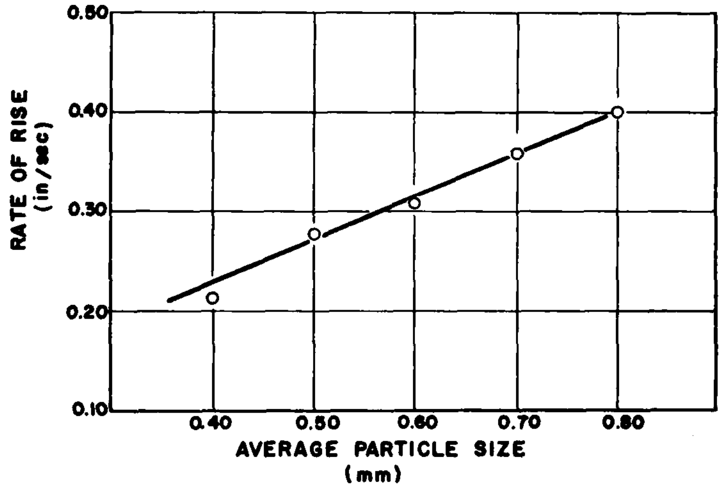


Figure III-16. Effect of average particle size on rate of rise: 100 ppm lime; 20 ppm bentonite; 20 percent recycle.

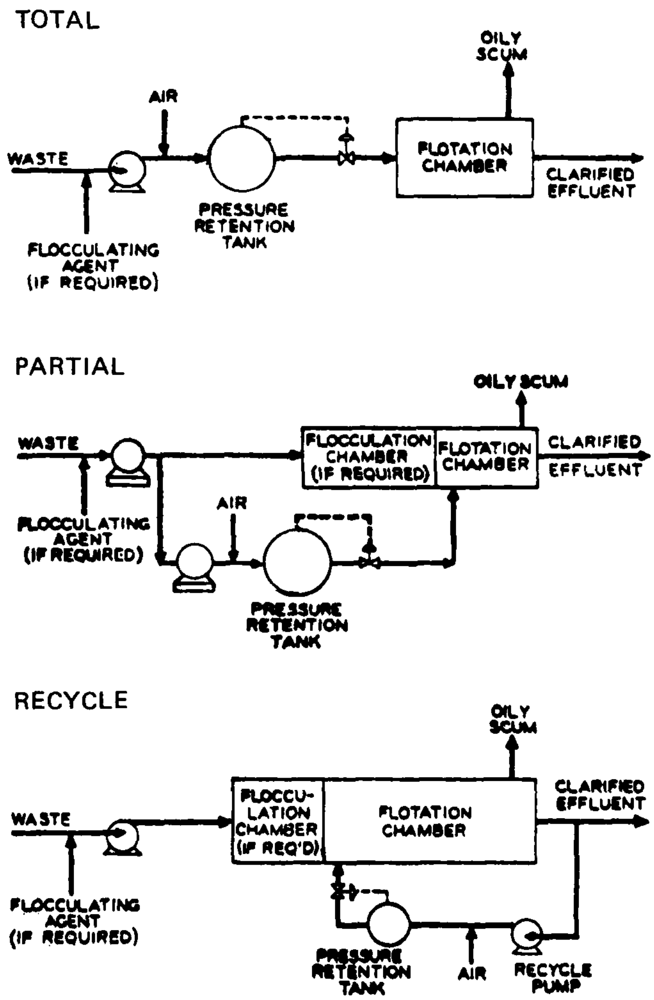


Figure III-17. Points of chemical injection and use of flocculation associated with total and partial pressurization and recycling.

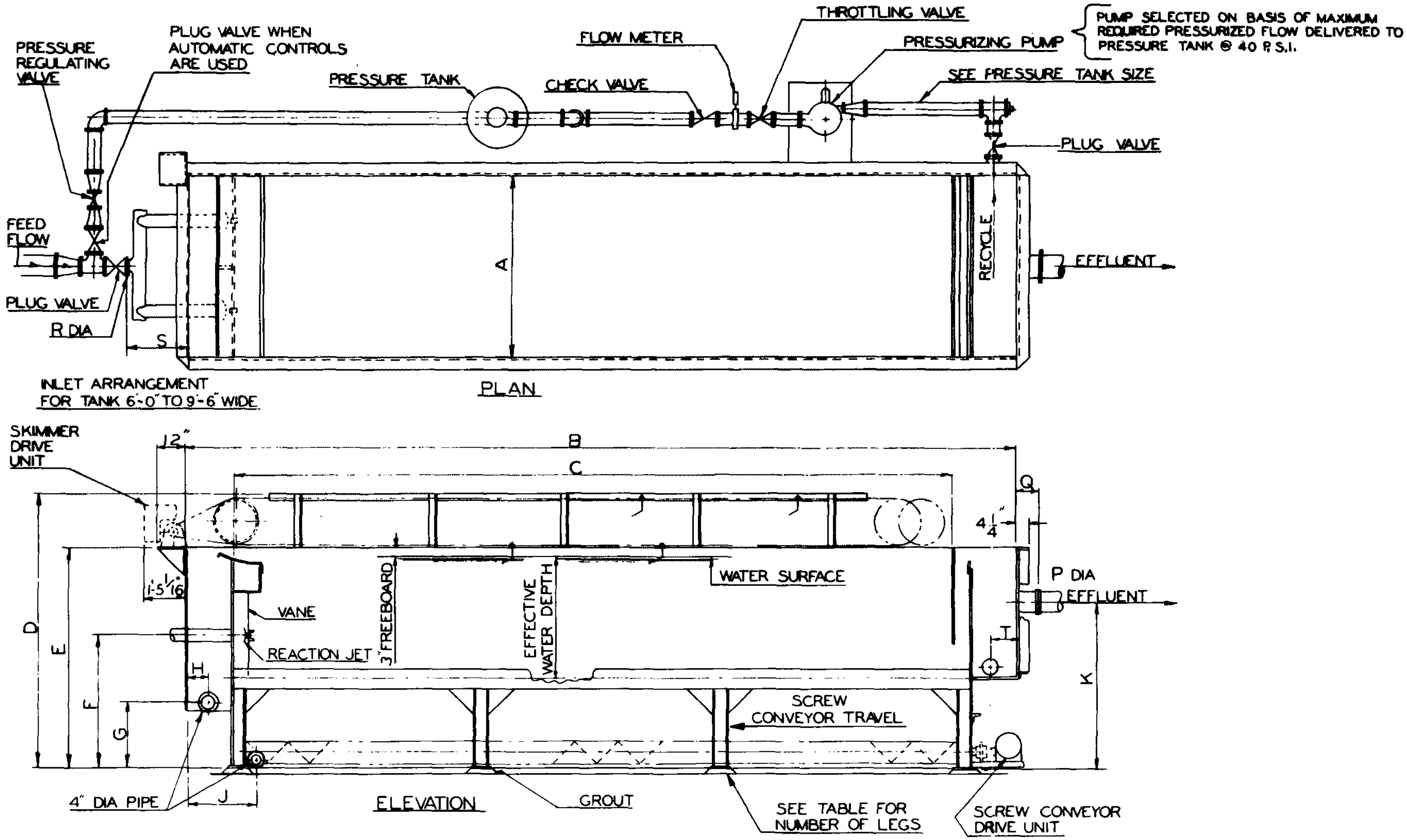


Figure III-18. Steel tank with skimmer and sludge-removal facilities. (Courtesy of Rex Nord, Inc.)

Table III-3.—*Operating horsepower for Rex Nord Model 6020*

Item	Horsepower
Flash mixer	0.5
Flocculator	.5
Skimmer	.5
Bottom screw	.5
Recycle pump	7.5
Compressor	1.5
Total	11.0

Note.—Based on a 10-hour-day, 5-day-week operation, yearly operating costs equal: $214, at 1 cent per kW-h; and $321, at 1.5 cents per kW-h.

- Complete steel tank
- Pressure tank and associated air control system
- Recycle pump
- Compressor
- Recycle piping

Table III-3 lists the operating horsepower included in the unit described. Based on a 10-hour-day, 5-day-week operation, costs of running Model No. 6020 for 52 weeks are shown for electrical costs at 1 cent per kW-h and 1.5 cent per kW-h.

To give a full range of capital costs involved with steel-package flotation units, the largest unit, Model 9550A, would cost approximately $57,000 with the above-listed equipment. Model 2511, the smallest unit, would cost approximately $22,000 with the same components.

Tables III-4 and III-5 list operating results from units treating wastes of a mixed kill of hogs and cattle and from a ham-packing operation. Tables III-6 and III-7 show results from bench scale testing of different types of meat-processing waste and indicate degrees of treatment obtained in different methods of treatment.

In several of the results, the use of chemicals was necessary to meet treatment objectives. Table III-4 indicates the use of a cationic polyelectrolyte at a dosage of 0.75 mg/l. Based on a flow of 1,600 gal/min and a chemical cost of 40 cents per pound, the cost for the chemical for a 12-hour operation would be a little less than $3 per day. The cost of a simple polyelectrolyte feed system would be around $6,000.

As is the case with most industrial waste, treatability studies should be conducted to determine not only the design parameters for a flotation unit, but also to determine whether chemical treatment is a necessity to meet treatment objectives.

Pilot dissolved air flotation units are available from most manufacturers for treatability studies. The rental cost varies, but the normal rate is approximately $500 per month.

A laboratory bench scale test procedure developed to simulate the dissolved air flotation process has been used most successfully in the determination of design parameters for an air flotation unit.

Table III-4.—*Plant A operating results, hogs and cattle killing*
[Flow, 1,600 gal/min]

Sample	Hexane-soluble grease remaining, mg/l	Percent removal
Untreated	3,000	–
After gravity settling (25 minutes approximately)	1,200	60
After gravity settling followed by dissolved air flotation with chemical treatment, 33-percent pressurized flow:		
Type chemical, cationic polyelectrolyte A, dosage 0.75 mg/l	230	[1]80
Type chemical, cationic polyelectrolyte B, dosage 0.75 mg/l	80	[1]93

[1]Percent removal beyond that obtained by gravity settling alone.

Table III-5.—*Plant B operating results, ham packing, no killing*
[Flow, 200-gal/min design, 385-gal/min present]

Sample	Constituent remaining, mg/l	Percent removal
Untreated:		
Suspended solids	350	–
BOD	1,100	–
Hexane-soluble grease	600+	–
After dissolved air flotation, without chemicals, 33-percent pressurized flow:		
Suspended solids	300	17
BOD	400	64
Hexane-soluble grease	80	87

This flotation test (fig. III-19) is used to determine the suspended particle rise rate (V_T), which is the most critical design parameter in the design of the flotation unit. The rate is determined by filling the pressure cell with liquid to simulate closely the recirculation of the unit effluent of pressurization in a full size unit; this recycle water should be developed by several previous flotation runs. This liquid is then injected with air until a pressure of over 40 psi is obtained; the cell then is shaken vigorously to insure that the air is put into the solution. The pressurized liquid then is introduced into the waste. The exact amount of pressurized liquid is determined by trial and error for best results. As the minute bubbles are released from solution, they attach to the suspended particle and oil and rise to the surface. After flotation is complete, a sample of the effluent is taken and analyzed. During the test, observation of the rise rate of the major portion of the solid material with respect to time is recorded. From a graphic plot of these data a rise rate can be calculated. This rise rate, along with factors for turbulence and short circuiting, is used in the selection of the basin size necessary to accomplish treatment required.

Other Systems

Whereas the preceding section was limited to a discussion of rectangular dissolved air flotation systems, it should be noted that the same principles are applied to circular-shaped tanks by a number of equipment manufacturers. These tanks are similar to conventional clarifiers with center baffled

Table III-6.—*Plant C bench scale testing results, hog killing*

Sample	Constituent remaining, mg/l	Percent removal
Untreated:		
Suspended solids	3,700	–
BOD	2,800	–
Hexane-soluble grease	3,300	–
After gravity settling (laboratory time to simulate 30 minutes full scale):		
Suspended solids	800	78
BOD	600	79
Hexane-soluble grease	500	85
After gravity settling followed by dissolved air flotation, without chemicals, 33-percent pressurized recycle flow:		
Suspended solids	440	[1]45
BOD	380	[1]36
Hexane-soluble grease	190	[1]62
After gravity settling followed by dissolved air flotation, with chemical treatment, dosage 200 mg/l alum and 1 mg/l anionic polyelectrolyte:		
Suspended solids	230	[1]71
BOD	210	[1]65
Hexane-soluble grease	55	[1]88

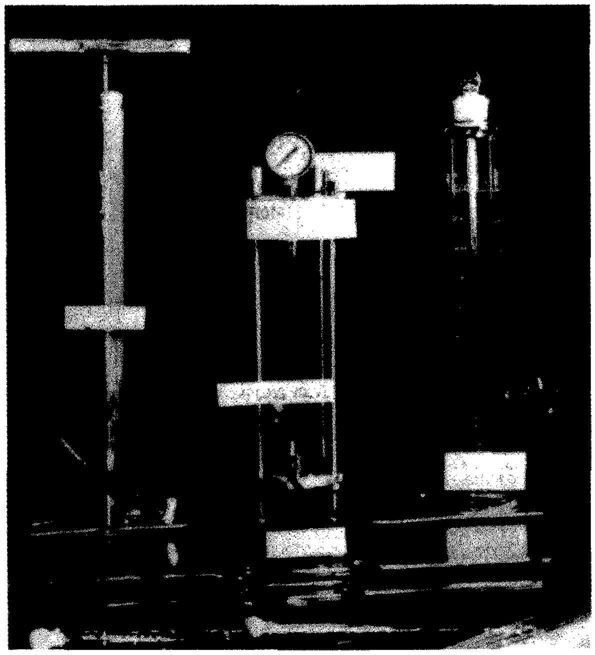
[1]Percent removal beyond that obtained by gravity settling alone.

Table III-7.—*Plant D bench scale testing results, lamb killing*

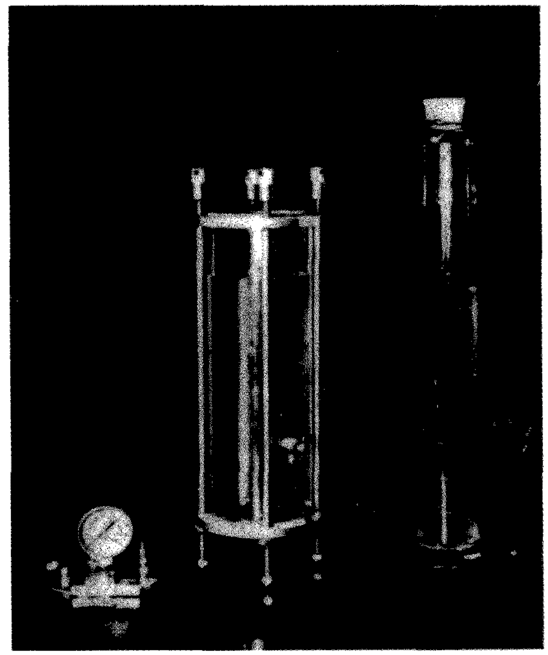
Sample	Hexane-soluble grease remaining, mg/l	Percent removal
Untreated (grab sample)	2,600	–
After dissolved air flotation, without chemicals, 33-percent pressurized flow	104	96
After dissolved air flotation, with chemicals, 33-percent pressurized flow, dosage 0.75 mg/l cationic polyelectrolyte	76	97

inlet, peripheral weir, bottom sludge removal scrapers, and surface skimmer arms discharging to a surface scum trough. The pressurized air recycle arrangements are the same as those used in rectangular tank systems. These circular systems average approximately $1,200 per foot of diameter to 20 feet in diameter, and $1,000 per foot of diameter above 20 feet. These costs include steel tank side sheets, sludge and scum removal mechanism, pressurizing pump, air saturation tank, and air compressor. Installation costs can be estimated at 40 percent of the equipment costs. Variations among manufacturers lie in proprietary details such as baffling of the influent, design of the skimming system, design of the effluent trough, and design of the scraper mechanism.

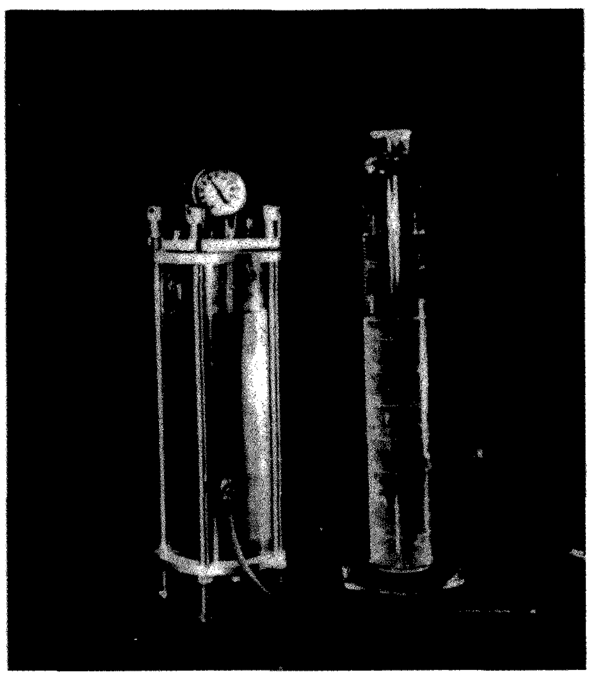
Figure III-20 shows suggested systems that are applicable to both circular or rectangular flotation units. The primary skim tank is a gravity catch basin and the Sediflotor Clarifier is a proprietary circular dissolved air flotation system. The systems shown in figure III-20(d and e), with proper chemical treatment, are claimed to produce 90-percent grease removal and 70-90-percent BOD and suspended solids removal. Figure III-21 illustrates the circular type of flotation system.



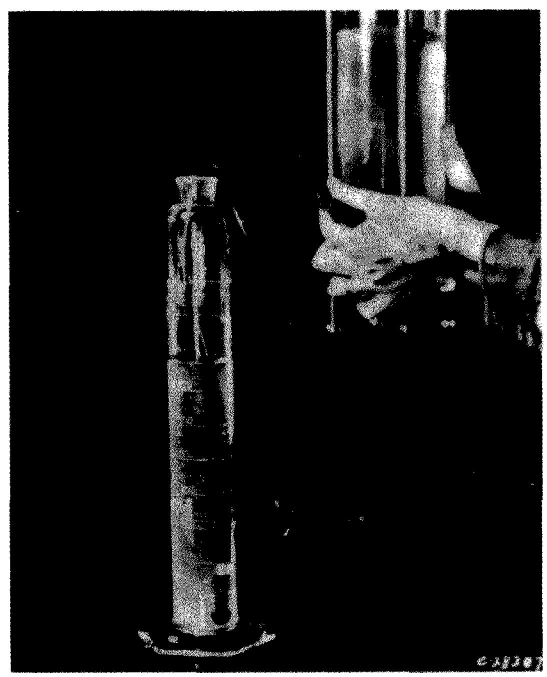
Component parts—Rex Flot-Aire Kit



Flot-Aire pressure cell with clarified effluent
Glass cylinder with raw waste

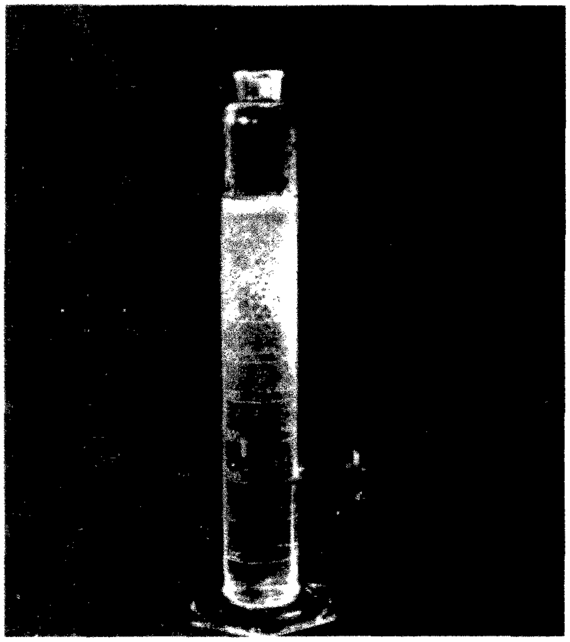


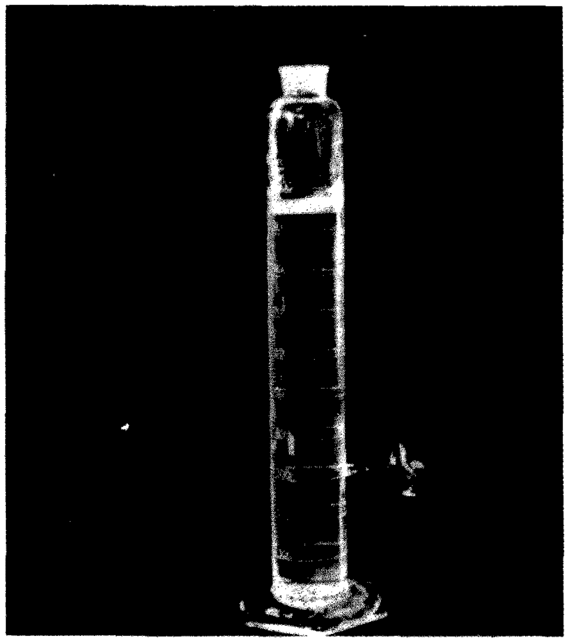
Clarified effluent in Flor-Aire pressure cell
pressurized to 40 psi



Pressurized effluent introduced to raw waste

Figure III-19. Laboratory bench scale test to simulate dissolved air flotation process. (Courtesy of Rex Nord, Inc.)


Minute air bubbles floating waste material to surface of cylinder


Flotation complete in cylinder


Clarified waste sample being withdrawn from cylinder

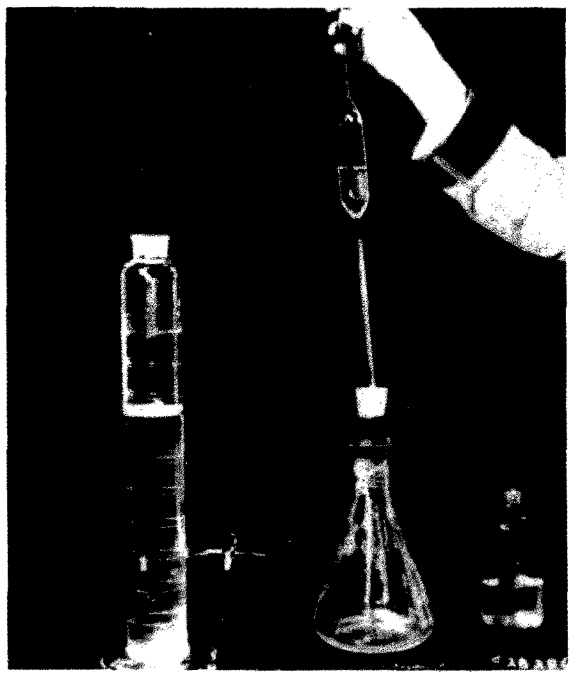

Analysis made of clarified waste

Figure III-19. Laboratory bench scale test to simulate dissolved air flotation process.—*Continued*

A. Assume that a recirculation ratio of 0.33/1 is to be tried.

1. Place 750 ml of a representative sample of the waste in a one liter graduated glass cylinder. (See Figure 3, Data Sheet 315-10.804.)

2. Fill the Float-Treat Pressure Cell approximately three-fourths full with liquid. (See Figure 3, Data Sheet 315-10.804.)

   (It is desirable that the operation of the Float-Treat Pressure Cell closely similate the recirculation of effluent as used in the Float-Treat Flotation System. The returned effluent (recycle water) may be developed by repeated flotation of several different portions of raw waste. After the recycle water has been developed and used in the flotation tests, samples may then be withdrawn for chemical analyses.)

3. Secure the cover gasket and cover of the Float-Treat Cell, making certain all the valves are closed.

4. Inject air into the cell until a pressure of 40 psi is attained and maintained during testing. (See Figure 4, Data Sheet 315-10.804.)

5. Shake the cell vigorously for thirty seconds.

6. Release 250 ml of the liquid which has been pressurized into the graduated cylinder. (See Figure 5, Data Sheet 315-10.804.) The volume of liquid in the graduated cylinder then totals 1000 ml (750 ml raw and 250 ml pressurized). The ratio of volumes of recycle water to the raw waste is termed the recycle ratio. This ratio is expressed in percent and is termed the recycle rate. Thus, the recycle rate used in this test is 33%. The most suitable recycle rate can be determined by repeated tests at varying rates of recycle and usually is not less than 20% and no more than 50%. To facilitate the introduction of the air-charged recycle water to the graduated cylinder, a rubber tube may be connected to the petcock on the pressure cell. After clearing the rubber tube of air, (Allow some liquid to escape through the tube by opening petcock. Sufficient liquid should be removed until it has a milky appearance) the air-charged recycle water is introduced through the rubber tube into the graduated cylinder. The end of tube should be placed near bottom of the cylinder. (See Figure 5, Data Sheet 315-10.804.)

Figure III-19. Laboratory bench scale test to simulate dissolved air flotation process.—*Continued*

The air bubbles rise through liquid in a manner similar to that in the Float-Treat flotation system.

7. Allow the contents of the graduated cylinder to come to rest and observe the flotation. (See Figure 6, Data Sheet 315-10. 805.) Allow sufficient time for the rising solids to come to the surface of the liquid. Usually ten minutes will be sufficient time for the flotation to be completed. (See Figure 7, Data Sheet 315-10. 805.)

8. After the flotation is completed, a sample of the raw waste and treated waste should be taken for analysis. (See Figures 8 and 9, Data Sheet 315-10. 805.) The treated waste should be carefully withdrawn from the graduated cylinder either through the use of a petcock installed in the side and near the bottom of the cylinder or through the use of a siphon inserted in the cylinder. Sufficient liquid should be withdrawn to complete the desired analysis, however, care should be taken to avoid the break up of the skum blanket.

9. Should chemical flocculation with flotation be desired, the chemical may be added into the raw waste after step "1" is completed, flocculation may be carried out, for convenience, in another vessel. Care should be taken not to break up the floc when transferring the waste to the cylinder. Enough time for flocculation should be allowed before introducing the air-charged recycle water. Under appropriate conditions, a floc may be formed by gentle agitation of the waste after the chemical is added. The procedure described above also applies when chemical flocculation is used. When using chemical flocculation, care should be exercised not to break up the floc particles in handling the flocculated waste.

   Because of the peculiarities of some floc formations, they will break up readily upon any excessive agitation after being formed. This is most readily noticed when a liquid with a preformed floc is transferred from the cylinder used in the jar mixing test to the cylinder used in the flocculation test. If the floc does break up and does not re-form immediately, it is suggested that the transfer to the flotation cell not be made and that flotation be accomplished in the vessel where the floc was formed. The procedure for running this test are the same. However, withdrawing of the clarified liquid, as described in step "8", will probably be through a siphon.

Figure III-19. Laboratory bench scale test to simulate dissolved air flotation process.—*Continued*

In flotation of a particular waste, it is quite possible that the test using the recirculation ratio of 0.33/1 may not yield the best results. It may be that some other recirculation ratio would yield the results needed to work in with the economy of a final plant design and effluent requirements. Therefore, the tests described above may be repeated with other recirculation ratios until the optimum ratio is obtained. In these tests the values shown in steps "1" and "6" will be changed accordingly.

When running flotation tests in the Rex Float-Treat demonstration kit, the observed rate of rise of the major portion of the solid material should be recorded. This value can be recorded in terms of inches per minute and will be used in determining the full scale plant requirements.

In order to insure the validity of results obtained, care should be taken that representative samples of waste are obtained before running tests. When results have been obtained, they should be recorded on Questionnaire for Design Data Sheets 315-10.101 and 315-10.102. These completed sheets should be returned to CHAIN Belt Company.

Figure III-19. Laboratory bench scale test to simulate dissolved air flotation process.—*Concluded.*

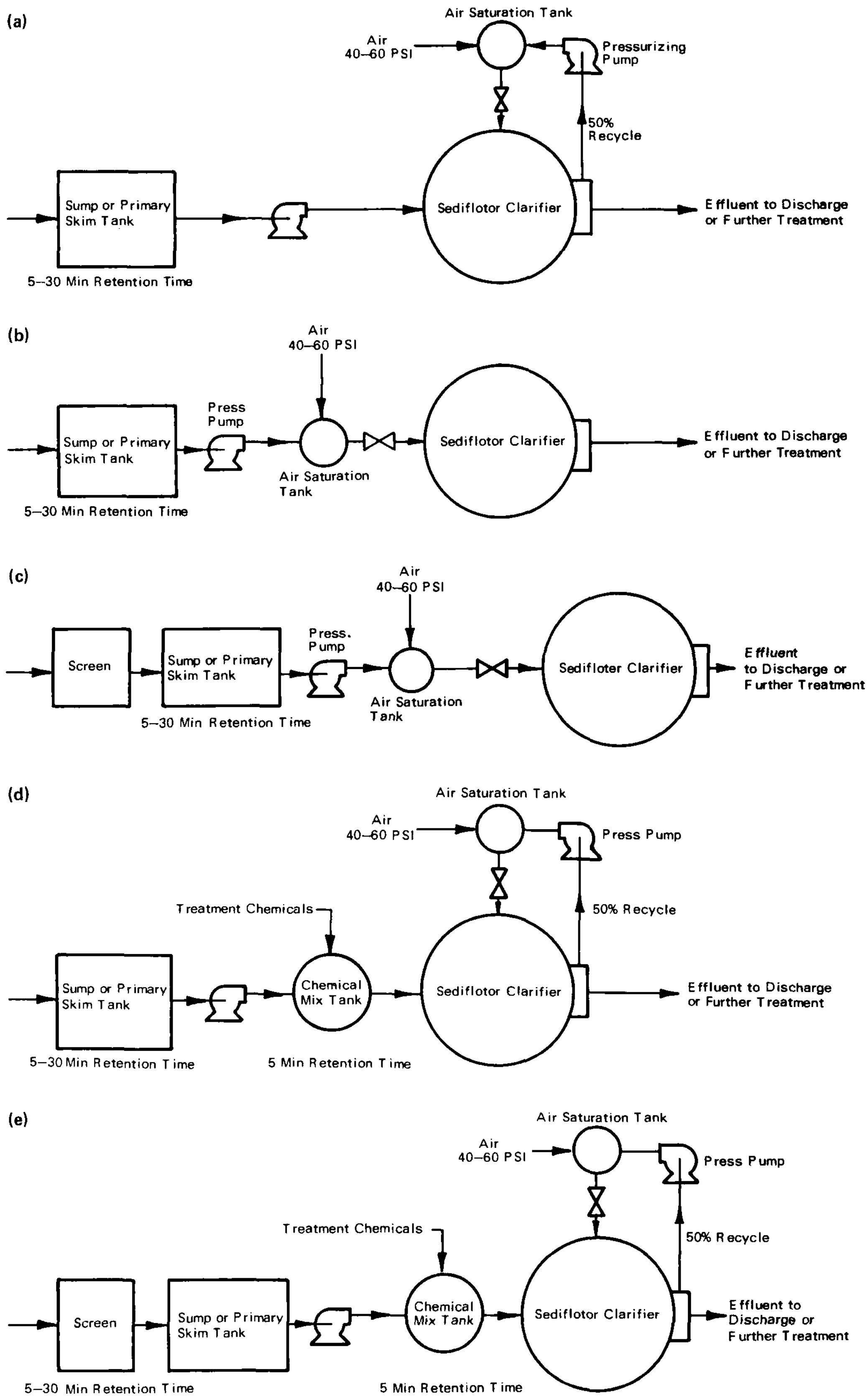
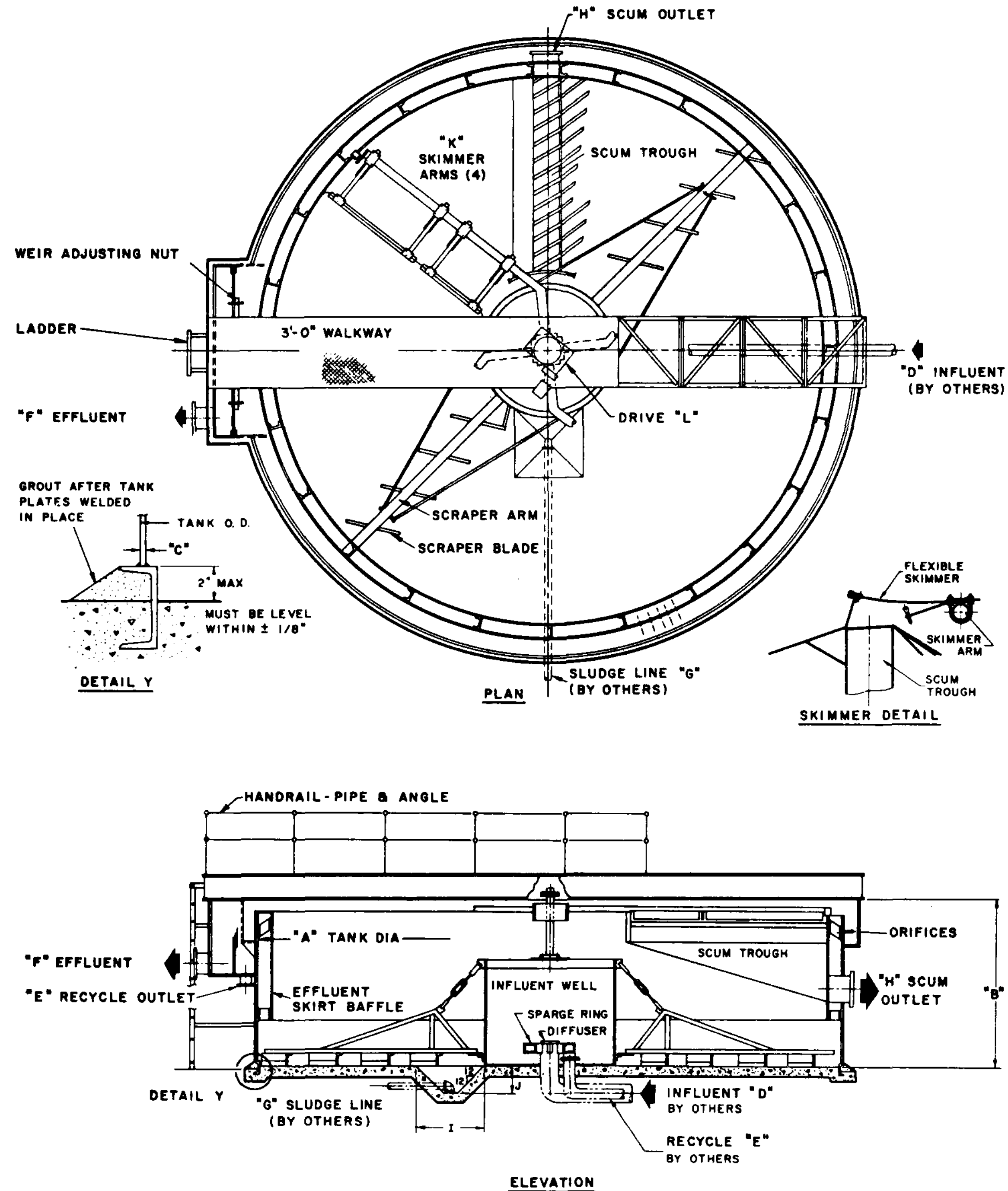


Figure III-20. Typical flow sheets for meat packing and processing industry. (Courtesy of Westinghouse Electric Corporation, Infilco Division.)



A	TANK DIAMETER	G	SLUDGE BLOWOFF
B	SIDESHEET HEIGHT	H	SCUM OUTLET
C	SIDESHEET THICKNESS	I	SLUDGE SUMP, WIDTH
D	INFLUENT	J	SLUDGE SUMP, DEPTH
E	RECYCLE	K	NUMBER OF SKIMMERS
F	EFFLUENT	L	DRIVE HORSEPOWER

Figure III-21. Infilco Sediflotor Clarifier. (Courtesy of Westinghouse Electric Corporation, Infilco Division.)

Table III-8.—*Operating data, primary skimming followed by air flotation*

Plant	Product	Head per day	Figure No.	System capacity, gal/min	Diameter flotation unit
A	Beef	1,100	III-20(a)	1,000	35 feet 9 inches
C	Beef	1,000	III-20(a)	1,500	50 feet 0 inch
J	Pork	300	III-20(e)	100	17 feet 6 inches

Operating results reported

Plant	Chemicals added	Pollutant	Influent, mg/l	Effluent, mg/l	Percent removed
A	None	Grease	1,150	150	87
C	None	Grease	2,150	213	90
J					
A					
C	None	BOD	1,710	760	55
J	$Fe_2(SO_4)_3$	BOD	1,306	200	85
A					
C	None	Suspended solids	6,200	410	93
J	$Fe_2(SO_4)_3$	Suspended solids	1,380	60	95

Table III-8 reports data for these systems.

There are many other proprietary devices, processes, and mechanical details that, it is claimed, enhance the efficiency of gravity separation and dissolved air flotation—too many to recount here. It must be stressed again that the system must operate, in pilot scale, on the wastewaters from the packing plant in question for several months before its value can be established for that particular plant.

Chapter IV
CASE HISTORIES

CASE 1

A hog killing plant of medium size in Iowa, producing fresh pork with no further processing other than edible and inedible rendering, has reduced BOD to 2.5 to 3 pounds per 1,000 pounds live weight kill mainly by way of water conservation. The plant kills about 504,000 pounds live weight using only 58,000 gallons of water. Peak kill reaches 544,000 pounds and peak water use 78,000 gal/day, with a minimum of 33,000 gallons on any operational day.

Yards and pens are all dry cleaned, using a manure spreader for direct disposal on farmland. The blood floor is prerinsed with a small-diameter hose equipped with a fan nozzle using water at 600 pounds pressure. The small amount of rinse water, 35 to 50 gal/day, goes to the blood tank. All blood is dried. The extra drying cost for the prerinse water is small compared with the cost saving in BOD reduction in final cleanup.

The plant is equipped with edible and inedible dry rendering, but paunches and edible stomachs are washed, and the wastewater is discharged to the sewer. The possibilities of further improvement in waste conservation by dry dumping have not been explored.

The plant produces a substantial saving in solids and BOD by its procedure in dumping the scalding tub. The tub is fitted with a drain 6 inches above the bottom of the tub, draining through a 2-inch line. The slow drain permits the sludge to settle. Then the residual sludge is scraped and shoveled to a large sluice gate that is kept closed during drainage. The sludge is hauled to farm fields.

The dehairing operation uses only 6 gallons per hog at 250 hogs per hour, with five men shaving and trimming. The wet hair is sold.

The grease sewer discharges to a small gravity catch basin 5 feet wide and 6.5 feet long, with a sloping end. A single scraper chain mechanism serves to drag the bottom sludge up the sloping end to a trough, and also pushes the scum to a scum trough. The scrapers ride up a beach at the scum trough and thence over the trough to complete the circuit. Bottom solids and skimmings go to rendering.

The effluent of this basin joins the nongrease sewer at a 12-foot-diameter holding sump, from which a 400-gal/min pump discharges to a circular dissolved air flotation unit also rated at 400 gal/min. The ratio of recycle to raw flow is 1 to 4. No chemicals are used. The effluent flow then is discharged to a portion of the pump sump, walled off to carry the effluent to lagoon treatment (the wastewater could be considered ready for discharge to a city sewer at this point). The walled portion of the pump sump is arranged to recycle effluent through the flotation unit during low-flow periods, to insure uniform treatment in the flotation unit.

The plant is washed down by a contract janitorial service after plant personnel dry clean the floors and equipment to remove scraps. The initial rinse on the blood floor is done by plant personnel. All driers are equipped with sprays for cleaning in place.

The owner gives major credit to water conservation for his overall success in reducing BOD as well as water consumption.

It should be noted that the operations at this plant are limited to slaughtering and rendering. Since individual process wastes in the meat industry have not been evaluated systematically, it is impossible to predict the effect of additional processing on the results of these wastewater conservation data.

CASE 2

A large meat packing plant, killing 470,000 pounds live weight beef and 1,380,000 pounds live weight hogs, operates a complete pork-processing system that includes smoking, sausage manufacturing, and curing, as well as sliced luncheon meat, canned meats, and lard manufacturing. The plant discharges less than 4 million gallons of wastewater daily and recycles 1,100,000 gallons of wastewater daily for various purposes in the plant. Blood is coagulated and the bloodwater is evaporated. Hides are sold green. Three-quarters of the hog hair is sold, the remainder going to landfill. Paunches are washed and the manure is removed by screening before the wastewater joins the major wastewater stream. The plant operates a laundry for shrouds and work clothes, and washing facilities for all rail cars. Tripe and stomachs are washed, but casings and chitterlings are tanked direct. Viscera are hashed and washed. Wet rendering is practiced for continuous edible rendering and for inedible rendering of skimmings. Pretreatment consists of screens, gravity catch basins, and dissolved air flotation. Manure sewer wastewaters are screened separately. The raw BOD is 1,600 mg/l, suspended solids 1,750 mg/l, and grease 800 mg/l. After pretreatment, these data drop to 850 mg/l (47-percent BOD removal), 500 mg/l (71-percent suspended solids removal), and 150 mg/l (81-percent grease removal).

Chapter V
SUMMARY

In any effort to improve the quality of the wastewaters from a meat packing plant, the first step must be a complete evaluation of in-plant waste-conservation opportunities. These opportunities include

- Recovery of product
- Removal of solid wastes and inedibles at the source (dry, where possible)
- Recycling of waters, such as cooling water and can quenching
- Reuse of wastewater for inedible purposes, such as condenser water in the tank house

In the offing, and possibly already inaugurated in many communities, are new regulations setting forth pretreatment requirements and surcharge systems to charge back to the meat packer those costs of municipal treatment for which he is responsible. The cost of purchased water, plus the cost of waste treatment (pretreatment costs plus municipal surcharges), and possibly the value of recoverable byproducts offer economic incentives for waste conservation. After all feasible steps in waste conservation have been taken, the degree of pretreatment of the various waste flows must be determined, first to satisfy regulations, and second to determine whether pretreatment beyond that required legally will produce economic advantages. The basic pretreatment will be required by law; any pretreatment beyond this base is an economic decision. Thus there is an economic breakpoint where the pretreatment can stop. Possibly the legal requirements are the stopping point and nothing can be gained by going further.

Other variables enter the picture.

- Possibilities for increases in municipal surcharges
- Adequacy of the municipal plant to treat the wastewaters
- General growth potential of the community, both in industry and in population

The meat packer also must consider his own future business plans, such as changes in processing, additional processing, overall expansion, or possible reduction in operations. If wastewaters are treated by the packer for direct discharge to a watercourse, he must consider obsolescence of the treatment plant, possible changes in legal requirements, and the costs that are part of a wholly owned facility (taxes, maintenance, operation, amortization, etc.).

Within these elusive variables, the meat packer must determine

- The amount of in-plant waste conservation he should economically undertake. It should be noted, however, that a substantial amount of waste conservation often can be accomplished at insignificant expense.

- The degree of pretreatment (for each of the segregated plant waste streams) that he should undertake in order to arrive at an economic breakpoint. For example, he may find that a small amount of biological treatment, beyond the physical and chemical treatment discussed in this study, will drop the BOD and suspended solids to a level equivalent to domestic sewage, and that surcharges levied by the city based on plant wastewater concentrations beyond the level of domestic sewage will drop to zero.

- Whether the long-range possibilities for increases in municipal surcharges warrant consideration of a completely independent wastewater treatment system that discharges to a watercourse, thereby eliminating all dependence on the municipal system.

Most of the biological treatment systems discussed in "Waste Treatment"[6] are also applicable to treatment before discharge to a city sewer, should such treatment become necessary to satisfy municipal regulations or become economically feasible.

There follows an outline suggesting procedures for developing a decision matrix for waste conservation and pretreatment before discharge to a public sewer.

1. Employ a waste conservation supervisor. In a small plant, this supervisor may have other duties, such as safety engineering, and he may have responsibility for compliance with the Occupational Safety and Health Act. In a large plant, a full-time waste conservation supervisor should be employed. He should have some engineering background, preferably in environmental engineering. He will be responsible for waste conservation surveys, flow measurement, sampling surveys, cost analyses of waste conservation and treatment, and continuing surveillance of the waste conservation and treatment program, including supervision of the operation of any treatment facilities.

2. Install flow measuring and automatic sampling to collect and analyze wastewater samples at sufficient frequencies and over a sufficient length of time to develop data on flow during the maximum hour and the maximum day, as well as on averages.

3. Make an in-plant waste conservation survey as detailed in this study. Develop annual costs for each possible change to include

- Amortized cost of improvements, installed

- Power costs, such as heating, cooling, and pumping for recycling and water reuse

- Chemical costs, if some in-house treatment is required in recycling a waste stream

- Labor cost (maintenance and operation)

4. Make a study of possible pretreatment systems, with annual costs developed as in paragraph 3.

5. Determine the annual cost of municipal surcharges if wastewaters are discharged to the city sewers, and select in-plant improvements based on comparative cost. If wastewaters are discharged to a private treatment facility for disposal to a watercourse, the same type of cost analysis should be made.

6. Select the elements of paragraphs 3 and 4 that are justified economically.

7. Design selected improvements to achieve the required results, considering such elements as

- Flexibility for alteration and expansion
- Operating skills required
- *Quantity of residual solids and grease and feasible means of disposal*

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Chapter VI

PANEL DISCUSSION ON ODOR CONTROL

INTRODUCTION[a]

Odor is the number one air pollution problem for the red meat and related byproducts industry. While the actual quantity of foreign matter entering the atmosphere from the meat industry is relatively minor, some of the materials can be quite odorous. Years ago it would not have been difficult to locate some rendering plants by simply "following your nose." The red meat industry increasingly has been required to practice odor control to overcome nuisance complaints and to comply with newly enacted air pollution regulations.

Historically, odor control has been practiced as response to nuisance complaints. It is curious that the standard for nuisance has changed over the years. What the public was willing to accept even a few years ago is now unacceptable—a major reason for an increasing number of complaints. Odor is now considered air pollution, and is unlike an abstract pollutant, like BOD, in that the public feels expert in understanding when odors are present.

In response to public awareness and demands, the various regulatory agencies have been increasingly aggressive in enforcing requirements for odor control. The basic compliance requirement is to proceed on any corrective program that will result in a reduction of odor complaints. Any meat packer with a nuisance odor problem is expected to conform at least to this level of compliance.

Meat packers now have additional odor-control requirements that in certain localities take the form of specific ambient-air quality standards for odor or of specific emission limits for odors.

The discussion of odor in quantitative terms continues to be a major problem to everyone—those with the odor problems, those offering odor-control resolution know-how and equipment, and the regulatory agencies that attempt to write and enforce meaningful regulations. The current practice is to define odor in terms of the magnitude of dilution required to attain a concentration that will no longer present an odor. A quantity called an "odor unit" now appears in many regulations, as does "odor unit per cubic foot" or "odor unit per standard cubic foot."[b] Since "odor units," or odor concentration, is strictly a dilution value, the term makes no comment on whether the odor is pleasant or unpleasant. Nor do odor units distinguish between a single odor and a blend of odors. For example, the odor units measured in the ambient air downwind from a packing plant probably will not be the same if the sample is taken on a concrete parking lot instead of in a field of pollinating plants. Adding to the complexity is the problem that control of odor in terms of odor-unit removal does not necessarily mean that nuisance complaints will be eliminated.

Current methods for deriving odor units are still subjective; panels of qualified individuals are used to sniff samples at various dilutions.[9] The resulting odor-unit values are not absolute, and they should not be used without qualification as to the type of testing and the nature of the test conditions.

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[a]Prepared by Kenneth M. Ries, of Armour and Company.

[b]Terms related to odor measurement and control are defined in appendix B.

Several methods for odor measurement are now in use (see app. B). These methods of deriving a dilution value (odor units) are not equatable; a direct correlation would have to be demonstrated to establish any relationships between two test methods.

The subject of odor control has several features that make it unique to the field of pollution control

- While the technical profession is engaged in the elusive battle to quantify odor in scientific terms, the lay public has no trouble at all in identifying odors.
- Everyone comes equipped with instantaneous analytical devices (olfactory system) that are always "plugged in."
- While many pollution problems concern the matter of degree, odor for the public is normally an on-off, or yes-no, proposition.
- Odor, as such, is a property of a pollutant, and not the pollutant itself. Thus it is correct to say that odor can cause no disease, and why odor perception can actually be eliminated by dilution.
- Totally effective odor control for a period, followed by a single day of malfunction of odor-control equipment, can generate more complaints than if no control equipment were installed at all—the downwind public is more apt to react to a sudden increase in odor or presence of a new odor than to a continual background odor level.

It is important to understand that odors originate from both point sources (stack or vent) and non-point-sources. Emission standards would be difficult to define for non-point-sources. In the meat industry, the potential odor sources are from bacterial activity on organic matter, the heating of animal matter, and the handling of warm animal matter.

Odor control can be summarized as

- Source control, where the odor is eliminated by means such as sanitation and rapid handling
- Confinement and treatment of unpreventable odors
- Perception elimination, for example, by dilution

Further advances in control technology are necessary if adequate odor control is to be attained within an economically and ecologically sound framework. With the greatly increased interest and activity in the field of odor control, these advances are expected.

PANEL DISCUSSION

A. J. STEFFEN: It was originally intended to hold this odor-control discussion as part of the session this afternoon. You can imagine the problem we would have had in squeezing it in. The idea of holding it tonight was first to get it into the program because the meat industry wanted it. Second, and this is a very special reason, we can assemble here a panel of experts who, incidentally, are not affiliated with any odor-control company and so are free to express themselves. All of these experts have had some problems and, I understand, are free to talk about them.

First I would like to say a few words about this problem of odor pollution, and then turn the meeting over to the panel. I would like to mention the fact that there are many, many ways of controlling odor. You can put in a counterodor, you can put in a scrubber. A point source is one problem that can be corrected in one way. A general source is another problem that can be corrected another way.

Now I would like to introduce the panel—W. James Wells, of Bell, Galyard & Wells, whom you met this afternoon; Donald O. Dencker, from Oscar Mayer; William H. Prokop of the National Renderers Association; and Kenneth M. Ries, from Greyhound Armour, or is it Armour Greyhound?

K. RIES: Greyhound. Armour and Company is a wholly owned subsidiary of The Greyhound Corporation.

STEFFEN: Don Dencker and Bill Prokop are going to speak on rendering. Ken Ries is going to take everything else in the plant. Jim Wells is going to take everything outside—odorless lagoons, that sort of thing.

First Ken Ries will give you a few impressions.

RIES: Since Jim Wells is going to review odors outside the plant and Don Dencker and Bill Prokop are going to discuss what I consider the most serious odor problem in the meat industry—the rendering problem—it falls to me to pick up the pieces that are left over.

One whole category of odor sources has one thing in common in our industry, namely, the points at which putrescible materials accumulate and at which bacteria can, with time, operate on these materials in a suitable environment to produce objectionable odors. In this category of general sources, livestock unloading areas and stockpens will be considered first. Paved stockpens, of course, lend themselves to prompt cleaning, and a prompt cleanup minimizes the odor. A second area for attention is the handling of the manure collected in some of these pens (if that is the method of solid waste disposal). Prompt handling and good sanitation practices are the most effective methods of minimizing odors from these operations. I know of no more effective means of solving these kinds of problems other than these measures. Then it is hoped that dilution will dissipate remaining odors.

Here let me make one comment about dilution. I know that "dilution" is viewed as a bad term by many regulatory agencies. But dilution is, in fact, a legitimate method of odor control in certain cases. Odor is not a pollutant, it is a *property* of a pollutant. Odor, itself, is not hazardous to one's health; it is basically a problem in esthetics. Where dilution can be demonstrated as a method of eliminating any esthetic objection, then it should be viewed as a viable method of complying with an odor-control requirement.

Blood collection and storage is a third area in which objectionable odors from bacteria are created. Again the method of control is prompt handling. Keeping blood on the floor just for a few hours can result in serious problems from the standpoint of odor, so one should strive to remove and handle this blood as promptly as possible.

Another odor source is paunch manure handling. Odors can result from this activity, particularly where paunch manure is stored prior to disposal, whether by screening or by dumping into a truck or other conveyance for removal from the plant site. If left standing, paunch manure can cause odors. Also, the ultimate disposal of paunch manure presents some difficult odor problems. One of the unsolved problems in the meat packing industry is development of an acceptable and practical method for handling this type of solid waste.

Another area for odor control is that of hide handling. Again, whether you store hides on site for delivery to processor or process them yourself, rapid handling and good sanitation practices are advised.

Inside the packing plant itself, the scraps that hit the floor—be it in the kill area, or in cutting, breaking, fabricating, or boning—produce waste matter. If this matter is left on the floor, it can cause odor problems. However, thanks to USDA, most federally inspected plants do not have a serious problem from this standpoint, because these floor scraps must be picked up promptly.

Last in the category of bacteria-generated odors from solids would be the entire area of solid waste handling, be it trash or garbage. Long-term storage of solid wastes can cause some very objectionable odors.

There are other odor sources that should be mentioned briefly without going into detail; we can do this in the questioning.

Livestock trucks present problems; as any of you know who drive down a highway, there is no question that a livestock truck can be odorous. Then, in some plants, feed is manufactured for livestock, and improper control of dust from feed operations can present some odor. Dust control usually resolves this odor problem.

In a hog plant, a potential odor source is the operation where hog carcasses are singed, producing a burnt, foul odor. In many plants the practice has been to dilute this odor with the exhaust air being ventilated from the building. This practice has been effective.

Another minor odor source is edible rendering. Most of you who are familiar with this process know that the primary problem is one of vapors produced by cooking of the edible grease for the recovery of the tallow. These fumes are not particularly malodorous. Only fresh material of high sanitary quality is handled.

In some cases, plants that process hides will produce collagen, and the unhairing operations on hides can produce odors from the chemicals used. Again, the odor-control technique used is dilution.

The other areas in the plant concern cooking—for example, boiling and, in the case of convenience food preparation, searing of meat. Vapors are produced and, again, these are not particularly objectionable. They are noticed as odors in the building, but when discharged outside they are usually not noticeable.

One area in the plant is common to all packing plants—the refrigeration system. The refrigeration equipment normally used employs the ammonia system. Uncontrolled ammonia discharges, of course, can be objectionable, and should be attended to by mechanical improvements in the refrigeration equipment.

If these odor sources are significant, then vent air from the restrooms is also an odor source. Again dilution is the technique selected, as is the case, for example, in this building.

Meat smoking is one meat-processing operation that deserves special consideration. This operation presents a third potential major problem area in addition to the two problems that will be discussed by the other panelists. The problem is twofold. First the smoke—particulate matter that is submicron in size—presents a visible emission. The smokehouse emission can be seen, and sometimes violates some of the codes on opacity. The second problem is one of odor—in this case the wood smoke odor. The meat smoking process concerns two operations; first the meat is cooked and then is smoked in two separate periods of a batch cycle. In the cooking cycle exhaust air is emitted to the atmosphere. This smokeless exhaust does contain a slight odor. This odor source is normally not considered objectionable, and emission controls are not required. The remaining portion of the cycle, where the smoke occurs, can present some odor problems, and in some instances odor has been noticed downwind resulting in a complaint.

The current technology for control of smokehouse emission recommends treatment of this odor, as it may be applicable in certain plants. The best technical solution is incineration. In this method of control, the smoke-containing gases coming from the smokehouse are passed through an afterburner. The waste exhaust itself has essentially no Btu value of its own, heat recovery is often impractical, and incineration is normally required to be at or above 1,200° F, resulting in a significant fuel requirement. The incineration approach has some serious drawbacks. One is that fuel for this purpose is getting scarce; second, the use of fuels other than natural gas has been shown to produce more pollutants than are removed, due to the contaminants in the fuel. Equally effective alternative control methods are not currently available. At least one meat packer is investigating various scrubber techniques, including the use of a scrubber and electrostatic precipitation in combination. Liquid smoking as an alternative process is being explored. Another area that must be explored is process modification. It is hoped that these developments will result in a control method more satisfactory than incineration.

STEFFEN: Thank you. We will let questions accumulate. Those of you who are thinking about them please make a note of them. Perhaps you may decide later whether one of the other panelists would be better able to answer your question than the one you had first selected.

Now I would like to introduce Mr. Don Dencker who is an old packinghouse hand. I have known him for many years. In fact, he hired Tom Roberts, one of our Purdue graduates, quite recently, so we are almost related. Don is going to talk about the irksome problem of inedible rendering odors. Rendering produces an odor that cannot be hidden. It is easily identified as a rendering odor. You cannot talk about it as being just an odor of prosperity.

D. DENCKER: We deal primarily with fresh stock—at least in Oscar Mayer, we have fresh material—and this helps immensely. There are a couple of terms that are used extensively in the regulations as applied to the control of odors.

One of the terms is "odor units." The regulation limits are usually based on odor units. An odor unit is the number of cubic feet of odor-free air required to dilute 1 cubic foot of odorous air to the point of detectability by a median number of observers in an evaluation panel. In other words, the odorous air is diluted so that most of the people cannot smell it, or cannot tell it from the blank. Usually these evaluation panels have a minimum of 6 to 10 people, having a normal sense of smell.

Another term is "odor threshold," which simply means the least concentration at which odor is detectable by 50 percent or more of the observers. Regulation by odor threshold is infrequent and I do not know whether it has really been enacted where applicable to rendering. Threshold limits were proposed a year or so ago in Illinois. For instance, some of the odorous substances from rendering operations are detectable at a part per billion. The proposed Illinois regulations spelled out odor thresholds of some 100 substances, and would virtually have put every waste-treatment plant in the State of Illinois in immediate violation. So the odor-threshold principle is fortunately not too active, but there is extensive use of odor-unit regulations.

Odor-control regulatory approach in the past was on the nuisance basis. If your neighbors were unhappy and found some legal basis for charging you with interference with their just, due right to a comfortable environment for living—or if you bothered their outdoor picnic—you could be slapped with a nuisance action. This approach has been felt to be too subjective, so regulations are now going to ambient-air intensity-concentration measurements. But this approach is just one of switching from one rather vague approach to another very subjective judgment. The approach was based on an ASTM method published in about 1957, and modified; it also uses an odor panel—a group of select sniffers—to evaluate odor intensity, and to determine if they could still smell the odor after a dilution of 2 to 1 on residential, 10 to 1 on commercial, and 20 to 1 on industrial sites, for example.

Now the regulatory trend in many instances is toward specified emission limits from specific processes. The EPA has taken this tack in preliminary efforts to develop new source emission standards for the inedible-rendering industry. And, therefore, the original proposal is to limit the emission to 200 odor units per cubic foot of emission from any point source within the plant. The problem of plant-ventilation air is not dealt with fully in this initial approach.

The odor-regulation measurement techniques I have touched on briefly are the nuisance approach (a certain number or a certain percentage of the people complain), the ambient-air approach with a Scentometer (or the ASTM method, Mills modification), and the stack- or vent-emission rate in odor units. The ASTM method is under fire. The renderers, in particular, through their Fats and Protein Institute in conjunction with EPA and with some support by the American Meat Institute, have been working with the Illinois Institute of Technology. The IIT Research Institute has developed a dynamic, more accurate method of measuring odor levels that eliminates some of the bias of the members of the panel that is built into the ASTM technique. The EPA, at the present time, is conducting a number of tests to evaluate the suitability or the reliability of these subjective test procedures.

Sources of emissions you probably all know within your respective plants are cookers, driers, and evaporators. Typically you are venting or exhausting around 50,000 odor units per cubic foot, which is a ballpark number. If you have an exhaust rate of 500 cubic feet per minute, emission is 25 million odor units per minute. I believe there is one State—Minnesota—that proposes to limit any total emission to 1 million odor units per minute. So you can see what the problem is if you have a good-sized rendering plant.

Cookers, evaporators, tank-odor evaporators, presses, expellers—all would be covered in new source standards. The EPA, in its new source standards, is also considering what it calls a "processing tank," which is basically any open vessel that contains a rendered product at 160° F, or 180° F, or above.

Blood driers are another source of odor emissions. Typically, the blood-drier emission rate might be 100,000 odor units per cubic foot. Other areas are the material receiving area, the holding tanks, and so on. There are many, many odor-control methods that have been employed, tried, experimented with; but there are three basic approaches that generally are followed.

First, if you have a vaporous emission, condense the condensable odor fractions. Then, either vent to the atmosphere and depend upon dilution to handle the remaining noncondensables, or pass the noncondensables through an afterburner or a thermal destructor. The trick, of course, is to condense the condensables. By this approach you may reduce your afterburner heat requirements to 5-10 percent of a noncondensing approach.

Condensers of various types are employed; the direct-contact type of condensers with a cooling water spray on the vapors, the shell and tube, the surface condensers, and air-cooled surface-type condensers have been used in a number of installations. Afterburners have been used—the conventional ones and those employing catalysts (catalyst fouling has been a problem). Even feeding the noncondensable gases to boilers for boiler-makeup air is a good approach in some instances.

I mentioned two of the three major methods—the vapor condensers and the afterburners or incinerators. The third method is the use of scrubbers. IIT has conducted extensive tests on scrubbers, and they appear to be a very good solution—perhaps the only reasonable solution when you must handle the plant air. Scrubbers can be spray towers or packed towers using water or chemicals—potassium permanganate, calcium hydroxide, chlorine, or some other oxidant in the spray solution.

Another approach that has been used with generally poor success is ozonation. Activated carbon adsorption, chemical counteractant addition, masking chemicals, and so on—these all have limited effectiveness, in my opinion.

To conclude, the other thing I did mention is that the Federal people are very much interested in the odor-emission problem. Apparently they surveyed the State regulatory agencies a couple of years ago after passage of the Clean Air Act of 1970. The responses from the State air-pollution-control authorities were that the most frequent odor problems were caused by rendering plants. The EPA proceeded to start work on the new source-emission standards as required by the act. The first sources were some of the more critical industrial processes, such as sulfuric acid plants, cement plants, and incinerators; the second group was to include inedible-rendering plants. My information, through the National Renderers Association, is that this action is now being held in abeyance because the authorities want to work on the more critical emissions that have a health effect. They do not have the staff to attempt immediately to police the more nuisance type of odors. This may mean, though, that there will be more activities by individual States, counties, and cities. And it may mean that individual requirements may be more stringent than a national Federal standard.

I believe that is all I have to say for the moment. Thank you.

STEFFEN: Thank you very much, Don. Don has covered the general areas of control very well.

I wonder where this place of abeyance is, where everything is being held. We heard about it this morning from the EPA people; this standard was being held in abeyance for a while, and so on. I am not looking for this place, because wherever it is, it has a pile of stuff.

We also have Jim Wells with us.

I must plead guilty to having caused some of the problems, I guess, with the odors from what I consider to be very good and inexpensive ways of treating wastewaters. I have sometimes felt that we were just changing from one problem to another. I hope that Jim has some of the answers because, frankly, the only answer I had was to plant some evergreens around the plant. Jim, it is your turn.

J. WELLS: I did not have that down on my list of acceptable procedures for correcting the problem, but it may be a good idea.

In dealing with waste-treatment systems outside the plant, in particular, I feel that first we should talk a little about lift stations, flow-measuring systems, and coarse screens. In and around the lift station there is a tendency to forget that this area is an odor source outside the plant. However, any time that grease or solids accumulate for any length of time in the wet pit of a lift station, or in and around flow-measuring equipment, or on coarse screens, you are going to have odors. Unfortunately, nobody wants to spend time looking after anything outside the plant area—anything that is not making money. It is very difficult, because most of the personnel responsible for assigning people on their staffs to do jobs must be able to show that those people are absolutely essential to making money. Well, it is hard to show that you need somebody to make money in looking after your waste-treatment system, but as time goes on, I think you will find that it is more and more important that you assign an individual to this responsibility.

You not only need good housekeeping in and around the lift station, flow-measuring system, and coarse screens. In settling tanks and clarifiers it is very important to get the grease off quickly and to remove bottom solids continuously. I have seen too many clarifiers with grease about a foot thick. You ask, "How long has it been since you cleaned this?" They say, "Well, we clean it every day, we clean it regularly." You know full well they do not. After three or four of these instances, you finally take someone aside and say, "Look, I'm on your side, tell me what you're doing here."

Grease removal is an area you do need to look after. It is to your advantage, of course, to get that grease off quickly in rendering. The longer it stays, the more problems you are going to have in trying to handle it.

It is also important that you have a system for removing the bottom solids on the settling tanks. In a settling tank you remove the grease because it makes money; you are not worried about what settles to the bottom because it does not. If you say, "Well, I'll hose it down once a week," this tank is going to be a source of odors. It is going to be a problem in operation; it is going to affect your grease operation. So you should remove those solids regularly.

My next point is one that I think Al Steffen was alluding to—the matter of anaerobic lagoons. As was discussed in our session earlier today, we remain convinced that anaerobic lagoons are a boon to the meat packing industry and an essential part of a great number of systems. But unless we begin to approach the problem of odors from the anaerobic làgoons we are going to find some continued reluctance on the part of certain States to approve them.

As far as anaerobic lagoons are concerned, we primarily have been relying on location to prevent odors from becoming a problem. You do not locate a lagoon within a thousand feet or a quarter of a mile of anybody, and usually they are placed at least a half mile and preferably two or three miles out of town. Well, this really is just a dilution system, and one that does not always solve the problem, depending upon temperature conditions.

Further, there are situations in which we have a problem maintaining a grease cover. We discussed some of these matters in the earlier session, so I will not go into them now—but it is essential that we do maintain a grease cover.

One other thing has been done. We have a plant at Sioux Center, Iowa (Supreme Packing Company), with a 6-foot board fence all the way around the lagoon. This fence does two things. First, it helps to keep the wind off, which then helps to keep the odors from being dissipated. Further, it keeps the cover from being moved around. Without protection you will find a weak cover on one side one day and back on the other side the next, just because the wind is blowing.

The latest thing that has come up concerning anaerobic lagoons is the matter of attempting to develop a cover for them. Now to be sure, a cover is an expensive system—probably costing in the neighborhood of a dollar a square foot, or $43,000 an acre. On the other hand, perhaps the alternatives to the anaerobic lagoon are much more expensive, so it is still a relatively economical system.

At Monmouth, Ill., there is an anaerobic-lagoon cover in a meat packing plant. I visited that plant a month or two ago, and took some pictures while I was there. I think I might show them at this time to give you some idea of what the cover looks like, what it consists of, how effective it is, and, perhaps, what some of the problems are.

The cover at Monmouth is nylon-reinforced Hypalon. There are nylon ropes that stretch all the way across the cover and are anchored into the side. There is a concrete parapet wall that runs all the way along the bottom, all the way around the pond.

The method of sealing around the edges was to bring the cover across, then double it back. Then there are anchor bolts going through 2 x 4's that anchor down into the concrete. The problems with this design have been the nonuniform surface on the parapet wall, which has resulted in some leakage of gas underneath the cover, and possible corrosion, which has caused a loss of seal.

Incidentally, Monmouth was forced into a cover because the wastewater is very high in sulfates, and there was a lot of hydrogen sulfide being given off. There was an attempt to try to keep the system aerobic, but it was not successful.

You can get some idea of the maze of ropes laid across. These channels are made of Styrofoam, and are laid on top of the wastewater in the pond. Their purpose is gas collection, to remove gas from the system. They have openings that bring the gas inside the collectors, and they are spaced across the pond. Also, around the periphery of the pond, there is perforated PVC pipe that also draws off gas. All the piping is brought together down at one end; it is hooked to a gas compressor, and the suction side is then hooked to the pond.

In a closeup of the parapet wall, you can see where the cover has been doubled through and then back under; then the bolt is clamped down. I walked all the way around the periphery. There were certain areas where you could tell the cover was leaking because the odor was very strong, but, by and large, it had made a tremendous difference in the odors from the pond. We did not detect any odors when we walked away, only right down next to the pond.

The gas compressor is inside. The suction line comes through a flexible connection, through a plug valve, over an elbow, on down, and becomes the suction line that goes out to the anaerobic-lagoon cover. The building is not completely enclosed. Probably a foot or two all the way around is open to the atmosphere, so in the wintertime it is quite cold. In order to insure against freezing—this gas is very moist—there are infrared lamps directed onto the piping.

There is a pressure-reducing valve, a flame arrester, and then a waste-gas burner located outside. Quite a bit of flame can be seen coming out. They are not adding any natural gas or anything—the flame is from the methane that is collected underneath the cover and is being burned.

QUESTION: Do they have any protection for hail, or rain, or things of this nature?

WELLS: No. I would say that the cover material—nylon-reinforced Hypalon—is probably the best material that they could have. You could get cheaper materials, but that is probably one of the best. Whether it would stand up under a very intense hail storm, I do not know, but I would say it would stand up as well as, or better than, most other products.

QUESTION: How much did this cost?

WELLS: I do not know specifically what this one cost. We ran though some costs for another installation, and it looked like about a dollar a square foot. I am not sure, but I would say cost for this installation was very close to that figure. It might have been somewhat less, but—particularly when you include the parapet wall, the cover, the ropes, the gas collection—probably $43,000 an acre is not a bad figure to look at.

QUESTION: Is there enough methane to keep it burning?

WELLS: Yes, I would say so. You probably ought to have a propane or a natural gas pilot on the system, but there is enough methane to keep it going. It will support combustion. You do not need to plan to spend for natural gas or propane.

QUESTION: What are the nylon ropes for?

WELLS: I would say that one purpose would be to make very sure the cover did not blow away with a great big wind. Second, gas bubbles will be created underneath the ropes. Particularly if the system is operated intermittently, if either the time clock fails to come on or the operator does not have it set often enough or does not look at it, some gas bubbles will build up. If the compressor is turned off, a big bubble starts to form. And probably the ropes are just a means of confining that bubble and keeping wind from being a problem.

DENCKER: This cover was designed after they looked at one at Greenville, Mich., at an Ore-Ida potato-processing plant. That was why the ropes were added, to restrain big bubbles that developed.

WELLS: The Greenville cover was, I think, a 30-mil PVC. I went up there to see it. It was an anaerobic treatment system for potato waste, and there was a problem with some mountainous bubbles. I suspect that is why they used ropes in this installation.

COMMENT: They would have to walk out and push the bubbles down with their hands.

WELLS: The other thing I want to cover is the problem in aerobic lagoons in a spring-thaw breakup. Ycu have a functional system that works beautifully in the summertime; in the wintertime an ice cover develops on it. But during a period in the spring, when the ice goes off, you do have some odor problems. I want to suggest how you might resolve that particular odor problem.

If you were to broadcast approximately 200 pounds of ammonium nitrate per acre over the lagoon system, and then follow that with a makeup dosage of about 100 pounds of ammonium nitrate per acre every week until the end of this problem period, it would help considerably. This method supplies nitrates in the form of NO_3. The bacteria like that form of oxygen much better than they do the sulfates, so they will take the nitrates first. So, if in the spring your neighbors get on you and the flack becomes a little much, this method will get you over the hump until reaeration from wave action can bring the pond back to an aerobic condition.

QUESTION: I have a question on that. What do you do about the ammonia?

WELLS: Well, we will assume that that is not a problem. Otherwise, you will have to treat it.

STEFFEN: That is in that place we call "abeyance."

WELLS: We could use sodium nitrate until the authorities start cracking down on that. But the idea is to come up with a cheap source of nitrates, and if you do not like ammonium, we will use something else.

STEFFEN: Thank you, Jim. I am happy that these speakers left quite a lot of questions untouched, on purpose. We wanted to keep the subject somewhat—I almost said that phrase, "in abeyance." Perhaps we might pause for those of you who have questions. Please address them to the speaker you think can best answer; and he is free to enlist another of the panelists or anybody in the audience who might have a good answer to the problem. So, if you please, come to the mike. If you want to announce your name, fine. If you do not want to, fine, too. This is not going to be one of those sessions with finger pointing. We are all here for the same thing. We want some answers, and we want some low-cost answers.

QUESTION: This is to Mr. Dencker. I am wondering if you have done any work on collecting the odors from expellers—in incinerating them, scrubbing them, or something of that type. Also, what about this problem of rendering-ventilation air?

DENCKER: We have solved our expeller odors so far by diluting them, quite frankly. I think this would be a good time to hear Mr. Prokop's remarks on rendering. The National Renderers Association had a real go-around, I think, on the matter of plant-ventilation air. They have had many discussions with the EPA.

W. PROKOP: Although my remarks on odor control are based primarily on experience with rendering plants that are independent of meat packing or slaughterhouse operations, they can be applied also to the on-site rendering plants. However, the packinghouse material and the blood handled by these rendering plants are usually quite fresh. It should be recognized that the independent rendering plants process a wider variety of raw material and that it usually is older, which tends to result in higher levels of odor to be controlled.

The primary source of high-intensity odors in a rendering plant are the noncondensables from the cooker exhaust and those emissions resulting from the screw press operation. These emissions range in odor intensity from 5,000 to 100,000 odor units by the ASTM syringe method. Other sources of high-intensity odor emissions include centrifuges, tallow-processing tanks, and the perc pans, which are open to the room atmosphere and receive the discharge from batch cookers.

The raw material is another source of odor, but normally it is not significant when processed without delay. It is commonly known that animal byproduct material deteriorates rapidly upon exposure to air and sun. The quantity of odor emitted from the rendering process is affected greatly by the degree of deterioration that has preceded the cooking process.

No simple generalized approach for solving odor-control problems is applicable to all rendering plants. Each individual situation must be evaluated separately based upon the plant building features, process equipment, raw material, and so forth. However, the renderer can improve his odor-control capability by conducting the following periodic reviews.

Confinement of high-intensity odors, such as cooker noncondensables and screw press vents within the system, should be evaluated. Excessive emission of fat aerosols to the building atmosphere not only increases odor levels but deposits grease on platforms and walkways, causing slippery surfaces that relate to OSHA safety problems. Further, these excessive grease deposits require increased cleanup labor and water use, which results in additional wastewater treatment to process the greater volume and higher grease concentration in the plant effluent. The gasket seals on cooker inlet and discharge doors and the tightness of odor-pickup duct connections should be checked periodically.

With the advent of continuous rendering systems, the ability to confine odors within the equipment has been improved substantially. Manufacturers of these systems are becoming more concerned with equipment details that relate to providing gasketed seals where odor emissions may occur (e.g., inspection covers) and the location of suction pickup vents for improved collection of odor emissions. Even batch cooker systems have a potential for improvement. Some plants have provided their batch cookers with a manifold duct system separate from the exhaust system to draw off odorous vapors with low steam content as the cooker is being filled through the sealed dome. Several attempts have been made to provide batch system percolation pans that are essentially closed.

The entrainment separator between the cookers and the condenser should be checked periodically to determine that it is efficiently removing any solid or fat aerosol particles in the cooker exhaust. An efficient separator not only will improve product yield but will result in less odor in the noncondensables and less solids and grease in the condensate that ultimately must be processed in a wastewater-treatment plant.

The condenser that removes steam vapors from the cooker exhaust should be provided with adequate cooling capacity. The condensate temperature should not exceed 120° F to minimize the presence of volatile odorous components of high intensity. The barometric or direct-contact condenser is generally being replaced by either a shell-and-tube condenser or an air-cooled condenser because of the trend to minimize water use and wastewater-treatment costs. The air-cooled condenser is preferred because water circulation is not required for cooling and condensing.

Overcooking and overpressing should be avoided. These are operating problems and depend on the operational techniques developed in relating product quality to process variables such as cooker time and temperature.

Odor-control equipment should be kept in good operating condition. Operating procedures should be clearly defined to insure proper operation and control of odors.

Good housekeeping and sanitation practices should be maintained to reduce odor emissions from spilled material and to create a good visual image. Cleanup water hoses should be provided with automatic shutoff valves to conserve water.

Neighborhood areas should be checked periodically for effectiveness of plant odor control. Whenever a meteorological temperature inversion occurs, conduct your own odor investigation and determine the effectiveness of your odor control under adverse weather conditions.

Present odor-control methods used in rendering plants consist primarily of incineration and wet scrubbing with chemical oxidant solutions.

Direct flame incineration can be an effective method of control for relatively small volumes containing high-intensity odors. These volumes normally are limited to 1,000-2,000 cubic feet per minute, and the odorous streams being incinerated usually consist of cooker noncondensables and screw press vents. It is particularly important to avoid excess air being drawn into the odor duct system, because fuel costs increase significantly. Afterburners with heat recovery sections have been installed to process large volumes (up to 25,000 cubic feet per minute) of rendering-plant air that contains odors. In spite of 50-percent fuel savings, however, the fuel costs were so excessive that these units were soon abandoned in favor of wet scrubbing systems.

Instead of providing an afterburner for incineration, with the related additional capital and operating costs, it sometimes is feasible to use the boiler firebox to incinerate low-volume, high-odor-intensity gases. Maximum fuel economy is achieved by using the odorous stream as primary combustion air; however, the necessary precautions must be taken to clean up this stream by removing solid and fat aerosol particles before passage through the burner and controls. Some boiler manufacturers and fire insurance companies recommend against using this odorous gas as primary combustion air. If the gas is used as secondary air, then additional fuel is probably required. Also, the boiler must be equipped with suitable burner controls to insure that the minimum firing rate is sufficient to incinerate the maximum volume of effluent gas passing through the boiler firebox, regardless of the steam requirement.

Current and future trends dictate severe fuel shortages. The supply of natural gas is dwindling rapidly. The availability of low-sulfur fuel oil is also decreasing. As a result, higher sulfur-content fuels will have to be burned, resulting in increased sulfur dioxide emissions that will probably exceed the quantity of odorous compounds to be incinerated. Further, fuel oil costs are increasing at an alarming rate due to the fuel oil crisis that has developed during the past months. For these reasons, incineration as a method of odor control is expected to decline in the future.

The use of wet scrubbing systems that employ chemical oxidant solutions to control rendering-plant odor emissions has increased significantly during the last 2 years. The use of chlorine and sodium hypochlorite has exceeded the use of potassium permanganate as a chemical oxidant, primarily because of lower costs and ease of handling in solution. Sulfuric acid and caustic soda or soda ash have also been used as chemical scrubbing liquids to effect further reduction of odorous constituents to less-odorous compounds.

STEFFEN: What do you do with the liquid effluent?

PROKOP: The chemical oxidant solutions used in wet scrubbers normally are recirculated or recycled to conserve water and minimize chemical and wastewater-treatment costs. Where the strength of the solution is reduced to such a level that it has to be dumped, this effluent has to go through a waste-treatment system. If it goes into the municipal sewer system the pH would be adjusted. That certainly would be the minimum that would be done.

The concept of balancing the oxidant chemical addition rate with the chemical use rate is important to achieve most effective use and minimum cost. It is advisable to treat gas streams containing solid and fat aerosol particles with a preconditioning device, such as a low- to medium-pressure-drop venturi scrubber, to remove this particulate before passing to the chemical scrubber. Since the mass of the particulate matter suspended in the gas stream may exceed significantly that of the gaseous odor components, the rate of chemical oxidant consumption could rise quickly because the presence of the particles in the recirculating solution will tend to use up most of the oxidizing agent.

Relatively few wet scrubber systems are being operated that handle exclusively rendering process air emissions containing high-intensity odors, as opposed to plant ventilating air that may contain these process emissions but diluted to a lower odor level. A two-stage system consisting of a venturi scrubber with water sprays and a countercurrent-flow packed-tower scrubber with recirculation of sodium hypochlorite solution is treating a combination of raw feather storage odors, feather cooker and drier exhaust, blood drier exhaust, noncondensables and screw press vents. A three-stage, crossflow, packed-tower scrubber with gaseous chlorine addition, dilute sulfuric acid recirculation, and dilute caustic soda recirculation is treating a poultry byproducts plant effluent consisting of feather drier exhaust and offal cooker noncondensables. These scrubbers are achieving up to 99 percent reduction in odor level where the scrubber inlet odor concentration ranged from 5,000 to 20,000 odor units (ASTM method).

Plant-ventilating-air-type scrubbers include two basic types. A countercurrent-flow, horizontal-spray-type scrubber with either one or two stages is being used extensively, with soda ash or caustic soda solution recirculated through the first stage, and gaseous chlorine addition to water recirculated through the second stage. The two-stage system is normally used to treat all sources of rendering odors present in the ventilating air and where odor-control requirements are more stringent due to closer proximity of neighbors. The countercurrent-flow packed-tower scrubber is being used with a variety of chemical oxidants that include sodium hypochlorite and a sulfuric acid solution containing a powerful oxidant that is regenerated by a simple electrolytic cell. These scrubbers, too, are treating the high-intensity odor streams along with the plant-ventilating air. These types of scrubbers are achieving up to 95 percent reduction in odor level where the scrubber-inlet odor concentration ranged 200 to 2,000 odor units (ASTM method).

Atmospheric dilution with a properly designed stack is an important part of the overall solution to plant odor control. In order to obtain adequate dispersion of odors, the stack height should extend sufficiently above the roof to compensate for the location of adjacent buildings and the surrounding topography. Under normal atmospheric conditions, a hundredfold or more dilution is expected with such a stack.

The fundamental problem with odor control and governmental regulation of odor emissions from industrial plants is the lack of a reliable odor sensory method of measurement. Considerable attention has been given to analytical measurement of odor emissions from rendering plants by gas chromatography and other means. However, due to the number and complexity of odorous compounds present in rendering-plant emissions, these methods are hopelessly complex and expensive for routine use. As a result, the only practical approach remaining is to provide a measurement based on the olfactory senses of the human nose.

Odor perception by various individuals is highly subjective and can vary widely. Odor sensory evaluation conducted with nine-member panels at IIT Research Institute indicated that a tenfold variation in sensitivity normally exists among panel members, and occasionally the difference is as high as a hundredfold.

The problem of odor perception is complicated further because different odor-level values are obtained by the various odor sensory methods currently available, even though the same identical odorous air sample is being tested. These differences are due primarily to the method of presentation of the odor stimulus to the panel members. Two current methods of odor sensory measurement are being used as a basis for compliance with State or local odor regulations—the ASTM syringe method and the Scentometer method.

The ASTM syringe method is currently specified in the regulations of three States to determine the odor concentration of exhaust stack emissions. This method consists of taking samples in a 100-cubic-centimeter cylinder or a 250-cubic-centimeter glass tube, and then diluting the samples with odor-free air to predetermined odor-dilution levels for presentation to a panel of eight persons. Each panel member must smell momentarily a rapidly expelled pulse of odorous air from the 100-cubic-centimeter syringe. The median odor threshold level is defined as that dilution level where 50 percent of the panel barely detects the diluted odor stimulus.

This method lacks a defined procedure for odor stimulus presentation, since the various odor dilutions are to be presented randomly to the panel by mixing the order of strong or weak odor stimuli. Sometimes a blank or odor-free sample is substituted to check the panel's reaction. Since a weak stimulus is much less detectable after a strong one, this approach can result in a false response. Further, this method has no satisfactory provision to check the reliability of positive-negative responses of the panel. Odor sensory evaluation of a single sample normally requires from 30 to 45 minutes.

The Scentometer has a history of compliance use across the country as a measurement of odor in the ambient air. This instrument consists of a small rectangular chamber that contains two sniffing tubes on top for insertion into the nostrils. Normal breathing draws the odorous air from the surrounding environment through the bottom panel and also through the two side panels that contain activated carbon to provide odor-free air for dilution. The bottom panel is provided with four holes of varying diameter to vary the dilution ratio. These holes correspond to ratios of dilution to threshold of 2, 7, 31, and 127.

The Scentometer has three basic disadvantages. First, this instrument is normally used by only one individual. Odor sensory responses by different individuals are highly subjective, and the Scentometer method does not provide for the selection of an odor sensory panel to average high and low individual responses. Next, the construction of the instrument does not provide positive means for an individual to isolate his or her nose from the odorous environment being monitored. Depending on the individual's pattern of breathing and ability to seal off the nasal passages with the two sniffing ports, it seems reasonable to expect that any odor in the ambient air could bypass the instrument and be sensed directly by the nose, thus resulting in a false positive response. Finally, the Scentometer is inherently limited to diluting the odor stimulus to four specified levels, and there is no adequate provision for achieving a graduated degree of dilution between adjacent levels. Since a number of Scentometer regulations are specifically setting limits at low levels (2 and 7 odor units) to define an objectionable odor nuisance for either residential or nonzoned areas, it is essential to have available an odor sensory method that is capable of accurately determining the odor-dilution level at these lower levels.

Our association has been extremely concerned about the reliability of the ASTM syringe and Scentometer methods. As a result, we initiated a project under the Fats and Proteins Research Foundation, Inc., with IIT Research Institute to develop a dynamic method where the diluted odor stimulus is continually discharged at a controlled flow. The *dynamic olfactometer* is based on a forced-choice triangle statistical design. One diluted odor sample and two nonodorous air blanks are presented continually at each dilution level. Each panelist is required to judge which of the three ports is odorous and to signal a choice. The three ports are arranged in a circular symmetrical pattern to achieve a double-blind sample presentation, since neither panelists nor the panel leader know the correct choice until after the judgment is made. The results can be related to statistically significant confidence levels. For a nine-member panel, a correct choice by six panel members would indicate a 95-percent confidence level that the choice did *not* occur by chance.

The test work is essentially complete for applying this method to measure stack-emission odors. This work includes relating the odor test results with those obtained by the ASTM syringe method. Work is now being initiated to apply the IIT Research Institute dynamic method to ambient-odor sensory measurement and to relate the results of the method to those obtained by the Scentometer.

The EPA published in the *Federal Register* of June 11 proposed performance standards for new stationary sources in seven industrial categories. The rendering industry was omitted from this group of industries and, therefore, no odor emission standards are being published at this time by the EPA. As a result, it is anticipated that there will be increased activity by the individual State agencies to develop and promulgate new odor regulations. As indicated before, however, there is considerable need for a reliable odor sensory method of measurement to be available for compliance use.

RIES: I have a comment on this subject, partially in answer to the question that was addressed to Don. My comment concerns an experience that Armour and Company had recently.

In January 1973, an inedible-rendering plant was installed at a beef abattoir. The State regulatory agency had just before that time enacted a very stringent law that covered the area of rendering. The regulatory agency asked that all ventilation air be incinerated, and the plant management thought this was prohibitively expensive. The State wanted some sort of control, so the compromise position was to install a scrubbing device. This rendering installation has five batch melters, three blood driers, and two expellers. The melter tank vapors were conventionally handled by direct water-contact condensing. This condensation removed about 95 percent of the original volume of the melter vapors. The noncondensable gases remained. Fresh material is rendered at this plant, and this material is not odorous when introduced into the melter. Therefore the melter vapors, or the noncondensable gases, are less odorous than the gases from rendering dead and decaying stock.

The system that was installed for scrubbing incorporated the collection of the noncondensable gases and ventilation air at selected points just above the percolation pans, expellers, and blood driers. A maximum of 1,000 cubic feet per minute were handled from the hot well where the noncondensable gases were trapped, and 9,000 cubic feet per minute were handled from the ventilation ducts with inlets above the non-point-sources within the building. It was expected that removal of this volume of air would, in a large measure, remove most of the odor present in the rendering building.

We have just put this system on stream, and I have brought with me some test results. These data are in the form of Hemeon test odor units. For those who are familiar with odor testing, there is an alternative device that has not been mentioned—a dilution analytical technique.[c] The device is used to derive odor intensity (or odor units) on a given air sample, which is, in essence, the dilution ratio. This number, incidentally, is not directly correlatable to ASTM odor units, but a recently published curve[10] shows a correlation between these two techniques for deriving odor units.[d] This curve is only a clue to the probable relationship of values for odor units, and cannot

[c]See "Odor meter" in appendix B.
[d]See figure VI-1.

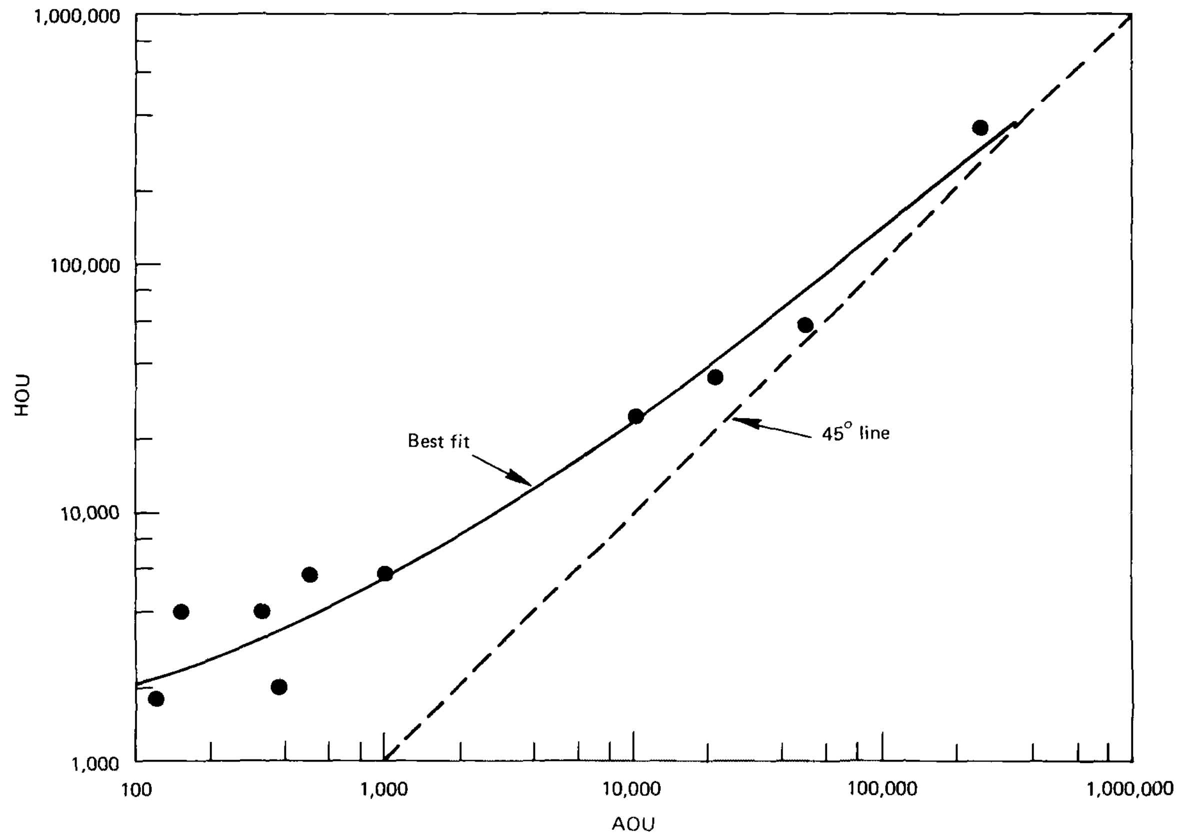

Figure VI-1. Comparison of odor measurement techniques: ASTM odor units per cubic foot (AOU) versus Hemeon odor units per cubic foot (HOU). (After Johnson and Bourne.[9])

be used without considerable qualification. The science of odorometry is still too new to permit us to discuss odor units in absolute terms. The scrubber that we installed on the 10,000-cubic-foot-per-minute ventilation system consisted of gas chlorine addition preceding two packed-bed cross-flow scrubbers, each with water and chemical recycle. The first packed bed used an acid scrub (10 percent sulfuric acid). In the second packed bed a 10-percent caustic scrub is used. Mist eliminators follow each packed bed to prevent windage loss of chemicals. The total installed cost for the entire 10,000-cubic-foot-per-minute scrubber system and ducts was below $25,000. The gases coming in to this unit were found to have 12,000 odor units, 32,000 odor units, 18,000 odor units, and 3,500 odor units on four random inlet samples.

The degree of odor control was over 90 percent removal, with outlet-gas discharge odor concentrations of 500, 250, 300, 500, and, in one case, 1,600 odor units. In the case of 1,600 odor units, all the chemicals were removed from the scrubbing solutions and water alone was used. The resulting odor removal was 54 percent. This was a good verification that the chemicals do perform the required technique of improving capture of odorous matter present in the exhaust air. The regulatory agency is satisfied with this solution.

QUESTION: I want to ask about the Hemeon units. I understand that they are on the order of magnitude of four or five times the more conventional units, is that right? What is the correlation?

RIES: The correlation curve I mentioned was published in a paper by Charles A. Johnson and Joseph R. Bourne, of Air Quality Systems, Carrier Corporation.[10] At the end of the article there appears an empirical curve showing a comparison of Hemeon odor units to ASTM odor units.[e] At values of ASTM units above 100,000 odor units, the Hemeon and ASTM methods seem to give comparable figures. But as the concentration decreases, the Hemeon odor unit tends to generate higher odor unit values than the ASTM method. According to this curve, at very low odor concentrations, where ASTM values approximate 100 odor units, the comparable Hemeon odor units are over 2,000. The Johnson and Bourne article is the first publication I have seen that relates these two types of testing.

The Hemeon method was used in our case because of its convenience. A panel of only three people was used and the odor units for a given sample could be computed in about 15 minutes. For evaluation of equipment performance, this analytical method was satisfactory for the regulatory agency.

DENCKER: I had read that under normal control levels it would be pretty poor to depend upon the Hemeon method, because if you wanted 200 odor units per cubic foot, the Hemeon reading is liable to be 800 or 1,000. The Johnson curve seems to point that out. That is one reason I did not mention that method.

For control of expeller odors we have not gone to scrubbers, but I have heard of installations where they have collected the expeller gases and directed them to the makeup air for gas-fired burners for ring driers. That approach might be applicable in some instances.

STEFFEN: OK, anybody else now?

D. NEUBAUER: My name is Dave Neubauer, with the Omeco-St. John Company. We talk about odor units. I would like the opinion of any member of the panel or in the audience—when we talk about measuring the odor units, at what point do they measure them? Where odor is produced—say, at the expeller or at the percolator pan? At the discharge, or at the property line? Or, in the case of a lagoon, at the lagoon? Or some distance away? I wanted to get some idea what we might expect—of what we get in the present regulations, and what we might expect in the future.

DENCKER: As you point out, there are two different approaches. One is called the outside, or the ambient-air approach, and was the original attempt at quantifying odors. For instance, you have a plant neighboring residential property. With a Scentometer, a few years back, you would dilute a cubic foot (or a known volume) of odorous air, or supposedly odorous air, blowing off your property. If you could not smell the odor at a dilution of 2 to 1 you passed. If you could smell it at a higher dilution you failed. That is an ambient-air test method.

But the regulatory approach of the Federal Government is, I think, the more conventional stack-sampling approach of actually measuring emissions at the point the exhaust leaves the building, or at some convenient place before any dilution takes place with outside atmosphere. In this case odor units are used. And part of the problem of making this approach worthwhile—at least such is the argument of many people in this area—is the attempt to adapt an ambient-air testing procedure to a stack-emission procedure. There is no set answer. The regulatory people might choose to take the ambient-air approach at the property line, they might choose to take the specific stack-vent-emission approach at the plant building itself, or they might try to get you both ways. You cannot tell.

NEUBAUER: Do you have any idea of the consensus of the existing State regulations—whether Minnesota, or California, or locally? Are they property-line tests or tests at the emission from the stack?

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[e]See figure VI-1.

DENCKER: I do not know. I would even hesitate to guess. The renderers have taken a survey.

PROKOP: I would say that there are probably more ambient-air standards than there are stack-emission standards. And I sense that the States are going to be leaning toward the ambient-air approach. This will take into account zoning—in other words, the residential, industrial, rural areas. Offhand, I think this is a reasonable approach, because then different zoning would not be stuck with the same stack-emission standard. I think the *big* problem right now is having a good and proper odor-answer method.

STEFFEN: Anybody else on any part of this subject at all?

J. MAZURA: Joe Mazura, Rose Packing Company, Chicago. The gentleman from Armour stated that Armour smokes with natural woodsmoke. I was wondering if his feeling is that incineration is better than water scrubbing for that type of emission.

RIES: No, as I started to point out in my introductory remarks, incineration is currently viewed as the best technology. It does destroy odor. You cannot disregard the fact that it does work. My disagreement with this solution is that it is not economical; it is very costly to operate.

The second disadvantage to incineration is that it produces more problems than it solves. To give a test case, some figures were computed for a given plant just to show the magnitude of the problem. At one processing plant, 65.8 tons of smoked meat are processed per day in 11 smokehouses. This is done throughout a 24-hour period. Both direct stack testing and U.S. Public Health Service emission factors, which in this particular case correlated fairly close to the actual emissions from this process, indicated that processing this volume of meat produced a total of about 20 pounds of particulate matter per day, which is the smoke emission to the atmosphere. The organic load in this emission was also about 20 pounds a day.

Fuel oil use—a requirement in this case because gas was not available from the gas company—would have been 1,170 pounds a day to burn these 20 pounds of organic matter. Now that does not make much sense. Computation of the anticipated discharge of pollutants from fuel oil (assuming No. 2 fuel oil with sulfur at 0.5 percent) resulted in values of 83 pounds of sulfur dioxide a day and 70 pounds of nitrogen dioxide a day. These 153 pounds of pollutants would be generated by burning 20 pounds of organic matter. That does not seem like pollution control in the right direction.

The scrubbing approaches previously mentioned may be quite a bit less costly and would not generate oxides of nitrogen and sulfur. The problem right now is that it may not have the odor-control effectiveness of incineration. From testing performed to date, venturi scrubbing has been found effective in removing particles larger than 0.3 micron in diameter, but removal of particles smaller than 0.3 micron has not been achieved. Unfortunately, most of the odor is associated with the smaller particles. Evaluations of odor removal via venturi scrubbing suggested that, with removal of almost all particulates down to 0.3 micron, only half of the odor units were removed from the raw gases. Venturi scrubbing is effective in control of visible emissions, but water scrubbing has not totally solved the problem of a detectable odor in the atmosphere. This technology is still under evaluation; scrubbing with chemical solutions reduces odors significantly.

MAZURA: My second question is, Can you foresee, say in the year 1985, that regulatory agencies will ask for the control of emissions from a smokehouse?

RIES: Our company has three plants that are under order to control emissions right now—so it is not 1985, it is now. At this time, our plan is to not put incinerators in; we are going to do something else. Our company is currently conducting studies to find a satisfactory alternative solution to incineration of smokehouse exhausts.

W. COLVIN: Bill Colvin. Are you being asked to control your odors or your particulate emissions?

RIES: Both. The primary problem in smokehouse emission has always been particulate emissions. People can see smoke coming out of the packing plant, and it is therefore an obvious discharge and a candidate for control. The more recent regulations have identified smokehouses as violators of opacity, and also have identified them as point sources of odor. Personally, I do not particularly see them as odor sources. The smoke is not an objectionable odor. In most of the plants where our company conducts smoking, the odorous emissions that drift downwind have never been, to our knowledge, the source of any complaints. However, regulations may require controls of odor if the emission violates a specific odor emission regulation.

R. GERHARD: I am Bob Gerhard with Hormel. I have two questions. One may seem quite far out, but it regards the equivalent of water pollution by 1982 zero discharge. Is there any possibility of that standard being applied to the odor area? Second, in the process of these various rendering facilities, there is a lot of heat generated. Has there been any approach so far by the Government as regards thermal pollution?

DENCKER: Well, some afterburners have some waste heat recovery, which I think is a good approach in preheating the incoming stream to assist combustion. I do not like afterburners either. I think they are a tremendous waste of a natural resource—of natural gas— and afterburners are thermal polluters. In areas with a photochemical smog problem, such as Los Angeles, the regulations lead to afterburners, and then speak of ridiculously high operating temperatures. Higher operating temperatures increase the emission of oxides of nitrogen. An afterburner is, as I see it, in some instances a patch or bandage for the benefit of the public—they cannot see the smoke. You do not have to operate the afterburner at 1,200° or 1,500° F for 3/10- or 5/10-second residence time to get rid of the visible smoke. If that is the requirement, you should operate it at a minimum temperature, which may be only 600° or 700° F, just to eliminate the visible emission. As to zero discharge, there is no such thing. It defies the laws of conservation of energy. In going toward zero in one direction, you are bound to increase the problem in another direction.

QUESTION: Where do we stand with this ozone treatment that some people have tried? Are any of you familiar with that?

DENCKER: I will pass that on to Ken. He had an ozone installation at Sterling, Ill., if I remember right.

RIES: Yes, our company did have an installation of ozone equipment on a rendering problem. In this case, an inedible-rendering operation at an abattoir (where only fresh offal was rendered) had melter vapors discharging to the atmosphere. In this particular plant an ozone generator was installed to introduce ozone directly into the wet vapor. Loss of ozone-generating efficiency was experienced due to the high moisture content of the air near the generator. The ozone generator did produce ozone, however, when the air was dry. Company engineers observed that the ozonator destroyed odors in the stream emission completely.

This ozonation application was discontinued in favor of direct water-contact condensers.

I do not want to leave you with the impression that ozone is no good. The installation was primarily a field test, based on the manufacturer's recommendation, and our knowledge of the problem. It was not intended to be an exhaustive experimentation on the potential for ozonation in controlling rendering odors. Maybe ozone does have an application in rendering-odor control, particularly where the ozone can be contained. There is one problem that you must consider when using ozone—in itself, it is a pollutant. The contact of ozone with the gases must be confined and controlled in a manner that results in no discharge of unreacted ozone. This additional problem must be solved if ozone is under consideration.

STEFFEN: Any other questions? Any questions on lagoons? We all are, I think, in agreement with Jim. I think we have at least a consensus here that the anaerobic lagoon has been a godsend to the meat packing industry, and we would like to see its use continued. This is one of our real problems. Don, do you want to comment a little on the questions that you raised to our biologists? I do not remember all the answers because I am not a biologist—maybe you can help me out on that.

DENCKER: Professor Steffen refers to purple sulfur bacteria. This form of bacteria is a phenomenon that has been noticed in a number of lagoon systems that have had a high sulfur-sulfide content. In the subject system, the bacteria have eliminated or greatly reduced the odors, except that, as in the anaerobic process, bacteria are temperature sensitive. I suspect that, if you could construct a proper vessel for an aerobic lagoon—you would need light to keep the bacteria happy, as well as enough water and enough food—they would then handle your hydrogen sulfide problem under controlled conditions. We played around with a very unsuccessful fishbowl pilot plant.

STEFFEN: Did you not find that the sulfur in the water had something to do with it?

DENCKER: Yes, the amount of H_2S odor is directly related to sulfate content of the water supply that you take into the plant. If you have a low-sulfate water, you probably will not have an H_2S odor problem from the anaerobic lagoon or its effluent. If you do have a high-sulfate water, you are bound to have a problem, as I see it.

STEFFEN: It is a rather interesting and rather important conclusion that the sulfates in the raw water you are using in the plants, rather than the waste you are adding to the water, may well cause some of the problems in the lagoon.

W. HELLMANN: Bill Hellmann from Smithville Packing. You are saying, "Stay with the anaerobic lagoon." In 1977 we are required to have the best practical method. Is an activated-sludge system going to be considered the best practical method over an anaerobic lagoon? And if so, if we are planning additions now, what route should we go?

DENCKER: Of course, when the authorities talk about best practical treatment, they are going to come up with the effluent standards relating back to best practical treatment. Whether you go with a completely aerobic system, such as activated sludge, or whether you go into a two-stage system with anaerobic lagoons followed by perhaps extended aeration and nitrification, the resulting effluents of those two systems could well produce comparable results, even to the point where the partial anaerobic system might produce superior results. So that the adoption of best practical treatment, in my book, will not necessarily rule out anaerobic lagoons. We hope to keep them as a tool—but remember that they are just one tool. They are not necessarily everybody's answer.

DENCKER: This is really the importance of the anaerobic lagoon—it is a first stage. When you are dealing with a 1,500- or 2,000-mg/l BOD_5 waste, straight activated sludge is a bit of a problem. If you can knock that down with the anaerobic lagoon and then go into aeration, the anaerobic-lagoon effluent can easily be converted to an aerobic condition. You can still follow with activated sludge, or any other type of treatment. But the anaerobic lagoon is a real, low-cost means of knocking down the major part of the BOD.

QUESTION: Do you think an aerobic lagoon following an anaerobic lagoon increases or decreases air pollution?

DENCKER: An aerated lagoon following an anaerobic lagoon, I would say, obviously would increase air pollution, because the effect would be that a portion of the dissolved hydrogen sulfide in the anaerobic effluent is going to be discharged to the atmosphere before it is oxidized in an aerated lagoon. I do not think there is much doubt about that. We have been involved with an aerated lagoon following an anaerobic lagoon where water sulfates were rather high, and we picked up some high hydrogen sulfide levels, even around the aerated lagoon. I am sure the reason is that the hydrogen sulfide was dissolved in the anaerobic effluent, and the action of the aerators in an aerobic lagoon released a lot of it to the atmosphere before it was oxidized.

MAZURA: Joe Mazura again. Mr. Wells, do you have any information on the efficiency of microscreens?

WELLS: Several papers were prepared, in the *Journal of the Water Pollution Control Federation,* on the microstrainer installation at Hanover Park in Chicago. This installation was done in parallel with a sandfilter system, so there were data on both sand filtration and microstrainers following a waste-treatment plant. Several companies make these microstrainers. I would suggest that the best data source is the *Journal of the Water Pollution Control Federation.* The Hanover Park installation was a good installation. I am sure there probably have been some since then. I have a file at home that has those articles in it. I can make a copy for you if you cannot run them down.

P. MINOR: Paul Minor, EPA Office of Technology Transfer. The Technology Transfer Suspended Solids Manual has a section on microscreening. You can fill in the card for your copy.

STEFFEN: I know there are many, many problems in odor control that we have not even touched tonight. Some of you are sitting on your hands. Some of you are, I am sure, reluctant to ask some of the more nitty-gritty questions. You can maintain your anonymity. But we do want you to come away from this meeting on odor control with a feeling that you have had answers to your questions. Do not hesitate. Anybody else now?

We can now assume, then, that all the questions on odor control have been answered in this panel, and that was far beyond my fondest hopes—in fact, it is beyond my belief. But I am delighted that the panel was so well informed, so well equipped, and so well prepared. In fact, one panel member even brought some charts that no one can see but himself—which shows how bashful even the panel is in giving information. Everybody seems to be very much afraid of this odor problem, and well we should be.

Now for one serious note. Odor is pollution, and we are going to be facing that fact in this business. You cannot sweep it under the rug. It is going to be with us. We have to recognize it as a problem. We have to see how far regulatory agencies will be going with us, whether they will recognize that there are reasonable limits to what can be done. And, as was mentioned here, there is the very fact of energy transfer from one phase to another. Put in an afterburner and you create a temperature problem, and so on. And with the energy crunch, it would be a little embarrassing for Washington to tell us to use all of these Btu's to get rid of a small amount of odor.

So there are real problems, I am sure, not only for you but also for the regulatory agencies.

PROKOP: Professor, I do not like your definition.

STEFFEN: Of what?

PROKOP: Odor is not pollution. It has to be objectionable in some . . .

STEFFEN: I am not saying what I think it is; I am saying what the regulatory people say it is.

PROKOP: Well, we hope that they stay in the realm of objectionable odors. Chanel No. 5, or musk oil, on your wife—I do not think of that as a pollutant, but it is an odor.

STEFFEN: Well, it might be even an attractant. And at my age that might be a problem too. But some of us, I think, do not agree with the definitions of pollution as they are stated by the regulatory agencies. I am not spelling out what I consider pollution to be; but I believe I can rightly say that the regulatory authorities believe, and take the stand, that odor is pollution. Don, am I right about that?

DENCKER: I would say some authorities are more reasonable than others.

STEFFEN: What about it, you in EPA? Is odor a pollutant?

EPA REPRESENTATIVE: I think if any of you have small children, and you pass by a manufacturing plant, and there is an odor—the first thing your children will say is, "Pollution." And I do not think there is any question that an objectionable odor is pollution. How far we can control it economically may be another question.

STEFFEN: But the word was an "objectionable" odor, and that is like a definition of pollution. Pollution is anything that affects the quality of life. There is a study underway at Michigan State University that is being funded by the Federal Government to define the quality of life. When this is done we will have a definition of pollution.

PROKOP: I would like to make a comment on objectionable odors as regarding people of different ages. A gentleman by the name of Linvall, in Sweden, has been making a study of children and odors. Pre-school-age children find all odors very interesting, not necessarily objectionable. It is after they are in school, and have been in contact with adults, that they find the odors are objectionable.

STEFFEN: I can say from my own experience that I flunked the course with my kids. When I was with Wilson and Company, my kids thought I had an odorous job. I remember when we went to Albert Lea, Minn., on the way out west with the kids. The superintendent of the plant at that time, Eddie Ruble, took the kids through the plant. The two girls did not want to go through the plant. I said, "You go with Eddie, he's got a convertible." So they went, and he started them through the smokehouse where they could pull a hotdog off a smokehouse tree. So they munched hotdogs as they walked through the plant, and when they came back to the picnic park where my wife and I were sitting waiting for them to return, they said, "Daddy, you never told us how nice it was in a meat packing plant." This is actually true. Eddie Ruble had the right psychology. Anybody else now?

We will then adjourn, with thanks to the EPA for giving us this opportunity tonight. And thank you for being with us. A particular thanks to our panel of experts. Thank you very much.

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Appendix A
LIST OF EQUIPMENT MANUFACTURERS

Following is a list of manufacturers[a] of equipment discussed in this study. The types of equipment are listed in the order in which they are presented. Any mention of products or services here or elsewhere in the study is for information only, is not selective unless it is used to illustrate a point, and is not to be construed as an endorsement of the product or service by the Environmental Protection Agency or the authors.

Although the list is intended to be complete, there may be some oversights. Such oversights are not to be construed as reflecting on the merits of the product or service.

The author will appreciate being advised of errata, in order to improve subsequent editions of this list.

Blood Coagulation Prevention System	Swift Research & Development Laboratories Chemical & Engineering Group 119 Swift Drive Oak Brook, Ill. 60521
Static Screens (Wedge Bar):	
Bauer Hydrasieve	Bauer Bros. Company Subsidiary of Combustion Engineering, Inc. P.O. Box 968 Springfield, Ohio 45501
Static Sieves	F. J. Clawson & Associates 6956 Highway 100 Nashville, Tenn. 37205
Other Models	Dorr-Oliver, Inc. Havemeyer Lane Stamford, Conn. 06904 Hendricks Manufacturing Company Carbondale, Pa. 18407 Hydrocyclonics Corporation 968 North Shore Drive Lake Bluff, Ill. 60044 Peabody Wells Roscoe, Ill. 61073
Vibrating Screens:	
"Selectro," "Gyroset," "Kelly"	Productive Equipment Corporation 2924 W. Lake Street Chicago, Ill. 60612
Other Models	Allis-Chalmers Manufacturing Company 1126 S. 70th Street Milwaukee, Wis. 53214 DeLaval Separator Company Poughkeepsie, N.Y. 12600

[a]Manufacturer's address is given with the first entry only. Thereafter only the name appears (*indicates address given earlier).

Vibrating Screens—Continued:

	Envirex, Inc., A Rex Nord Company Water Control Division (formerly Rex Chainbelt, Inc.) 1901 S. Prairie Waukesha, Wis. 53186
	Link-Belt Material Handling Division FMC Corporation 300 Pershing Road Chicago, Ill. 60609
	Simplicity Engineering Company Durand, Mich. 48429
Rotary Barrel Screens:	
Allison Screen for Hide Brining	Green Bay Foundry and Machine Works Box 2328 Green Bay, Wis. 54306
North Green Bay Screen	Green Bay*
Other Models	Dorr-Oliver* Envirex* Link-Belt Material Handling*
Rotating Disk Screens	Envirex* Link-Belt Material Handling*
Eccentric-Weighted Horizontal Disk Screens:	
Aero Vibe	Allis-Chalmers*
Sweco	Sweco, Inc.* 6033 E. Bandini Boulevard Los Angeles, Calif. 90054
Syncro-Matic	Eriez Syncro-Matic 1401 Magnet Drive Erie, Pa. 16512
Other Models	Hydrocyclonics* Kason Corporation 231 Johnson Avenue Newark, N.J. 07108
Centrifuges:	
Eimco	Envirotech Corporation Municipal Equipment Division 100 Valley Drive Brisbane, Calif. 95005
Merco Bowl	Dorr-Oliver*
Other Models	Bird Machine Company South Walpole, Mass. 02071 Beloit-Passavant Corporation P.O. Box 997 Janesville, Wis. 53545 DeLaval* Pennwalt Corporation Sharples-Stokes Division 955 Mearns Road Warminster, Pa. 18974
Gravity Grease Recovery and Separation:	
Hardinge	Hardinge Co., Metal Products Division Koppers Co., Inc. York, Pa. 17405

Gravity Grease Recovery and Separation—Continued:

Infilco . . . . Infilco Division, Westinghouse Electric Company
901 S. Campbell Street
Tucson, Ariz. 85719

Other Models . . . . Belco Pollution Control Corporation
100 Pennsylvania Avenue
Paterson, N.J. 07509

Beloit-Passavant*

Ralph B. Carter Company
192 Atlantic Street
Hackensack, N.J. 07601

Chicago Pump Division, FMC Corporation
622 Diversey Parkway
Chicago, Ill. 60614

Clow Corporation, Waste Treatment Division
1999 N. Ruby Street
Melrose Park, Ill. 60160

Crane Company, Environmental Systems Division
Box 191
King of Prussia, Pa. 19406

Dorr-Oliver*

Dravo Corporation
One Oliver Plaza
Pittsburgh, Pa. 15222

Envirex*

Environmental Services, Inc.
1319 Mt. Rose Avenue
York, Pa. 17403

Environmental Systems
Division of Litton Industries, Inc.
354 Dawson Drive
Camarillo, Calif. 93010

Envirotech*

Graver, Division of Ecodyne Corporation
U.S. Highway 22
Union, N.J. 07083

Jeffrey Manufacturing Company
961 N. Fourth Street
Columbus, Ohio 43216

Keene Corporation, Fluid Handling Division
Cookeville, Tenn. 38501

Lakeside Equipment Company
1022 E. Devon Avenue
Bartlett, Ill. 60103

Link-Belt Environmental Equipment
FMC Corporation
Prudential Plaza
Chicago, Ill. 60601

Walker Process Equipment, Inc.
Division of Chicago Bridge & Iron Company
Box 266
Aurora, Ill. 60507

Zurn Industries, Inc.
1422 East Avenue
Erie, Pa. 16503

Dissolved Air Flotation:

Graver "Aerofloter"	Graver, Division of Ecodyne Corporation U.S. Highway 22 Union, N.J. 07083
Other Models	Black-Clawson Company Middletown, Ohio 45042 The Carborundum Co.—"Pacific" Buffalo Avenue Niagara Falls, N.Y. 14302 Envirex* Environmental Systems* Envirotech* Infilco, Westinghouse* Keene* Komline-Sanderson Engineering Corporation Peapack, N.J. 07977 Permutit Company Division of Sybron Corporation E. 49 Midland Avenue Paramus, N.J. 07652

Appendix B

TERMS, METHODS, AND DEVICES USED IN ODOR MEASUREMENT AND CONTROL

ASTM method. American Society for Testing and Materials static method of diluting samples via 100-ml hypodermic odor-free room, to derive the value of odor units per cubic foot of sample).[11]

Dilution ratio. The value odor units per standard cubic foot or dilution threshold.

Dilutions to threshold. (d/t) The number of cubic feet of odor-free air that must be added to a cubic foot of odorous air sample to produce a mixture at the odor threshold.

Hedonic. Involving the psychological range of feelings from pleasant to unpleasant.

IITRI methods. Procedures and equipment developed by the Illinois Institute of Technology Research Institute. Sampling procedure where sample is passed through an adsorbent tube where odorous vapors are retained but water vapor passes on. The tube is then sent to a central odor science laboratory that elutes the sample from the adsorbent and performs instrumental analysis and sensory responses. Gas chromatographic analysis coupled with sensory response to significant peaks produces an odorgram specific for the sample. Mass spectrographic analysis may also be made. A new device called a "dynamic forced-choice triangle olfactometer" is being offered as a device for improved odor measurement. (Contact Dr. Andrew Dravnieks, Technical Director, Odor Sciences Center, IITRI, Chicago, Ill.)

Malodor. An odor capable of producing an unpleasant reaction when sensed by humans.

Mills modification (to ASTM). Static and dynamic methods for dilution of samples and presentation to a six- to eight-member test panel in an odor-free room, to derive the value of odor units per standard, cubic foot, from a graphic solution on log probability paper.[12]

Minimal identifiable odors. (MIO) The odor threshold, normally for pure compounds.

Odor. The sensation resulting from the human sense of smell.

Odor concentration. The number of cubic feet that 1 ft^3 of sample will occupy when diluted to the odor threshold; a measure of the number of odor units per 1 cubic foot of sample, and expressed in odor units per cubic foot (ASTM).

Odor emission rate. (ou/min) The product of the odor unit per cubic foot times the volume rate of discharge in cubic feet per minute (ASTM). For a point discharge, the odor emission rate is $ou/ft^3 \times ft^3/min = ou/min$)

Odor intensity. Odor concentration. The concentration expressed in terms of multiples of the odor threshold. Note that intensity does not relate to the character, quality, or hedonic quality of an odor.

Odor meter. A semiportable apparatus that dynamically blends odor-free or room air with sample air from a plastic bag for presentation to a three-member test panel, to derive an odor intensity value for the sample. Developed and marketed by Hemeon Associates, Pittsburgh, Pa.

Odor threshold. The odor concentration that produces a median odor detection response in humans. Threshold is not an absolute value; it varies with changes in the test method, test conditions, test panel members, and many other independent variables. Many of the methods for determining odor intensity involve a determination of the threshold for each sample.

Odor unit. (ou) One cubic foot of air at the odor threshold (ASTM). The quantity of any odorous substances or of any given mixture of odorous substances that, when completely dispersed in 1 cubic foot of odor-free air, produces a median threshold odor detection response in humans (Mills).

Odor units per cubic foot. (ou/ft^3) The number of odor units in a cubic foot of sample.

Odor units per standard cubic foot. ($ou/stdft^3$) The number of odor units in a cubic foot of sample at standard conditions (70° F and 14.7 psia).

Olfactory. Relating to the sense of smell.

Organoleptic. Affecting or making an impression on organs of special sense (taste, smell, sight).

Scentometer. A device consisting of a portable clear plastic box with a sniffing port. Beds of activated charcoal provide odor-free air that is mixed in various dilutions with ambient air for determination of dilutions to threshold. Limited to 170 d/t. (Developed by the U.S. Public Health Service and commercially available from Barneby-Cheney, Columbus, Ohio.)

METRIC CONVERSION TABLES

Recommended Units

Description	Unit	Symbol	Comments	Customary Equivalents
Length	metre	m	*Basic SI unit*	39.37 in.=3.28 ft= 1.09 yd
	kilometre	km		0.62 mi
	millimetre	mm		0.03937 in.
	micrometre	µm.		3.937 X 10^{-3}=10^{3}A
Area	square metre	m^2		10.764 sq ft = 1.196 sq yd
	square kilometre	km^2		6.384 sq mi = 247 acres
	square millimetre	mm^2		0.00155 sq in.
	hectare	ha	The hectare (10 000 m^2) is a recognized multiple unit and will remain in international use.	2.471 acres
Volume	cubic metre	m^3		35.314 cu ft = 1.3079 cu yd
	litre	l	The litre is now recognized as the special name for the cubic decimetre.	1.057 qt = 0.264 gal = 0.81 X 10^{-4} acre-ft
Mass	kilogram	kg	*Basic SI unit*	2.205 lb
	gram	g		0.035 oz = 15.43 gr
	milligram	mg		0.01543 gr
	tonne or megagram	t Mg	1 tonne = 1 000 kg 1 Mg = 1 000 kg	0.984 ton (long) = 1.1023 ton (short)
Time	second	s	*Basic SI unit*	
	day	d	Neither the day nor the year is an SI unit but both are important.	
	year	year		
Force	newton	N	The newton is that force that produces an acceleration of 1 m/s^2 in a mass of 1 kg.	0.22481 lb (weight) = 7.233 poundals
Moment or torque	newton metre	N-m	The metre is measured perpendicular to the line of action of the force N. Not a joule.	0.7375 ft-lbf
Stress	pascal	Pa		0.02089 lbf/sq ft
	kilopascal	kPa		0.14465 lbf/sq in

Recommended Units

Description	Unit	Symbol	Comments	Customary Equivalents
Velocity linear	metre per second	m/s		3.28 fps
	millimetre per second	mm/s		0.00328 fps
	kilometres per second	km/s		2.230 mph
angular	radians per second	rad/s		
Flow (volumetric)	cubic metre per second	m^3/s	Commonly called the cumec	15,850 gpm = 2.120 cfm
	litre per second	l/s		15.85 gpm
Viscosity	pascal second	Pa-s		0.00672 poundals/sq ft
Pressure	newton per square metre or pascal	N/m^2 Pa		0.000145 lb/sq in
	kilometre per square metre or kilopascal	kN/m^2 kPa		0.145 lb/sq in.
	bar	bar		14.5 b/sq in.
Temperature	Kelvin	K	*Basic SI unit*	$\frac{5F}{9} - 17.77$
	deqree Celsius	C	The Kelvin and Celsius degrees are identical. The use of the Celsius scale is recommended as it is the former *centigrade scale.*	
Work, energy, quantity of heat	joule	J	1 joule = 1 N-m where metres are measured along the line of action of force N.	2.778 X 10^{-7} kw hr = 3.725 X 10^{-7} hp-hr = 0.73756 ft-lb = 9.48 X 10^{-4} Btu
	kilojoule	kJ		2.778 kw-hr
Power	watt	W	1 watt = 1 J/s	
	kilowatt	kW		
	joule per second	J/s		

Application of Units

Description	Unit	Symbol	Comments	Customary Equivalents
Precipitation, run-off, evaporation	millimetre	mm	For meteorological purposes it may be convenient to measure precipitation in terms of mass/unit area (kg/m^3). 1 mm of rain = 1 kg/m^2	
River flow	cubic metre per second	m^3/s	Commonly called the cumec	35.314 cfs
Flow in pipes, conduits, channels, over weirs, pumping	cubic metre per second	m^3/s		
	litre per second	l/s		15.85 gpm
Discharges or abstractions, yields	cubic metre per day	m^3/d	1 l/s = 86.4 m^3/d	1.83 X 10^{-3} gpm
	cubic metre per year	m^3/year		
Usage of water	litre per person per day	l/person day		0.264 gcpd
Density	kilogram per cubic metre	kg/m^3	The density of water under standard conditions is 1 000 kg/m^3 or 1 000 g/l or 1 g/ml.	0.0624 lb/cu ft

Application of Units

Description	Unit	Symbol	Comments	Customary Equivalents
Concentration	milligram per litre	mg/l		1 ppm
BOD loading	kilogram per cubic metre per day	kg/m^3d		0.0624 lb/cu-ft day
Hydraulic load per unit area; e.g. filtration rates	cubic metre per square metre per day	m^3/m^2d	If this is converted to a velocity, it should be expressed in mm/s (1 mm/s = 86.4 m^3/m^2 day).	3.28 cu ft/sq ft
Hydraulic load per unit volume; e.g., biological filters, lagoons	cubic metre per cubic metre per day	m^3/m^3d		
Air supply	cubic metre or litre of free air per second	m^3/s l/s		
Pipes diameter	millimetre	mm		0.03937 in.
length	metre	m		39.37 in. = 3.28 ft
Optical units	lumen per square metre	$lumen/m^2$		0.092 ft candle/sq ft

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