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Summary Report

In-Vessel Composting of Municipal Wastewater Sludge

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September 1989

This report was developed by the
Risk Reduction Engineering Laboratory
Center for Environmental Research Information
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268.

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NOTICE

This report has been reviewed by the U.S. Environmental Protection Agency and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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Chapter 1
Introduction

1.1 Purpose and Scope

Since the 1970s, composting has become a very important method for stabilizing and processing municipal sewage sludge in the United States. The development of this technology has been extremely rapid, from less than 10 facilities operating in 1975 to nearly 200 under design or in operation in 1989. Today much of the compost produced is being used in accordance with the U.S. Environmental Protection Agency's (EPA's) policy that encourages the beneficial use of sewage sludge (49 FR 24358, June 12, 1984).

More recently, because of odor, labor, and materials-handling problems, a greater number of composting systems are being designed and built to contain the materials within a vessel and extensively use conveyors and other materials-handling equipment. Although the evolution of these "in-vessel" systems is very rapid, municipalities continue to encounter serious problems in dealing with odors, removing moisture, handling the materials in the system, and consistently marketing the product. Furthermore, guidance in the selection, design, and operation of suitable systems is not yet readily available to municipalities and their engineers.

To learn from the experiences of these new, mostly first-generation in-vessel sludge composting systems and their operators, EPA studied representative in-vessel facilities in the United States. The information collected on system performance related to odor generation, mix ratios, moisture removal, detention times, materials handling, production of quality product for a market, and costs have been analyzed and structured to present accurate information to the engineering and sludge management communities on in-vessel

To gather the necessary information, onsite visits (surveys) were conducted at 8 of the 13 full-scale facilities operating in the United States in early 1988. Only two of the facilities had operated for more than 2 years. The eight plants studied included all six types of in-vessel systems existing at the time. These six were the first plants of their kind to be built in this country. Table 1.1 provides background data for each installation at the time of the plant survey.

Table 1.1 System Status at Time of Site Visit

Location	System Supplier	Startup Date	System Status at the Time of Site Visit[a]	Sludge Processing Rate (average dt/calendar day)[b] Design	Actual
Akron, OH	Compost Systems Co. Paygro System	Dec. 86	Operating at reduced capacity	73	25[c]
Cape May County, NJ	Purac Engineering	May 85[d]	Operating at reduced capacity	20[c]	11
Clayton County, GA	Taulman Composting Systems	Aug. 86	Processing all the sludge available	2.9	1.4
Newberg, OR	Ashbrook-Simon-Hartley	Aug. 87	Undergoing acceptance testing	3.5	—
Plattsburgh, NY	Compost Systems Co. Fairfield System	Mar. 86	Processing all the sludge available	34	28
Portland, OR	Taulman Composting Systems	Mar. 85	Operating at reduced capacity	60	26
Sarasota, FL	Purac Engineering	Aug. 87	Processing all the sludge available	6.3	4.3[e]
Schenectady, NY	American Bio Tech	July 87	Not operating while modifications are being performed	15	—

[a]The visits took place between April 27 and November 17, 1988.
[b]Dton/day × 0.9072 = dt (metric ton).
[c]Actual loading is 44 dton/day, 4 day/week.
[d]Startup date for original configuration.
[e]Plant modifications made in 1987-1988 increased the capacity to 20 dton/day.

The surveys revealed that while problems have been encountered in these initial systems, much has been learned from these problems. Of the eight plants surveyed, most have had severe problems with odors and materials handling (drag chains have been particularly troublesome). Nevertheless, the survey also revealed that newer plants have improved designs, which avoid many of the problems found at first-generation plants. Because in-vessel technology is changing rapidly and many new facilities are being built, readers interested in specific systems may wish to contact the system suppliers to determine the location of currently operating plants. It should also be noted that in-vessel systems have been in use in Europe and Japan for some time, so that prospective buyers may want to investigate the European and Japanese experience as well.

This report highlights design and operating considerations for possible incorporation into future in-vessel and other sludge composting systems. It is not meant to single out one design as superior to another. The document also aims to heighten awareness that a sludge in-vessel composting system includes much more than the vessel itself. Indeed, many of the difficulties encountered at in-vessel facilities have resulted from a failure to recognize the totality of the system that must be managed.

1.2 Organization of the Report

This summary report is divided into 13 chapters. Chapter One presents the purpose and content of the report, an introduction to how the surveys were conducted, and an overview of in-vessel composting.

Chapters Two, Three, and Four summarize the "lessons learned" from the successes and failures of the sites visited. These chapters also present problems encountered during the processes of selecting, procuring, designing, and operating an in-vessel composting facility, as well as solutions developed in response to these problems.

Chapters Five through Thirteen present detailed information on the plants visited. Chapter Five introduces the case studies and includes tables that summarize the information gathered during the onsite investigations. Chapters Six through Thirteen present the eight case studies including a detailed description of each plant, and information on the history, performance, and operations of the facilities (see Table 1.2). The historical background is presented to provide a context for the site visit information, but the factual data (such as mix ratios, loading rates, and operating practices) are accurate only for the time of the site visit. More recent information, where available, is included in the "Update" section at the end of each case study.

Appendix A is a glossary of sludge composting terms. Appendix B lists the metric-to-English unit conversions used in the document. Within the document text, numerical measurements are given in metric units, followed in parentheses by their English unit equivalent. In tables where data are presented in English units, the metric conversions are included as footnotes. To distinguish metric from English tons, metric tons are abbreviated dt (dry ton) and wt (wet ton); English tons are abbreviated dton and wton. Finally, a sample of a Request for Proposal (RFP) used in a 1989 procurement of an in-vessel composting system is included as Appendix C.

Table 1.2 Information Contained in the Case Studies

INTRODUCTION

HISTORY OF THE PLANT
- Procurement
- Capital Costs
- Operating History and Current Status

DESCRIPTION OF THE PLANT
- Systems Overview
- Feed and Mix Characteristics
- Materials Handling
- Reactors
- Exterior Curing/Storage
- Nonprocess Air Handling
- Odor
- Support Facilities

PERFORMANCE
- Reactor Control Strategy
- Mass Balance and Reactor Detention Time
- Product Quality

OPERATIONS
- Staffing
- Marketing and Distribution
- Operating Costs

UPDATE

1.3 In-Vessel Composting

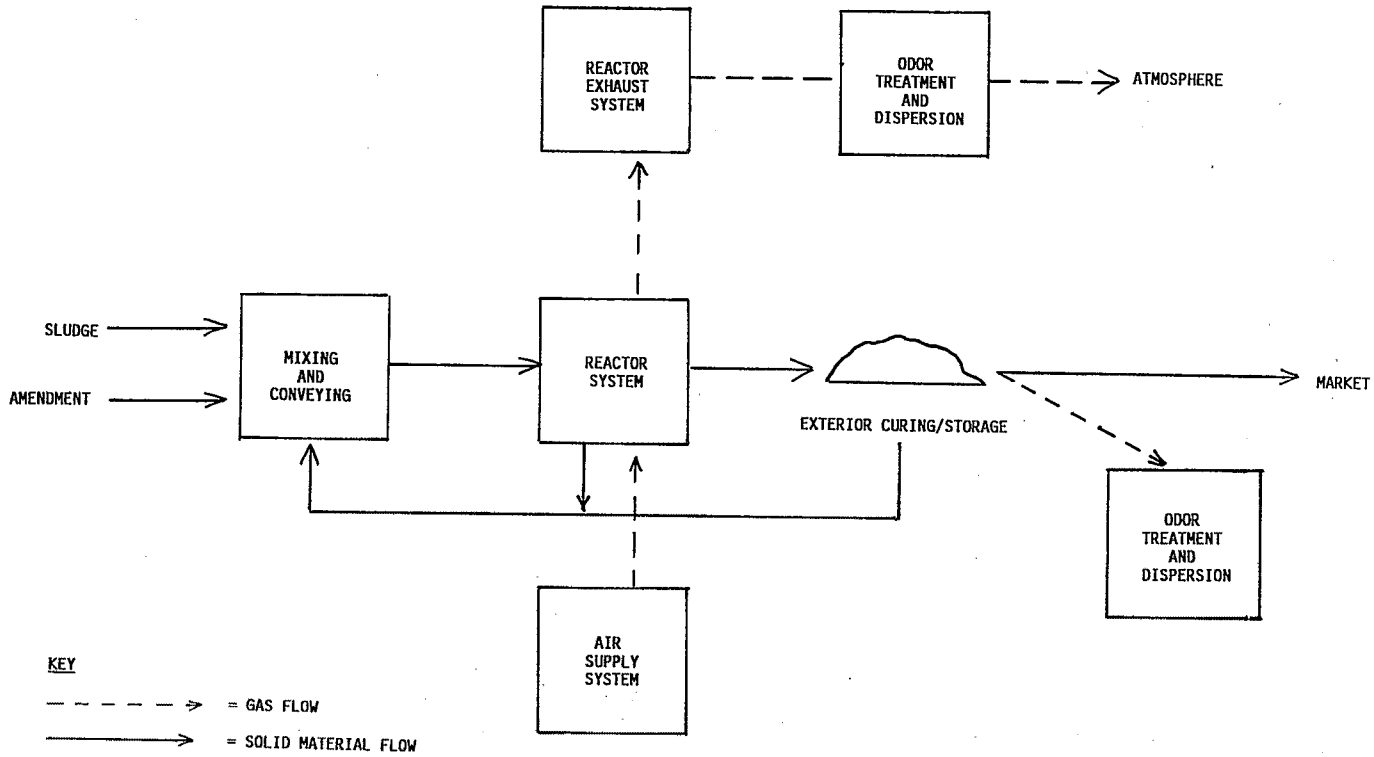
In-vessel composting is a total system that comprises a number of integrally related components, including:

- Materials (sludge cake, amendment, and recycle)
- Materials handling (including storage, mixing, and conveyance)
- Reactor system
- Aeration system
- Odor control system
- Exterior curing/storage facilities
- Marketing

A generic flow diagram of in-vessel composting is shown in Figure 1.1.

The three ingredients — sludge cake, amendment (usually sawdust), and recycle — are mixed together and placed into one or more aerated reactors for composting. Air is diffused into the reactor system for temperature control, moisture removal, and biological metabolism. Air is then usually exhausted directly to an odor treatment system before being dispersed into the atmosphere. After the desired detention time, the material is removed from the reactor for further curing/storage outside.

Figure 1.1 Flow Diagram of In-Vessel Composting



Changing one component of an in-vessel system affects the entire system. For example, if a component such as odor control or product marketing is overlooked in the design phase, the entire system may have to be shut down due to odor problems or lack of compost storage space. Furthermore, system suppliers do not usually provide all components for the system. Although they provide conveyors, they may not supply odor control equipment or certain other key features. Also, the system suppliers usually do not identify a market for the product and may not install the monitoring devices (i.e., for moisture content, stability, odor control, etc.) necessary to assure that an aesthetically acceptable and marketable product is produced. Therefore, it is up to the individuals procuring the in-vessel system to ensure that all system components work together effectively.

The following sections of this chapter discuss the overall design of existing in-vessel composting systems. Subsequent chapters will present details on the various systems and the problems that specific facilities have encountered with equipment, design, and operations.

1.3.1 Materials

The materials required for in-vessel composting are sludge cake, amendment, and recycled compost. Sludge cake and recycled compost are usually referred to simply as "sludge" and "recycle," respectively. The mixture of sludge, amendment, and recycle is commonly referred to as the "mix."

Before composting, sludge must be dewatered. All facilities surveyed in this report used belt filter presses to dewater sludge. Most in-vessel systems use sawdust as amendment, but wood shavings, ground-up wood, or shredded bark also are used. Some facilities that originally used sawdust have switched to coarser materials to permit more air penetration. The source of recycle can be

either material discharged from the reactor system or material from exterior curing/storage piles.

1.3.2 Materials Handling

1.3.2.1 Storage

Since most compost reactors are loaded for only a portion of each day, storage facilities for sludge, amendment, and recycle are needed to match the volume of feed delivered to that needed by reactor operations. A variety of storage facilities are used, including piles, bins, covered sheds, and portable containers.

1.3.2.2 Mixing

Mixing appropriate proportions of sludge, amendment, and recycle is essential to create a desirable compost structure with respect to porosity, moisture content, and energy balance. The mix ratio also directly affects the composting process. Proper porosity promotes easier materials handling and thorough aeration. Proper moisture content supports the biodecomposition of the organic material present in the mix. Too little water retards the process; too much water results in a loss of porosity and development of septic conditions and odors.

Amendment and recycle are added to the sludge to increase the solids concentration of the mix. Most facilities use as much recycle as possible because it is less expensive than purchasing amendment. The exact amount of recycle used, however, is limited by its porosity, which decreases as the recycle ages. Also, as the proportion of recycle in the mix increases, the overall solids retention time in the system increases. The proper moisture content and ratio of mix materials also depend on the length of the air path in the system (see Chapter Three).

The energy required for the latent heat of evaporation and for heating the incoming solids, water, and air is generated by the aerobic biodegradation of the solids in the mix. Composting ceases if the heat requirements and energy balance are not maintained. Section 3.9 provides more information on process monitoring and energy requirements.

Most in-vessel composting systems use pugmill and plow-blade mixers to create a homogeneous mix. Often, existing systems have had to adjust these mixers to enable effective and efficient composting (described in more detail in Section 3.5.1).

1.3.2.3 Conveyance

Mechanically and operationally, conveyance systems are the dominant physical features of in-vessel facilities. Conveyors were the second biggest cause of system problems at the sites (after odor production). Although a high degree of automation for conveyor systems is not required, most in-vessel composting facilities chose automation to minimize labor costs.

Generally, in-vessel systems use three kinds of conveyors: belt conveyors (for horizontal or gently inclined transfer), screw conveyors (for steeply inclined transfer), and drag chain conveyors (for vertical or steeply inclined transfer). Vertical conveyance can also be accomplished using a cleated belt conveyor or a bucket conveyor. Sawdust is sometimes conveyed pneumatically. Specific problems encountered with these conveyance systems are discussed in later chapters, particularly in the case studies.

1.3.3 Reactor System

1.3.3.1 Composting Stages

The composting system is often divided into two stages: (1) a first-stage, high-rate phase and (2) a second-stage, curing phase. The first stage is characterized by high oxygen uptake rates, high temperatures, rapid degradation of biodegradable volatile solids, and high potential for odor production. The second stage is characterized by lower temperatures, reduced oxygen uptake rates, and a lower, but significant, potential for odor production. No precise definition or distinction exists between these two stages, however. Moreover, although the first stage of composting is performed in reactors at all in-vessel facilities, the second stage can be performed in a reactor, an exterior pile, or both. To avoid confusion, the term "first reactor" or "first-step reactor" is used in this handbook to denote the first vessel that the compost enters. "Second reactor" or "second-step reactor" is used to denote the second vessel the compost enters in series. (At many plants, there is no second reactor.) "Exterior curing/storage piles" refer to any compost piles located outside the reactors. Table 1.3 summarizes the composting system configurations at the sites visited.

1.3.3.2 Types of Reactors

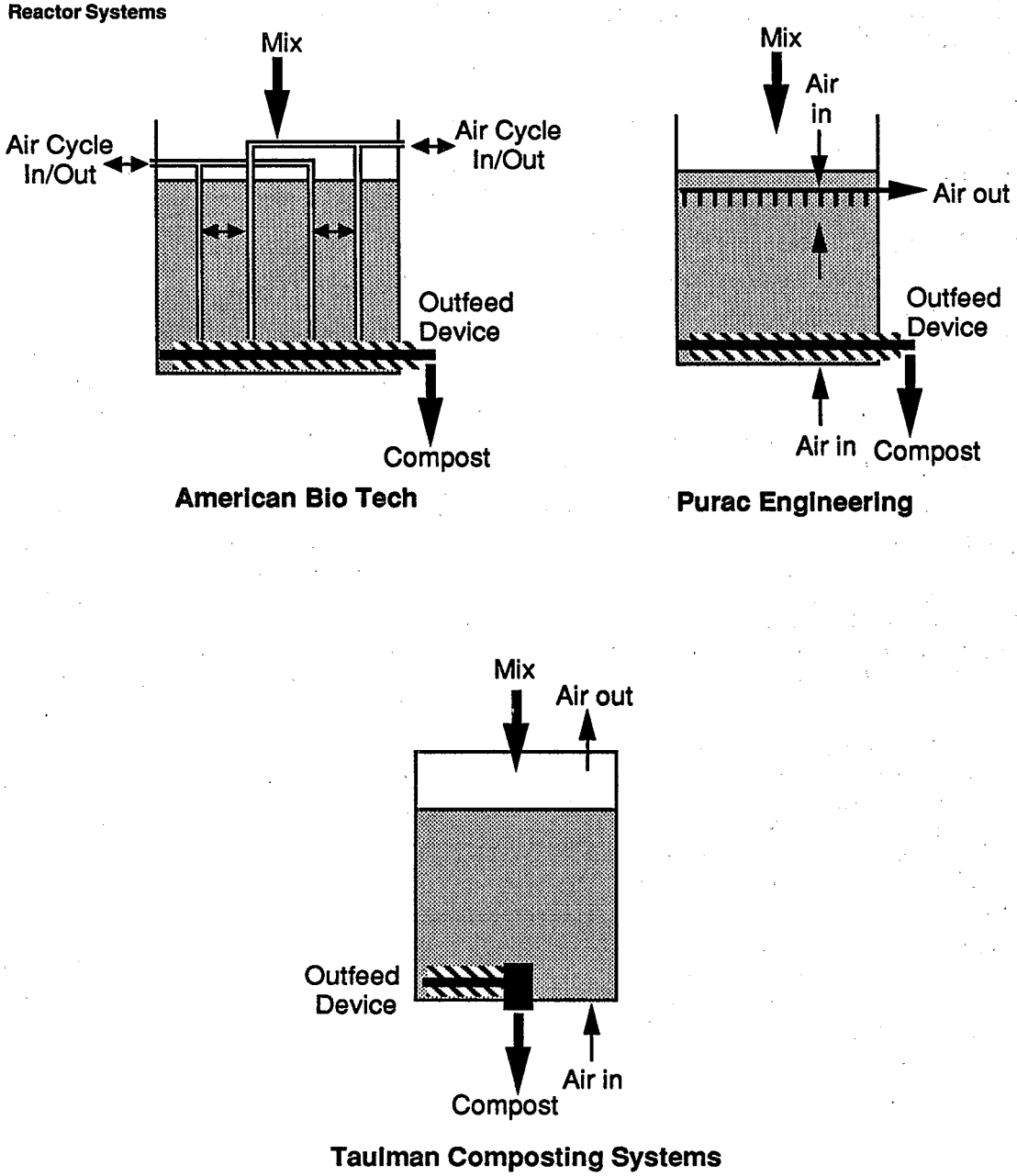
There are two general classes of reactors: plug-flow reactors (vertical and horizontal) and agitated bed reactors

Table 1.3 Plant Configurations

Location	Type of Reactor	Composting System				
Akron, OH	Paygro	Reactor	→	Unaerated piles		
Cape May, NJ	Purac	Reactor	→	Aerated piles[a]	→	Unaerated piles
Clayton County, GA	Taulman	Reactor	→	Reactor	→	Unaerated piles
Newberg, OR	Ashbrook-Simon-Hartley	Reactor	→	Aerated piles		
Plattsburgh, NY	Fairfield	Reactor	→	Unaerated piles		
Portland, OR	Taulman	Reactor	→	Reactor	→	Unaerated piles
Sarasota, FL	Purac	Reactor	→	Reactor	→	Unaerated piles
Schenectady, NY	American Bio Tech	Reactor	→	Reactor	→	Unaerated piles

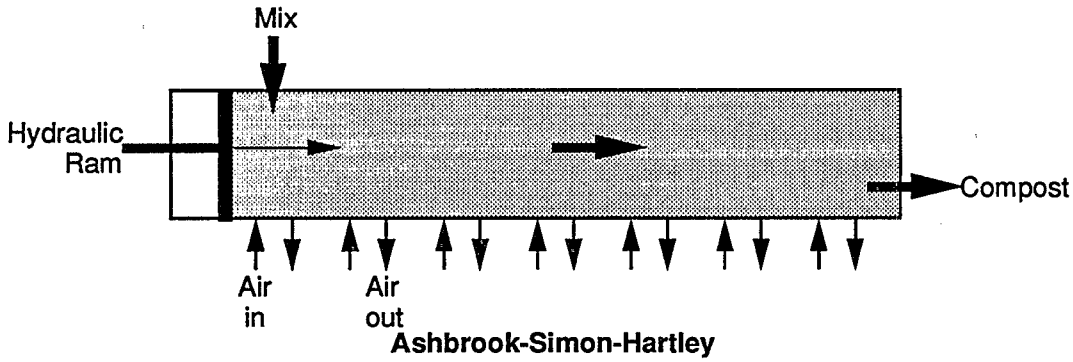
[a]After 1987 modifications. Plant was originally constructed with two reactors in series followed by unaerated curing/storage piles.

Figure 1.2 Reactor Systems



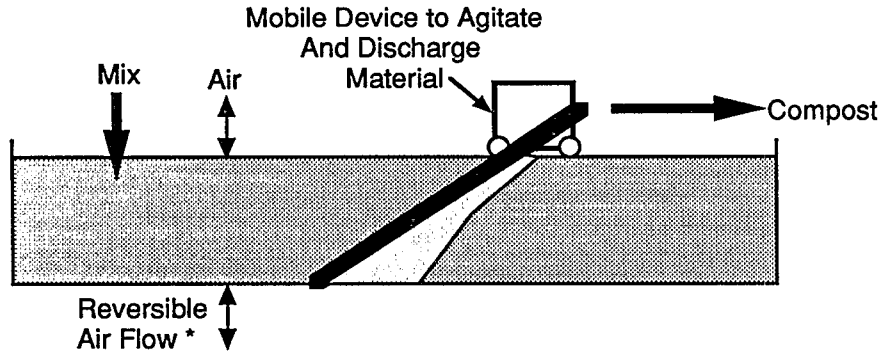
VERTICAL PLUG-FLOW REACTORS

Figure 1.2 Reactor Systems (continued)



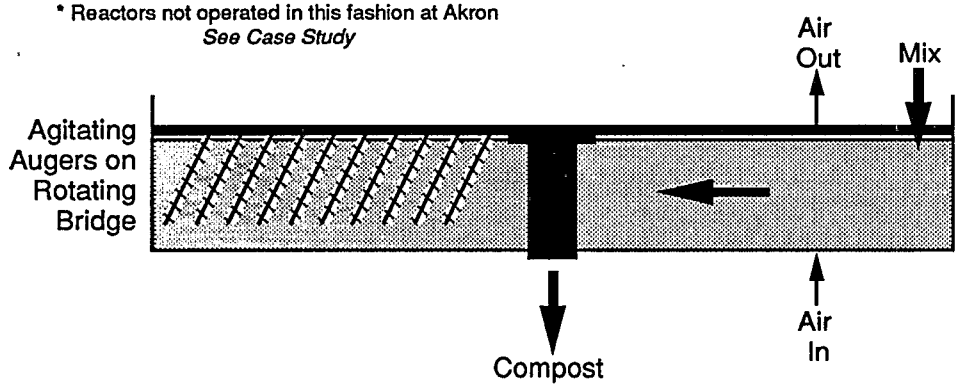
Ashbrook-Simon-Hartley

HORIZONTAL PLUG-FLOW REACTORS



Compost Systems Co. (Paygro)

* Reactors not operated in this fashion at Akron
See Case Study



Compost Systems Co. (Fairfield)

AGITATED BED REACTORS

(circular and rectangular). Figure 1.2 illustrates reactor systems from each of these classes and subclasses.

In a vertical plug-flow reactor, the mix is placed in the top of the reactor and moves as a plug to the bottom, where it is discharged by a rotating screw. Vertical plug-flow reactors are manufactured by Taulman Composting Company (Taulman), Purac Engineering (Purac), and American Bio Tech (ABT). The primary differences among these reactors are the configurations of the aeration systems and the discharge devices.

Table 1.4 Potential Sources of Odors

Liquid Sludge Facilities
- Sludge storage tanks
- Pump rooms
- Wet wells

Dewatered Sludge Facilities
- Dewatering equipment
- Sludge cake storage bins or portable containers
- Conveyors between dewatering facilities and the composting plant
- Open doors

Composting Facilities
- Sludge storage bins or portable containers
- Recycle storage bins
- Amendment storage binsa
- Mixing room (conveyors, mixers, spillage)
- Reactors - exhaust airstream from compost bed (process air)
  - ventilation air for work space or building above the reactor
  - ventilation air for work space containing discharge device
- Recycle conveyors
- Heat exchangers for supply air
- Odor control systemb
- Open doors

Exterior Curing/Storage
- Discharge conveyors
- Aerated piles
- Unaerated piles
- Product storage piles
- Stacking or moving materials with mobile loaders

Miscellaneous Facilities
- Runoff storage ponds
- Amendment receiving facilitiesa
- Publicly owned treatment work processes
- Adjacent facilities, such as refineries, rendering plants, paper mills, and other manufacturing activities

[a]Amendment (sawdust) facilities can emit an odor that some people consider objectionable.
[b]If not properly managed, wet scrubbers using sodium hypochlorite can emit a "chlorine" odor that some people consider objectionable.

In a horizontal plug-flow reactor, the mix is introduced at one end of the tunnel, or rectangular tube, and travels the length of the tube as a plug. The material is propelled by a mechanism such as a moving floor or a hydraulic door. The Ashbrook-Simon-Hartley (Ashbrook) reactor is an example of this reactor type.

In agitated bed reactors, the mix is placed in the reactor and mechanically mixed either in place or as it is moved through the reactor. Agitating mechanisms and the point at which mix is introduced to the reactor vary from supplier to supplier. The Paygro and Fairfield systems (both supplied by Compost Systems Co.) are examples of agitated bed reactors.

1.3.4 Aeration System

There are three basic demands on the aeration system — temperature control, moisture removal, and biological metabolism. Determination of the proper air supply in the compost mass is complex and depends on several interrelated variables, including:

- The desired quality of the final compost product (which depends on user-defined criteria, such as moisture content and stability)
- Reactor-specific factors, such as air distribution and collection system, agitation (if any), and potential for short-circuiting
- The EPA requirement for pathogen destruction (i.e., the temperature must remain above 55°C (131°F) for at least 3 days)
- The porosity of the mix (which depends on particle size and moisture content)
- The total volume of air supplied (which depends on both the airflow rate and the detention time)

See Section 3.3 for further discussion of aeration.

1.3.5 Odor Control System

Odor control was the greatest problem found at most of the sites surveyed, as will be discussed in later chapters. There are many potential sources of odors at in-vessel composting facilities (see Table 1.4). Although process air is the most odorous, all potential odor sources must be evaluated and controlled. If they are not, the odor problems may well result in the shutdown of the plant.

At in-vessel plants, four techniques have been used to control odor:

- Diluting the odors with large volumes of air
- Bubbling odorous air through mixed liquor at an adjacent wastewater treatment plant
- Passing the air through compost ("earth") biofilters
- Treating the air chemically (either through ozone oxidation or scrubbers)

The first method, dilution alone, does not control odors, but can be used as a final step after other treatment methods. The other three techniques have had limited success. As will be discussed later, odor treatment facilities are only one element in a comprehensive odor control strategy. Section 3.8 provides considerable detail on odor identification, characterization, meteorological modeling, and control.

1.3.6 Exterior Curing/Storage Facilities

Exterior curing/storage facilities are typically uncovered paved areas located near the in-vessel facility. Pavement enhances leachate collection and control. (The leachate is usually collected and either treated at the adjacent

wastewater treatment plant [WWTP] or sent to the local sewer.) Some plants construct a roof over the paved areas to control the moisture content of the compost. Some plants also aerate curing/storage piles to avoid anaerobic zones and increased odor production, and to enhance product quality. The need for aerated curing/storage piles will be discussed in more detail in Sections 2.7.4 and 3.3.3.1.

1.3.7 Marketing

Although in many areas the potential uses for "finished" compost are great, such as in land reclamation areas or where government agencies actively support compost use, functioning markets for compost usually must be developed. Thus, plant owners should not assume a market exists, just because a facility can produce a product that is in compliance with Federal, State, and/or local regulations.

First, product users are concerned with many product quality criteria not covered by government regulations. Such factors as product stability, anaerobic versus aerobic nature of the compost, pH, lime content, nutrient content, and amendment content need to be carefully monitored and controlled for specific user markets. For example, some users demand a consistent product; for others, product consistency is less important. During the facility's planning stages, potential markets must be explored and a marketing plan developed that ensures that specifications and quality criteria for a marketable product are incorporated into the design.

Second, even if a facility creates a well-developed marketing plan, it should not assume that every batch of compost will meet product specifications and be salable. The facility must continuously monitor product quality to make sure that the product actually meets specifications and user needs.

Developing a marketing plan involves investigating potential uses and demands for the compost, competing products, applicable regulations and quality criteria for various compost uses, packaging requirements for maintaining product stability, marketing agents, purchasing arrangements, contingency plans, and pricing structures. See Section 2.7 for further discussion of compost marketing.

Chapter 2
Project Planning Considerations

This chapter catalogs the project planning experience gained by the in-vessel composting facilities surveyed for the report. The information is not a comprehensive list of all factors to consider in planning an in-vessel composting system. Rather, the purpose of this chapter is to aid readers in designing future in-vessel systems by describing specific problems and situations encountered by these plants.

Throughout the section, the term "owner" generally applies to the initiating public agency, although a private enterprise may own the composting project. The term "system supplier" applies to the in-vessel composting equipment manufacturer and/or supplier. The term "engineer" applies to the agency's engineering staff, a consulting engineer hired by the agency, or a system supplier's staff or consultant.

2.1 Choosing In-Vessel Composting

The purpose of composting is to beneficially reuse sludge in a way that can not be accomplished with untreated sludge — by creating a marketable product. Composting is not commonly chosen merely as a predisposal treatment process. At the sites surveyed, in-vessel composting was selected for the following reasons:

- State restrictions or bans on land application or incineration
- More consistent product quality
- Fewer personnel required
- More effective odor control
- Better public acceptance due to aesthetics
- Space constraints

2.2 Siting

2.2.1 Siting to Minimize Odor Effects

The preeminent issue in choosing a site for an in-vessel composting facility is its potential to minimize odor impacts to local residents. If the plant has an odor problem, all other advantages associated with a site are unimportant. Because no odor treatment system is 100 percent effective, the odor dispersal characteristics of any proposed site should be identified during project planning. Local conditions such as meteorology, other odor sources, and the proximity of a Publicly Owned Treatment Works (POTW) influence the degree of odor control to be designed for the facility. Section 3.4 further discusses odor sources and control options.

2.2.2 Siting at a Wastewater Treatment Plant

It is common practice to site the compost plant on the local wastewater treatment plant (WWTP) site for a number of reasons. First, the land is usually owned by the public agency already. Secondly, locating the compost plant near the source of sludge saves transportation costs. Finally, the WWTP is often located in an appropriately zoned area with few residential neighbors (an industrial area or the rural fringe of the city), which minimizes siting debates with local residents.

Of the eight plants surveyed for this report, six were located at existing treatment plant sites and a seventh (Newberg) was built concurrently with a new treatment plant. The only facility not sited near a WWTP was the Plattsburgh composting plant; it was built at a separate site because there was not enough room at the WWTP.

Despite the apparent advantages of siting at a WWTP, plant owners need to consider a number of additional factors, including general suitability, potential for site development, legal and economic issues, and potential for future problems (see Table 2.1).

2.3 Public Participation

2.3.1 Involving the Public in Planning

The public should be involved in the planning process for several reasons:

- The money for the facility will come from the tax payers.
- The plant's construction and operation may affect local residents.
- It is required by law.
- It can help promote interest in the compost product.
- It is cost-effective.

Even the most expensive and time-consuming public participation process will, in the end, be less expensive than building a fully operational facility only to have it sit idle or be underutilized because of adverse public reaction (usually related to odor problems).

Table 2.1 Factors to Consider in Siting a Composting Plant

General Suitability for Intended Use

Size
Odor dispersal characteristics (micrometeorology)
Proximity to other uses

Site Development

Terrain (earth-moving required)
Foundation conditions (soils, geology, depths to ground water)
Drainage
Utilities at the site
Vehicular access (local roads)
Development costs

Operational Issues

Distance from the treatment plant(s)
Traffic impacts on local roads and residents
Buffer zones (to mitigate visual, noise, odor impacts)

Legal and Economic Issues

Acquisition costs
Encumberances
Ownership
Local zoning

Potential for Future Problems

Local growth and development
Expansion needs

Another key goal of a public participation program is to build a local market for the compost. Local markets can return the greatest revenues to the plant because of lower transportation costs. Perhaps more importantly, local residents may be more forgiving of minor problems experienced by a composting facility if they receive something tangible (the compost product) for their trouble.

2.3.2 Public Relations Programs

The main goal of a public relations program is to build credibility with the community. A program used at the Montgomery County Composting Facility (in suburban Washington, D.C.), a static pile facility that was not surveyed, included the following elements (1):

- Speak to the local community near the facility and meet with them monthly.
- Distribute flyers acknowledging community concerns, presenting plant problems, and explaining how the program addresses community concerns.
- Set up an objective odor evaluation process.
- Develop brochures and information packages to give to visitors.
- Print posters. The Montgomery County Composting Facility used the motto "A Plant You Can Live With."
- Keep the reception area looking professional.
- Publicly demonstrate the usefulness of the product (compost).
- Visit local schools to educate students and get them involved.
- Stage plant visits for members of the community, school children, etc.

2.4 Procurement

Table 2.2 summarizes the procurement processes used by the eight plants surveyed. As the table shows, the methods ranged from turn-key (Portland) to multiple sets of plans and specifications (Cape May). In all cases, a system supplier prequalification step was included in the procurement process. Sometimes the final choice of systems was made during the prequalification step. Other times, the final choice was based on the construction bids.

These projects were funded primarily by EPA grants with the exception of the Portland and Clayton County facilities, which were funded locally.

Table 2.2 Summary of Procurement Methods

Location	Prequalification	Engineering
Akron, OH	One system supplier chosen as sole source.	Consultant based design on sole source.
Cape May, NJ	Two system suppliers prequalified and "Or equal" clause.	Consultant prepared a design for each prequalified system supplier.
Clayton County, GA	One system supplier chosen as sole source.	Consultant based design on sole source.
Newberg, OR	Two system suppliers prequalified. "Or equal" clause in bid documents.	Consultant prepared a generic design that fit the two prequalified system suppliers. The low bid included a third system supplier whose system was accepted under the "or equal" clause. System supplier prepared final design.
Plattsburgh, NY	One system supplier prequalified. "Or equal" clause in bid documents.	Consultant based design on prequalified system supplier. A second system supplier's system was bid under the "or equal" clause. It was not the low bid.
Portland, OR	One system supplier chosen for a turn-key contract.	Design by system supplier.
Sarasota, FL	Three system suppliers prequalified.	Consultant prepared design based on preferred system supplier. Low bid (accepted) included another prequalified system supplier. Final design prepared by system supplier.
Schenectady, NY	One system supplier chosen as sole source allowed after submitting binding equipment bid.	Consultant based design on sole source.

The basic steps in the procurement process include assigning responsibility for engineering and facility design, prequalifying system suppliers, and writing and issuing the Requests for Proposals (RFPs). Details of the procurement experiences at the plants can be found in the case studies.

2.4.1 Project Engineering

There are three potential sources of engineering expertise: the facility owner, the system supplier, and independent consultants. Usually, engineering responsibility is divided among these three, because consultants cannot design the proprietary reactor systems and system suppliers may not have the capability to do the site, structural, and architectural designs. However, splitting or sharing responsibility for the design can be risky, and may lead to certain design elements not meshing well or being overlooked. For these reasons, project responsibilities must be clearly divided and assigned according to expertise. For example, the owner might assign all process responsibilities (materials-handling systems, reactors, controls, and odor control systems) to the system supplier and all structural and site design responsibilities (building, foundations, and utilities) to the consulting engineer.

The Schenectady plant experienced the type of project coordination problem that can occur. When the odor control system proved to be too small, the city tried to identify the responsible party. Odor control design was supposedly the responsibility of the consulting engineer, but the consultant claimed that the system supplier had underestimated the odor potential of the system and the system supplier claimed that the consultant's design was flawed.

Owners should seek qualified consulting engineers who possess general civil and environmental engineering backgrounds and are experienced in all aspects of public works procurement. More importantly, they should have specific knowledge and experience with composting of wastewater sludges, odor control, materials-handling systems, and ventilation.

2.4.2 Prequalification of System Suppliers

2.4.2.1 The Prequalification Process

The procurement methods appropriate for in-vessel systems differ from normal public works procedures. The heart of an in-vessel composting facility — the reactors, feed devices, and discharge devices — is assembled from proprietary equipment. Consequently, a system supplier should be chosen early in the process. Without prequalifying system suppliers, the public agency must either prepare multiple designs or a generic design to fit all possible bidders. Both options have disadvantages. Preparation of multiple complete designs is costly and inefficient, whereas generic designs leave many of the design details up to the bidders, placing the agency in a position to potentially lose control of the project.

Another advantage of prequalifying a system supplier is to elicit system supplier protests early. System suppliers protested the choice of system at most of the plants surveyed. The Plattsburgh protest took 4 months to resolve and required participation of the city and EPA. Clayton County officials had to tour several European composting facilities to satisfy a protesting system supplier's concerns. Since system supplier protests are time-consuming and expensive, it is better for both the public agency and the system supplier to resolve disputes over the system choice before either side commits large resources to the project.

2.4.2.2 Single Prequalifiers

If, through a RFP/prequalification bid process, the agency can choose a single system supplier before starting the detailed design, it can create a design package that satisfies operations and maintenance requirements, life-cycle costs, and other concerns. The agency can make the bid documents very specific, even to the choice of standard equipment packages on which all construction companies would bid. At Clayton County, managers credited this approach with a very smooth bidding and construction process.

The City of Schenectady used an innovative two-bid approach to include economic competition in the prequalification process. After talking with system suppliers and visiting existing plants in the United States and Europe, city officials prequalified three systems. Then they followed a two-step bidding process. The first step was the bidding of an equipment contract which included the reactors; feed and discharge devices; mixer; conveyance system; sludge and amendment storage facilities; aeration system; and service provided during design, construction, and startup (2). American Bio Tech (ABT) was chosen on the basis of its low equipment bid. Thereafter, plans and specifications were developed by the city's consulting engineer with extensive input by ABT. The second step of the bidding process was for a standard construction and installation contract executed by a general contractor.

2.4.2.3 Multiple Prequalifiers

The advantage of opening the bidding procedure to a number of system suppliers is decreased costs due to increased competition. On the other hand, there are several disadvantages of accepting multiple system suppliers. Engineering costs may be higher if the "equality" of different bids must be evaluated. The probability is high that a system supplier will protest a decision that his or her system is not equal. Prequalification of multiple system suppliers has been used at several locations, and in some cases, all prequalified bidders went through the entire bidding process. The Cape May Authority's consulting engineer prepared two sets of plans because EPA required the contractor to be selected based on bids responding to design packages prepared by conventional architectural engineering services.

2.4.2.4 Use of "Or Equal" Clauses

The public agency should take care not to lose control of the procurement process through imprecise "or equal" specifications. The agency should select and include in the bid package the criteria for judging whether an alternative bid is equal before advertising the job.

At Plattsburgh, the city chose agitated bed in-vessel composting systems, and then prequalified the Fairfield process. The plant was designed around the chosen technology but the specifications allowed for submittals of "equal" systems. The low bid for the construction contract included the Fairfield system. Another system supplier protested the award of the contract; the protest was disallowed, but only after a 4-month review process by EPA.

2.4.3 The Request for Proposal

The prequalification starts with a Request for Proposals (RFP) or Request for Qualifications (RFQ). In this section, "RFP" will be used to refer to either.

2.4.3.1 Defining System Requirements

The goal of the RFP is to elicit proposals that are complete and can be evaluated on a comparable basis. Exactly what information is required to evaluate different proposals depends on the project's purposes, goals, and functions. Table 2.3 lists information that should be requested. Appendix C (City A) presents the technical information section in a sample RFP. Among the plants surveyed, the following system requirements were encountered:

Table 2.3 Minimum Technical Information Needs for Evaluating In-Vessel Systems (1,2)

1. Plant Configuration

2. Process Information
   - (a) Sludge, Amendment, and Mix Properties (for range of conditions)
     - Type and Amounts of Sludge, Amendment, and Recycle
     - Volatiles Content - Sludge, Amendment, Mix
     - Initial Solids Content - Sludge, Amendment, Mix
     - Porosity/Bulk Density - Mix, Product
     - Mix Ratio
   - (b) Reactor Shape, Dimensions, and Volume
   - (c) Detention Time in:
     - Each Reactor
     - Aerated Curing
     - Product Storage
   - (d) Solids Retention Time in:
     - Reactors
     - Facility
   - (e) Aeration (both in and outside reactor)
     - Method
     - Rate (cfm)
     - Volume of Air (cf/unit of sludge or mix)
     - Static Head Pressure
     - Range of Straight Line Airflow Distances
   - (f) Moisture Content of the Mix When Discharged from the:
     - Reactor
     - Composting Facility
   - (g) Monitoring and Control
     - Temperature
     - Oxygen Levels
   - (h) Mass Balance
   - (i) Energy Balance

3. Product Quality
   - (a) Ability to meet pathogen reduction time and temperature criteria
   - (b) Ability to meet other product quality standards

4. Odor Control
   - (a) Inventory of all potential odor sources
   - (b) Control plan for each source, including:
     - Capture and Containment System
     - Treatment Facilities
     - Method of Dispersal

5. Materials Handling
   - (a) Configuration of System
   - (b) Description of Components
     - Physical Descriptions
     - Materials of Construction
     - Maintenance Requirements
     - Operating History in this Application (reliability)
     - Repair Procedures for Most Common Problems
     - Energy Requirements
   - (c) Control System

6. Aeration and Exhaust Systems
   - (a) Configuration of System
   - (b) Description of Components
     - Physical Descriptions
     - Materials of Construction
     - Maintenance Requirements
     - Operating History in this Application (reliability)
     - Repair Procedures for Most Common Problems
     - Energy Requirements
   - (c) Control System

7. Reactor Systems (including discharge device)
   - (a) Configuration of System
   - (b) Description of Components
     - Physical Descriptions
     - Materials of Construction
     - Maintenance Requirements
     - Operating History in this Application (reliability)
     - Repair Procedures for Most Common Problems
     - Energy Requirements
   - (c) Control System

8. Operations
   - (a) Labor Needs
   - (b) Skills Required for:
     - Operating the Equipment
     - Controlling the Process
     - Maintenance and Repair of Equipment
   - (c) Proposed Operating Schedule

- Must be odor-free at all times
- Must use an existing site (usually at a WWTP)
- Must meet certain time constraints for construction
- Must be acceptable to the public
- Must minimize total costs
- Must be owned and operated by private enterprise
- Must be reliable
- Must produce a marketable product

Design requirements should be considered in the earliest stages of the procurement process and be included in the RFP. In every design, there are tradeoffs between costs and system capabilities.

To promote comparability among proposals, the RFP should be as specific and clear as possible in describing the information sought. Definitions should be provided for terms like "solids retention time," "curing," and compost "stability." Where appropriate, the RFP should contain numerical standards to be met. In short, the RFP should be written with the same care used in writing a construction specification (although the degree of detail will be much less).

2.4.3.2 Developing Evaluation Criteria

Before issuing an RFP, the public agency should thoroughly consider the basis for choosing one in-vessel system over another. This approach serves four purposes:

- It forces the public agency to decide how the choice will be made.
- It helps the agency write a focused RFP so that the proposals respond to those issues of importance to the agency.
- It makes the selection criteria a matter of public record, thereby decreasing the potential for system supplier protests.
- It provides a common basis for judging different proprietary systems. System suppliers may not agree with the criteria, but if their products are fairly judged according to these criteria, they will have little ground for protest.

Detailed selection criteria should be published in the RFP. These criteria, set for the public agency's vital interests, help system suppliers decide whether or not they want to risk their resources in developing an alternative design and bid, and form the technical basis for settling potential disputes.

When developing criteria, the agency should consider publishing a draft RFP and requesting comments from system suppliers. This will help ensure that the RFP does not inadvertently favor one system or eliminate another from competition. Comments from system suppliers will also help clarify ambiguities and identify important selection criteria that may have been omitted inadvertently.

The criteria should include clear definitions such as residence times, aeration, odor control, etc. The definitions should include specific methods or formulas for calculating values such as detention time. The sample RFP in Appendix C details the selection criteria used at several plants.

2.4.3.3 Realistic Physical Parameters

RFP requests for designs and costs should be based on realistic estimates of physical parameters such as sludge production, sludge and amendment characteristics, and allowable odor emissions rates. Sludge production rates and cake solids are particularly important because the size of the system depends heavily on these values. The RFP should involve average values and daily and seasonal variations.

Sludge Production

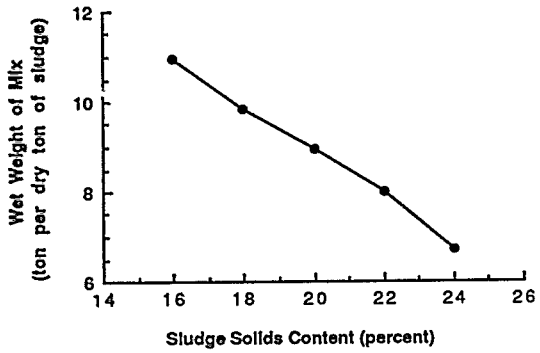
Most systems are modular in design so that sludge loading variations can be accommodated by the use of multiple reactors. Nevertheless, system suppliers need to know these variations so that they can size their equipment properly. The sizes of system components are based on materials volumes, which in turn, are sensitive to sludge solids contents. In areas where the population is growing, in-vessel systems should be designed to accommodate future sludge production rates or constructed in stages.

Sludge and Amendment Characteristics

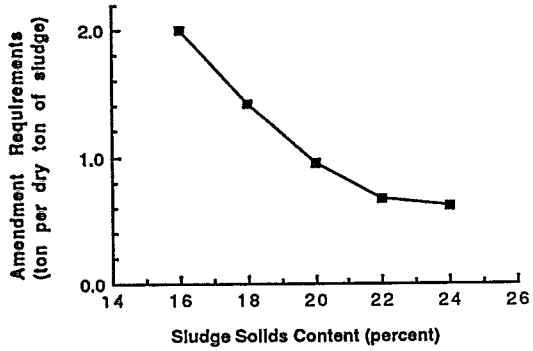
Using the typical values for moisture contents, bulk weights, and desired mix solids content, the mix weights and amendment requirements for sludges with different solids contents were calculated using the method presented by Haug (3) and Haug and Tortorici (4). As can be seen in Figure 2.1(a), approximately 6.7 wt mix per dt sludge (7.4 wton/dton sludge) would be created if the sludge cake solids content is 24 percent. If the solids content drops to 16 percent, the quantity (8.7 wt/dt sludge [9.6 wton/dton sludge]) of mix would increase to 11.0 wt/dt (12.1 wton) sludge, a 63 percent increase. To maintain the same plug-flow detention times, the reactor would have to be 63 percent larger. The materials handling system would have to convey materials 63 percent faster or work 63 percent longer on a daily basis. As can be seen in Figure 2.1(b), amendment requirement triples over this range of sludge solids. Thus, variations in sludge cake solids content can have a large impact on both the capital and operating costs of a composting system.

At many plants, the dewatering systems were installed concurrently with the composting facilities. Because of the importance of the assumed sludge solids content to the overall design, public agencies should consider building a temporary dewatering system to develop a performance data base. Equipment can be rented, or one unit of the planned dewatering facility can be purchased and housed in a temporary location.

Figure 2.1 The Effect of Sludge Dryness on Mix and Amendment Quantities



(a) Mix Quantities as a Function of Sludge Solids Content



(b) Amendment Requirement as a Function of Sludge Solids Content

Note: In this example, the ratio of sludge to amendment was not allowed to drop below 1 : 0.6 by volume for porosity reasons.

Odor Emissions Rates

The design of odor control systems should be based on allowable odor emission rates established by dispersion studies or modeling of realistic worst-case weather conditions. None of the eight plants surveyed performed this kind of analysis during project planning, although a study was performed at Akron in support of the odor control modifications plan (5).

Stability and Solids Retention Time (SRT)

One of the difficulties in writing a product specification for compost is defining "stability." A stable product is one in which the rate of biological activity is low because of a relative lack of easily degraded organics. (Biological activity is also slowed in materials that are too dry or are sterilized by excessive temperatures, but these materials are not considered "stable" in the sense used here.)

Several indicators of stability have been proposed, including temperature increase, oxygen consumption, effects on seed germination, and chemical changes in the composting material (4). To date, no one test has gained universal acceptance, although an increasing body of data is being collected using oxygen consumption as the indicator. A respirometry-based test procedure for compost oxygen consumption has been developed (1). Commercial respirometers for this purpose are also available.

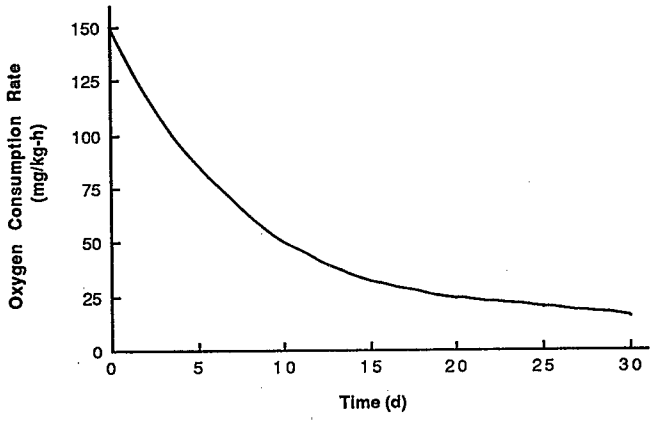
Regardless of the measurement used, stability increases with the compost solids retention time (SRT), which is the average residence time of the solids in the system, including the effect of recycle. The relationship between oxygen consumption rate and SRT is illustrated in Figure 2.2.

Planners and designers must consider the SRT of the whole compost system rather than just the SRT of the reactors. At all eight plants surveyed, the compost emerging from the reactor system was still biologically *active*, although to varying degrees depending on the SRT of the reactor system.

The design SRT should be that necessary to produce the desired product quality. This depends on the compost system and amendments used, because the biological degradation rates are affected by temperature, moisture, and the availability of oxygen, nutrients, and organic materials.

Unfortunately, few data are available relating stability measurements with SRTs or different product uses. Of the eight plants visited, only the Akron facility attempted to measure stability (using oxygen uptake rate). The enclosed static pile system at the Montgomery County Composting Facility has measured oxygen uptake rate

Figure 2.2 Stability as a Function of Detention Time (6)



for several years. Operators there have found that an SRT of 51 days (with continuous aeration) is sufficient to reduce the oxygen uptake rate of the product to about 25 mg/kgh, a rate low enough to allow bagging and retail sale of the material (7). As a first approximation, Haug (8) recommends a minimum system SRT of 60 days to produce a compost with sufficient stability to avoid reheating and phytotoxic effects. Longer SRTs may be needed for product uses that require highly stable materials.

2.5 The Budget

2.5.1 Capital Costs

Capital costs for the eight plants visited are shown in Table 2.4. These costs show the order of magnitude of dollars involved in building an in-vessel facility. These figures, however, should not be used to compare different systems. Since in-vessel composting is a new and extremely competitive business, new technology will continue to be introduced and equipment prices may change in response. Also, since most of the plants are first-generation facilities (i.e., the first implementation of the technology in this country), a number of plant modifications have been required to correct unexpected problems. The costs for these modifications, which range from complete reconstructions of odor control systems to minor changes in individual conveyors, were often unavailable. Many of these costs were absorbed by system suppliers, who made the changes in order to meet their warranties or performance test criteria.

Other factors that affect cost and make costs difficult to compare are:

- Site-specific factors such as the physical layout, geotechnical conditions, climate, and the tradeoff between capital and operating costs
- Sludge type, cake solids
- Local construction market
- Local regulations

Finally, at several locations, the capital costs included modifications to local wastewater treatment plants. It was not always possible to separate all of these noncomposting costs from the total construction costs.

The impact of odor control costs should be noted. Based on the figures in Table 2.4, odor control systems can account for as much as 25 percent of the total construction cost.

Table 2.4 Summary of Capital Costs

Location	Original Construction ($1,000,000s)	Subsequent Modifications	Future Modifications Anticipated in 1988
Akron	30.5, which includes 8-9 for dewatering facilities	—	Odor control system upgrade ($7.5M estimated by odor consultant)
Cape May	8.4 control upgrade and increased aeration	$3M for odor	—
Clayton County	2.0	$80K for product and spare parts storage building	Rebuild reactors because of structural design error (cost not available)
Newberg[a]	2.84	—	Rebuild reactor because of structure design error (cost not available)
Plattsburgh	13.07	—	Provide covers on reactors ($500K budgeted). Odor control upgrade estimated at $4.8M
Portland[b]	11.6	Amendment dust control system ($55K) and miscellaneous work ($150K).	Compost plant will share new spare parts storage building with WWTP.
Sarasota	4.2	—	Odor control system upgrade ($200K budgeted)
Schenectady	6.67	—	Odor control system upgrade ($470K budgeted)

[a]Plant still in startup.
[b]Modifications funded by system supplier.

2.5.2 Operating and Maintenance Costs

Annual operations and maintenance cost estimates for six of the eight plants visited are shown in Table 2.5. Because of their limited operating experiences, costs are not available for the Newberg and Schenectady plants. Unless otherwise noted, the values reflect the 1988 budgets of the various facilities. Based on the sludge processing rates reported during the site visits, estimates were made of the sludge quantity processed during the year. This figure was used to calculate the operations cost per dry ton of sludge processed. As the table shows, operation and maintenance costs varied from approximately $91 to $345 dt/day ($100 to $380 dton/day) of sludge.

Table 2.5 Operating Cost Data

Location	Total Costs ($1000/yr)	Costs per Dry Ton ($)	Capacity Dry Ton/Day (design)(1988)
Akron	1,125[a]	135[b]	73
Cape May	1,038[c]	215[d]	20
Clayton County	148	290	2.9
Plattsburgh	1,020[e]	100[b]	34
Portland	1,100	115	60
Sarasota	600[d]	380	6.3

[a]1987 expenditures.
[b]$/dry ton × 0.9072 = $/dt.
[c]1989 budget estimate.
[d]Based on expected sludge processing rate of 12.1 dt/day (13.3 dton/day), assuming that the plant is allowed to move to the next stage of operation. Based on actual expenditures of $474,000 (Jan.- Sept. 88) and actual sludge processing of 1,100 dt (1,200 dton) (Apr.- Sept.), the unit cost was $435/dt ($395/dton).
[e]Not including sludge disposal costs.

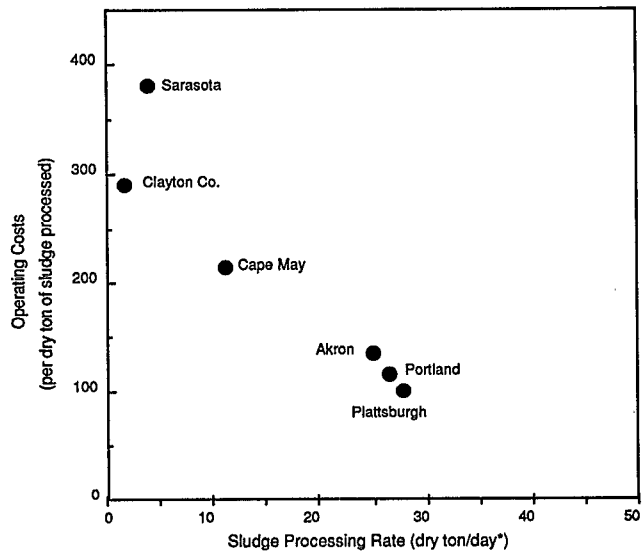
These costs exhibited an important economy of scale effect. In Figure 2.3, operating costs are plotted as a function of the actual sludge processing rate. The plants with actual throughputs of less than 13 dt/day (12 dton/day) reported "per ton" costs that were significantly greater than plants with throughput capacities of greater than 28 dt/day (25 dton/day).

An owner should exercise caution in applying these costs to other situations. The costs reflect a number of site-specific factors such as the local unit costs for labor, amendment, power, etc., that may not be applicable elsewhere. Moreover, all of the plants are currently operating at less than design capacity. Since their fixed costs are not distributed over the total design amount of sludge processed, the reported "per ton" costs are higher than would be the case if these plants were operating at their design capacities.

2.5.2.1 Labor

The high degree of mechanization in existing in-vessel composting plants has, in most cases, resulted in relatively small operating staffs. However, the staff must have the skills to operate and maintain this complex equipment. Consequently, although labor requirements are small, individual staff members must be skilled.

Figure 2.3 Operating Costs as a Function of Sludge Processing Rate



*dton/day x .9072 = English dt/day.

From a planning perspective, greater investments in training and incentives to minimize staff turnover should be instituted. The loss of staff can mean large disruptions in operations. Disincentives to working at a composting plant include unpleasant working conditions (high humidity and temperatures, odors, dust) and limited upward mobility. Composting staff requirements are discussed further in Chapter Four.

Because of different bookkeeping systems (maintenance labor sometimes is included with operations labor and only the combined value reported), operating labor costs are available for only three of the eight plants visited. At these three plants, labor costs range from 18 to 43 percent of the composting budget (i.e., approximately $33 to $132 dt [$30 to $120/dton] of sludge processed).

2.5.2.2 Amendment

Amendment costs usually are the largest single cost item after operating labor. At five of the eight plants visited (not including Clayton County, which uses wood chips grown at the Clayton County Water Authority's land treatment system), amendment costs range from 18 to 41 percent of the composting budget (i.e., approximately $22 to $143 dt [$20 to $130/dton] of sludge processed).

One reason for this wide cost variation is the range in unit costs for sawdust. Unit costs for amendment at six of the eight plants visited are reported in Table 2.6. On a dry weight basis, amendment costs vary by nearly a factor of four.

Table 2.6 Amendment Unit Costs[a]

Location	Amendment Cost per Cubic Yard
Akron	
- Shredded bark	$ 9.4[b]
- Sawdust	5.0
Cape May	14.25
Clayton County	
- Authority grown chips	1.0
- Purchased chips	2.7
Plattsburgh	4.5
Portland	3.0
Sarasota	11.5

[a]Costs reported are from the time of the site visit.
[b]$/cy × 0.7646 = $/m³

When deciding, on the basis of costs, whether to use sawdust or wood chips, the owner may find it useful to consider the relationships between amendment, desired porosity, aeration uniformity, and screening cost. Managers should be aware that amendment usage has consistently been greater than anticipated in the design. Table 2.7 compares the volumetric mix ratios projected at the time of design to the actual mix ratios. Except for the Sarasota plant, which uses less amendment than anticipated, actual amendment usage at the eight plants visited was up to 300 percent greater than anticipated during design.

Table 2.7 Comparison of Design and Actual Mix Ratios in Use at Time of Site Visit

	Volumetric Mix Ratio (sludge/amendment/recycle)	
Location	Design	Actual
Akron, OH[a]	1/0.66/1.33	1/1/2
Cape May, NJ	NA	1/0.6/1
Clayton County, GA	1/1/1	1/1.4/1.4
Newberg, OR[b]	1/0.35/5	1/0.5/10
Plattsburgh, NY	1/0.67/1.67	1/1.4/3.3
Portland, OR	1/0.4/0.6	1/1.6/0.6
Sarasota, FL	1/1/2	1/0.56/2.44
Schenectady, NY	NA	NA

[a]Amendment is both shredded bark and sawdust. Design: 0.33 parts each. Actual: 0.4 and 0.6 parts, respectively.
[b]Data are from the time of the site visit when the plant was in startup. Process not at steady state.
NA = Not available.

Two factors account for this increase: (1) in some plants, the dewatered sludge and/or recycle have been wetter than anticipated, requiring greater use of the driest material to achieve the desired mix solids content; and (2) at some plants, the design mix solids content was undesirable either because it caused materials-handling problems or because it led to a product that was too wet. Table 2.8 compares design and actual mix solids contents.

Table 2.8 Comparison of Solids Contents in Design and Actual Mixes

	Solids Content of Mix (percent)	
Location	Design	Actual[a]
Akron, OH	40	44
Cape May, NJ	40	37
Clayton County, GA	—	34
Newberg, OR	38	38[b]
Plattsburgh, NY	40	40
Portland, OR	32	37
Sarasota, FL	35	40
Schenectady, NY	35	37

[a]Target values. Actual mix solids vary slightly from these values on a day-to-day basis.
[b]Plant in startup; process not a steady state.

2.5.2.3 Power

In contrast to preconstruction amendment estimates, estimates of power usage have been relatively reliable. In fact, power or energy requirements are often included as a performance criterion that must be met during the acceptance test. In a few cases, motors have been replaced with larger units during startup, but undersized motors have not been a widespread problem.

Power costs at six of the eight plants visited range from 11 to 27 percent of the composting facility budget (i.e., approximately $17 to $83/dt [$15 to $75/dton] of sludge processed). The electricity usage in kWh per unit of sludge or product was not available at the time of the site visit.

Variations in power usage can be attributed to several factors. The air volume used and the air distribution method, which affects headloss, vary from system to system. In addition, the energy requirements of materials-handling systems depend on the kinds and numbers of conveyors used and on the length of time they are operated.

2.5.2.4 Maintenance Budgets

Obtaining consistent maintenance cost data was difficult because facilities have different bookkeeping systems. At many plants, maintenance is provided by the WWTP staff or some other central office. At other plants, maintenance labor is combined with operations labor. Reliable information was available from only three of the eight plants visited. At these plants maintenance costs range from 13 to 24 percent of the composting budget (i.e., approximately $28 to $88/dt [$25 to $80/dton] of sludge processed). Although, maintenance costs at the eight plants visited were highly variable, in almost all cases, they were greater than expected.

The service life of compost equipment is not well known. Most equipment that did not exhibit obvious problems

during startup has not been operated long enough to show problems caused by normal wear. Nevertheless, if the experiences of drag chains and reactor discharge devices are an indication (see Chapter Three), plant managers can anticipate that equipment service life in composting systems will not be as long as in other applications of the same equipment. Therefore, managers should be conservative in estimating maintenance budgets and consider purchasing extended warranties from the system suppliers.

2.5.3 Revenues from Product Sales

There is little reliable information on which to base expectations of revenues from compost sales. Not surprisingly, the plants operating for longer periods of time have realized more revenue gains. At most of the plants, however, the demand for compost had not caught up with the supply. Most plants were stockpiling excess product or essentially giving it away as landfill cover material. At the time of the site visits, Plattsburgh and Sarasota were paying to have the product hauled away as a waste.

Only two of the eight plants reported an income from sales that covered more than 5 percent of their composting operating costs. These plants were Clayton County (about 25 percent) and Portland (about 35 percent). In their original procurements, both plants required the system supplier to purchase all compost produced. North American Soils (NAS), a subsidiary of Taulman pays $7.50/m3 ($5.75/cy) for Clayton County compost, and $39/dt ($35/dton) for sludge composted at Portland. However, such an arrangement does not guarantee compost sales. If the product is not adequate for the market, it will inevitably accumulate.

Although marketing the compost may not increase revenues substantially, product sales can represent significant avoided costs when compared to alternative sludge disposal options. At the Cape May plant, for instance, operations and maintenance costs exceed $220/dt ($200/dton) of sludge. The alternatives, however, are much more expensive — $441/dt ($400/dton) to incinerate it locally and $880/dt ($800/dton) to land apply it in Pennsylvania.

2.6 *Marketing*

2.6.1 Identifying and Quantifying Compost Product Markets

A marketing study that investigates all of the potential uses of the product as well as the criteria associated with each use should be part of the planning effort of any composting facility. Real and potential uses identified from existing plants include:

- Large-scale landscaping (bulk sales to private landscapers, golf courses, public works projects, parks, schoolyards, highway median strips, etc.)
- Local nursery industries (as potting material)
- Greenhouses
- Urban gardeners
- Land reclamation projects (strip mines, etc.)
- Landfills (daily cover or permanent cover for sections of landfills being closed)

The marketing study should verify that there is sufficient market demand to absorb the anticipated amount of compost. Projections of market demand should be done with some care; underestimating the market is vastly preferable to overestimating it. Competing products, if any, should be identified. For example, at the present time, landscapers, nurseries, greenhouse growers, and urban gardeners use peat moss, pine bark, composted hardwood bark, and spent mushroom soil to improve soils and blend with potting media. These materials frequently are in short supply, are imported from other states or countries, and typically cost more than $9/m3 ($12/cy). Sludge compost might be an attractive alternative for this market.

2.6.2 Compliance with State Regulations

State regulatory agencies generally have jurisdiction over the sale and distribution of compost. All State agencies require the composting process to meet EPA's pathogen reduction criteria — a 3-day residence time at a temperature exceeding 55°C (131°F) (9). Beyond this minimum requirement, most States have regulations designed to assure that toxins, particularly heavy metals, do not accumulate in the food chain. Different uses are permitted depending on the metals content of the compost. Some examples of State regulations are shown in Table 2.9.

Table 2.9 State Standards for Unrestricted Compost Use
Maximum contaminant concentrations (mg/kg) allowed in the least restricted use category

	State				
Contaminant	Florida[a]	New Jersey[b]	New York[b]	Ohio[c]	Oregon[a]
Arsenic	—	1	—	—	—
Cadmium	30	40	10	12.5	25
Chromium	—	1,000	1,000	—	—
Copper	900	1,200	1,000	—	800
Lead	1,000	4,800	250	500	1,000
Mercury	—	10	10	—	—
Nickel	100	1,250	200	—	100
PCBs	—	—	1	5	—
Zinc	1,800	2,400	2,500	—	2,000
Cadmium/Zinc ratio	—	—	—	0.015	—

[a]General application to agricultural land.
[b]May not be used on food crops.
[c]No use restrictions.

Many States require a permit to market compost, but it may take months or even years to obtain one. Product accumulated at the Schenectady plant for months while the city waited for a State permit to sell it. The Cape May

Municipal Utilities Authority did not receive its license to distribute compost until 3 years after the plant began operations. Although much of the compost was sold to an independent broker who had a distribution license, inventories still built up to a year's worth of production. In addition, some States, such as Massachusetts, consider most compost products akin to sludge and require users to have application site permits.

2.6.3 Choosing a Target Compost Market

There are two major approaches to marketing compost. One is to build the facility and then look for a market for the product. This is a high risk approach.

In the second approach, the compost use and target market is chosen in advance. Then product characteristics are used to guide the design of the plant and composting process. For example, the product particle-size distribution and metals content help define the allowable characteristics of the feed materials. The target levels of product stability and moisture content help determine the solids retention time, aeration rate, and monitoring practices of the facility. Stability and moisture content targets and the need to avoid septic conditions also affect how the compost product is cured and stored. Additionally, product characteristics define the need for postcomposting processes such as screening or blending with other materials.

If the intent of composting is to manufacture compost for horticultural use, it is necessary to design, construct, and manage composting facilities to ensure a quality product. Unacceptable compost is almost as expensive to produce as quality compost, so facility owners should consider the economic benefits of aiming their product at the high end of the market.

2.6.4 Quality Criteria Required by Potential Users

Each compost use has associated with it particular quality requirements and standards. Horticultural outlets, for example, can provide a ready market for high-quality compost.

Because of the intimate relationship between product quality and facility design, the importance of defining process goals during facility planning cannot be overemphasized. Plant owners/operators should consider writing a specification for compost that reflects the qualities desired by the expected users. In the past, this has not been an easy task because "compost" has not been easily defined. Table 2.10 lists characteristics that are important to potential compost users. The lack of a stringent definition of compost and tests to determine whether or not a compost has achieved the desired "quality" are endemic problems that need further study.

Finished compost should have a comparatively uniform particle-size distribution and texture. Metals and salts should be within State limits. If high metals concentrations are a problem, source reduction through industrial pretreatment or blending of the compost with cleaner materials may have to be implemented. Improper use of hydrated lime or alum at the WWTP or materials high in cellulose and low in lignins adversely affect the quality of the product. The compost specifications required for various horticultural uses are described by Gouin (10) and shown in Table 2.11.

Table 2.10 Compost Characteristics that May Be Used in a Product Specification

Pathogen Destruction
Concentrations of Specific Constituents (metals, nutrients, etc.)
Particle Size
Texture
pH
Moisture Content
Odor
Oxygen Demand or Respiration Rate (index of stability)
Aerobic/Anaerobic State
Weed Seed Inactivation
Phytotoxicity
Reduction of Volatile Solids
Consistency of Product

Table 2.11 Horticultural Compost Requirements (10)

	Odor	pH	Particle Size	Moisture Concentration	Other
Container nurseries, landscape diameter contractors, greenhouses	Minimal	6.0-7.0	≤ 1/2 in. (.01 m)	50%	No lime added
Home gardeners	Minimal	6.0-7.0	≤ 1/2 in. (.01 m) diameter	40%[a]	No lime unless required by state[b]
Field grown nursery, plants and sod[c]	NS	6.0-7.0	< 1 in. (.03 m) diameter	NS	NS

[a]Especially important if product is bagged.
[b]If required by state, lime should be added after composting and not before to allow the facility to manufacture two types of compost instead of one.
[c]Compost levels should not exceed 50 dry tons per acre and soil testing is highly recommended.
NS = Not specified.

Improper composting or storage can result in a wet, odorous product. Testing conducted by Willson and Dalmat (6) suggests that compost with a respiration rate of 100 mg/kg hr is acceptable for most field applications. For horticultural uses with sensitive plants, a respiration rate of less than 20 mg/kg hr may be desirable.

Consumer demand may necessitate the implementation of additional quality control criteria, including weed seed inactivation, phytotoxicity (toxicity to plants), and volatile solids content. Sewage sludge often contains seeds with the potential to germinate in the product, if not inactivated

during the composting process. Tomato seeds are particularly hardy in this respect. Meeting EPA time and temperature requirements for pathogen reduction is usually sufficient to eliminate weed seeds.

Phytotoxicity, particularly to germinating seeds, is a major concern for the nursery industry. Excess ammonia, salts, or certain chemicals in the compost may be harmful to seedlings. The ammonia may be a residual from the composting process, or may be produced by further biological degradation after sale of the compost. Thus, the degree of stabilization of the organic materials in the compost is important.

Changing the form of compost packaging may affect the compost stabilization required. At the Portland plant, the compost produced had a very slight ammonia odor that was not a problem for bulk consumers because the ammonia quickly dissipated after the compost was applied to soil. When the plant switched to bagging, however, the plastic bags prevented the ammonia from evaporating. Consumers faced a strong and unpleasant ammonia odor when opening bags of product. To avoid this situation, the plant operation is being modified (lower sludge loading rates, longer reactor detention times) to provide more complete compost stabilization bagging.

2.6.5 Marketing Agents

Compost can be marketed by the public agency (owner), the system supplier, or a third party (broker). The choice is a tradeoff between risk and revenues. To the extent that the owner passes off the risk to other parties, his or her financial return usually is reduced. Marketing by the owner maximizes return, but also requires the owner to develop the necessary marketing capabilities. Few public agencies want this responsibility.

As seen in Table 2.12, selling the compost to a broker or other marketing agent is the most popular option. At Clayton County, the system supplier agrees to buy all of the compost at a set price. At Akron, the owner and system supplier share the costs of marketing and the profit from the sales.

Table 2.12 Compost Marketing Agents

Location	Marketing Agents[a]
Akron, OH	Same subsidiary of composting system supplier that is operating the plant
Cape May, NJ	Owner
Clayton County, GA	Subsidiary of composting system supplier
Newberg, OR	No product yet (plant in startup)
Plattsburgh, NY	City
Portland, OR	Subsidiary of composting system supplier
Sarasota, FL	Owner (looking for broker)
Schenectady, NY	Owner (looking for broker)

[a]As of December 1988.

Marketing contracts usually specify minimum and maximum quantities to be sold, minimum quality criteria to be met, and a fixed price over a defined time period. The broker may have the ability to blend the compost with other materials to make a product with the specific characteristics that the market demands; this flexibility also lessens the risk. It is not necessary to restrict sales to a single broker.

2.6.6 Contingency Plans

Occasionally, the facility may have excess product due to insufficient market demand or product that does not meet the specifications. The metals content of the sludge may increase temporarily, or unstable batches of compost may be produced because of mechanical problems. Contingency plans for disposing of sludge and unmarketable compost should be developed during project planning.

Potential backup measures vary with the problem and with the individual plant, but may include creating additional storage space, incineration, land application, and giveaway programs. Table 2.13 summarizes backup measures appropriate for various problems. As the table indicates, several backup measures require additional equipment or space, which should be included in the initial plans for the facility.

Table 2.13 Potential Backup Measures for Various Composting Problems
(Locations where these backups have been used are shown in parentheses.)

PROBLEM:	*Wet or understabilized product*
BACKUPS:	a. Recycle material back into the reactor (All plants) b. Temporary aerated static pile operations (Possible at Cape May, contingency plan for Newberg) c. Landfilling or land application (Newberg, Sarasota) d. Shift product to users who have lesser quality standards (Plattsburgh - landfill cover material)
PROBLEM:	*Increase in metals or other constituent* (Not found to be a problem at plants surveyed)
BACKUPS:	a. Compost storage and dilution with good material b. Landfill or landfill cover
PROBLEM:	*Compost plant out of service*
BACKUPS:	a. Land application of sludge (Portland) b. Landfilling of sludge c. Storage of liquid sludge at the WWTP (Akron - sludge storage tanks, Clayton County - DAF unit, Portland - sludge lagoon, Sarasota - sludge storage tanks) d. Aerated static pile operations (Newberg) e. Combustion of sludge in an existing incinerator (Akron, Schenectady)
PROBLEM:	*Insufficient demand*
BACKUPS:	a-e. Same as for compost plant out of service f. Compost storage on site (Akron, Plattsburgh, Portland, Schenectady, Newberg)

2.7 Pilot Plants

Pilot composting plants can be used to approximate production of representative compost with the same sludge and amendment that will be used in the full-scale unit.

A product sample from the pilot facility also could be useful during the market study. Potential users may not know how to specify product quality requirements, but know whether or not they can use a specific product. In Portland, for example, the nursery industry was identified as a potentially large market. After the plant was built, however, nursery owners were unwilling to buy large quantities of compost until they had conducted long-term tests themselves. If sample product had been available before plant construction, the nurseries could have begun testing earlier. Using a pilot plant, the users and the public agency together may be able to develop a product.

A pilot plant also could be used as part of a public education program to demonstrate the composting process and show that compost is not simply a mixture of sludge and sawdust. At several of the plants visited, operators gave away compost samples to interested members of the public to try for themselves. The response was overwhelmingly positive. This type of public relations activity during the planning stage can be very effective in building good will.

A pilot plant operation may also be useful for testing certain process parameters. For example, the suitability of potential amendment materials that are locally available and inexpensive can be tested with the actual sludge. Such a test can identify undesirable amendments before they are tried at full scale. At Schenectady, for example, some of the sawdust originally specified contained an excessive amount of hardwood powder. When mixed with the sludge, it created a paste-like material with little porosity that dried into hard balls in the reactor. A pilot test might have identified this problem in advance. At Plattsburgh, a 3.0 m (10 ft) high pilot reactor constructed from a 0.61 m (24 in.) diameter metal tube has been used to test a variety of amendments for the New York State Energy Research and Development Authority.

A pilot operation also can test the odor constituents of reactor process air and provide information on odor emission rates. This information then can be used in dispersion modeling and odor treatment facility design. The original odor control system at the Plattsburgh facility was designed to remove hydrogen sulfide, which was a problem at the WWTP dewatering room. A pilot operation might have revealed that ammonia would be a major constituent of the process air at this site. Designers could have included ammonia removal in the odor control system from the start, rather than retrofitting the plant later.

A pilot operation may not reliably predict the amount of odor that will be produced by a full-scale plant. At full scale, a site's odor-dispersing capacity may be exceeded during stagnant air conditions. Facilities should use meteorological modeling in addition to odor emissions data from the pilot plant to predict impacts at full scale.

The scale of the pilot plant is related to its use. If a pilot plant will be used only for marketing and public relations, a static pile or enclosed static pile operation will suffice. On the other hand, testing of porosities, mix ratios, aeration requirements, and degrees of drying will necessitate a model pilot plant that simulates the full-scale reactor.

2.8 References

1. Murray, C. Managing Odor Control Programs. Presentation at the 19th Annual Biocycle National Conference. Washington, DC. May 1989.

2. Connor, D.A. and J.A. Stearns. A Method for Evaluation and Procurement of In-Vessel Composting Systems. Public Works. April 1986. p. 64.

3. Haug, R.T. Composting Process Design Criteria, Part I — Feed Conditioning. Biocycle. August 1986. p. 38.

4. Haug, R.T. and L.D. Tortoriei. Composting Process Design Criteria — Part IV — Case Study. Biocycle. November/December 1986. p. 34

5. Akron Composting Facility Odor Study. Draft Final Report. Odor Science and Engineering, Inc. July 1988.

6. Willson, G.B. and D. Dalmat. Measuring Compost Stability. Biocycle. August 1986. p. 34

7. Murray, C. Personal communication. June 1989.

8. Haug, R.T. Composting Process Design Criteria, Part II — Detention Time. Biocycle. September 1986. p. 36.

9. U.S. EPA. Reductions of Pathogen Municipal Waste Sludge. CFR 207. 1989.

10. Gouin, F.R. Compost Standards for Horticultural Industries. Biocycle.

Chapter 3
Design Considerations

This chapter summarizes design considerations and experiences at the eight in-vessel composting facilities visited. It is not a comprehensive discussion of the issues involved in designing an in-vessel composting facility. Rather, the chapter's purpose is to present facility designers with a number of design options, and to illustrate past successes and failures for the benefit of future designs. Table 3.1 lists the items covered in this chapter and the sections where they are discussed.

Table 3.1 In-Vessel Composting Design Considerations

Topic	Section
General System Considerations	3.1
Environmental Conditions	3.1.1
Operating Conditions	3.1.2
Equipment Access	3.1.3
Materials Handling	3.2
General System Considerations	3.2.1
Materials Receiving and Storage	3.2.2
Conveyor Systems	3.2.3
Mixers	3.2.4
Reactor Discharge Devices	3.2.5
Aeration	3.3
General System Considerations	3.3.1
Air Collection/Moisture Removal	3.3.2
Hardpan	3.3.3
Curing/Storage Aeration	3.3.4
Odor Control	3.4
Compost Process Control	3.4.1
Inventory of Potential Sources	3.4.2
Collection and Containment	3.4.3
Treatment	3.4.4
Dispersal	3.4.5
Additional Considerations	3.4.6
Process Monitoring and Control	3.5
Analytical Equipment for Process Control	3.5.1
Process Sensors	3.5.2
Instrumentation	3.5.3
Support Facilities	3.6
Maintenance Work Area	3.6.1
Onsite Spare Parts Storage	3.6.2
Staff Facilities	3.6.3
Fire Prevention and Control	3.7

Much of the chapter is devoted to conveyors and odor control equipment because the majority of plant problems have been caused by failures of this equipment rather than of the composting reactor system. Conveyor problems have forced short-term shutdowns or otherwise disrupted operations at nearly all of the plants surveyed, and four plants have either temporarily shut down or curtailed operations because of odor problems.

Reactors have also had problems, however. Both the Newberg and Schenectady reactors have had structural problems, and reactor discharge devices have experienced problems at Portland, Schenectady, Clayton County, Plattsburgh, and Sarasota. Formation of a compacted "hard pan" layer at the bottom of the reactor which blocks airflow has occurred at Akron, Cape May, Clayton County, and Plattsburgh.

3.1 General System Considerations

3.1.1 Environmental Conditions

In-vessel composting plants experience extreme environmental conditions inside the process building, such as high temperatures, humidity, and dust levels; corrosive atmosphere; and wet, sticky materials. In addition, conveyors at many plants connect hot, humid interiors to cold exteriors. For example, Plattsburgh has experienced ice build-up on conveyor belts that travel from the humid interiors of the reactors to the mixing room via the exterior of the buildings. Dust has been a problem at some plants, including Portland, where it has caused bearing failures in the motors that power the hydraulic system, and Schenectady, where it has caused problems with motor controllers.

Environmental conditions should be considered when choosing construction materials and corrosion protection systems. At Plattsburgh, the fog inside the reactor buildings is corroding the feed and agitation machinery; epoxy coatings on the auger motors are peeling. Epoxy coatings are also degrading in the hot and wet work space over the Cape May reactors. At Cape May, galvanized equipment seems to be performing better than epoxy-coated equipment. Zinc-based paint might be another option to deal with corrosion. Wilber (1) found that the aromatic organic solvents that evolve during composting do not attack zinc-based paints.

3.1.2 Operating Conditions

Sludge, amendment, recycle, and mix characteristics such as moisture contents, volatile solids contents, bulk

weights, porosities, and particle-size distributions are not constant. These properties may change daily. Table 3.2 shows the ranges of moisture contents of sludge, amendment, recycle, and mix observed at the eight plants visited. Composting systems must be designed to accommodate all foreseeable materials conditions.

Materials-handling systems should be designed to move materials with a range of bulk weights, consistencies, and particle sizes. The transfer rates of conveyors used in creating and moving the initial mix should be adjustable over a wide range so that operators can make and transport an acceptable mix.

Aeration systems should be able to respond to varying conditions in the reactor. Wet mixes or sludge batches with a high volatile organic fraction will require higher airflow rates. Variable speed blowers or inlet throttling are normally provided to facilitate airflow rate adjustment. Blowers should also be designed so that their discharge pressures can overcome headloss, even when the mix porosity is low.

3.1.3 Equipment Access

Designers should lay out and specify equipment to facilitate operations, monitoring, and preventive maintenance. Critical locations, particularly wear points and places where materials can jam, should be made as visible and accessible as possible so that operators can observe equipment operations and resolve problems before they become catastrophic. At several plants, operators or system suppliers have installed additional inspection and access hatches, especially in materials-handling systems.

In addition, operators should be provided easy access to equipment wherever preventive maintenance activities or regular repairs take place (e.g., lubrication points, inspection ports, bearings, cleanouts, etc.). If the composting equipment cannot be serviced from the floor, elevated walkways, monorails, and other means of access should be provided.

Table 3.2 Variations in Moisture Contents for Different Materials

	Solids Content (% by weight)			
Location	Sludge	Amendment	Recycle	Mix
Akron	20-26	50-60	60-68	40-50
Cape May	20-30	65-70	53-65	—
Clayton County	16-18	52-66	45-52	34-35
Newberg[a]	12-20	—	35-45	30-40
Plattsburgh	20-25	—	42-55	—
Portland	23-28	60-95	38-40	—
Sarasota	12-16	—	50-55	34-46
Schenectady	20-28	—	—	35-39

[a]Data shown were collected in Sept. to Oct., 1988 during acceptance testing.

System layouts should allow sufficient space around equipment for maintenance activities. Where appropriate, enough space should be provided so that a unit can be repaired while an adjacent unit is operating.

In the mixing room at Plattsburgh, the enclosed screw cross conveyors are located about 4.5 m (15 ft) above the floor (see Figure 3.1) with no built-in access. Moreover, access hatches were not provided in the screw housing. To clear a simple materials jam, the operators had to climb ladders and cut through the housing with a torch.

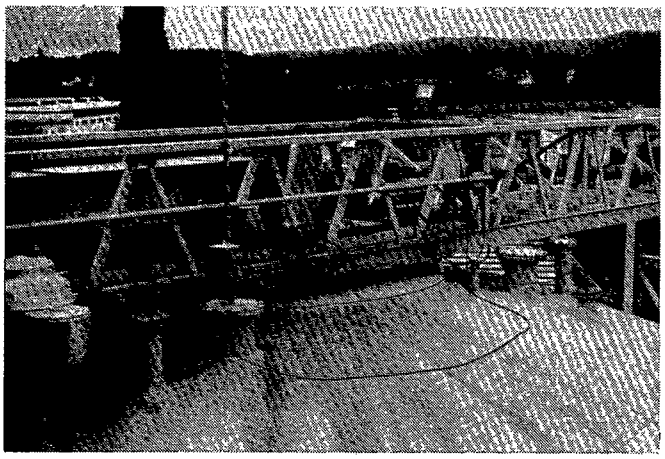
Figure 3.1 Plattsburgh Screw Conveyer

At the Portland plant, the hydraulically operated conical "slingers," which distribute the compost mix as it is fed into the reactors, are located at the apex of the domes that cover the reactors. Only a narrow walkway leads to them (see Figure 3.2). There is no mechanism to remove the slinger from the reactor and no place to put it. Consequently, when a problem develops in a slinger, the operators must approach it from inside the reactor by walking over the top of the compost bed, a potentially hazardous maneuver.

Accessibility is equally important for equipment that must be monitored regularly, particularly mixers. The whole composting process depends on the quality of the mix, which operators must monitor regularly. At the Clayton County and Portland plants, the mixers are located at the tops of the reactors in small sheds, so operators, who are stationed in the ground-level control room, cannot monitor them. To test the mix, an operator must climb the exterior stairs, take a sample, then descend to the ground level, where the testing equipment is located. If the mixer must be adjusted, the operator may have to make several

trips. To avoid this situation, the mixer should be located near the control room, and the testing equipment should be located near the mixer, as it is at Sarasota (see Figure 3.3).

Figure 3.2 Top of Reactor at Portland



Note: No working space is provided above the "slinger," located inside and just below the roof of the reactor.

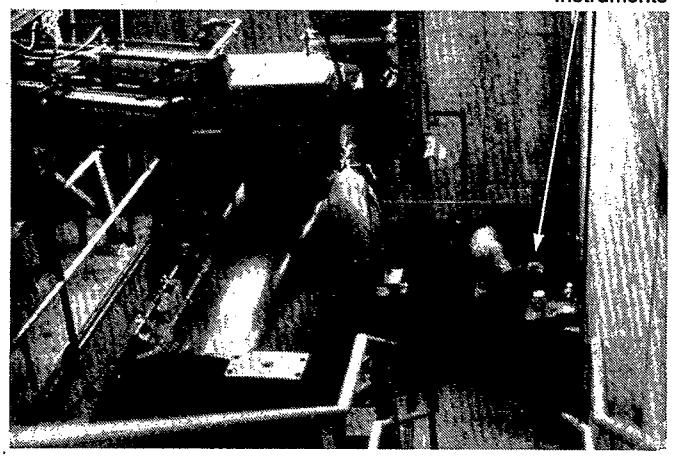
3.2 Materials Handling

3.2.1 General System Considerations

3.2.1.1 Equipment Reliability

The materials-handling system must remain operable for the composting plant to function. It usually is not economical or necessary to provide full materials-handling equipment redundancy (i.e., permanent standby units). Because sludge can be stored, short-term interruptions in operations can be tolerated.

Figure 3.3 Sarasota Mixing Area



Note that the instruments for determining mix solids content are located immediately adjacent to the mixer for operator convenience.

The key to maximizing the reliability of the system is to minimize the frequency and duration of these interruptions. To accomplish this, materials-handling systems should be built with equipment that is durable and easy to repair. In addition, a fast response to mechanical failure requires an adequate supply of easily accessible spare parts and a commitment to provide adequate numbers of appropriately trained staff.

3.2.1.2 Operational Flexibility

Based on the experiences at the sites visited, and despite the best efforts to minimize downtime, there will probably be occasions when a piece of equipment is out of service for an extended period. Where possible, alternative pathways for materials should be provided so that the entire system is not paralyzed. The Sarasota facility's materials-handling system, shown in Figure 12-3, can transfer materials from the bottom of either reactor to the top of either reactor, and both reactors can be used first or second in the process. Additionally, the mixers can feed either reactor. (Note that the Sarasota plant is a second-generation facility.)

If multiple process trains are used, bypasses and crossovers should be provided so that alternate conveyance routes can be used. In contrast to the Sarasota system, the almost complete lack of connections between the two parallel compost trains at the Portland plant has contributed to extended periods of downtime.

The designers of the Akron plant used an innovative approach to circumvent mechanical problems. Rather than providing numerous connecting conveyors to bypass trouble spots, they provided the means to take materials out of the system, move them with mobile equipment (i.e., front-end loaders), and reinsert the materials at different point. In this way, broken conveyors can be bypassed while they are repaired. If necessary, the mix can even be prepared on the mixing room floor using front-end loaders.

Some designers of materials-handling systems have tried to reduce costs by using one piece of equipment to perform two functions, but such layouts limit the flexibility of the materials-handling system. For instance, at the Clayton County plant, a single screw conveyor beneath the reactors transfers recycle to the feed system when turning in one direction, and transfers compost out of the plant when turning in the other direction. Clayton County operators cannot simultaneously remove product from the second reactor and load the first reactor. The capital cost savings from these kinds of installations must be balanced against the potential for increased labor and power costs.

3.2.1.3 System Bottlenecks

A bottleneck, or chokepoint, is a conveyance point where the downstream conveyors have a lower capacity than the upstream conveyors. Chokepoints limit the conveyance capacity of the entire system. To avoid chokepoints, all conveying equipment should cover approximately the

same range of capacities. At the Clayton County plant, the discharge conveyor that transfers product outside the building to waiting trucks cannot accommodate the full flow rate of the screw conveyor that brings the product from the second reactor.

Analysis for chokepoints should be done under all operating conditions. Again, at the Clayton County plant, the elevator drag chain becomes a chokepoint when the sludge is very wet. The sludge hopper discharge drag chain runs at a constant speed. Therefore, when the sludge is very wet, the large amounts of sawdust and recycle needed to create a proper mix cause overloading of the elevator drag chain.

3.2.1.4 Centralized Computer Control

Centralized computer control of the materials-handling system enables a small number of people to operate a large amount of equipment. A centralized computer can also interlock the conveyors so that when a problem develops, all upstream devices shut down. Sequential startup of conveying systems is another feature provided by a central computer.

The software should include capabilities to both execute a completely programmed function (e.g., feed the first reactor, transfer compost from one reactor to another, etc.) and to run individual items of equipment from a central location. Clear visual displays can also be very helpful. Manual controls should be provided near the individual conveyors.

Centralized systems of this kind have been installed at all of the eight plants visited. Except for a few minor problems, operators have been unanimous in their approval.

3.2.1.5 Tracking Materials Flow

As part of process monitoring, a mass balance should be created and updated regularly. To create a mass balance, the flow of materials must be known. Scales (including truck scales) and other measuring devices should be provided to track the flow of materials throughout the plant. At some plants (e.g., Akron and Plattsburgh), scales in the conveying system are tied into the computer system, allowing the computer to control the mix preparation. One problem with scales experienced at Plattsburgh, however, was that old sludge adhered to the scales and belts became heavier over time.

3.2.1.6 Detecting and Cleaning Plugs at Transfer Points

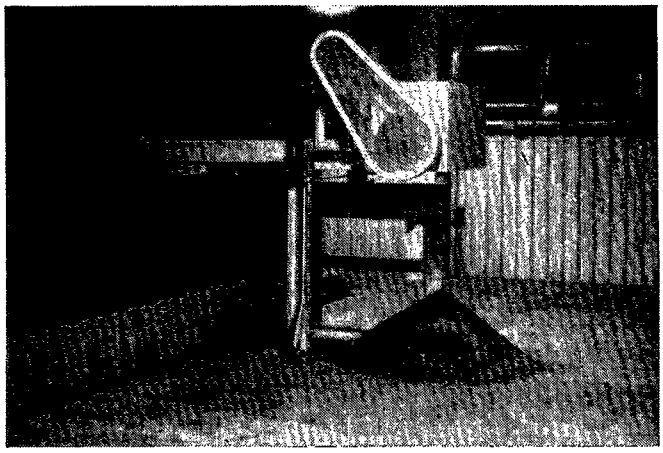
Funnels, chutes, and other transfer devices between conveyors have been problematic because of the sticky nature of sludge, mix, and recycle. Plugs occur even in vertical funnels. Sensors should be provided at all key transfer points to detect plugging. These sensors should also be tied into the central computer so that upstream conveyors shut down in the event of a plug.

Periodic cleaning of funnels and chutes by operators can alleviate many plugging problems. Access doors should be provided for this purpose.

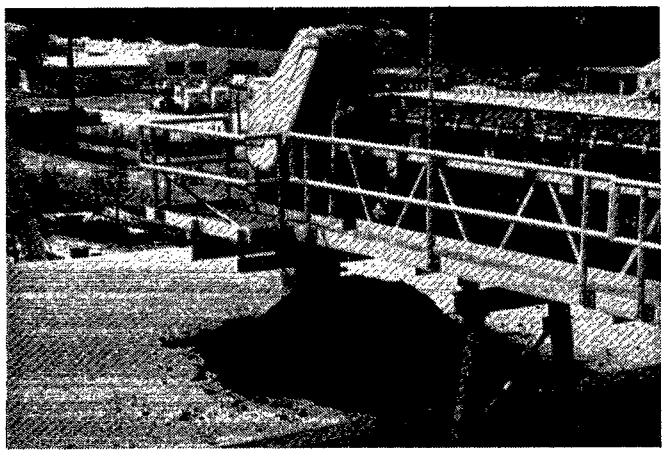
3.2.1.7 Preventing and Containing Spillage at Transfer Points

Spillage, particularly from belt conveyors, generates a continual stream of cleanup chores and is a chronic problem at many plants (see Figure 3.4). Providing catch pans and belt scrapers reduces the labor needed to keep plant areas clean. The cleated belt conveyor at Akron had severe spillage problems, which are discussed in detail in Section 3.2.3.1. The Schenectady plant contains several features that make the area easy to clean, including sloping floors, fire hoses, and open drains that can accept solids.

Figure 3.4 Minor Spillage Associated with Conveyors



Schenectady



Sarasota

3.2.1.8 Operating Schedule

The materials-handling system schedule should be designed so that the required amount of mix can be loaded during the time when the operators are at the plant. In most cases, composting plants operate only one shift per day. Because operators must perform other tasks, it is seldom possible to convey materials for an entire shift. Variations in the amount of materials to be loaded also must be considered. The materials-handling system should be sized for reasonable worst-case combinations of operator availability and materials flow.

At the Cape May plant, the conveyors were sized to move the average quantity of material in 8 hours. Because operators cannot run the system for 8 hours per shift and sludge quantities exceeding the average amount cannot be handled in 8 hours, the plant must be staffed for two shifts. It was estimated by local officials that $100,000 per year could be saved if a one-shift operation could be established.

3.2.2 Materials Receiving and Storage

3.2.2.1 Dust Control at Amendment Receiving Facilities

At some plants, dust generation has been a problem during the delivery of sawdust. A hood around the receiving facility should be provided to contain fugitive dust. At the Portland plant, both a hood and a vacuum system were installed after the plant was built (see Figure 3.5) because the receiving facility is so close to other equipment. A simple containment bin installed at the Sarasota plant is shown in Figure 3.6. Even with a receiving bin, some dust inevitably is generated during delivery.

Figure 3.5 Ventilation System at Sawdust Receiving Facility, Portland

3.2.2.2 Protective Screens

Several plants have found large chunks of wood, rocks, or other debris in their sawdust deliveries. If a piece of equipment such as a screw conveyor or funnel cannot convey large particles, screens should be included in the system to prevent their entry. The Cape May plant has a simple vibrating mesh screen over its bulking agent receiving hopper. At the Schenectady plant, a rotary disk screen is located at the exit of the amendment storage silo.

3.2.2.3 Amendment Storage

In almost all cases, the amendment materials are the driest of the three feed materials; facilities should be provided to keep these materials dry, such as silos, covered bins, and covered storage yards. Although covered bins or storage yards are less expensive than silos, they frequently have problems with wind-blown sawdust. They are, however, satisfactory for wood chips and bark.

The Schenectady and Clayton County plants both have aeration systems that dry stored amendments. To date, neither system has been used much, since the amendments are usually sufficiently dry when received.

3.2.2.4 Recycle Surge Bins

Some facilities are designed so that during loading, recycle is discharged from the reactor and conveyed directly to the mixer. This configuration requires that the reactor discharge device operate at a rate that exactly matches the recycle feed rate needed at the mixer. It is difficult to match these rates and, in addition, if the compost is compacted or excessively dry, it will not always discharge at an even rate.

Providing a surge bin between the reactor and the feed system adds flexibility (the reactor discharge rate doesn't have to match the mixer requirements) and allows operators to run the discharge device and the reactor feed system at different times. In addition, a surge bin can be used as a loading hopper for recycle when filling a reactor for the first time or after an annual inspection.

3.2.2.5 Curing/Storage Space

Exterior curing/storage space must be sized to accomodate the solids retention time needed to produce a product that is stable enough to market, since only part of the composting process is performed in the reactor(s).

The kind of aeration also should be considered. Windrows require more space than forced air systems. Piles that are too high may not receive enough air, and may produce acidic by-products and become phytotoxic. State regulatory agencies also have storage time requirements that need to be considered. Finally, the curing/storage space should be large enough to accommodate low quality batches of compost that need extra curing time, seasonal variations in the compost markets, and slow development of the local market. Since market development can be a slow process, it may be worthwhile to arrange temporary offsite storage for the first few years of plant operations.

Curing/storage yards should have impermeable surfaces (concrete or asphalt). Some regulatory agencies require that runoff be controlled and returned for treatment. Concrete or asphalt surfaces also reduce housekeeping chores. The area should be covered depending on the climate and the desired moisture content of the final product.

3.2.3 Conveyor Systems

Typical parameters used in evaluating various conveyor systems include:

- Properties of conveyed materials (bulk weight, moisture content)
- Load evaluation
- Load path (geometry)
- Conveyor function
- Conveyance rates required
- Physical dimensions
- Horsepower requirements
- Appurtenances required
- Operation and maintenance costs
- Capital costs
- Reliability
- Ease and speed of typical repairs
- Ease of cleaning

3.2.3.1 Conveyor Reliability

All of the facility conveyors have been used reliably in industry for years; none are experimental. Yet due to differences in materials characteristics, conveyors at in-vessel plants have experienced problems with jamming, breakage, excessive wear, and spillage. A poorly operating conveyor consumes time, labor, and money and can effectively shut down the whole plant.

Table 5.3 lists the kinds of conveyors used at the eight plants visited and their functions. Operating experiences with these conveyors are presented in the case studies (Chapters Six to Thirteen), and are summarized in Table 3.3. Lessons learned from these experiences are discussed below.

Screw Conveyors

Screw conveyors have been the most successful type of conveyor at the eight plants surveyed. In different forms,

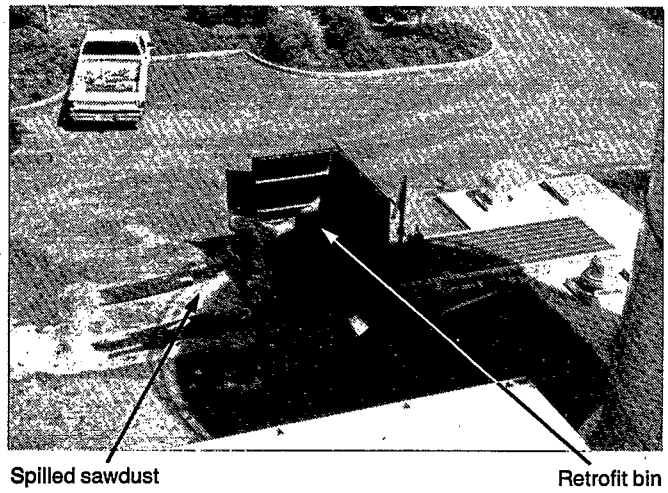
Table 3.3 Common Conveyor Problems and Modifications

Problem	Modifications Performed
Plugging/Compaction Problems	
Build-up and compaction of material in drag chain conveyors caused motor overload. (Newberg)	Flight height reduced from 4 in.[a] to 1.5 in.
Vertical discharge chute from the mixer to belt conveyor becomes plugged with mixture. (Plattsburgh)	Installation of motion indicators at this and several other locations being considered.
Divider gate that directs compost to recycle or to storage conveyors becomes plugged. (Plattsburgh)	Gate is now manually cleaned several times daily. Permanent mechanical modification being considered.
Compaction of material in drag chain conveyors led to jamming. (Sarasota)	Every other flight removed.
Build-up and compaction of material in drag chain conveyors caused bending of steel flights. (Portland)	Half the flights removed. The other half were replaced by smaller, plastic flights. Over-size steel flights were installed at 15-ftb intervals to clean the housing.
Enclosed screw conveyors clogged when sludge accumulated between screws and housings.(Clayton County)	Screw conveyor housings were lined with plastic.
Spillage Problems	
Belt conveyor contents spill at discharge points. (Plattsburgh)	Changed head and tail pulleys to smooth (rather than cleated) lagging.
Sludge sticks to the cleated belt conveyor and eventually falls to the floor. (Akron)	Cleated belt is now "dusted" with sawdust before sludge is applied.
Spillage occurs at transfer points between conveyors. (Akron)	Installing drip pans is under consideration.
Wear/Abrasion Problems	
Positive displacement drag chain conveyors were designed with close tolerences between flights and housing especially at turns and bending of flights. (Cape May)	The flight area has been reduced. Chain, flight, and housing replacement costs still approximate $100,000/year.
Cleated belts have become worn and occasionally tear because of full width idlers (support rollers). (Akron)	Stub idlers, which support the belt only on the flat portion of the belt outside the cleat wall, have been installed.
Drag chain housing suffered severe abrasion at turns. (Portland)	Portions of the housing were replaced with abrasion resistant steel.
Miscellaneous Problems	
The free end of the shaftless screw conveyor in the sawdust bin rises out of the sawdust. (Sarasota)	Horizontal hold-down bars have been installed.
Dust is generated wherever compost is dropped onto belt conveyors. (Portland)	Exhaust hoods were installed over strategic sections of the conveyors.
Icing of exterior belt conveyors. (Plattsburgh, Portland, Schenectady)	Operation of conveyors during icing conditions, even when materials transfer is not required.

[a]in. $\times 2.540 \times 10^{-2} = m$
[b]ft $\times .3048 = m$

they serve many functions. They are used to empty storage bins at almost all of the plants (see Figure 3.7); shaftless, spiral-type screws (see Figure 3.8) empty both amendment and sludge storage bins. Enclosed screws are used to convey the different materials found at a compost plant. Screws are also used as leveling devices for reactors and sludge bins. Many of the reactor discharge devices are based on screws as well. (These devices are discussed in Section 3.2.5.)

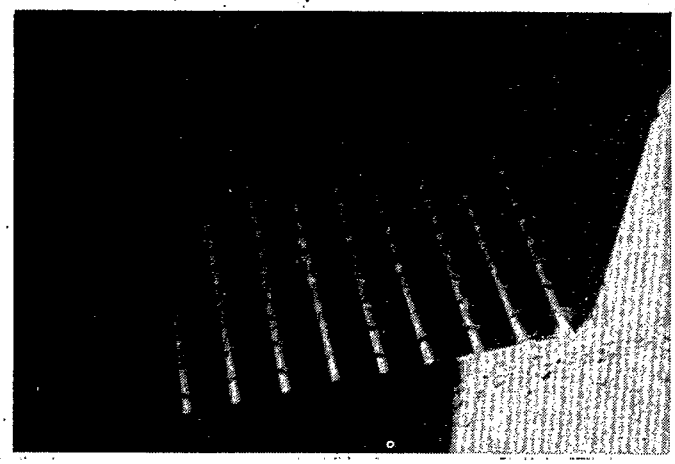
Figure 3.6 Retrofit Bin to Contain Dust at Sarasota



In these many applications, screw conveyors have been relatively trouble-free. The few reported problems are related to excessive wear and the accumulation of material on flights and housings. Materials accumulate on the

Figure 3.7 Example of Screw Conveyors that Empty Bins at Plattsburgh.

(Typical of other plants as well.)

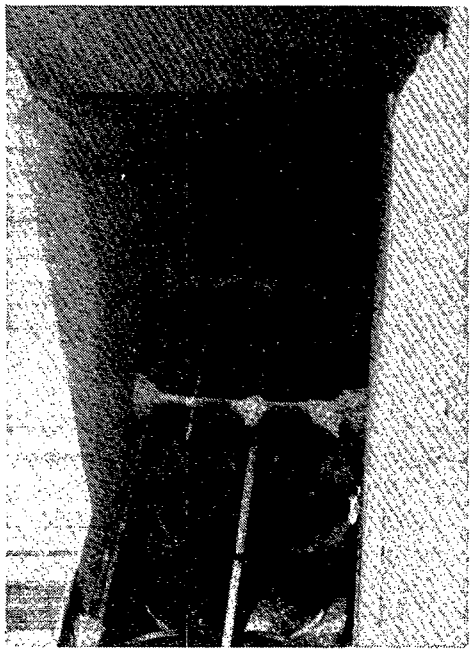


flights at Plattsburgh, but regular cleaning prevents problems. At Clayton County, materials accumulated between the housing and the screw flights, causing undesirable vibration. This problem was eliminated by lining the housings with ultra-high molecular weight plastic. At Portland, the accumulators, which are double screw conveyors, wore out quickly, but replacing them with single screw units solved the problem.

Belt Conveyors

Belt conveyors have worked successfully at many plants. In almost all installations, belt conveyors are shaped into troughs to better contain the materials (see Figure 3.9).

Figure 3.8 Shaftless Screw for Emptying the Sawdust Receiving Bin at Sarasota



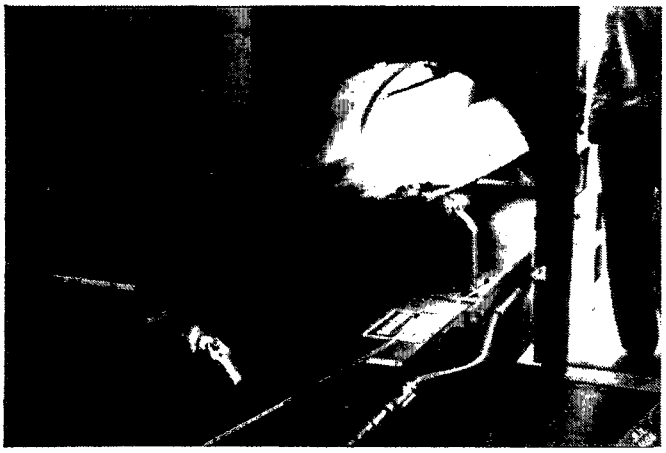
Spillage is a recurring problem with belt conveyors. Wet materials, which adhere to the rubberized belts, do not transfer completely. The remaining material is carried past the transfer point and subsequently falls on the floor, creating a cleanup problem. This problem can be minimized by using belt scrapers. Another tactic is to reduce the contact between wet materials and the belt fabric by placing a layer of dry material, such as sawdust, onto the belt before adding a wet material, such as sludge.

Screws and belt conveyors are limited to straight-line paths and cannot move materials vertically without long inclined runs. When faced with the need to move materials vertically, designers have turned to other types of conveyors, particularly drag chain conveyors.

Drag Chain Conveyors

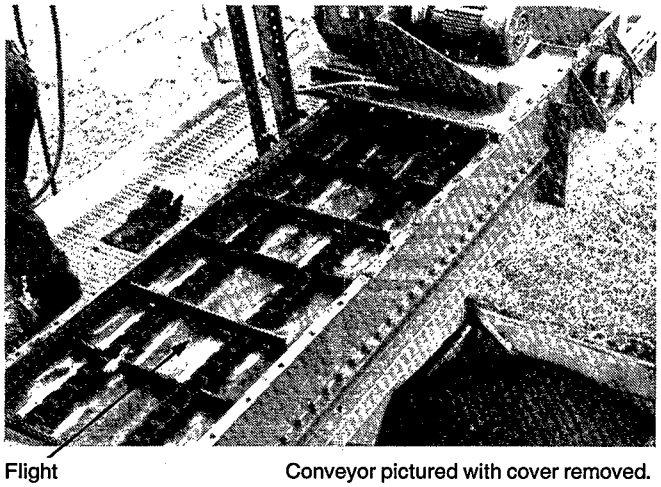
Drag chain conveyors are versatile devices, particularly suited for moving materials between different floors of the compost plant. A typical installation is shown in Figure 3.10. In practice, drag chains have not performed well, suffering from plugging and excessive wear. Composting materials, particularly the wet mix, adhere to the

Figure 3.9 "Flat" Belt Conveyor at Newberg



Usually the conveyor belts are formed into a trough-like shape as shown here.

Figure 3.10 Drag Chain at Clayton County



Flight

Conveyor pictured with cover removed.

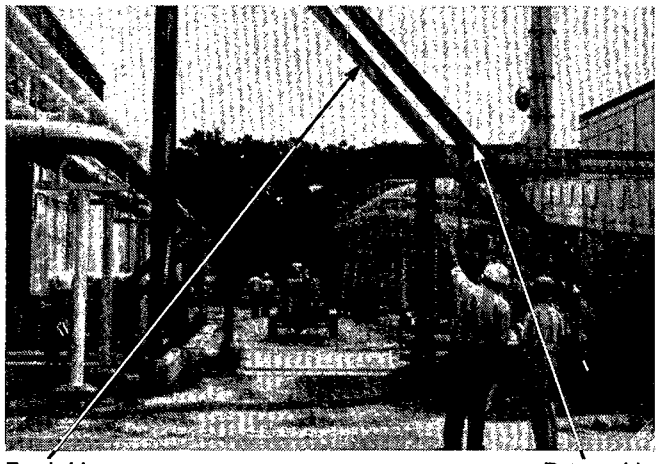
metal walls of the drag chain housing. As these materials dry, they create a rough surface. When the flights push wet material over this high friction surface, the wet material is compacted against the flight and between the walls of the housing and the flight, particularly in curved sections of the conveyor. Eventually, so much compacted material accumulates that the flights bend and the chains break. This problem has occurred at Cape May, Portland, and Sarasota.

Modifications to the drag-chain conveyors at the eight plants surveyed have involved increasing the space between flights, increasing the space between the flights and the conveyor housing, and decreasing the area of the flights themselves. These modifications allow the composting material to push backwards over or around the flight, so it won't be compacted. These modifications, however, also reduce the capacity of the conveyor.

At the Cape May facility, the designs specified close tolerances between the flights and the housing. These tolerances were achieved by placing the "feed" chain in the narrow housing normally used for the "return" and placing the "return" chain in the wider housing normally used for the "feed" chain (see Figure 3.11). Flights with large cross-sectional areas were also specified (see Figure 3.12a). In the narrow "feed" housing, compaction of compost materials and consequent jamming was particularly frequent. In 1988, plant staff estimated that drag chain maintenance cost the equivalent of one and one-half persons full-time and about $100,000 per year in replacement costs for broken chains and flights and worn housings. Modifying the flight shape alleviated the problem.

At Portland, half of the flights were removed and the remaining flights were trimmed to 25 percent of their original area (see Figure 3.12b). In addition, most flights were rebuilt and every 4.6 m (15 ft) along the chain, a reinforced steel scraper flight having a slightly larger area than the other flights was installed. These measures have greatly reduced the conveyor jamming.

Figure 3.11 Drag Chains at the Cape May Plant



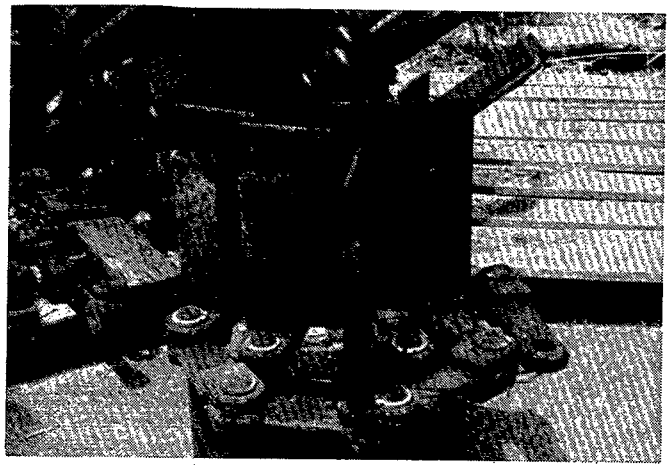
Feed side

Return side

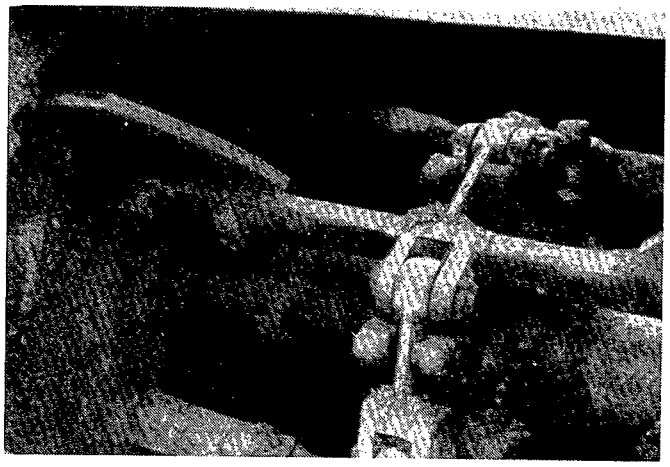
The Schenectady facility, which uses drag chains, has not experienced problems. There, the drag chain is equipped with 0.2- by 0.33-m (8- by 13-in.) double-leg (open center) flights. This drag chain is primarily a vertical lift device with no curved sections.

Another modification that helps prevent jamming is to line the conveyor housing with plastic. Mix materials do not adhere to the plastic and the housing surface stays smooth, thereby reducing mix materials compaction. This modification was used successfully on a drag chain at the Clayton County plant.

Figure 3.12 Drag Chain Flights at the Portland and Cape May Facilities



(a) Cape May



(b) Portland

Drag chains with large flights (a) have experienced jamming and breakage problems at several facilities. Cutting down the flight area as pictured in (b) has generally alleviated these problems.

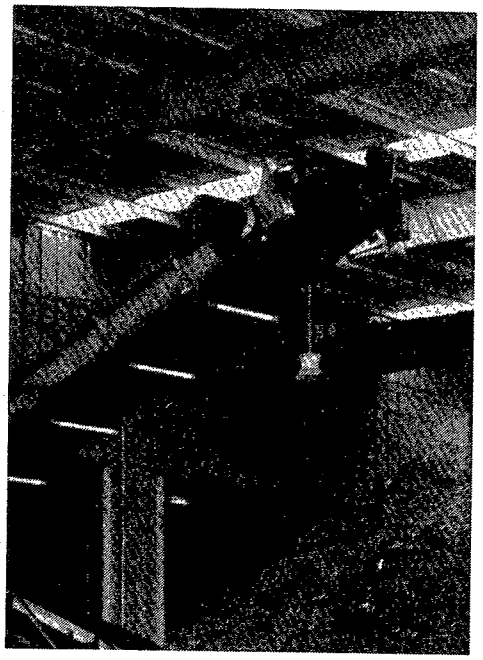
Drag chains have been highly problematic at in-vessel plants and should be used with great caution. When used, the cross-sectional areas of flights should be substantially reduced, the spacing between flights should be increased, curves should be eliminated as much as possible, and operators should consider lining the drag chain housings with plastic.

Cleated Belt Conveyors

Cleated belt conveyors are another means of moving materials up steep inclines. In a cleated belt conveyor, folds (or cleats) sewn into the belt fabric create a series of buckets (see Figure 3.13). Cleated belt conveyors were encountered only at the Akron plant.

The Akron cleated belts have had a number of problems. The major problem was that wet material, especially sludge, sticks to the belt fabric and does not discharge at

Figure 3.13 Cleated Conveyor at the Akron Facility



the transfer point. During the plant startup, approximately 10 percent of the feed, or more than 27 wt/day (30 wton/day) spilled on the discharge side of the conveyor (see Figure 3.14). Spillage has been reduced to 1 to 2 percent by dusting the belt with sawdust before applying the sludge. This solution may apply to plants that have experienced similar problems with other types of conveyors.

A second problem at Akron was that the conveyor idlers (support rollers) originally supplied with the cleated conveyors spanned the full width of the belts and caused excessive wear on the cleat edges. When a cleat wall tore, it caught on the idler, tearing the belt apart. These problems have been solved by replacing the original rollers with "stub" idlers that support the belt only on its edges.

A third problem is excessive spillage when handling very dry material. Apparently a static charge builds up on the cleats, causing the dry materials to cling.

Although subsequent modifications have made the system functional, cleated belts do not appear to be well-suited to composting operations. Currently, the City of Akron is seeking EPA funding to replace its cleated belt conveyors.

3.2.4 Mixers

3.2.4.1 Mixing Equipment

Of the eight plants visited, four had mixers that used plow blades mounted on a rotating shaft; the other four used pugmill mixers (see Figure 3.15). In general, the mixers have needed minor modifications after which they have worked satisfactorily.

Figure 3.14 Spilled Material at Akron

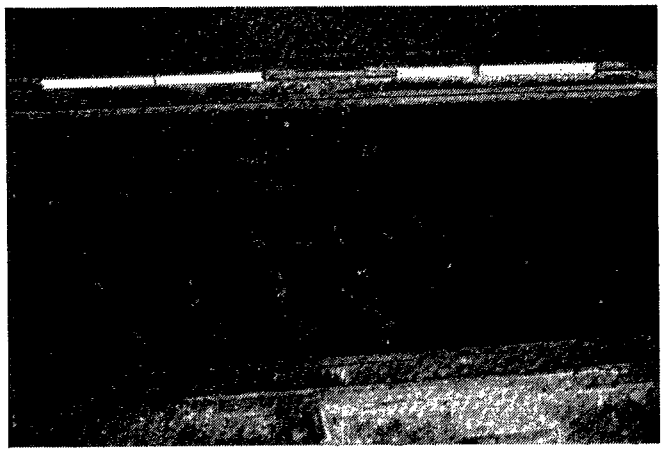
Spilled mix material

Clean-up crew

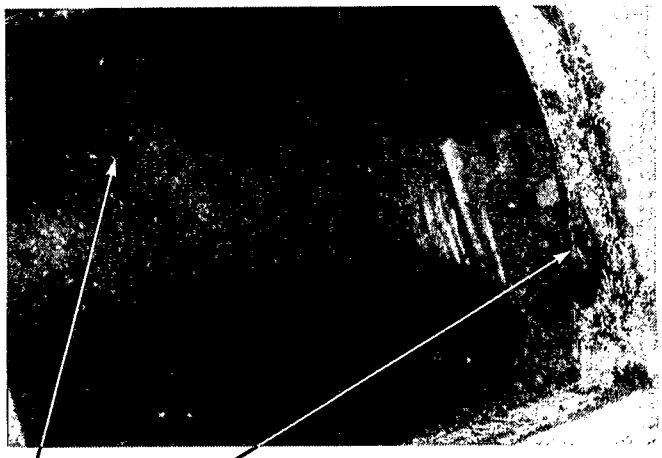
Only Schenectady has reported problems with a plow-blade mixer. An overloaded mixer caused jamming and was thus unable to accept its rated throughput ratio. To correct this problem, the mixer discharge hole was enlarged. It is not known whether the problem has been solved because the mixer has not been tested at capacity since the modification was made.

Accumulation of the mix materials on mixer paddles and consequent plugging of the mixer was reported at three

Figure 3.15 Two Kinds of Mixers Used at In-Vessel Facilities



Pugmill (Cape May)



Shaft Blade Close-up of Plow Blade (Sarasota)

pugmill installations. At Plattsburgh, the plugging problem was greatly alleviated when the solids content of the sludge was increased from 18 percent to 25 percent. At both Akron and Cape May, the plugging problems were resolved by removing half of the mixer flights. (At Akron, the drive motors were also enlarged.)

3.2.5 Reactor Discharge Devices

Reactor discharge devices are key components of the materials-handling system; their function cannot be easily duplicated. If a discharge device fails, the reactor cannot be used.

Discharge devices are proprietary items supplied as a package with the reactor. Many of the discharge devices are adaptations of machinery used in the paper and pulp industry, where they have a long history of reliable operation. In adapting these devices to in-vessel composting operations, designers should make sure that the discharge devices can move the relatively high bulk weight of the compost under all foreseeable conditions.

3.2.5.1 Discharge Device

The discharge devices at some plants have experienced structural problems. At the Schenectady plant, the pins connecting one of the screws to its drive mechanism failed. Also, many of the bolts broke in the steel channels that serve as tracks for the gear drive (which propels the screw through the reactor) and are being replaced with stronger bolts. At the Plattsburgh plant, four of the vertical screws in the Fairfield reactor broke and have been replaced.

3.2.5.2 Hard-Surfacing on Auger Flights

Compost is a surprisingly abrasive material, especially when it is compressed at the bottoms of vertical reactors. Excessive wear of auger flights has been observed at several plants.

At Sarasota, the original screws were hard-surfaced by hard steel welding on the flight edge only. The screw in the first reactor lost 15 percent of its flight thickness in 6 months because of wear on the flight face. Additional hard-surfacing needed to be added to the flight face. The discharge screws at Cape May were originally surfaced with Triten steel and have not suffered excessive wear. At Portland, the screws, though originally not hard-surfaced, were expected to last 7 years. After 14 months, however, four of the screws were replaced due to excessive flight wear; the replacement screws are hard-surfaced. (Although the need for hard-surfacing is apparent from the experiences at other plants, Portland operators believe that the wear on the screws was exacerbated by the ash from the Mt. St. Helens volcanic eruption.)

At Plattsburgh, the vertical augers are wearing out much faster than expected despite being hard-faced. To date, four augers have been replaced because of wear. Eighteen others show excessive wear and the city is considering ceramic coating, ceramic wear strips, special hard coatings, and polyurethane coatings as replacements or additions to standard hard-surfacing.

3.2.5.3 Propelling the Discharge Device through the Compost Bed

Occasionally, compost becomes either dry and hard or, under wet conditions, gooey and viscous. Both conditions make it difficult to move the compost with a discharge device. Reactors must be provided with discharge devices that work reliably, even under worst-case conditions.

Although their discharge devices are slightly different, both Portland and Clayton County have experienced difficulties with their discharge augers. At Portland, if the compost is too wet ("oozing compost"), the composting material collapses around the screw and traps it. Oozing compost also physically blocks the path of the peripheral drive mechanism (see Chapter Eleven for a detailed description of this problem.)

The oozing compost at Portland may be partly attributable to the large diameter of Portland's reactors. Oozing sludge has not been observed at the Clayton County plant, whose reactor diameter is 7.6 m (25 ft) (compared to the 14.3-m (47-ft) diameter of the Portland first reactors and the 18-m (59-ft) diameter of the second reactor. The pressure at the bottom of a large diameter reactor may be greater than in a smaller diameter reactor because the wall friction per unit volume (and therefore structural support) is less.

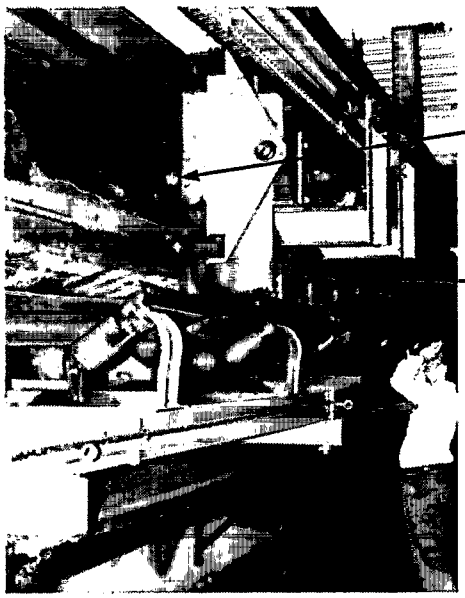
Despite the smaller reactor diameter, the auger at Clayton County has not escaped getting stuck in the compost. (The screw turned, but would not advance.) At the time, the mix and compost characteristics were not unusual and the screw had not been stationary for an unusual length of time. A hole was cut in the reactor wall so that the screw could be examined. Although no definitive cause for the sticking was found, the drive mechanism that pushes the auger through the compost bed was modified to increase and more evenly distribute the driving torque. (See Chapter Eight for a detailed description.)

3.2.5.4 Machinery Access

Consistent with the strategy of assuring reliability through quick repair and preventive maintenance, operators should be given easy access to the discharge device machinery. The work spaces around the machinery should be large enough to allow maintenance personnel to work comfortably. If possible, the discharge device should be removable from the compost bed to facilitate maintenance and inspection. The discharge device installation at the Schenectady plant exemplifies these recommendations (see Figure 3.16). The discharge devices at the Akron, Cape May, and Sarasota facilities can also be removed from their respective reactors without disrupting operations.

At Plattsburgh, there is good access to the vertical auger drives but the augers cannot be removed and must be dug out of the compost bed by hand for repair or inspection. At the Portland and Clayton County plants, access to the auger machinery is difficult due to the cramped facilities. The discharge screws at these plants can be removed through doors on the outside walls of the reactor but at both plants, there have been times when the augers could not be aligned with these doors. On one occasion at Clayton County, the funnel that conveys compost out of the center pivot became blocked. Compost, which is pushed into the center pivot housing for discharge, backed up, lifting the screw off its drive mechanism and pushing the screw into the wall of the reactor. A hole had to be cut into the steel outer wall of the reactor in order to remount the screw. At Portland, the flights on one screw were so worn that the screw could not advance. Unfortunately, this situation was not recognized in time to stop the screw in front of one of the reactor doors; the screw stopped between the doors and had to be dug out.

Figure 3.16 Discharge Device Installation at Schenectady



Note the large amount of room around the equipment.

3.3 Aeration

3.3.1 General System Considerations

There are three basic demands on the aeration system: (1) heat removal, (2) moisture removal, and (3) biological metabolism. A comprehensive discussion of proper aeration equipment selection is beyond the scope of this report. However, aeration systems should be (1) flexible to allow for changing conditions, (2) controllable to allow for proper process control, and (3) well monitored to allow operators to specifically identify how the aeration system is performing.

The aeration systems at the sites visited have been relatively trouble-free. (See Tables 5-4 and 5-5 for a summary of the equipment found at these facilities.) The systems appear to be adequately sized to meet the biological and heat removal requirements; only Schenectady had problems with elevated temperatures. The major problems have been related to moisture removal: condensation and fog formation above the reactors and formation of a "hardpan" layer. Inadequate aeration for curing/storage piles was a third major problem. These three items are discussed below. Other areas of concern can be summarized as follows:

- Standby capacity: The oxygen level in an actively composting material can drop to zero in a few hours or less if air supply is stopped; therefore, standby capacity with standby blowers and/or with standby power is essential. Table 3.4 summarizes standby blower systems at the eight plants visited.
- Noise: At Akron, neighbors complained about the noise from 32 roof fans; Akron is planning to add noise attenuation.
- Preheating supply air: Akron, Plattsburg, and Schenectady all preheat the air going into the reactor. However, the systems that do not preheat have not had specific problems.
- Temperature: The desired operating range depends on site-specific conditions. Generally, temperatures above 70°C (158°F) will slow biological metabolism. The EPA pathogen reduction requirement calls for at least 3 days at 55°C (131°F).
- Reactor pressure requirements: The air supply system must have sufficient pressure to move the air through the distribution piping and composting mass in worst-case (wet mix) conditions.
- Exhaust pressure requirements: The air exhaust system must have sufficient pressure to move the air through exhaust piping and odor control equipment, including dispersion. Note that five of the eight plants visited have modified or will modify their odor control systems, requiring additional exhaust capacity.
- Work space ventilation: If the work space is too noxious due to lack of ventilation or other breakdown, operators will not be able to repair the problem in that area.

3.3.2 Air Collection/Moisture Removal

In-vessel composting systems should provide for adequate collection of air after it has passed through the compost (2). Important considerations are the collection system configuration in the vessel, the efficiency of moisture removal, and the extent of condensation that could occur.

Thermodynamically, air can hold four times as much water at 60°C (140°F) than at 40°C (104°F). Therefore, if the temperature drops before the air leaves the vessel, it does not remove as much water, and condensation occurs within the vessel and composting mass. If the air collection system extends into the composting mass,

Table 3.4 Standby Blower Systems

Location	Air Supply	Exhaust
Akron	Two blowers per section of reactor. Except for high demand early in the compost cycle, only one blower is used; the other is standby.	No exhaust blowers.
Cape May	No standby with original plant. Standby blowers added later.	No standby for reactor exhaust in original plant. Standby blowers added later. One standby for the reactor head-space ventilation system.
Clayton County	One standby blower for each reactor.	No standby blower.
Newberg	One standby blower for each reactor.	One blower supplied, but because it must be used in series with the other exhaust blower because of odor control system back pressure, there is effectively no standby capacity.
Plattsburgh	No standby.	No standby blowers.
Portland	One blower per reactor train that can act as an auxilliary or standby blower.	No standby blowers.
Sarasota	No standby.	No standby blowers.
Schenectady	One standby blower for four reactors[a]	One standby blower for four reactors[a]

[a]Not including the conditioning cell.

Note: Standby power capacity not investigated.

parts of the system can become exposed due to natural settling and uneven subsidence. Such exposure can cause odors to escape, saturated air to cool, and condensate to form within the vessel.

Systems such as Akron and Plattsburgh discharge the warm, moist air from the compost bed into a building or work space above the reactor. In each case, the introduction of too much cold outside air into these same areas results in the condensation of the water vapor and the formation of fog. At Akron, the fog does not directly affect operations, although its long-term corrosion effects are not known. At Plattsburgh, the fog hampers the stabilization of the product, promotes corrosion, and is so thick that operators cannot see to work.

3.3.3 Hardpan

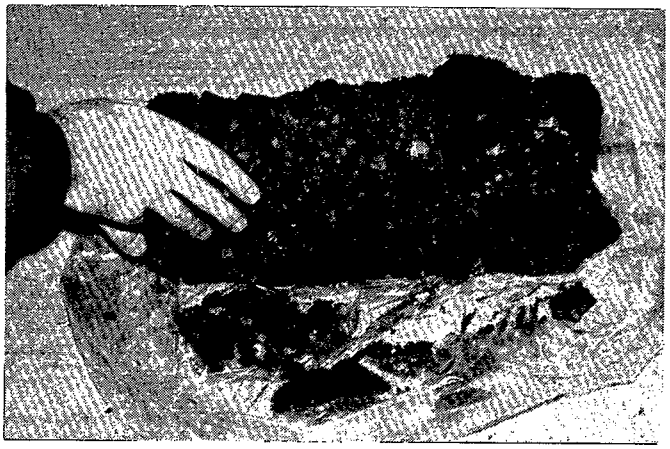
At several plants, leachate combined with compost and other materials at the bottom of the reactor to form a "hardpan" layer that was nearly impermeable to air. In 1987, plant operators at Plattsburgh discovered that the layer of wood chips placed over the base gravel bed to keep compost fines from entering the air distribution piping had turned into "hardpan." This hardpan prevented the flow of air into the compost bed (see Figure 3.17). At Clayton County, the annual inspection of the first reactor interior revealed that leachate was seeping into the 0.01-m (0.5-in.) unwashed river stone layer on the bottom of the reactor, "cementing" the gravel particles together and plugging the holes in the aeration piping. The gravel was replaced with 0.02-m (0.75-in.) washed round river rock, and the aeration piping was remounted in the middle (rather than the bottom) of the gravel layer, separating it from the pooling leachate.

During the first year of operations at Cape May, a hardpan layer formed, which was attributed to excessive leachate generation. The mix ratio and amendment specifications were changed to obtain a more porous initial compost mix, which significantly reduced leachate generation. Also, the aeration system was modified to give the operators better control of the airflow. The hardpan problem has not recurred since these changes were made.

3.3.4 Curing/Storage Aeration

The curing/storage process is an important step in the overall sludge composting process. The composting process does not stop when material is removed from the reactor(s); the compost continues to have an oxygen demand.

Figure 3.17 Piece of "Hardpan" Material Removed from the Plattsburgh Reactors



3.3.4.1 Extended Curing/Storage

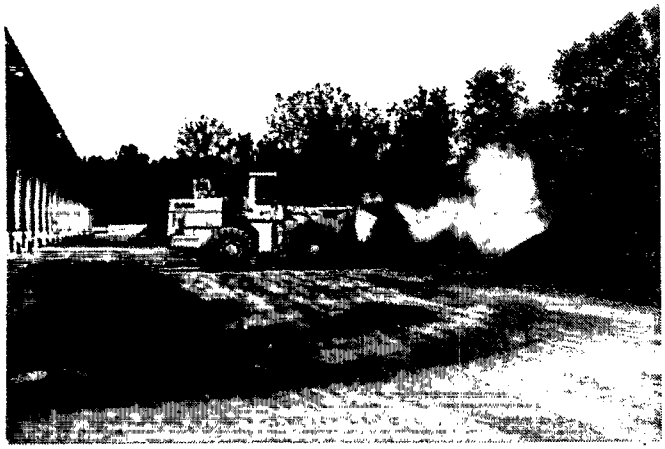
Even where compost is processed in second reactors (at Clayton County, Portland, Sarasota, and Schenectady), the unaerated curing/storage piles have reheated. Depending on the stability of the compost, oxygen demand may be elevated to the point where anaerobic

conditions develop, and moving the piles causes odors to be emitted (see Figure 3.18). At Akron, Cape May, and Newberg, the exterior curing/storage piles are aerated or will be aerated in the future. The aeration systems at Akron and Cape May were added due to odor problems; Newberg's system (unused at the time of the site visit) was included as part of the original construction. At Plattsburgh, the curing/storage piles are odorous, and planning is underway to determine whether they should be aerated.

3.4 Odor Control

Effective odor control is a critical requirement for the success of a composting facility. Fear of potential odors engenders public opposition to proposed plant sites. Odor complaints can cause a regulatory agency to shut down or curtail the operations of an existing facility. Plant odors can hurt product sales.

Figure 3.18 Storage/Curing Piles



Steam and odors being released from a curing pile during moving. (Akron)

Compost product (after curing) reheats when it is placed into storage piles. (Portland)

Of the eight composting facilities surveyed in this project, six had received odor complaints from the local community. At five of these sites, the complaints were serious enough to cause the plant owners to retrofit the facilities with additional odor treatment equipment. Two plants ceased operations while the new equipment was being installed. A third plant was operated at reduced capacity to limit odor production while the new treatment equipment was piloted, designed, and installed. The last two plants continued to operate but were proceeding with the odor treatment system retrofits as quickly as possible.

Almost all of these problems can be attributed to incomplete odor control plans. To be effective, an odor control plan must include at least five elements:

- Control of the composting process
- An inventory of potential odor sources
- An odor collection and containment system
- An odor treatment system
- Effective dispersal of residual odors

These elements are discussed below.

3.4.1 Compost Process Control

Controlling the composting process is crucial in minimizing odor production. This entails providing sufficient aeration, keeping temperatures and moisture contents in the appropriate ranges, maintaining the porosity of the composting materials, and properly mixing the compost ingredients. Anaerobic conditions, in particular, lead to increased odor production.

Although process control is a necessary condition for minimizing odor production, it is not sufficient in itself. Even the plants surveyed provided adequate oxygen (as evidenced by measurements of the gases from the reactors) still produced some odors. The ammonia produced at the Plattsburgh plant is one example. Therefore, designers should not depend on process control to eliminate the need for other odor control measures.

Stabilizing sludge before composting may affect odor production. The two plants surveyed that have not experienced odor problems are composting relatively stable sludges. At Portland, the sludge is anaerobically digested before composting, and at Newberg the sludge from an underloaded oxidation ditch is partially aerobically digested before composting. Nevertheless, there are static pile systems (not surveyed) that compost anaerobically digested sludge yet still experience odor problems.

Chemical treatment of sludge can reduce nonprocess odors in the dewatering and mixing areas of composting plants. At Plattsburgh and Schenectady, potassium permanganate is added to the sludge before dewatering. At Cape May, a masking agent is added to the sludge, sawdust, and recycle at the mixer. These chemical additions have not significantly changed odor emissions from the reactors.

3.4.2 Inventory of Potential Sources

Although the reactor outlet air is the primary source of odor asssociated with an in-vessel facility, it is not the only source. Odors can be generated at numerous points in the system. A list of potential sources of odor, based on the experiences of the eight plants visited, is shown in Table 1.4. During design, a complete inventory of potential odor sources, types, and amounts, should be made and a comprehensive control strategy should be developed for the entire facility.

The odor inventory should also include offsite odors so that after the composting plant is started up odor complaints can be directed to the proper offending source.

Identifying the specific odor-causing compounds may be important in designing treatment systems. At the Plattsburgh plant, for instance, the single-stage wet scrubber was designed with a caustic chemical feed system that was completely ineffective in removing ammonia, the primary odor-causing gas. This issue is discussed below in relation to treatment systems.

3.4.3 Collection and Containment

All odor sources should be evaluated for inclusion in the containment and collection system. Some emissions may be small enough that they can be dispersed satisfactorily without treatment. (See discussion below on odor dispersal.) All other odors sources should be contained and the malodorous air collected for treatment.

The containment and collection system should be coordinated with the building ventilation systems. If the work space is inadequately ventilated, operators will open doors to increase circulation and inadvertantly allow odors to escape. At the Sarasota plant, for example, sludge odors are released from the dewatering room through a garage door that is opened in warm weather because the ventilation system cannot sufficiently mitigate the internal heat, humidity, and odors generated by the belt presses. Similarly, doors are left open around the process building at the Portland plant to help dissipate ammonia odors generated when the reactor discharge devices are operating.

3.4.4 Treatment

Odors found at compost facilities are caused by a large number of different compounds that originate in both the sludge and the amendment. In-vessel systems may produce more amendment-related odors than static pile or windrow systems because the sawdust used at most in-vessel facilities has a greater surface area than the wood chips usually used in the other systems.

These odor-causing compounds fall into a number of classes that differ in their physical and chemical properties. Some are acidic; some are basic. Some can be destroyed by oxidation; others cannot. These compounds are not equally soluble in water, nor equally amenable to adsorption. Moreover, the mix of compounds in the odorous gas stream can change over time, depending on the composting materials and the reactor operating conditions. For this reason, treatment systems must employ a broad spectrum of removal mechanisms to be effective. Treatment systems that rely on only one or two removal mechanisms such as single-stage wet scrubbers and ozone oxidation chambers generally have not been successful.

Four basic odor treatment options were found at the eight plants surveyed. A fifth option, activated carbon, was tested at one location but was not part of any plant's odor treatment system. All five options are discussed below.

3.4.4.1 Wet Chemical Scrubbers

At the time of the site visits, packed tower wet scrubbers were in use at three of the eight plants visited: one-stage units were operating at the Cape May, Plattsburgh, and Schenectady plants; and a two-stage unit was in use at the Cape May plant. Two-stage units will be installed as part of the odor control system upgrades planned for the Akron, Plattsburgh, and Schenectady plants. A two-stage unit was constructed at the Sarasota plant in the spring of 1989 (after the site visit). The odor sources treated and the chemicals used in these scrubbers are listed in Table 3.5. Typical scrubbers are illustrated in Figure 3.19.

Table 3.5 Wet Scrubber Installations

Location	Number of Stages	Source of Odorous Air	Chemicals Used
Cape May	1	Sludge storage building	Sodium hypochlorite and sodium hydroxide.
	1	Mixing building	Sodium hypochlorite and sodium hydroxide.
	2	Reactors	First stage: Sodium hypochlorite and sodium hydroxide. Second stage: Sulfuric acid.
Plattsburgh	1	Reactors and mixing room after it passes through the compost.	Originally sodium hypochlorite and sodium hydroxide. Later, changed to sulfuric acid and DeAmine, a proprietary chemical.
Sarasota	2	Reactors, mixing room, dewatering room	First stage: sulfuric acid Second stage: hypochlorite.
Schenectady[a]	1	Reactors and mixing room	Sulfuric acid and DeAmine, a proprietary chemical.

[a]Existing ozone contact chamber is being used as a cooling tower upstream of the scrubber.

One-stage scrubbers have not provided adequate treatment of odors from the reactors. At the Cape May plant, the single-stage scrubber, which was designed to control odors from both the mixing building and the reactor exhaust, was not successful. In August 1986, a two-stage scrubber was installed to treat the reactor exhaust air, while the original unit was retained for the mixing building. Replacement units are being designed for Plattsburgh and Schenectady, as well.

There may be several reasons for the failures of the single-stage scrubbers. However, the fundamental reason for their ineffectiveness is that the odors in compost offgases are caused by a variety of compounds that require several removal mechanisms, some of which cannot be combined in a single-stage scrubber. Additional problems have been caused by overloading the scrubbers and using inappropriate chemicals. Single-stage scrubbers may have a place at compost plants for treating odors from sources in which hydrogen sulfide or another single compound is the primary odor source. As noted earlier, the mixing and sludge storage buiildings at the Cape May plant are serviced by single-stage scrubbers.

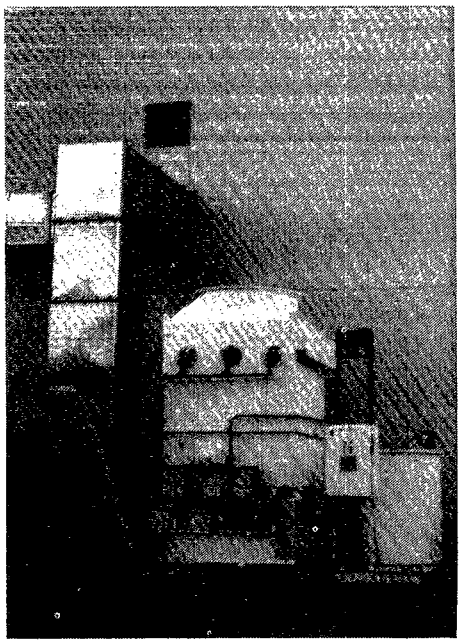
Because of the need to provide a spectrum of removal mechanisms (including both acid and caustic scrubbing), two stages are the minimum number needed for effective odor treatment. Packed tower wet scrubbers were the only scrubbers observed at the eight plants studied. Mist-type scrubbers have been used successfully at the Montgomery County, Maryland, facility, an enclosed static pile operation. As discussed below, adequate dispersion of the scrubber discharge is a key element of a successful odor control device. (Note the lack of a stack for dispersion on the Schenectady scrubber shown in Figure 3–19.)

3.4.4.2 Compost Biofilters

At the Akron facility, odorous airstreams from the dewatering room, the mixing room, and the negatively aerated reactor cells were passed through compost beds. (See Chapter Six for a description of this system.) Measurements made at the site and summarized in Table 3.6 showed that the biofilters were able to remove large fractions of these odors.

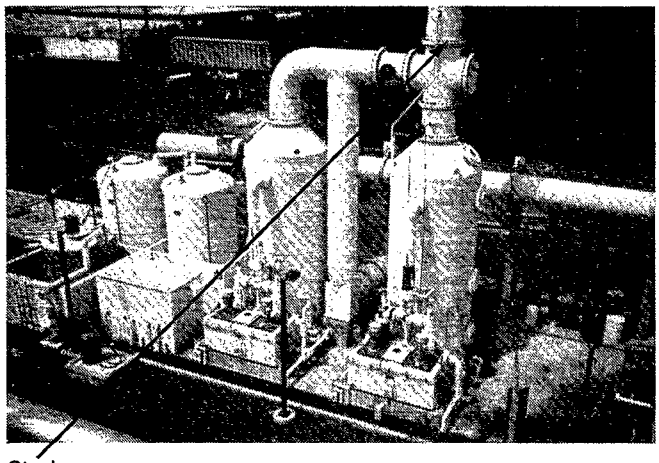
Biofilters (soil and compost filters) may have potential in this application because within the biofilter a variety of mechanisms — physical adsorption, chemical oxidation and neutralization, and biological degradation — are available to remove the odors. Nevertheless, design parameters such as loading rates, residence times, and moisture contents are not well established. Biofilters require relatively large land areas and are discharged at ground level, which makes dispersal of the odors not removed in the biofilter difficult.

Figure 3.19 In-Vessel Scrubbers



Single-Stage Scrubber at Schenectady

Locating the scrubber exhaust near the building wall and below the roof line prevents proper dispersion.



Two-Stage Scubber at Cape May (Tanks to left are chemical storage tanks)

3.4.4.3 Bubbling Odorous Air through Water

At the Portland, Newberg, and Clayton County facilities, which are smaller facilities that use a more stabilized sludge, the odorous air is bubbled through water for treatment. At Clayton County, the reactor exhaust air is bubbled through 0.71 m (28 in.) of water in the wastewater plant's emergency bypass holding pond (see Figure 3.20). Operators have received some odor complaints, but the odors generally are not problematic, partly because of the rural setting of the plant. The Portland and Newberg facilities have not received any odor complaints; both plants are located in outlying industrial

areas and both compost relatively stable sludges. These mitigating factors make it difficult to project the effectiveness of this technique at other locations.

Table 3.6 Odor Removal by Compost Filters at the Akron Composting Facility (3)

Time of Sampling	Odor Level(d/t)[a] Inlet Air	Outlet Air
March 29, 1988		
11:50	281	—
12:00	—	<10
12:17	—	3
12:50	—	5
April 5, 1988		
11:25	346	—
11:26	269	—
11:36	—	14
April 7, 1988		
8:36	615	—
8:41	—	26
8:55	758	—
12:25	—	18

[a]d/t = dilutions-to-threshold.

Figure 3.20 Odor Control System at Clayton County

Reactor offgas bubbled through pond water.

Bubbling the odorous gases through biologically active suspensions such as activated sludge aeration tanks might be considered a combination of biofilter and wet scrubber techniques. Like biofilters, the design parameters associated with this technique are not well established. Also like biofilters, a ground-level discharge is created.

3.4.4.4 Ozone Contact Chambers

An ozone contact chamber was used only at the Sarasota facility. The ozone concentration was 1 to 2 ppm and the detention time at the design airflow rate was about 20 seconds. The system was not effective at reducing compost-generated odors.

3.4.4.5 Activated Carbon

None of the in-vessel composting plants surveyed use activated carbon as part of their odor control systems. Activated carbon was tested as a possible treatment method at the Akron plant. Odor removal (measured as dilutions-to-threshold) varied from 85 to 95 percent at the beginning of the test and diminished thereafter as the adsorption capacity of the carbon diminished. The testing program was not sufficiently detailed to develop an adsorption isotherm or establish system economic parameters.

3.4.5 Dispersal

No treatment system is 100 percent effective; some concentration of odorous compounds will be discharged after treatment. Likewise, no containment and collection system is perfect. Fugitive releases of odors are very likely to occur despite the best prevention efforts. To avoid undesirable effects on local residents, the odorous emissions must be diluted and/or dispersed so that ambient air concentrations of the odorous gases fall below detection thresholds.

Sometimes, the dispersion characteristics of a site exacerbate odor problems. One such example is the Akron facility. It is located in a narrow river valley enclosed by 60-m (200-ft) high ridges. During periods of atmospheric stagnation, emissions from the plant are trapped in the valley and accumulate. When the wind returns, it transports these accumulated odors through residential and commercial areas also located in the valley.

Because of local conditions, odors may travel for miles. At Akron, odor complaints have been received from residents 2.4 km (1.5 mi) away and odors have been detected 4.0 km (2.5 mi) away. Moreover, wind patterns can sometimes bypass local residents and transport odors to distant neighborhoods.

It is advisable to model the dispersion characteristics of proposed plant sites during project planning. Dispersion modeling should consider the effects of local meteorology (including seasonal and diurnal variations and worst-case weather conditions such as inversions), topography, the location and proximity of neighbors, and the characteristics of the odorous discharges (i.e., elevated, ground-level, point source, or area source).

The modeling results can be used to screen sites with poor dispersion characteristics. Modeling can also be used to establish maximum allowable odor emissions for treatment systems and the need for supplemental dispersion such as stacks or mechanically induced ventilation. Finally, model results can be used to develop a flexible odor control plan that varies according to the weather. An example of one such plan is discussed in the Akron case study (see Chapter Six).

3.4.6 Additional Considerations

3.4.6.1 Curing/Storage Pile Aeration

Curing/storage piles are biologically active and without enough air, anaerobic conditions may develop, which can lead to odor emissions. See Section 3.3.4.1 for a detailed discussion of curing/storage pile aeration.

3.4.6.2 Odor Control System Reliability

Odor control systems should not, under any circumstances, be inoperable for more than a day. If they fail to function, odors will likely be released in sufficient amounts to elicit neighborhood complaints. Therefore, odor control systems should be designed with a high degree of reliability. To ensure reliability, the strategies discussed earlier — standby blowers, standby power, and/or quickly reparable equipment — are applicable. Chemical feed pumps, valves, instruments, and controls should be easily accessible and replaceable. In addition, appropriate spare parts should be kept on hand.

3.4.6.3 Backup Plan

A backup plan should be developed to reduce the potential for odors in the event of compost process problems or mechanical breakdowns. The backup plan should include moving the sludge or compost offsite (e.g., emergency landfilling) or aerating the material onsite with temporary odor treatment measures (e.g., compost biofilters). Untreated sludge or incompletely composted materials should not be stored at the plant. The majority of odor complaints were received at the Clayton County plant, for example, when the contents of one reactor were piled outside while the reactor received its annual inspection.

3.5 Process Monitoring and Control

Composting is a biological process that, to date, has been operated on a semi-empirical basis although many advances in quantitative analysis have been made (i.e., by Haug, Wilber, and Murray [4,5,1,6]). Designers should provide generous monitoring and control capabilities to aid operators in diagnosing problems and documenting process performance. Table 3.7 lists the monitoring needs of an in-vessel facility. The centralized computer control system should be capable of recording the running times and speeds of various conveyors. The computer should be programmed to convert these into volumes and weights.

3.5.1 Analytical Equipment for Process Control

The solids content of the feed materials and the mix must be determined on a regular basis. In the standard test, the sample is dried in an oven to a constant weight (usually overnight). This does not provide "real time" process control, however.

Other tests include use of analytical microwave devices, homemade microwaves, and heat lamps. The analytical microwave devices produce results quickly (about 20 minutes), but can analyze only a very small sample (several grams). Operators note that it is very hard to choose a representative sample of this size. The operators at Cape May have developed their own test using a kitchen microwave oven. Other facilities use heat lamps to dry the solids. The facilities using homemade tests or heat lamps usually use the standard oven technique to analyze at least one representative sample from each batch of material loaded into the reactors.

Another test that must be performed on a regular basis is the determination of bulk weight. This test can be done easily with a standard bucket and a scale. Bulk weights of mixes are sometimes used as surrogate measurements of porosity.

Table 3.7 Monitoring Needs

Purpose	Parameter
Process Control	Temperature Aeration rate Backpressure Oxygen Mass balance (materials flow)
Odor Control	Scrubber chemistry Odor emissions Meteorology
Regulatory Requirements	Temperature Constituents (especially C metals)
Marketing or Product Quality	Moisture content Stability Constituents (especially C metals) Phytotoxicity

Operators at some plants attempt to measure compost stability with oxygen uptake devices. Consideration should be given to equipping the plant with this or some other type of equipment for measuring compost stability.

For odor control, the chemicals going in the scrubber should be metered and the odors emitted from the scrubber should be monitored. Oxygen and temperature should also be monitored (see Section 3.5.2).

Designers should consider sampling and monitoring needs while specifying and laying out equipment. Situations such as those at Clayton County and Portland, where the mixers are at the top of the facilities and the control room and analytical equipment are located on the ground floor, should be avoided. Such logistics make monitoring extremely difficult.

3.5.2 Process Sensors

3.5.2.1 Temperature and Oxygen Measuring Devices

Although most in-vessel plants use temperature to control aeration rates on a day-to-day basis, equipment to measure oxygen should be provided for diagnostic pur-

poses. An operator cannot tell if temperatures are low simply because the volatile content of the mix is low or because there is insufficient oxygen in the system. At Sarasota, automatic controls that vary the aeration rate in response to the temperature (i.e., as temperature increases, the aeration rate is increased, and vice versa) are not used because the operators are concerned that the computer will misinterpret low temperatures caused by insufficient oxygen, and exacerbate the situation by decreasing the aeration rate. Oxygen probes at several of the plants visited were inoperable because they were not designed for the high humidity of the reactor exhaust airstream.

3.5.2.2 Temperature Probes

It is difficult to define how many temperature probes are "enough" as the number will vary with the geometry of the reactor. The number and positioning of the probes, however, should relate to the ultimate use of the data collected. If, for example, the temperature data are used to distribute the airflow among different sections of the reactor, each reactor section should contain temperature probes. The regulatory requirements for temperature data should be considered when specifying the number and location of temperature probes.

3.5.2.3 Airflow Rate Measuring Devices and Pressure Sensors

For process control, an operator should know the actual amount of air passing through the reactor as well as the minimum, average, and peak aeration rates. For centrifugal or centaxial blowers, blower speed is not a good indicator; as reactor back pressure increases, the amount of air delivered decreases, even though the blower speed is constant. Flow rate measuring devices must be provided for these types of blowers and throttling valves must operate over the entire range of conditions. For positive displacement blowers, however, blower speed can be directly correlated with airflow rate, provided the outlet pressure is relatively constant. Procedures presented by Haug (3) allow the designer to estimate the quantity of air required and the minimum, average, and peak aeration rates for various process conditions and feed substitutes.

The reactor pressure is useful for monitoring compost porosity. Increasing pressures indicate a loss of porosity, which may be due to wet conditions, a breakdown of material structure, or improper aeration. Pressure sensors can also be connected to alarms to protect aeration equipment.

3.5.3 Instrumentation

3.5.3.1 High Temperature Alarms for Fire Detection

Fires in compost reactors have occurred at Cape May and Schenectady. When the solids content of compost is greater than 65 percent and the temperature exceeds 80°C (176°F), it is possible for a series of exothermic reactions to result in full combustion. A temperature alarm might warn operators of this potentially dangerous condition.

Compost temperatures, however, are not good indicators of fire conditions. Since compost is an excellent insulator, temperatures can be quite different, even a few feet away from a probe. At the Schenectady plant, for instance, the temperature data did not indicate that the compost was on fire. During design, every facility should develop a fire prevention and firefighting plan.

3.5.3.2 Control Indicator Calibration

When possible, gauges, dials, and other control indicators should be calibrated in actual units rather than surrogate variables and should be easy to read. For instance, airflow rates should be indicated in appropriate volume units, such as cfm, rather than as a percentage of maximum blower speed. Supplying correct units on dials facilitates data collection and intra-plant data comparison, while decreasing conversion errors. The scales on the dials should be adjustable or replaceable so that changes in calibration parameters can be correctly indicated on the dials.

3.5.3.3 Automated Data Logging

Automated data logging — the maintenance of a record of plant conditions by the central computer — offers several advantages over manual recording. Plant conditions can be monitored even when the plant is not staffed. This information is useful for diagnosing problems. Moreover, the data can be saved in a form that is compatible with other computer systems so that it can be incorporated into reports for regulatory agencies, recorded for budgeting purposes, or manipulated for diagnostic purposes.

The kinds and frequency of data logging should be coordinated with regulatory agencies during the design phase. At the Cape May plant, the regulatory agency wanted to use the actual computer records. Because the computer monitored the temperature every 30 minutes, minor temperature fluctuations were recorded and the compost bed did not always appear to meet the time-temperature criterion (i.e., the temperature did not always exceed 55°C [131°F]). After 2.5 years of Salmonella testing, which showed that a significant reduction in pathogens was taking place as long as the average 3-day temperature exceeded 55°C (131°F), the regulatory agency revised its requirements.

3.6 Support Facilities

3.6.1 Maintenance Work Area

Even if the compost plant is located at a wastewater treatment plant, a small maintenance work area (e.g., a bench and set of tools) should be provided nearby. Operators need the tools and work space to do the everyday jobs that are too small to justify calling in maintenance personnel from the central shop. Even if maintenance personnel are called in on the job, having a place to work

at the site minimizes unnecessary transportation of parts and equipment.

3.6.2 Onsite Spare Parts Storage

Every facility should have a maintenance management program, of which a spare parts inventory is a key component. Locating an adequate supply of spare parts on site, or at least close by, is essential in minimizing downtime. Yet a number of the plants surveyed had little or no organized spare parts storage space. At the Cape May plant, spare parts were stored in stairwells and in an old truck trailer. At the Newberg plant, spare parts were stored on the roof of the bathroom (see Figure 3.21).

Figure 3.21 Spare Parts Storage on the Roof of the Bathroom at Newberg

The Portland, Sarasota, and Schenectady plants had no spare parts storage at all, although in each case the compost plant shared some of the wastewater plant's storage space. The importance of spare parts storage was recognized at Clayton County, where the first modification to the plant after construction was the addition of a storage facility.

3.6.3 Staff Facilities

An enclosed control room, with a separate ventilation system to keep out dust and odors from the compost building, should be provided. The room should be located near the mixer to facilitate frequent observations of the mix by the operator and should be large enough to double as a staff meeting room. A separate office should be provided to allow staff to do paperwork or use the telephone. (The noise and activity in the control room interferes with these functions.) The office ventilation system should also be separate from that of the compost building. Air conditioning should be considered since many parts of the compost plant are hot and operators may need a cool place to rest.

Restroom facilities should be provided, including toilets, showers, and lockers. If the compost plant is located at a wastewater treatment plant, the showers and lockers could be located in the main administrative building, but restrooms should be provided at the compost plant for purposes of hygiene and first aid.

3.7 Fire Prevention and Control

Fire prevention and control considerations affect many aspects of plant design. Both spontaneous combustion and accidental ignition (e.g., welding accidents) have caused fires at the plants surveyed.

Spontaneous combustion fires occurred when the composting materials were held in reactors for too long because some other part of the system slowed or stopped processing material through the plant. Materials-handling systems should be reliable enough to prevent this from happening. When sizing reactors to accommodate growth in sludge quantities or seasonal variations in sludge production, excessive detention times must be avoided. Several smaller reactors may be better than a few large units.

A firefighting plan should be worked out with local officials during the design so that necessary equipment or facilities, such as local water supplies or distribution piping, can be provided. Some equipment, especially reactor discharge devices and ventilation systems, must continue to function in a fire. These should be identified in the firefighting plan and designed accordingly.

Other fire control considerations include the placement and types of sensors and the choice of reactor materials based on fire-resistance. Whether required or not, local fire codes should be followed and plant designs should be coordinated with local fire officials.

At the eight plants surveyed, design features to detect or combat fires varied, and coordination with local officials was rare.

3.8 References

1. Wilber, C. Odor Source Evaluation and Control Options. Lecture Transcript. Presented at Biocycle Conference. June 6, 1989.

2. Walker, J., N. Goldstein, and B. Chen. Evaluating the In-Vessel Composting Option, Part I. Biocycle. May-June 1986, pp. 23-27.

3. Odor Science and Engineering, Inc. Akron Composting Facility Odor Study, Draft Final Report. July 1988.

4. Haug, R.T. Composting Process Design Criteria, Part III: Aeration. Biocycle. October 1986.

5. Haug, R.T. Composting Process Design Criteria, Part II: Detention Time. Biocycle. September 1986.

6. Murray, C. Managing Odor Control Programs. Lecture Transcript. Presented at Biocycle Conference. June 6, 1989.

Chapter 4
Operations Considerations

The purpose of this chapter is to highlight the operations and maintenance issues that are peculiar to in-vessel composting facilities and to summarize the operations experiences of the eight plants surveyed. The chapter focuses on management issues, including staffing and training requirements, staff assignment policies, and maintenance policies. In addition, strategies for carrying out specific tasks, such as preventing and controlling fires, specifying amendment characteristics, and monitoring and controlling the composting process, are presented. Table 4.1 lists operations considerations and the sections in which they are discussed.

Table 4.1 In-Vessel Operations Considerations

Topic	Section
Startup Issues	4.1
Performance Test Plan	4.1.1
Conducting the Performance Test	4.1.2
Additional Personnel	4.1.3
Operating Procedures	4.2
System Suppliers Specifications	4.2.1
Monitoring and Recording Process Variables	4.2.2
Monitoring Product Quality	4.2.3
Monitoring Feed Material Characteristics	4.2.4
Impact of Wastewater Treatment Plant Operations	4.2.5
Fire Prevention	4.3
Fire Detection	4.3.1
Fire Suppression	4.3.2
Staffing Issues	4.4
Operations Staff	4.4.1
Operator Training	4.4.2
Staff Rotations	4.4.3
Acquiring Necessary Maintenance and Repair Skills	4.4.4
Assigning Regular Maintenance Staff	4.4.5
Maintenance Issues	4.5
Preventive Maintenance	4.5.1
Operations and Maintenance Manual	4.5.2
Spare Parts Inventory	4.5.3

4.1 Startup Issues

4.1.1 Performance Test Plan

The performance test plan defines the conditions under which the system supplier will be freed from further financial obligation to the owner. The criteria for the performance test should be specified in detail in the bid documents and might include criteria for acceptance, testing protocols, and sampling frequencies. Regulatory officials, who are responsible for issuing an operating permit for the plant, should be consulted during the preparation of the plan to ensure that when the plant passes the performance test, it will be licensable and able to sell the product.

The test plan should specify the measurement parameters and methods. Measuring devices required for the performance test will need to be installed, at least for the duration of the test. Electrical meters, for example, may be needed to verify energy consumption and power demand criteria. The plan should also take into account that there will not be any recycle for the mix during startup.

4.1.2 Conducting the Performance Test

All equipment that is operated under normal conditions should be operated in the performance test. In addition, the test should be conducted for a long enough period to establish steady-state conditions in the composting process. If the plant is designed to run under a variety of conditions (e.g., ranges of sludge cake solids, sludge quantities, or mix solids), all of these conditions should be included or simulated in the test.

4.1.3 Additional Personnel

Additional personnel should be provided during startup. Some parts of the system inevitably will not work as planned and operating personnel will have to run the plant (probably in a less-than-fully-automated fashion) while simultaneously trouble-shooting problems. In addition, personnel will be needed to collect the data required for verifying compliance with the terms of the performance test. In most of the plants surveyed, the additional startup staff was provided by the system supplier or by the wastewater treatment plant (WWTP).

4.2 Operating Procedures

4.2.1 System Supplier Specifications

During startup, operators should make every effort to run the plant as specified by the system supplier. Situations commonly arise in which operators claim that equipment doesn't work properly while system suppliers claim that systems are not being operated correctly. If the plant is operated according to the system supplier's specifications, this kind of conflict will not be an issue.

More often than not, individual plants must adapt to local conditions, and departures from the original operating procedures are inevitable. If a facility begins with a standard operating procedure, however, operators can judge whether proposed changes are indeed improvements.

Since similar plants may face analogous problems, operators should become familiar with plants using the same composting system. In-plant training at other facilities and communication with colleagues help operators expand their knowledge base. Exchanging information and ideas among the different facilities may lead to improved operations at all plants.

4.2.2 Monitoring and Recording Process Variables

Good records of process performance are extremely useful. They can help detect and diagnose problems and can also be used to determine whether the product is meeting marketing requirements.

Data should be logged on a daily basis. If the computer system does not provide automated data entry, operators should fill out a daily process log. The Clayton County plant's log is shown in Figure 4.1; similar log sheets were used at all eight plants. When automated data collection

Figure 4.1 Clayton County Daily Process Log

NORTHEAST COMPOST FACILITY

DAILY PROCESS LOG

DATE _____ POWER METER _____

TIME _____ DATA ENTRY ☐

REACTOR DATA	BIO	CURE	
0% O_2 (EXHAUST AIR)			
AIR FLOW (C.F.M.)			AUX. BLOWER
EXAUST TEMP. (°C)			
TOP TEMP. (°C)			
MIDDLE TEMP. (°C)			
BOTTOM TEMP. (°C)			
REACTOR LEVEL (% FULL)			
INTENERAL PRESSURE			
BACK PRESSURE (SUPPLY)			AUX. BLOWER
BACK PRESSURE (EXHAUST)			

FEEDRATE	1	2	3	4	1	2	3	4
ZONES 1-4 (SETTINGS)								
ZONES 1-4 (QUANTITY)								

N-NONE
VL-VERY LITTLE (< 1/2 GAL.)
L-LITTLE (1/2-1 GAL.)
M-MEDIUM (> 1 GAL., < 2 GALS)
H-HEAVY (> 2 GALS.)

OUTFEED SCREW SETTING				
OUTFEED ADVANCE SETTING				
OUTFEED RATE (FT³/HR)				

SLUDGE BIN LEVEL (% FULL)	
CARBON SILO LEVEL (% FULL)	
CARBON FEED SETTING (AVG.)	

FUNCTION TIMES	
FILL B/C (HRS.)	
TRANSFER B/C (HRS.)	
DISCHARGE B/C (HRS.)	
RECYCLE BIO (HRS.)	
RECYCLE CURE (HRS.)	

% SOLIDS			
SLUDGE			
SAWDUST			
RECYCLE B/C			
MIX			
PRODUCT B/C			
FEED SLUDGE		PH	

is provided, printing out a daily summary ensures the records will not be lost if a computer fails.

The data should be stored and displayed in ways that help the operator identify trends and relationships. Individual log sheets stored in a binder are not very useful because the data must be extracted and organized. Graphic presentations are ideal.

Mass and energy balances, when updated on a regular basis, can help analyze and track the performance of various system parts. Using a mass balance, an operator can determine whether wet product is caused by inadequate drying in the reactor, too much water in the mix, or insufficient volatile organics (insufficient biological energy) in the compost ingredients.

A computer is a great asset when managing data. An inexpensive personal computer with a spreadsheet program can perform all the data management activities normally needed.

4.2.3 Monitoring Product Quality

Product quality must be monitored to meet regulatory requirements, provide consumer information (i.e., to meet product labeling requirements), establish a data base for use in marketing, and protect the public agency from liability claims.

The parameters measured depend on the State regulatory requirements and the characteristics important in marketing the product. State regulations usually require in-vessel plants to measure the concentration of metals and other contaminants in the compost. For marketing purposes, parameters of interest to potential customers, such as phytotoxicity, nutrient content, stability, texture, moisture content, consistency, aerobic state, and particle-size distribution should be monitored.

4.2.4 Monitoring Feed Material Characteristics

The characteristics of the feed materials — degree of contamination by trash or heavy metals, particle size, moisture content, and biodegradability — strongly influence the compost process and product quality. Sludge contaminants, particularly heavy metals, can result in unmarketable compost. For this reason, heavy metals should be monitored on a regular basis.

Contaminants in the sawdust, such as rocks, large chunks of wood, or trash, can cause materials-handling problems in the composting plant. Specifications, which should be written and enforced, should prohibit the inclusion of these materials. Protective devices such as screens effectively prevent these materials from entering the composting process.

The particle size of the amendment influences the structure and porosity of the mix. Several plants have had problems with sawdust "flour" or sanding dust. When mixed with sludge, these materials create a paste-like substance that sticks to the materials-handling system and does not have the porosity needed for good composting. At the other extreme, particles that are too large do not mix thoroughly with the sludge. The amendment particle size specifications used at six of the eight in-vessel facilities visited are listed in Table 4.2.

To create a mix with the proper moisture content, the operator must know the moisture contents of the individual ingredients. Although amendment moisture content does not change substantially during most types of storage, it can vary from delivery to delivery; each batch should be tested. Table 4.2 also lists the amendment solids content specifications used at the surveyed in-vessel facilities.

Finally, the biological degradability of the mix ingredients should be considered. Biological degradation provides the energy that raises the compost temperature and evaporates the excess water. If amendments are not sufficiently degradable, achieving the desired temperature may be difficult. The Sarasota plant had this problem when it used cypress, which is a hardwood resistant to microbial decomposition, as an amendment. In general, hardwoods tend to degrade too slowly and cannot be visually identified in a batch of sawdust. This may be a problem, depending on whether the compost product will be screened or how it will be used. Several facilities surveyed specify that amendment suppliers provide softwood amendment.

If amendment materials are too easily degraded, however, the temperature inside the reactor may reach undesirably high levels, requiring large amounts of air for cooling.

Table 4.2 Example Amendment Specifications

Location	Solids Content (%)	Particle Size	Other
Cape May	min 60	<2% larger than 12.5 mm <20% smaller than 5 mm	Kiln-dried
Newberg	min 50 avg 60	Well graded. 0.125 in. max[a]	Bark allowed up to 50% by volume. Coniferous species <(15% hardwoods).
Plattsburgh	min 50	Must be able to be conveyed by sawdust bin augers.	Thin wood shavings allowed up to 50% by volume. Any combination of soft woods and hardwoods.
Portland	min 60b	Well graded. 0.067 in. max. Sanding dust is prohibited.	Bark allowed up to 50% by volume. May not deviate more than 20% in ability to alter moisture content of sludge.[c]
Sarasota	—	Nominal size 0.25 in.	Kiln-dried. Softwoods.
Schenectady	min 50	Average size 0.25 in.	Rough-cut pine.

[a]in. × 2.54 × 10-2 = m
[b]To receive full payment, sawdust must be at least 60% dry solids. Payment for sawdust between 50 and 60% solids may be made at the discretion of the plant manager. No payment for sawdust less than 50% solids.
[c]Defined by an equation developed by plant operators.

4.2.5 Impact of Wastewater Treatment Plant Operations

Consistent with other treatment objectives, the wastewater treatment processes should be operated to create a sludge that dewaters well. Efficient dewatering helps process performance and is cost-effective; poorly dewatered sludge is generally expensive to compost because more space and amendment are required. (Figure 2.1 illustrates the effect of sludge dryness on mix and amendment quantities.)

Wastewater treatment plant operators should be instructed concerning their roles and impact on the composting process. Arranging periodic meetings between compost operators and treatment plant operators and assigning wastewater plant operators to the compost plant for a short period of time may enhance this educational process.

4.3 Fire Prevention

Although one goal of composting is removing moisture, producing an excessively dry product inhibits the biological activity of the composting microbes, thereby hampering sludge stabilization. Excessively dry compost is also very dusty. The most important reason to avoid excessive drying, however, is fire prevention. At both the Schenectady and Cape May plants, spontaneous combustion fires were caused, at least in part, by excessively dry compost. Fires can start at surprisingly low temperatures in dry compost. Exothermic chemical reactions that can start at a low temperature liberate heat that elevates the temperature to a point where true ignition and smoldering fires occur. Tests at the Schenectady plant demonstrated that exothermic reactions started at temperatures as low as 90°C (194°F) in dry materials.

4.3.1 Fire Detection

Fires at composting plants are not unusual. Among the plants surveyed, nine fires occurred at three different facilities (not including minor smoldering fires in curing piles); six of the nine fires were related to composting processes, the remaining three were caused by welding work.

The best fire detector to date has been operator vigilance. Automated fire detection in reactors is problematic. As discussed in Chapter Three, monitoring the temperature of the composting materials may not reliably detect fires. A relatively small, smoldering fire deep in the compost bed may not raise the temperature of the reactor offgases sufficiently to trigger an alarm. Furthermore, heat or smoke detectors may not work reliably in the hot, steamy atmosphere of reactors.

4.3.2 Fire Suppression

Fire suppression plans must be formulated in advance of plant startup. Plant operators and local fire officials should develop these plans jointly.

One firefighting strategy is to disperse the compost as quickly as possible. Once dispersed, the compost cools, extinguishing the fire. Then, if necessary, water can be added. Unless there are flames, however, adding water to the compost in the reactor may not be necessary and will create a mess. At the Schenectady plant, when firefighters poured water onto the smoldering compost in the reactor, the compost turned to mud and was difficult to remove from the reactor. In later fires at the same plant, firefighters set up fans to remove the smoke from the building and used misting hoses to contain the fires in the reactors while operators emptied them. Damage from these fires was minimal.

To enhance fire suppression, the computer control system should be programmed to respond to fires by halting reactor feed systems, shutting off aeration systems, and issuing alerts so that reactor loading equipment can be moved to safe areas.

4.4 Staffing Issues

4.4.1 Operations Staff

During normal operations, process monitoring (watching controls, taking samples of mix, etc.); equipment monitoring (watching the equipment, routinely cleaning chutes, etc.); and general utility work (housekeeping, preventive maintenance activities, etc.) all must be conducted. The number of employees needed to run the plant depends on the size and layout of the plant, the degree of mechanization, and the number of operating shifts per week. The Clayton County plant, which is a small, compact, highly mechanized facility, operates with only two operators; the Cape May plant, which is larger and less mechanized, employs nine operators. The complexity of odor control equipment is also important in determining staffing. Table 4.3 lists the personnel employed at the eight facilities visited.

Table 4.3 Summary of Personnel Used at Composting Plants

	Number of Personnel Used		
Location	Operations	Maintenance	Other
Akron, OH[a]	8	4	4
Cape May County, NJ	9[b]	3	2
Clayton County, GA	2	Maintenance by WWTP staff	1
Newberg, OR[c,d]	1.5[d]	Maintenance by WWTP staff	0
Plattsburgh, NY	4	3	1
Portland, OR	6[e]	3[f]	1
Sarasota, FL	3	2.5[f]	1
Schenectady, NY	3	Maintenance by WWTP staff	1

[a]Personnel needed to operate at current reduced capacity. The plant manager estimates that operations at full design capacity would require 24 people plus 6 for the dewatering operation.
[b]Not including 5 summer employees used for groundskeeping and utility work.
[c]Includes dewatering operations.
[d]Plant undergoing acceptance testing.
[e]Operators rotate through composting plant. Value shown is an estimate of equivalent personnel.
[f]Maintenance by WWTP staff. Value shown is an estimate of equivalent personnel.

4.4.2 Operator Training

At present, most in-vessel composting plants are managed by operators with mid-level wastewater treatment plant certifications. Certified operators, because of their extensive experience, have the planning, budgeting, organizational, and equipment skills needed to run a composting plant. Operator certification courses include basic training on biological processes, but do not provide training in composting. Only one operator at the eight plants surveyed had previous composting experience.

Operators must be educated in the proper use, maintenance, and calibration of the sophisticated monitoring and controlling devices, as well as in the basic operations of the plant. In general, system suppliers provide training on how to operate and maintain the composting equipment and how to create appropriate compost mixes. Typically, system supplier representatives spend weeks to months working with plant operators during startup. Most plant operators reported that this on-the-job training was satisfactory.

Many operators expressed a need for more information on composting principles; at many sites, operators receive only 1 day of this type of training, at most. As a result, most operators approach the composting process in a relatively empirical manner, which makes it more difficult to diagnose problems or react to changing conditions.

Training in odor control has also been lacking. Operators should have a knowledge of the principles and chemistry of odor detection and treatment. The proper control of a chemical scrubber requires this kind of training, even if the mechanical operations are straightforward. Some background in the principles of odor dispersion and meteorology would also be helpful.

The public agency may want to include a provision in the construction contract requiring system suppliers to train operators in the principles of composting and in process control theory. Alternatively, the public agency may engage an outside consultant to provide this training. After startup, the consultant's expertise might also be valuable in assisting plant operators with process-related questions.

A written record of composting principles and related issues that will outlast the system supplier's tenure on the site and survive future staff turnover is essential. At the very least, the operations and maintenance manual should contain a thorough treatment of process theory and control (see Section 4.5.2).

Ongoing training programs allow operators to keep abreast of developments in sludge composting. In-vessel composting is relatively new and optimum operational practices are not yet established. Professional contacts with other composting plants, particularly "sister" plants, would increase the flow of information.

4.4.3 Staff Rotations

A permanent operations staff is preferable to a rotating one because its workers develop expertise in the composting process and the workings of the plant. In addition, permanence may foster a sense of "ownership" and pride in the composting plant and its operation.

There may be constraints, however, on assigning permanent staff. Compost plant duty may not be considered as desirable as treatment plant duty because of the working conditions at the compost plant (e.g., odors, dust, humidity, and heat). Moreover, operators may not be able to obtain higher certification grades without a greater breadth of experience than can be gained at a compost plant.

If a rotation policy is instituted, the rotation period should be long enough so that operators do not have to relearn the operation each time they return. At the Portland facility, operators rotate into the compost plant for staggered 2-week tours. Because there are so many other assignments in the wastewater treatment plant, operators do not return to the compost plant for months. As a result, at any given time, the Portland compost plant is staffed by one operator with 1 week of recent experience and one operator who must be reacquainted with the operation after a long absence. The Plattsburgh plant started operations with a similar rotational system but decided to recruit a permanent staff.

4.4.4 Acquiring Necessary Maintenance and Repair Skills

To minimize downtime, staff with the skills necessary to maintain and repair compost equipment should be readily available. Although WWTP and compost plant equipment have similarities, many compost plant items are not found in a wastewater treatment plant and require different skills. For instance, maintenance and repair of materials-handling equipment at an in-vessel composting plant requires at least one person with good welding skills. In addition, control systems are more complex at in-vessel plants. Although WWTP personnel possess many of the skills needed to maintain the compost plant, the skills and knowledge available should be inventoried before something goes wrong so that appropriate training can be arranged. Careful planning and recruitment procedures, combined with appropriate compensation, are required to obtain and retain the necessary skilled personnel.

4.4.5 Assigning Regular Maintenance Staff

If a composting plant is not big enough to justify its own maintenance staff, or if the public agency prefers to run its maintenance program out of a central office, the composting plant should be maintained by a small, defined group of personnel. Maintenance personnel should not be randomly assigned to the plant.

One reason for developing "compost plant specialists" is that it is more efficient to train a small group than to train the entire maintenance staff. More importantly, through observation and the performance of regular maintenance activities, the compost plant maintenance staff will develop a familiarity with the equipment that will allow them to anticipate and diagnose problems more quickly than personnel who see the equipment only occasionally. An additional benefit of this approach might be the development of a sense of "ownership" among the staff. Dedicated personnel may do a better job because they care how "their" plant is being maintained. Where maintenance crews rotate through a plant or are supplied by a central pool, maintenance tends to be reactive rather than preventive.

4.5 Maintenance Issues

4.5.1 Preventive Maintenance

The reliability of an in-vessel composting plant depends on the operation's ability to prevent and quickly remedy disruptive conditions. A preventive maintenance program is an important element in this effort.

4.5.2 Operations and Maintenance Manual

An up-to-date operations and maintenance manual is an important tool. The manual should contain descriptions of composting principles, as applied to the in-vessel system; operating procedures for all equipment; diagrams of the equipment ("catalog cuts"); spare parts lists; and maintenance requirements. The manual should be updated regularly and every modification to the plant should be recorded. In this way, the document will become a record that outlasts the individual operators and maintenance personnel.

4.5.3 Spare Parts Inventory

An adequate supply of spare parts is essential to respond quickly to mechanical breakdowns. In general, it is better to err on the side of having too many spare parts than not enough.

In determining what parts to stock, two factors should be considered: the importance of the part to the system, and the length of time required to obtain a replacement. Parts that take a long time to obtain should be kept in stock; it may be unnecessary to stock locally available parts. The difficulty of procuring parts should also be considered. If it takes 3 weeks to process the paperwork through the public agency's procurement process, it may be prudent to stock the part, even if it is locally available.

Chapter 5
Introduction to the Case Studies

5.1 Background

In-vessel composting technology is relatively new, and operating procedures are still rapidly evolving. Consequently, the engineering literature has not contained up-to-date information on the performance and operation of in-vessel composting facilities. Moreover, the literature is rarely detailed enough to provide guidance on the selection, design, and operation of systems that take advantage of technology advances and the lessons learned from currently operating facilities.

The site visit approach was proposed as the best means of establishing a data base that would allow developers of in-vessel composting facilities to draw information and benefit from past experiences. A peer review team of experts helped select the sites to be visited. Visits were planned early in 1988 to eight facilities representing the six types of in-vessel composting systems operating in the United States. These systems are:

- American Bio Tech (ABT)
- Ashbrook-Simon-Hartley (Ashbrook)
- Fairfield Process (Fairfield)
- Paygro Process (Paygro)
- Purac Engineering (Purac)
- Taulman Composting Systems (Taulman)

For the ABT, Ashbrook, Purac, and Taulman systems, the name of the composting system is synonymous with the corporate name of the supplier. The Fairfield and Paygro systems are both marketed and supplied by Compost Systems Company.

At least one example of each kind of in-vessel composting process was surveyed. The Newberg, Oregon; Plattsburgh, New York; and Schenectady, New York, plants were chosen because they were the only full-scale plants using the Ashbrook, Fairfield, and ABT technologies, respectively, to compost municipal wastewater sludge exclusively. The Akron, Ohio, plant was chosen to represent the Paygro process because it had a longer operating record than its sister plant in Baltimore.

For both Purac and Taulman, there were several candidate plants. In each case, one large plant and one small plant were chosen for site surveys. The large plants were located in Cape May, New Jersey (Purac), and Portland, Oregon, (Taulman); the small plants were located in Sarasota, Florida (Purac), and Clayton County, Georgia (Taulman). One reason for choosing two plants for these systems was to investigate any differences that could be attributed to size alone (independent of the type of reactor). The other reason was to investigate differences between so-called "first-generation" facilities and those built later.

The site visits were conducted between April and November of 1988. As shown in Table 1.1, not all of the plants were fully operational at the time of the site visit. The Newberg plant was undergoing acceptance testing. At the Schenectady plant, only a small "conditioning" reactor was operating while mechanical repairs and modifications to the odor control system were being performed. Three other plants (Akron, Cape May, and Portland) were operating at reduced capacities because of odor or mechanical problems. Three of the facilities (Clayton County, Plattsburgh, and Sarasota) were processing all of the sludge available.

A survey team of at least two members conducted each site visit over a 1.5 to 2-day period. The survey team interviewed plant supervisors, operators, and others familiar with each facility's procurement and operations. Contract documents and operating records were also examined when available. Table 5.1 lists the information collected during the site visits.

After each visit, the survey team prepared a report summarizing the information gathered and sent the report to each plant and system supplier for comment. The comments were then incorporated into revised site visit reports, which became the basis for the eight case studies in this summary report. The case studies detail experiences, problems, and unique situations at each facility. This information, in part, also formed the basis for Chapters Two through Four.

5.2 Accuracy of the Data

Each case study represents a "snapshot" of the plant taken at the time of the site visit. The factual data presented, such as mix ratios, loading rates, and operating practices, are accurate only for the time of the site visit and may have subsequently changed. To identify some of these changes, the survey team conducted telephone interviews just before publication of this document. This

Table 5.1 Information Collected During the Site Visits

- General Plant Information
- History of the Plant
  - Procurement and construction
  - Capital costs
  - Operating history and current status
- Materials Characteristics
  - Sludge characteristics
  - Amendment characteristics
  - Recycle characteristics
  - Mix characteristics
- Materials Handling
  - Storage facilities
  - Mixer feed system
  - Reactor feed system
- Reactors
  - Configuration
  - Agitation (if any)
  - Discharge device
- Exterior Curing/Storage
  - Description of facilities
- Air Handling
  - Aeration system in first and second reactors
  - Aeration system for exterior curing/storage area
  - Nonprocess air ventilation
- Odor Control
  - Characterization of problem
  - Process air odor control
  - Nonprocess air odor control
- Support Facilities
  - General site
  - Buildings
- Compost Product
  - Characterization
  - Restrictions on use
  - Marketing and distribution
- Operations
  - Staffing
  - Training
  - Operating costs

information appears in the "Update" section at the end of each case study. It should also be noted that the onsite plant personnel provided all of the information presented; the survey team did not independently verify the data.

5.3 Nomenclature

To keep the case studies as uniform as possible, the facilities were described as follows. First, because terms such as "bioreactor" and "cure reactor" are not used by all system suppliers, reactors are referred to only with respect to their location in the process train. The terms "first reactor" and "first-step reactor" are used for the first reactor in the train. "Second reactor" and "second-step" reactor refer to the reactor second in the train. Second, because no consistent measure of compost stability was used at the facilities, the survey team was not able to determine whether material in outside piles was "curing" or just being "stored." Therefore, the terms "curing/storage" and "cured/stored" are used throughout the studies to describe any outside piles of material, both aerated and unaerated.

5.4 Summary Data

This section summarizes the data collected during the site surveys in the following areas:

- Materials
- Mixing
- Materials-Handling Systems
- Aeration Systems
- Odor Control Systems
- Exterior Curing/Storage

5.4.1 Materials

Both waste-activated sludge (WAS) and mixtures of primary sludge and WAS are processed at the in-vessel facilities. Of the plants surveyed, only one (Portland) composts anaerobically digested sludge.

All of the plants surveyed use sawdust as an amendment; one plant (Akron) uses a combination of bark and sawdust. The amendment is not recovered or reused after composting at these plants.

Amendment materials are usually purchased from local industry, but there are alternative sources. At Clayton County, for instance, sawdust is made at the plant by grinding wood chips in a hammermill. The wood chips are produced from timber grown on lands irrigated with treatment plant effluent.

Table 5.2 summarizes the types of sludge composted and the design (when available) and actual solids contents of the sludge, sawdust, recycle, and mix. Table 4.2 shows amendment specifications used at six of the facilities.

5.4.2 Mixing

Table 2.7 compares the design mix ratios to the mix ratios in use during the site visits. Most plants use more sawdust and frequently more recycle in their actual mix ratio than anticipated in the design.

At all plants, analytical procedures are used to take mix samples and determine mix ratios. Some of the short-term tests for solids content (i.e., the heat lamp test) are approximated. Also, percentage of total solids in the sludge changes over time, even within one loading cycle. Thus, operators must use their judgment in determining mix quality.

In some cases, the operators enter the solids contents and other pertinent data into a computer. The computer uses this information to achieve the proper mix ratio of sludge, amendment, and recycle with respect to moisture and porosity, by controlling the speed of one or more conveyors supplying materials to the mixing device.

Table 5.2 Solids Content of Compost Ingredients (Percent)

		Sludge[a]		Sawdust		Recycle		Mix	
	Type of Sludge	Design	Actual	Design	Actual	Design	Actual	Design	Actual
Akron, OH	1° + WAS	—	26 (20-26)[c]	—	55 (50-60)	—	68 (60-68)	—	42 (40-50)
Cape May, NJ	1° + WAS[d]	20	23	50-70 (20-30)	—	≥40 (65-70)	—	40 (53-65)	37
Clayton County, GA	WAS[e] (34-35)	22	16	— (15-17)	60	—	50 (52-66)	—	34 (45-52)
Newburg, OR[f]	WAS[g]	—	17 (12-20)	60	60 —	—	— (35-45)	38	— (30-40)
Plattsburgh, NY	1° + WAS[h]	20	— (20-25)	>50	60	55	— (42-55)	40	40
Portland, OR	1° + WAS[i]	—	25 (23-28)	—	86 (60-95)	—	— (38-40)	—	37
Sarasota, FL	WAS	—	14 (50-55)	—	90 (34-46)	—	—	35	40
Schenectady, NY[h]	1° + WAS[g]	25	25 (20-28)	≥50	55	≥45	—[k]	35 (35-39)	—

[a]Sludge = dewatered sludge.
[b]Numbers in parentheses represent ranges.
[c]Same for bark and amendment used here.
[d]Ferric chloride added to primary clarifiers.
[e]Aluminum sulfide is added.
[f]Data are from the time of the site visit when the plant was in startup; process not at steady state.
[g]Partially aerobically digested during storage.
[h]Potassium permanganate is added.
[i]Both 1° and WAS are digested.
[j]Limited operating data.
[k]Not using recycle at the time of the site visit.

— = Not available or not collected.
1° = Primary sludge.
WAS = Waste-activated sludge.

Four of the plants surveyed use pugmill mixers and four use plow-blade mixers. Both types of mixers work satisfactorily, although at two sites, the pugmill mixers were modified to improve their performance. Akron replaced the original motors, removed half the paddles, and modified the drive mechanisms; Cape May removed half the paddles and replaced the remaining paddles with more effective, custom paddles.

5.4.3 Materials-Handling Systems

Conveyor systems are designed to carry sludge cake, amendment, mix, recycle, and finished compost. Therefore, their design must take into account the different bulk weights, moisture contents, temperatures, and other characteristics of these materials. In addition, the systems must account for changes to the materials due to mechanical action by the conveyance equipment itself. Site restrictions and the physical design of the reactors, which dictate the conveyor configurations, also influence the choice of conveyor types. Table 5.3 summarizes the different kinds of conveyors found at the in-vessel facilities surveyed and the functions they perform.

Generally, three kinds of conveyors are used: drag chain conveyors, belt conveyors, and screw conveyors. Belt conveyors are the predominant type of conveyor used at the plants surveyed and have experienced only minor problems (i.e., sticking of materials and spillage). Drag chains at in-vessel plants have not performed well and have required numerous modifications and extensive maintenance. In contrast, screw conveyors, including those in live-bottom bins, experienced few problems at the plants surveyed. Cleated belt conveyors, used at Akron (unsuccessfully) for wet and dry materials, experienced severe spillage problems because of materials sticking to the belts. At some plants, pneumatic systems are used to move sawdust; these have worked well. Schenectady uses a bucket conveyor to move sawdust. Conveyor successes and failures are discussed in more detail in Chapter Three (see Table 3.3) and in the case studies.

5.4.4 Aeration

At the facilities surveyed, all first and second reactors are aerated, while some curing/storage piles are not. (Curing/storage pile aeration is discussed in Section 4.3.6.) In most reactors, air is introduced at the reactor bottom. ABT reactors introduce and remove the air through lances that extend vertically into the composting material. In Purac reactors, most air is introduced from the bottom, but air is also pulled in through the top of the reactors, because the exhaust blowers draw a greater volume of air than that provided by the supply blowers.

Table 5.3 Types of Material Conveying Equipment Used

Location	Type	No.	Function
Akron, OH	Belt conveyor	18	A, B, C, D, E, F, G
	Cleated belt conveyor	7	A, B, C, D, E, F, G
	Radial stacking conveyor	1	G
Cape May, NJ	Belt conveyor	7	B, D, E, F, G
	Drag chain conveyor	4	B, D, E, F
Clayton County, GA	Drag chain conveyor	2	B, D, E, F, G
	Screw conveyor	3	A, D, G
	Pneumatic system	1	C
Newberg, OR	Belt conveyor	1	A
	Drag chain conveyor	8	B, E, F, G
	Screw conveyor	1	D
	Pneumatic system	1	C
Plattsburgh, NY	Belt conveyor	13	B, D, E, F, G
	Screw conveyor	4	E
	Radial stacking conveyor	1	G
Portland, OR	Belt conveyor	12	A, B, D, E, F, G
	Drag chain conveyor	3	E, G
	Screw conveyor	6	B
	Pneumatic system	1	C
Sarasota, FL	Belt conveyor	6	B, D, E, F, G
	Drag chain conveyor	2	F, G
	Screw conveyor	5	B, D, E
	Pneumatic system	1	C
Schenectady, NY	Belt conveyor	8	A, B, D, E, F, G
	Drag chain conveyor	1	F
	Screw conveyor	2	A, F
	Bucket conveyor	1	C

Legend for Materials Conveying Systems:

A. Transfer of sludge from dewatering to storage.
B. Transfer of sludge from storage to mixer.
C. Transfer of amendment from receiving to storage.
D. Transfer of amendment from storage to mixer.
E. Transfer of sludge, amendment, and/or recycle to mixer.
F. Transfer of mix from mixer to reactor infeed.
G. Transfer of compost from outfeed device to recycle and/or curing/storage.

Ashbrook reactors remove the air from the bottom of the reactor, the two Purac reactors remove the air from 0.9 to 1.8 m (3 to 6 ft) below the top surface of the compost (depending on the depth to which the reactor is filled), and the rest of the facilities remove the air from above the top surface of the compost.

Table 5.4 summarizes the reactor air-handling systems by location, including the capacities of both the aeration and exhaust systems and the straight-line distance the air must flow through the compost.

The types of air-moving equipment used at the plants surveyed are listed in Table 5.5. For air supply, Cape May, Clayton County, Newberg, Portland, and Sarasota all use positive displacement blowers. Centrifugal blowers are used at Akron, Plattsburgh, and Schenectady. The air supply systems were designed to provide a range of flow rates. Airflow rates can be varied by changing the speed of the blower motor, throttling the inlet or outlet, or operating different numbers of blowers. (Table 2.4 describes standby blower systems at the eight plants.)

With the exception of the Paygro system, the exhaust blowers are all constant-speed centrifugal blowers that direct the exhaust air to some kind of odor control system.

5.4.5 Odor Control Systems

Odor has been the most serious environmental/public relations problem at in- vessel facilities. All but one of the facilities surveyed treat the air coming directly from the reactors (the process air). Nonprocess air is sometimes treated and sometimes vented directly to the atmosphere. The odors from exterior curing/storage piles are not controlled. Although recently found to be a problem, odors from intermittent sources like these usually require less treatment than process air.

Despite odor control systems, six of the eight plants surveyed have received complaints from the local community. At five of these plants, the complaints have been serious enough to cause plant owners to decide to upgrade or replace their existing odor control systems.

Although ammonia and organic sulfides have been found at several plants, the spectrum of odor-causing compounds in composting reactor exhaust is not well characterized. At the time of the site visits, gas chromatographic studies of odorous air had been performed only at Akron, Cape May, and Sarasota. Plattsburgh has since performed this kind of analysis. A number of odorous compounds have been identified at the facilities, but the concentrations of these compounds vary from plant to plant. The causes of these variations are not understood and little analytical work has been done to correlate odor production with plant operating procedures.

At the eight plants surveyed, four strategies have been employed to control process odors:

- Diluting the odors with large volumes of air
- Passing the air through water at an adjacent wastewater treatment plant
- Passing the air through compost boilfilters
- Chemically treating the air either with ozone or wet chemical scrubbers

Table 5.6 summarizes the types of odor control systems used in the plants surveyed. (For a more detailed discussion of the odor control systems used at these plants, see Chapter Three and the case studies.)

5.4.6 Exterior Curing/Storage

All of the plants have some kind of exterior curing/storage facilities. Six of the plants have a paved area (to permit collection of any leachate). Three of the plants have covered facilities and two aerate the curing/storage piles. Table 5.7 summarizes the curing/storage facilities provided at the plants surveyed.

Table 5.4 Summary of Reactor Air-Handling Systems at Sites Visited

Location	Equipment Supplier	Installed Aeration Capacity: Total cfm[a]	Installed Aeration Capacity: Average Straight-Line Airflow Path Through Compost (ft)[b]	Installed Exhaust Capacity: Area Served	Installed Exhaust Capacity: Total cfm
Akron, OH	Compost Systems (Paygro)	240,000	8 to 10	Reactors plus building	870,000
Cape May, NJ	Purac	16,500[c]	21[d]	Reactors plus headspace	18,000[c]
Clayton Co., GA	Taulman	1,500	26	Reactors only	1,000
Newberg, OR	Ashbrook-Simon-Hartley	5,000	2 to 30[e]	Reactors only	5,000[f]
Plattsburgh, NY	Compost Systems (Fairfield)	32,000	8 to 10	Reactors plus	184,000[g] domes
Portland, OR	Taulman	7,800	26	Reactors only	6,000
Sarasota, FL	Purac	5,250	23[d]	Reactors only	5,700
Schenectady, NY	American Bio Tech	9,600	6 to 7	Reactors only	12,000

[a]cfm × .0005 = m³
[b]ft × .3048 = m
[c]After plant modification. Due to pipe size limitations, maximum rates achieveable are 12,000 cfm supply and 15,400 cfm exhaust.
[d]From bottom of reactor to exhaust nozzles.
[e]Usually no more than two consecutive zones run in the same mode.
[f]Only 2,500 cfm currently available.
[g]Including roof fans on domes.

Table 5.5 Summary of Blower Equipment

Location	Type of System	# of Reactors	Air Supply	Exhaust
Akron, OH	Paygro	4	96 constant speed, axial-flow blowers	32 roof fans
Cape May, NJ	Purac	2	3 variable speed, positive displacement blowers plus 2 constant speed, centrifugal blowers	5 constant speed, centrifugal blowers
Clayton County, GA	Taulman	2	3 variable speed, rotary lobe blowers	2 constant speed, centrifugal blowers
Newburg, OR	Ashbrook	2	2 variable speed, rotary lobe blowers	2 constant speed, centrifugal blowers
Plattsburgh, NY	Fairfield	2	2 constant speed, centrifugal blowers	2 constant speed, centrifugal blowers plus 2 roof fans
Portland, OR	Taulman	6	6 variable speed, and 2 constant speed positive displacement	6 constant speed, centrifugal blowers blowers
Sarasota, FL	Purac	2	3 variable speed, positive displacement blowers	3 constant speed, centrifugal blowers
Schenectady, NY	American Bio Tech	4[a]	3 constant speed, centrifugal blowers with inlet throttling	3 constant speed, centrifugal blowers with suction throttling

[a]Not including conditioning reactor.

Table 5.6 Odor Control Facilities

Location	Odor Control System[a]	Air Dispersal System
Akron, OH	Dilution of process air[b]	Roof fans on building
	Compost filter for de-watering and mixing rooms	Ground-level release
Cape May, NJ[c]	Two-stage wet chemical scrubber for process air	100-ft[d] stack
	One-stage wet chemical scrubber for mixing building	50-ft stack
	One-stage wet chemical scrubber for sludge storage building	20-ft stack
Clayton County, GA	Bubble air through water in storage pond	Ground-level release
Newberg, OR	Bubble air through water in oxidation ditch	Ground-level release
Plattsburgh, NY	One-stage wet chemical scrubber[e]	5-ft stack on top of scrubber building (35-ft above ground)
Portland, OR[f]	Bubble air through primary effluent	Ground-level release
Sarasota, FL	Ozone contact tower (replaced by two-stage wet scrubber in spring 1989)	Stack on top of ozone contact tower (80 ft above ground)
Schenectady, NY	One-stage wet chemical scrubber[g]	Released from top of scrubber, 10 ft above ground

[a]For process air, unless otherwise specified.
[b]Two-stage wet scrubbing planned.
[c]After 1987 modification.
[d]ft × .3048 = m
[e]Multiple-stage wet scrubbing planned.
[f]Anaerobically digested sludge.
[g]Two-stage wet scrubbing planned.
Note: Effectiveness of odor control and air dispersal systems is discussed in the case studies.

Table 5.7 Exterior Curing/Storage Facilities

Location	Covered	Paved	Aerated	Comments
Akron, OH	Partially	X	—	
Cape May, NJ	—	X	X	
Clayton County, GA	X	X	—	Aeration system constructed but no longer used.
Newberg, OR	—	X	X	Aeration system had not been used by the time of the site visit.
Plattsburgh, NY	—	X	—	
Portland, OR	—	X	—	
Sarasota, FL	X	X	—	
Schnectady, NY	Partially	X	—	

Chapter 6
Akron, Ohio

6.1 Introduction

The City of Akron owns the in-vessel composting facility, which is operated by Fairfield Service Company. The system used is the Paygro rectangular agitated bin process, supplied by Compost System Company (CSC). Burgess and Niple, Limited was the design engineering firm. The design capacity of the plant is 66 dt/day (73 dton/day), based on a two-shift operation, 7 days per week (464 dt/week [511 dton/week]).

The plant is located on a 77,300 m^2 (19.1-acre) site in the Cuyahoga River Valley. The city's 75-year-old wastewater treatment plant (WWTP) and landfill are to the east of the plant, across the river. A restaurant and a shopping area are to the south, and a large number of condominiums and expensive homes are to the west, with the nearest homes 91 to 152 m (300 to 500 ft) away. The Cuyahoga River Valley National Recreation area is to the north. Except for a small area north of the facility, there is little room for expansion and no buffer zone.

The site visit took place on June 9 and 10, 1988. Unless otherwise indicated, all information presented in this case study is representative only of that time.

6.2 Operating History

6.2.1 Procurement and Construction

The city decided to pursue composting as a sludge disposal option to supplement the existing incinerators, which were approaching full utilization. Originally, the city planned to install a static pile system at the site, which is adjacent to the environmentally sensitive Cuyahoga River Valley and National Recreation Area. Upon further investigation, the city decided that a static pile system would produce excessive odors and therefore would not be suitable.

The Paygro in-vessel composting system was chosen as an alternative because it demonstrated the ability to:

- Protect materials and equipment from the weather
- Compost municipal sludge with full-scale capability
- Provide adequate aeration (and thus prevent odor production)
- Handle periodically wet mixes without "catastrophe"
- Successfully complete a pilot operation using Akron sludge at a South Charleston, Ohio, facility

The city determined, with the approval of EPA, that CSC was the only company capable of providing the desired Paygro system. Consequently, CSC was selected as a "sole source" vendor. To open up bidding as much as possible, however, EPA minimized the scope of the work specified under the sole-source portion of the contract. As a result of this approach, the general contractor had to integrate various parts of the project and pieces of equipment, such as some of the materials-handling equipment, the curing system, and the odor control system. According to both the city's construction superintendent and the project engineer from Burgess and Niple, this integration process greatly complicated the job and may have resulted in higher rather than lower costs.

Startup of the facility was initiated in December 1986. Individual component tests and a 6-week integrated systems test were conducted during the summer and fall of 1987; they were completed in November of that year. All major tests were successfully concluded and the facility was legally accepted under the construction contract. Nevertheless, some of the cleated conveyors, the curing system, and the odor control system were not performing in accordance with the design criteria.

To cover the costs of improving these items, the city has applied for an EPA Modification/Replacement (M/R) Grant. Preliminary plans for the conveyor modifications and alternative curing methods, and the pilot testing of alternative odor control systems have been completed.

6.2.2 Capital Costs

The city based its original decision to invest in sludge composting on cost estimates for operating a static pile system, which was thought to be comparable to in-vessel composting. The cost estimates used by the city when it decided to pursue the in-vessel composting option were not available at the time of the site visit.

The preliminary 1981 construction cost of the plant was estimated to be $24.16 million, and the postdesign estimate made in January 1984 was $28.6 million. Actual construction costs were $30.5 million, including approximately $1.5 million in change order costs. All estimates included the costs of the dewatering facilities, which were

$8 to $9 million. An EPA Innovative/ Alternative (I/A) Grant covered 85 percent of the costs; the City of Akron paid for the remainder.

6.2.3 Operating History and Current Status

The plant has been operating continuously since January 1988. At the time of the site visit, the plant was processing 40 dt/day (44 dton/day) of sludge, in one shift, 4 days per week. This amount is equivalent to 160 dt/week (176 dton/week), or 34 percent of the design capacity and 50 percent of the WWTP sludge produced. All four of the system's reactors have been in use, but the facility has operated at a reduced rate to decrease odor problems. The WWTP incinerates the sludge that is not composted.

6.3 Description of the Plant

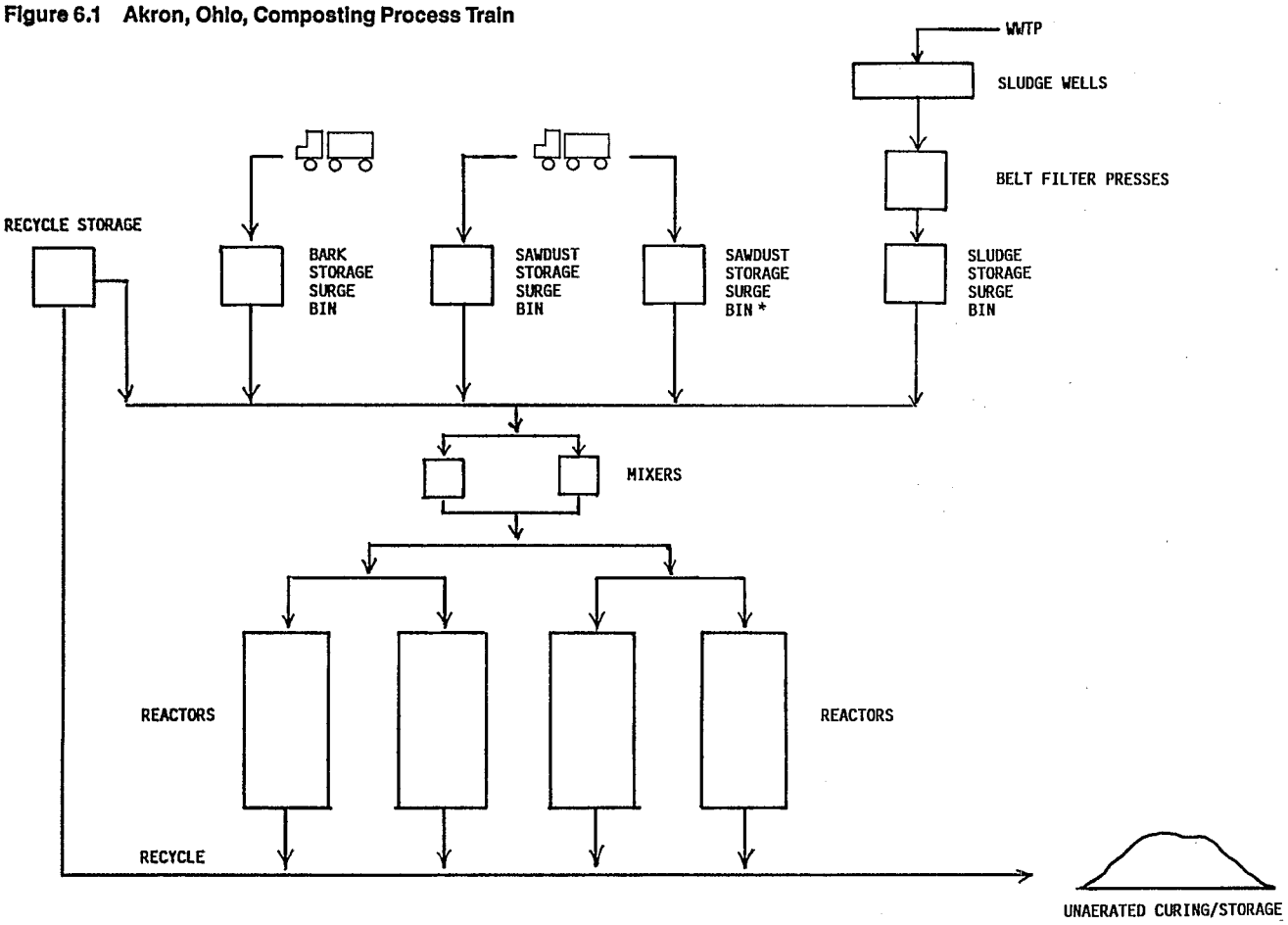
6.3.1 Systems Overview

At the Akron facility, the dewatering, mixing, composting, and administrative operations take place in one large building (317 by 73 m, 23,000 m³ [1,040 by 240 ft, 5.7 acres]). Curing/storage takes place outside this building in a 4,000 m² (1-acre) covered and a 20,000 m² (5-acre) uncovered area. A 5,300 m² (1.3-acre) odor control biofilter is also located outside the main process building.

Figure 6.1 presents an overview of the Akron Paygro composting process. Liquid sludge from the WWTP is pumped into sludge wells in the process building and dewatered by belt filter presses. The dewatered sludge, bark and sawdust amendments, and recycle are stored in piles and then in live-bottom surge bins prior to being conveyed to the two pugmill mixers.

The mix is transferred by a series of conveyors to any one of the four reactors. The reactors are long rectangular bins adjacent to one another that share two mobile excavation/conveyor ("extractoveyor") digging devices. The extractoveyors periodically either agitate the compost or move it to a different section of the reactor. The extractoveyors also transfer the compost from the reactors to a series of conveyors, which carry the compost to

Figure 6.1 Akron, Ohio, Composting Process Train



* THIS SLUDGE STORAGE BIN IS TEMPORARILY BEING USED TO HOLD SAWDUST TO DUST THE CLEATED CONVEYOR (SEE TEXT).

the recycle storage area or to unaerated curing/storage piles. Blowers supply air to the reactors via plenums located in the bottom of the reactors. The airflow in the reactors was designed to be reversible with a variable flow rate, but due to processing difficulties, the negative airflow mode is no longer use. Positive airflow occurs when the air is blown up through the compost mass. Process air from the positive airflow is discharged into the reactor area where it mixes with ambient air and is vented to the outside atmosphere by a series of roof exhaust fans. Mixing and dewatering room air are ducted to the compost biofilter.

6.3.2 Feed and Mix Characteristics

6.3.2.1 Sludge

The liquid sludge from the WWTP is an unstabilized mix of primary sludge and waste-activated sludge (WAS). It contains 4 to 6 percent total solids, depending on the primary sludge to WAS ratio and a number of other process variables. The volatile solids content of the sludge exceeds 70 percent.

The liquid sludge is delivered to the composting facility by pipeline from the WWTP. It is then deposited into six 283,838 L (75,000 gal) receiving wells prior to dewatering by 10 belt filter presses. Emergency storage of sludge occurs at the WWTP in open-topped, aerated sludge holding tanks with a combined capacity of 22,710,000 L (6,000,000 gal). Sludge is not normally held in the holding tanks for longer than 3 days.

Dewatered sludge was originally stored in two multiple-screw live-bottom surge bins, each 3.7 by 3.7 by 5.5 m high (75 m^3) (12 by 12 by 18 ft high, 2,592 cf). The bins hold 127 to 145 wt (140 to 160 wton) of sludge, which correspond to 27 to 36 dt (30 to 40 dton). At the time of the site visit, one of the sludge bins was used to store sawdust (see Section 7.3.3.2).

The bulk weight of the dewatered sludge is typically 881 to 929 kg/m^3 (55 to 58 lb/cf). After storage in the surge bins, the bulk weight of the dewatered sludge is 961 to 993 kg/m^3 (60 to 62 lb/cf).

6.3.2.2 Amendment

The Akron facility uses sawdust and shredded hardwood bark as amendment. The total solids content in both the bark and the sawdust materials is 50 to 60 percent, and both materials contain 90 to 95 percent volatile solids. The bulk weight of the bark is 320 to 401 kg/m^3 (20 to 25 lb/cf); the bulk weight of the sawdust is 288 to 352 kg/m^3 (18 to 22 kg/m^3).

The materials are delivered by truck to the covered storage area, where they remain in storage piles for up to 2 months. A front-end loader places the materials into a hopper, which then directs the amendment to a series of conveyors. The conveyors transport the amendment to storage bins in the mixing area (see Figure 6.2).

The facility has one bark storage and one sawdust storage bin. In addition, one of the sludge bins is used to store sawdust for dusting the sludge cleated conveyor (see Section 6.3.3.1). The bark and sawdust bins are each 3.7 by 4.9 by 61 m, 111 m^3 (12 by 16 by 20 ft, 3,840 cf). They are duplex units, each divided by a partition wall and equipped with a multiple-screw live-bottom discharge unit.

6.3.2.3 Recycle

Recycle is transported by a series of belt and cleated conveyors from one of the reactors or curing piles into one of two recycle storage bins located in the mixing room. The bins are 3.7 by 4.9 by 6.1 m, 111 m^3 (12 by 16 by 20 ft, 3,840 cf) and have a total capacity of 87 to 104 wt (96 to 115 wton). The bins are equipped with multiple-screw live-bottom discharge units.

The total solids content of the recycled compost is 60 to 68 percent. The volatile solids content exceeds 60 percent and the bulk weight is 401 to 481 kg/m^3 (25 to 30 lb/cf).

6.3.2.4 Mix

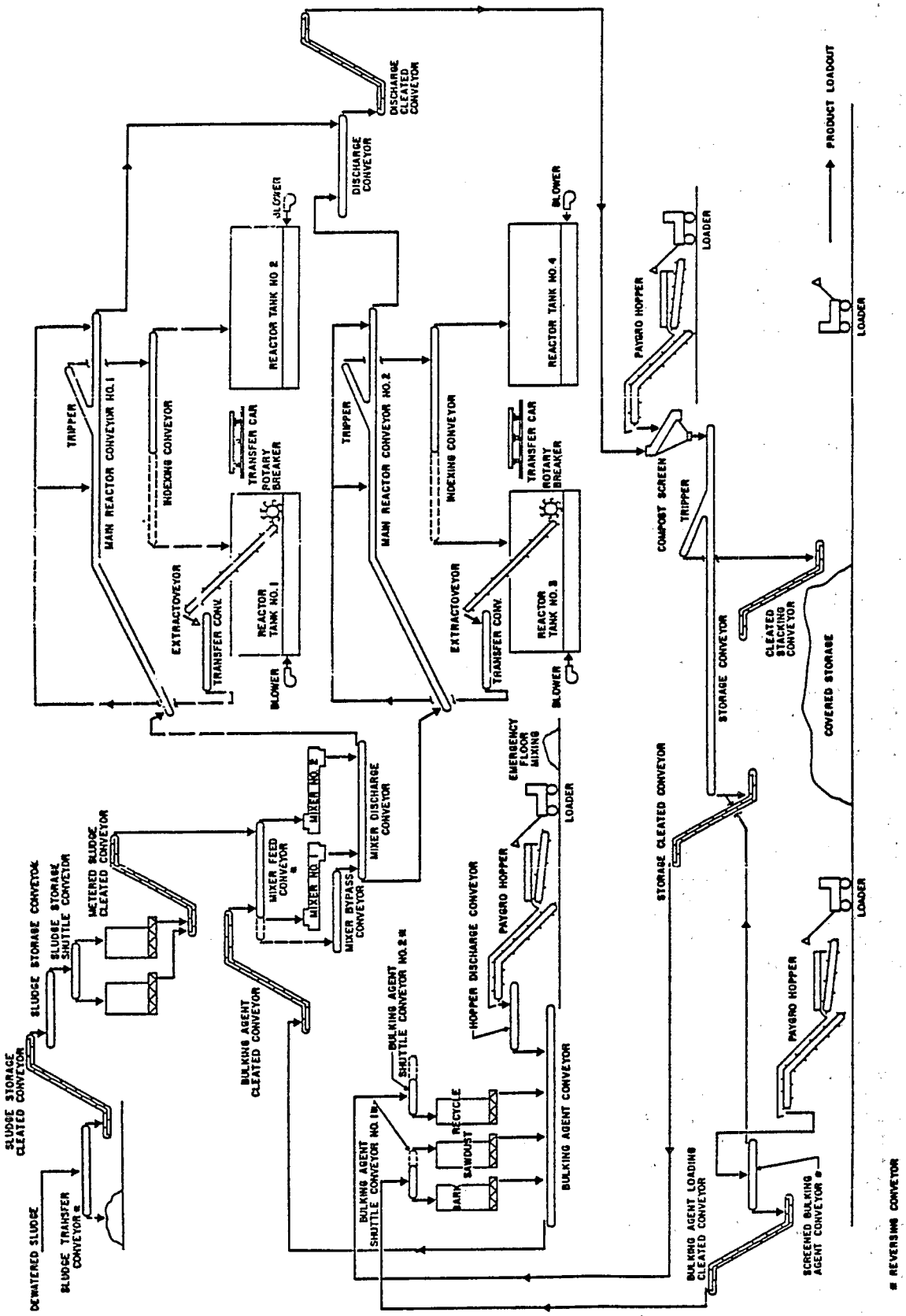
According to the system operators, porosity of the mix is a key variable in producing an acceptable compost product, and the ratio of the mix components is adjusted daily to achieve this desired porosity. A porosity test developed by the design engineer is conducted daily (see Section 6.4.1.4). The mix ratio depends on the varying moisture contents and on whether recycle or product is produced. The design volumetric mix ratio is 1/0.33/0.33/1.33 (sludge to bark to sawdust to recycle). The actual volumetric mix ratio at the time of the site visit was 1/0.4/0.6/2, 33 percent greater than the design value.

Since recycle is the largest fraction of the bulking agent, the quality of the recycle used has a great impact on mix porosity. When too much recycle is used in the mix, the compost contains too many fine particles, which decreases the porosity of the mix.

The target value for total solids in the mix is 43 to 45 percent, with an average of 42 percent and a range of 40 to 50 percent. This target value is higher than the design rate of 40 to 42 percent because during early operations the recycle was wetter than anticipated and, thus, more sawdust was needed in the mix. The added sawdust made it difficult to control the temperature and flow of air in the reactors. As soon as the mix solids reached 40 percent or greater, the situation improved. At the time of the site visit, the 43 to 45 percent target rate was considered the lowest solids content that could give a proper mix porosity.

The volatile solids content of the mix is approximately 70 percent. The bulk weight is 561 to 641 kg/m^3 (35 to 40 lb/cf) (609 to 673 kg/m^3 [38 to 42 lb/cf] by design). By adding additional sawdust, bark, and recycle (to maintain the proper porosity of the mix), the bulk weight of the mix can

Figure 6.2 Akron, Ohio, Materials Handling Train



generally be kept about 593 kg/m³ (37 lb/cf). Additional sawdust, bark, and recycle in the mix also help to reduce odors through maintenance of desirable porosity.

If the mix is too dry, the work area can become very dusty, especially near the reactor loading area during "fluffing" or unloading (see Section 6.3.4.2). The dust is annoying to the workers and requires additional cleanup efforts.

6.3.3 Materials Handling

The materials handling system is depicted in Figure 6.2. A number of different types of conveyors perform a variety of functions and offer the operators a great deal of flexibility in maneuvering the materials. For example, the compost can be "fluffed" in place or transported to another reactor at any time, and finished compost can be set out for curing or sent to the recycle bin without handling by a front-end loader.

All conveyors are interlocked through the central computer. In addition, throughout the plant, a number of material flow indicators are connected to the interlock system.

In general, the system's flat belt conveyors have worked well and convey mix material at a greater vertical angle than the "standard" maximum values used in conveyor design. Materials can be moved with portable equipment in some areas (on the floor of the mixing room or in the storage area outside the building) to bypass many of the conveyors. Excessive spillage has occurred at some of the transfer points between the flat belts and cleated conveyors (see Section 6.3.4.4). In a plant performance evaluation report, the city recommended that drip or spillage pans be installed at all cleated conveyor transfer points.

6.3.3.1 Mixer Feed System

The live-bottom multiple-screw system in the sludge, recycle, and amendment surge bins regulates the discharge of the materials from the bins onto an outfeed screw conveyor. The sludge bin deposits the sludge onto a cleated conveyor, and the recycle, bark, and sawdust bins deposit material onto a trough-shaped belt conveyor and then a cleated conveyor.

The discharge rates are controlled by a computer that uses gamma-ray mass weigh scales to measure the volume of the materials on the belts (radiation attenuation is correlated with the amount of material on the belt). The operator provides the computer with the volumetric mix ratio, which is chosen on the basis of moisture content measurements taken the previous day and periodic bulk density measurements taken during loading.

Cleated conveyors for the amendment, recycle, and sludge transport the materials up a 45-degree incline to the mixer feed conveyor and then to the mixers. The cleated conveyor is one item the city considers a "failure"; it is not well-suited for transporting dewatered sludge because the sludge tends to stick to the belt and does not completely discharge, even with the aid of the belt "beater" furnished with the unit. It appears that the sludge bin discharge screws change the sludge consistency from a friable cake to a sticky gelatinous mass. As a result of sludge stickiness, approximately 10 percent of the feed, or 36 wt/day (40 wton/day), spilled off the discharge end of the conveyor. Under the worst conditions, cleanup required 1 to 2 laborers working full-time.

As an interim solution, one of the sludge surge bins was converted to a sawdust bin, and the conveyor is now dusted with sawdust before the sludge is applied, preventing the sludge from sticking. This process has reduced spillage to a temporarily acceptable 1 to 2 percent. The operators are investigating the possibility of applying the proper amount of sawdust for the mix via a dusting mechanism rather than using the existing sawdust surge bin.

Another problem with the cleated conveyors was that the idlers (support rollers) originally supplied with the conveyor spanned the full width of the belts (see Figure 6.3). This configuration caused excess wear and vibration on the belts (as the cleats ran over the rollers), and minor but annoying spillage. More seriously, when one of the walls of a cleat broke, the broken piece caught on the idler and tore the belt. Replacing the original rollers with "stub" idlers, which support the belt only on its flat portion outside the cleat walls, has reduced vibration and eliminated the possibility of the belt getting caught on a worn cleat wall (see Figure 6.3).

6.3.3.2 Mixers

The system has two pugmill mixers that are used one at a time on an alternating basis. Either mixer can feed any one of the four reactors.

Each mixer was originally equipped with two 15,000 W (20 hp) motors. During startup, however, the electrical drive motors and drive mechanisms would often overload because too much material was being forced through the mixers. The 15,000 W (20 hp) motors were replaced with 19,000 W (25 hp) units, half of the pugmill mixer paddles were removed, and the drive mechanisms were modified. During the site visit, the mixers were operating well at design capacity and there was no apparent degradation of mix quality due to this modification.

In emergencies, mixing can be done by front-end loaders on the mixing room floor.

6.3.4 Reactor

6.3.4.1 Reactor Feed System

The mix is discharged from the mixer to a trough-shaped belt conveyor that transfers the material to the reactor area via one of two flat belt conveyors. The belt conveyors are located between reactors 1 and 2 and reactors 3 and 4, and run the length of the process building (see

Figure 6.3 Cleated Conveyor Modifications

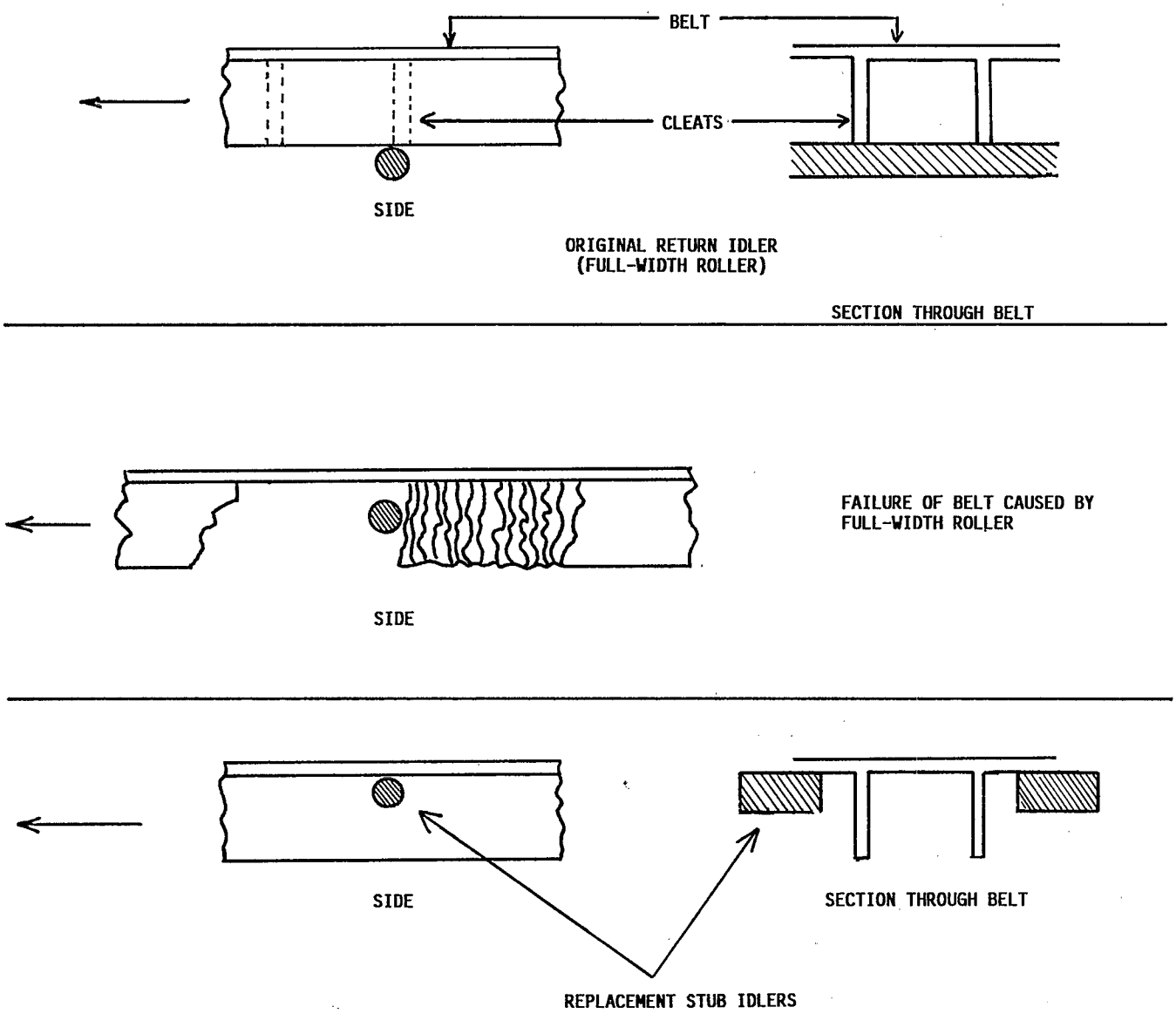


Figure 6.4). The mixed material is transferred to a tripper car and then to an indexing belt conveyor that spans the width of the reactors and deposits the mix into the desired portion of the reactor.

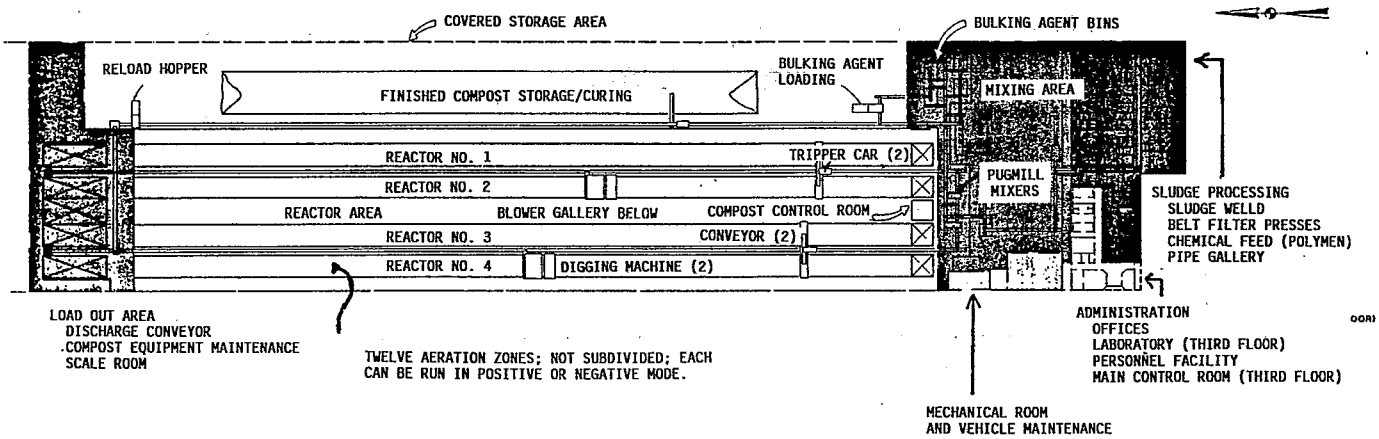
The feed conveyor and tripping system have a loading capacity of 0.06 m^3/s (7,500 cf/hr). The loading system can be operated either semiautomatically or manually. In either case, the tripper car is controlled by an operator stationed on site.

6.3.4.2 Configuration

The system is equipped with four concrete reactors, each 223 by 6.1 m (730 by 20 ft) with a composting depth of 3 m (10 ft) (see Figure 6.5). The total system volume is 16,500 m^3 (584,000 cf). The four reactors share two extractoveyor digging machines that span the reactor width and move on rails mounted on the outside walls of the reactors. Figure 6.6 shows the front of one of these extractoveyors.

The extractoveyors use toothed rotating drums that break up and mix ("fluff") the compost mass and drop the material onto a wide table conveyor inclined at a variable angle (see Figure 6.7). This conveyor either drops the compost back into the reactor behind the extractoveyor or lifts the compost out of the reactor (see Section 6.3.4.4). Fluffing is usually done on a weekly basis (i.e., at least twice during a typical 21-day detention period). As part of this fluffing operation, the system can move the composting mass to another reactor. The extractoveyors operate semiautomatically and are con-

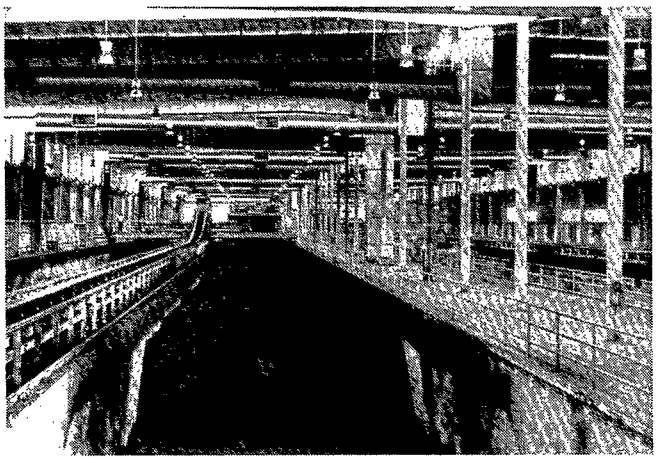
Figure 6.4 Akron Composting Facility Building Plan
Scale 1 in. = 80 ft.



trolled by an operator situated in an enclosed cab on the device.

Heat detectors and a dry standpipe system with hose stations provide fire protection in the reactor area.

Figure 6.5 Reactor Room



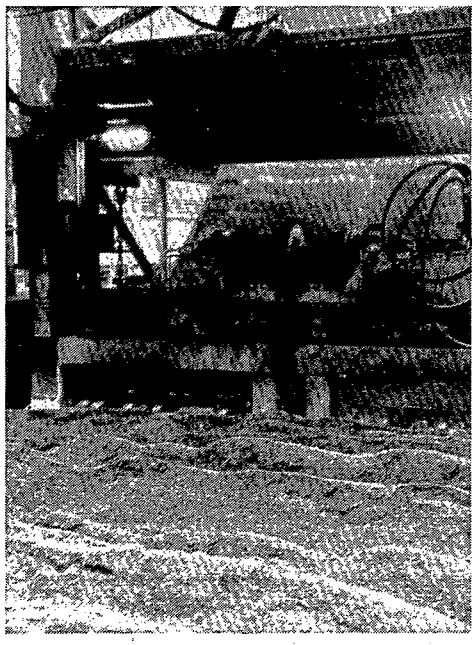
6.3.4.3 Reactor Aeration System

The reactors are aerated by a series of centaxial blowers via 0.46-m (18-in.) high concrete air plenums running beneath the full width of each reactor (see Figure 6.8). The blowers are located in long covered galleries between reactors 2 and 3 and the outside of reactors 1 and 4.

Each reactor is configured in a series of twelve 18-m (60-ft) long aeration sections. Although the compost mass itself is not separated into individual aeration sections, concrete block walls in each plenum separate the individual sections. Each aeration section is supplied with air using two blowers, for a total of 24 blowers per reactor; 96 for the whole system. Each blower has a capacity of 1.18 m^3/s (2,500 cfm) at a pressure of 0.2 m (8 in.) water column (W.C.) (see Section 6.4.1.2).

Galvanized steel grates which separate the plenums from the reactors allow air to flow to or from the compost. A 0.2-m (8-in) layer of washed gravel on top of the grating

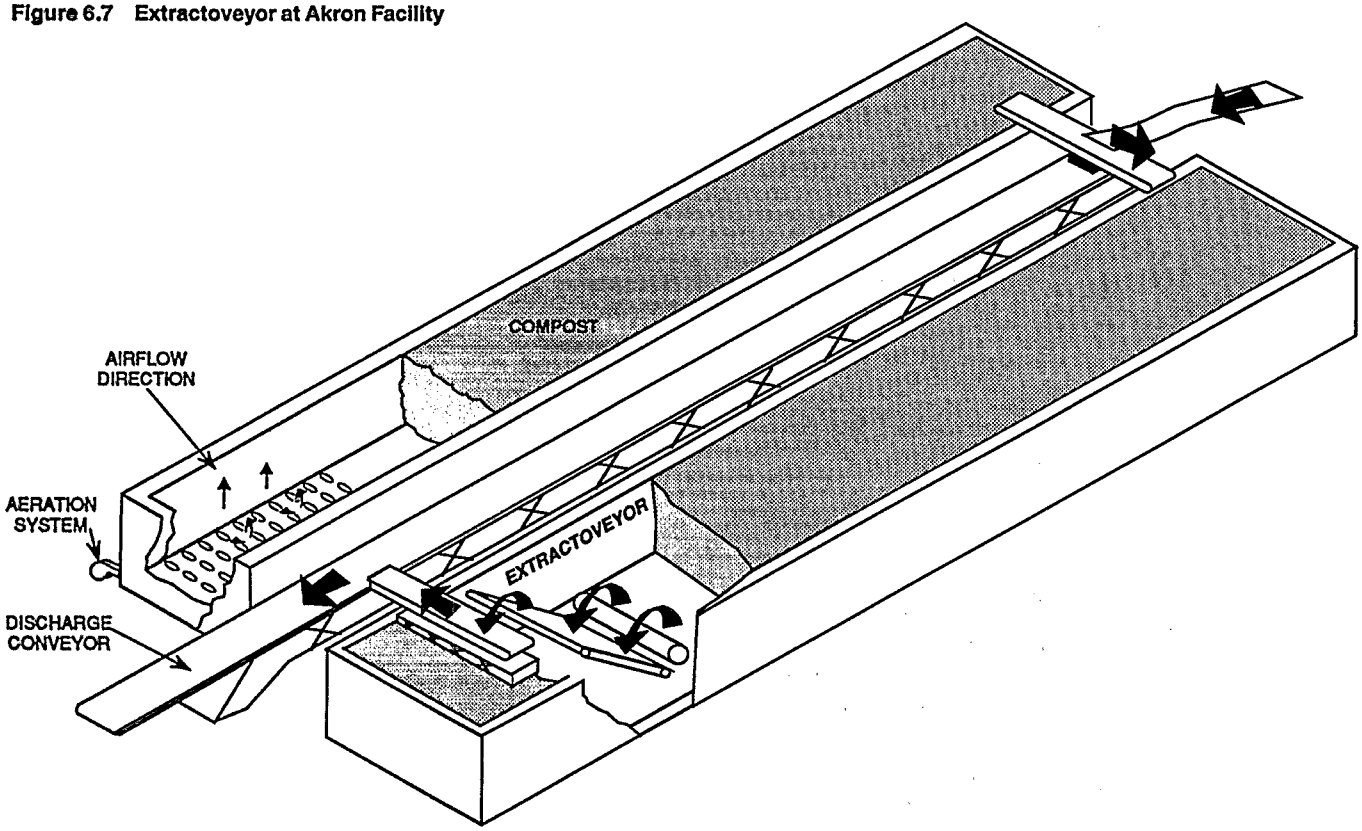
Figure 6.6 Front of Extractoveyor



serves to distribute air below the compost bed; 0.15 to 0.23 m (6 to 9 in) of bark on top of the gravel provide an additional support layer for the compost. Short-circuiting of air in the compost does not appear to be a problem.

By design, air can be supplied to the reactors in either the positive mode, in which air is blown up through the compost, or the negative mode, in which air is drawn down-

Figure 6.7 Extractoveyor at Akron Facility



ward through the compost. In the positive mode, outside air is pulled in from the roof of the process building through long vertical intake ducts that connect to the blowers in the blower gallery. Air is then forced up through the reactors into the process building, and is ventilated out the roof.

Thirty-two roof fans dilute the process air generated during the positive aeration mode and draw it out of the reactor building. The air is released 16 m (52 ft) off the ground. The total volume of air moved is about 425 m^3/s (900,000 cfm) or 6 air changes per hour. This dilution air enters the building through louvers on two sides of the reactor building. The design was intended to provide a 10:1 ratio of fresh air to process air.

Noise from the reactor roof fans has been excessive enough for neighbors to issue formal complaints, and thus the use of the fans has been reduced. When the fans are not operating, however, and the temperature of the incoming air is less than 7.2° to 10°C (45° to 50°F) (during winter), condensation in the building increases significantly. Under the worst conditions, visibility inside the building can drop to less than 6.0 m (20 ft). Moisture appears to be well managed when the roof fans are operating and the solids content of the compost is 15 to 25 percent higher than the incoming mix.

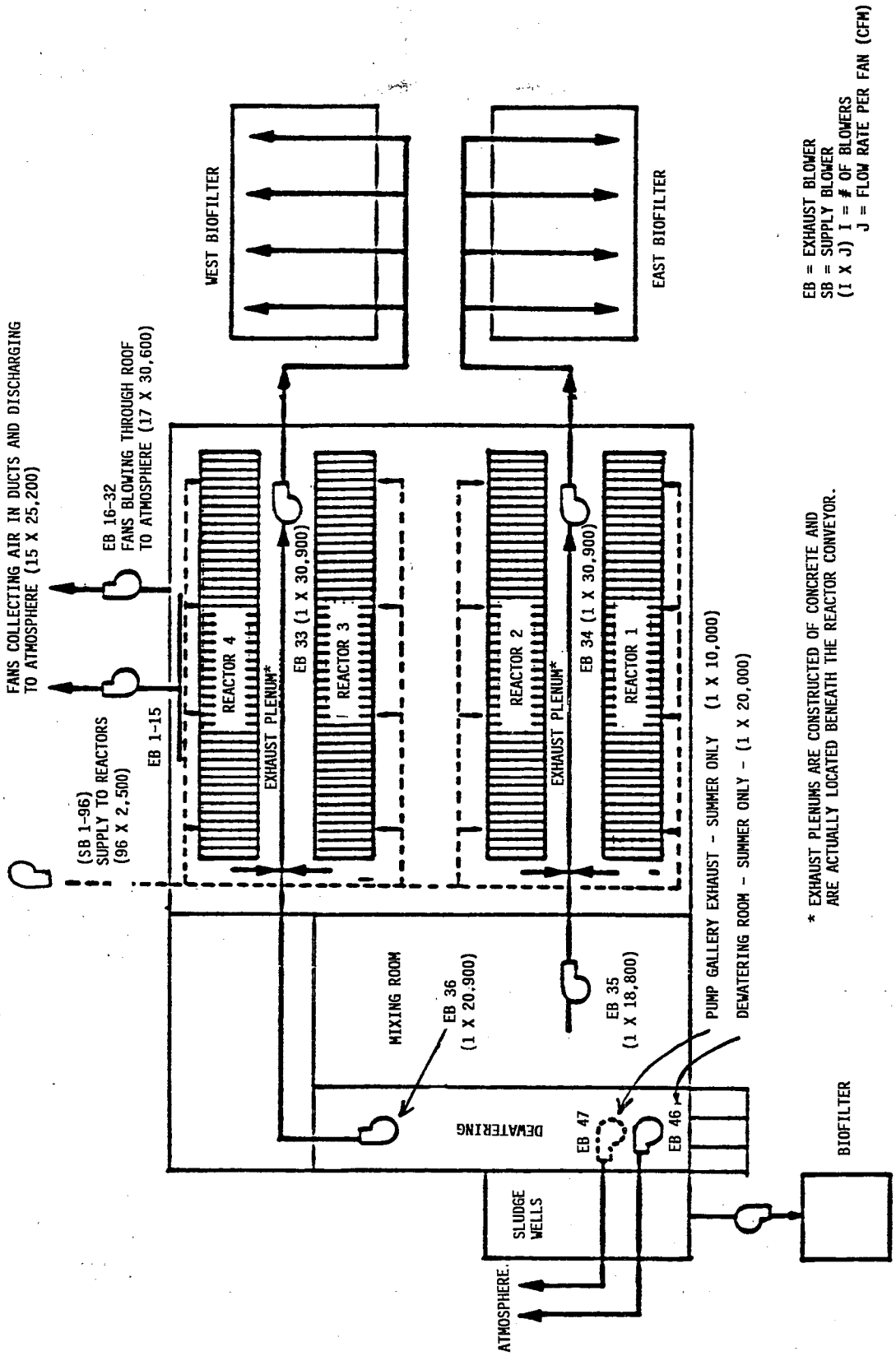
As designed, in the negative aeration mode, air is drawn from the process building through the reactors, into the plenum, and to the exhaust blowers, which send the air into a common plenum running the length of the blower gallery. This air is sent to a compost biofilter (see Section 6.3.7.4). The system was designed to operate in the negative aeration mode during the first few days of the composting cycle, when the potential for odor production is the highest. However, moist air drawn through the blowers during the negative aeration mode accelerated the wear on the blower bearings. Also, the bark layer became saturated with moisture and impeded the airflow. To avoid these problems, the negative aeration mode has been abandoned and all aeration is run in the positive mode. Section 6.3.7.4 describes the odor control system used when the reactors are aerated in the positive mode.

During the coldest part of the winter, the process air is preheated to remove additional moisture from the compost. Preheating is accomplished by using boiler-supplied hot water and metal coils in the vertical air intake duct. The system is designed to raise the incoming air temperature by about 44°C (40°F).

6.3.4.4 Outfeed Device

The outfeed process involves the use of extractoveyors

Figure 6.8 Air Handling System



as well as several additional conveyors. During the outfeed process, the compost is first discharged onto a mobile transfer conveyor that couples to the back of the extractoveyor. The transfer conveyor deposits the compost onto the main reactor conveyor, which is connected to a common discharge conveyor located at the end of each reactor. The discharge conveyor feeds another conveyor, which in turn goes outside the process building to a flat belt storage conveyor (see Figure 6.2).

The storage conveyor runs the length of the building and feeds a mobile cleated stacking conveyor, which deposits the compost onto piles for curing. If desired, the compost can be transferred from the storage conveyor to the recycle surge bin using the storage cleated conveyor and the amendment conveyor.

Excessive spillage has occurred at two different transfer points between flat belt conveyors and the cleated conveyors. This spillage occurred even though the rated capacity of the successive conveyors is the same.

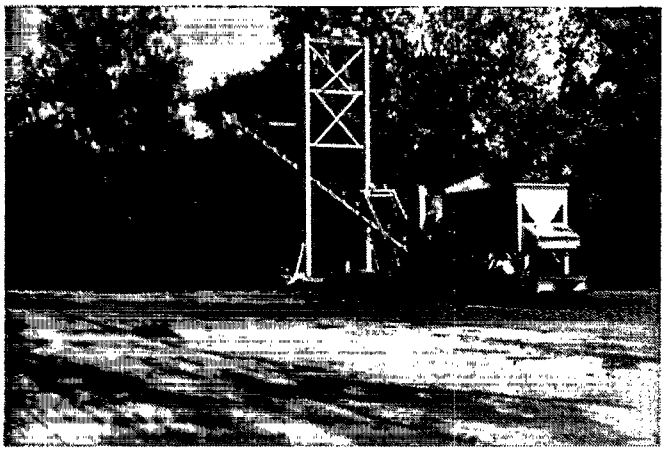
6.3.4.5 Leachate/Condensate

The plenums and air ducts are equipped with drains that were at one time used to handle the condensate produced during the negative aeration mode. The condensate was piped to a pump and then pumped to the WWTP.

6.3.5 Exterior Curing/Storage

The facility was designed to provide covered curing/storage for 2 months and uncovered curing/storage for an additional 4 months. At the time of the site visit, the piles were 3.0 to 4.0 m (10 to 12 ft) high and were built in the uncovered storage yard using front-end loaders. Uncovered piles can be built up to 7.6 m (25 ft high) using stacking conveyors (see Figure 6.9). The piles have been a source of odor, even after 6 months of curing/storage. All runoff from the piles is captured and returned to the WWTP.

Figure 6.9 Stacking Conveyor



The curing/storage piles are not aerated. During the design phase, it was expected that the compost leaving the reactors after 21 days would be stable enough for a 3-month unaerated curing/storage period, but the actual compost has not been as stable as expected. After composting for 19 to 21 days, the material reheated when stored in high (7.6 m [(25 ft]) piles. Even compost that had been cured/storage for 6 months reheated when placed back in the reactors.

At the time of the site visit, the feasibility of providing permanent aerated curing/storage was being studied. Although, it appears that supplemental aeration may be required in the higher piles to avoid anaerobic conditions, it might be possible to maintain aerobic conditions in smaller (3 to 3.7 m [10 to 12 ft]) unaerated curing piles or windrows. The smaller piles would increase the storage space requirements, however, and the available onsite curing/storage space is already limited.

6.3.6 Nonprocess Air Handling

Air from the mixing room 9.4 m^3/s (20,000 cfm) and the dewatering room 8.5 m^3/s (18,000 cfm) is vented out exhaust plenums (see Figure 6.8) to the biofilter (see Section 6.3.7.4). Large doors also naturally ventilate the mixing areas. The sludge receiving well is vented through an independent compost biofilter.

6.3.7 Odor

6.3.7.1 Predominant Site Characteristics and Weather Patterns

At the plant site, the Cuyahoga Valley is about a third of a mile wide. One mile north and south of the plant, the valley is one mile wide. The ridges along each side of the valley rise about 61 m (200 ft) above the plant site. This location greatly affects the dominant weather patterns and thus the dispersion of composting odors in the vicinity of the plant.

The wind direction and velocity are monitored by two weather stations located on the roof of the process building and at the top edge of the valley. Prevailing winds are from the west. When the air is calm, an air inversion occurs in the valley. The inversion traps the ventilation exhaust odors close to the plant. The strongest odors reach the community during the early morning hours, as the winds increase, break up the nocturnal inversion, and blow the odors trapped by the inversion into the neighboring area.

Residents living on the adjacent ridge of the valley are affected during the stagnant wind conditions that predominate for longer periods of time than the nocturnal inversions. When sustained winds finally occur, they move the odors that have accumulated in the restricted airspace around the plant to the residential and commercial areas throughout the valley; compost odors have been documented up to 2.4 km (1.5 miles) from the facility.

6.3.7.2 Odor Complaints

From March through December 1987, the plant received 63 odor complaints; from January through August 1988, 73 complaints were received. Most of the complaints were made by individuals residing or working in the nearby area. Despite the presence of background odor sources from the WWTP, local residents have distinguished a particular "compost odor" that they find objectionable. Generally, however, no correlation has been observed between community odor complaints and specific plant operations, except when the operators are digging into curing/storage piles on windy days.

6.3.7.3 Odor Studies and Sources

Odor Science and Engineering, Inc. performed an odor study for the city in mid-1987. Before the study was undertaken, odor emissions had not been specifically measured, but odor complaints had been investigated and addressed. The study's Draft Final Report (July 1988) concluded the following:

1. The major source of odors reaching the residents is the ventilation exhaust from the reactor building. (Odors in the building ranged from about 0 to over 200 D/T [dilutions-to-threshold].)

2. Other odor sources include the belt filter press room, sludge storage well, and curing/storage piles.

3. The compost odor has a characteristic "pungent, woody, earthy" odor that could be detected up to 4.0 km (2.5 miles) from the facility. Odor complaints have been received from distances of up to 2.4 km (1.5 miles) away. Odors from the incinerator across the river were detectable up to 3.2 km (2 miles) from the plant.

4. Community odor impacts depend primarily on wind and weather conditions. Preventing ambient odor levels from reaching nuisance levels during the inversion or stagnant wind conditions in the valley requires a 90 percent reduction (during full operation at full capacity) in odor emissions from the reactor room ventilation system. Under all other wind conditions, a reduction of about 50 percent is acceptable.

5. Curing/storage piles do not appear to contribute to the detectable odors downwind except if the piles turn septic.

Table 6.1 summarizes the measurements taken during the study.

Another odor source was leaky process air pipes in the vicinity of the compost filter, which have since been sealed.

6.3.7.4 Odor Treatment

To control the sludge well odors, an airflow of about 0.5 m^3/s (1,000 cfm) was directed at one time from the top of the sludge wells through a 15.3 m^3 (20 cy) pile of compost that served as a biofilter. Currently, the odor treatment system for the sludge well, mixing, and dewatering air is a compost biofilter, 23m^2 (250 ft2) in area by 1.1 m (3.5 ft) deep (see Figure 6.10). The filter is divided into two sections, each of which contains 30 aeration lines made of 0.3 m (12 in.) corrugated and perforated polyethylene tubing. Air is exhausted from the filter at ground level. The compost filter decreases odor concentrations by about 95 percent.

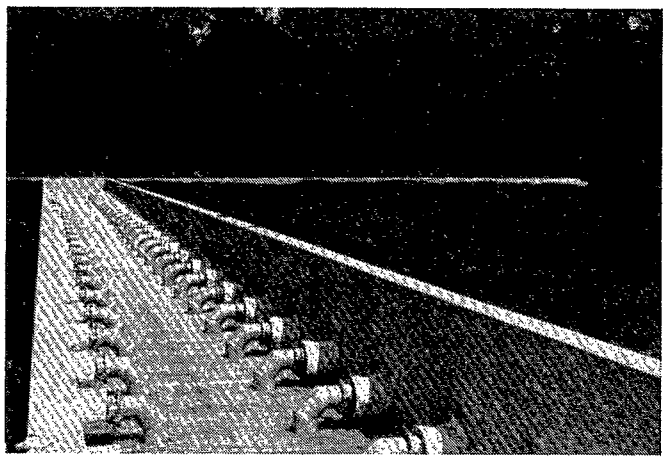
Table 6.1 Summary of Odor Measurements[a]

Location	n[b]	Range (dilutions-to-threshold)
Compost Building Exhaust Fans	19	11–228
Liquid Sludge Storage Tank	2	1,316–2,698
(after treatment by biofilter)	4	144–315
Dewatering Room (presses operating)	1	397
Sludge Pump Gallery	1	1,280
Large Biofilter		
(Inlet)	5	281–758
(Outlet)	6	3–26
Curing/Storage Piles	6	3–126

[a]From Akron Composting Facility Odor Study, Draft Final Report, Odor Science and Engineering, Inc. July, 1988.
[b]n = number of samples represented in reported range.

When the compost filter becomes dry, the compost piles crack and must be raked. At the time of the site visit, the compost had not been raked for 2 months. The filter also must periodically be replaced; the original filter material was replaced after 10 months of use. To prevent the compost filter from cracking and to extend its life, operators are also considering wetting the compost filter.

Figure 6.10 Compost Biofilter for Odor Control



Diluting the reactor building (process) air with outdoor air at a 10:1 ratio has failed to prevent odor impacts to the local community. To improve control of odors from the reactors, a 0.3-m (12-in.) layer of recycle is placed on top of the composting mass. Consequently, the effective reactor volume has been deceased by 10 percent. This layer of recycle was not included in the recycle fraction of

the initial mix discussed in Section 6.3.2.4. However, this additional recycle is taken into account in inventory records and mass balance calculations.

In general, inadequate process control (i.e., wet mixtures, low porosities, and poor air control) during startup has contributed to more odor production than expected. This situation was partially alleviated when drier recycle was produced. The operators have also increased the volumetric mix ratio by adding more amendment and have instituted closer control over the mix porosity. When proper porosity is attained by maintaining a mix bulk weight of less than 641 kg/m³ (40 lb/cf), a uniform airflow can be achieved, leading to aerobic conditions in the composting mass, good moisture removal, and lower (but not eliminated) odor production.

At the time of the site visit, the city was exploring the possibility of aerating the piles in the covered curing/storage area for 1 to 3 weeks prior to long-term storage. Permanent pile aeration facilities will be included in the M/R grant application.

6.3.7.5 Odor Treatment Recommendations

Odor Science and Engineering, Inc. recommended the following three-tiered approach to control the odors from the composting areas:

- Tier 1: The present ventilation rate of the roof fans [about 425 m³/s (900,000 cfm)] would be reduced to 142 m³/s (300,000 cfm) (77.9 m³/s [165,000 cfm] of process air and 63.7 m³/s [135,000 cfm] of additional building exhaust air). This air would be treated in a two-stage oxidizing wet scrubber. Tier 1 would be used at all times. Under worst-case weather conditions, this tier would be the only ventilation allowed, and odorous process operations such as fluffing and excavating compost beds would be prohibited.
- Tier 2: An additional 70.8 m³/s (150,000 cfm) from the reactor building would be sent to the two-stage scrubbers, which are expected to remove 90+ percent of the odors. Tier 2 ventilation would be used in addition to Tier 1 under all but the worst weather conditions.
- Tier 3: The existing roof fans would be modified to lower-noise units, and their capacity decreased to 212 m³/s (450,000 cfm). This system would be used only to maintain acceptable temperature and humidity levels in the reactor room, and only if weather conditions permitted.

Odor Science and Engineering, Inc. also recommended the diversion of ventilation air from the dewatering, mixing, and sludge well areas to a dedicated wet scrubber that would operate under all weather conditions.

6.3.8 Support Facilities

The administration area in the main process building contains an open reception area; a private office for the general manager; a private office for the city plant superintendent; a shared office for several other supervisory personnel; a lunchroom, conference room, and restroom for administrative staff; and a restroom and showers for operating personnel. Some unassigned storage space was converted into the lunchroom for the operating personnel. Odors entering the administration area from the dewatering area have been eliminated by careful sealing of the wall between the administrative area and the process area, and by modifying the ventilation system.

Maintenance facilities consist of a two-bay maintenance shop. Spare parts are stored above the shop and in other rooms nearby. There is one laboratory room with a hood and equipment to perform the solids and polymer jar testing for dewatering.

6.4 Monitoring and Performance

6.4.1 Reactor Control Strategy

Although the only regulatory requirement for the Akron facility is that the compost maintain a temperature of 55°C (131°F) or greater for 3 consecutive days, the operators' goals are to maintain aerobic conditions, minimize odor production, and adequately remove moisture in the compost by making sure that the mix is of sufficient porosity. The system usually meets the regulatory criterion and produces a compost product with a satisfactory solids content. If a batch does not reach 55°C (131°F), it is used as recycle.

6.4.1.1 Temperature Monitoring and Control

The original temperature probes were strung across the compost reactors and buried in the compost. Because they were difficult to see and remove, however, they were often accidentally dug up by the extractoveyor, and once removed from the compost, they were difficult to replace. Consequently, the original temperature probes have been replaced by lance-type probes, which are easier to use. The probes, which contain three thermistors, are placed by hand in the compost mass, where they remain except when the material is being fluffed. The probes reach to the bottom third of the compost mass.

The central computer takes the average of the three thermistor readings every 3 seconds and uses that temperature value to control the blowers, based on the oxygen requirements of the compost (see Section 6.4.1.3). A daily average temperature reading is also entered into a materials tracking database system. A temperature profile created from these daily data is shown in Figure 6.11.

6.4.1.2 Aeration Quantities and Rates

The aeration system is capable of providing a total flow of 113 m³/s (0.41 cfm/cf) of reactor volume, or 1.0 m³/s/dt (2,350 cfm/dton) of sludge. Actual air provided varies according to the temperature readings in the reactor. Each reactor is divided into 12 independently controllable aeration zones, and the blower schedules and temperature setpoints are varied by the operator. The total aeration rate is varied by operating either one or two blowers at a time.

The following four different aeration levels can be used, depending on temperature readings and the oxygen level in the compost:

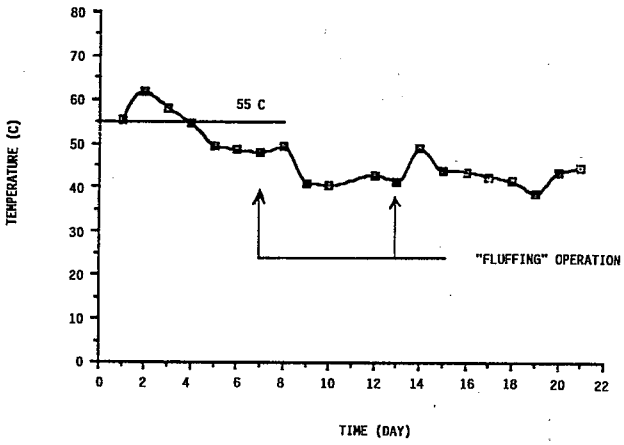
1. One blower per each aeration section operates intermittently.

2. One blower operates continuously.

3. One blower operates continuously and one blower operates intermittently.

4. Two blowers operate continuously.

Figure 6.11 Time-Temperature Profile



The temperature setpoints at which the four aeration levels become activated are changed seasonally and are based on prior experience. Level 1 aeration is usually adequate to supply the needed process air except for the early part of the composting cycle (see Section 6.3.4.3). The setpoints and aeration schedule in place at the time of the site visit are shown in Table 6.2.

Table 6.2 Aeration System Operation (June 1988)

Temperature Setpoint	Blower #1	Blower #2
0°C[a]	3 min on; 7 min off	Off
35°C	Continuous	Off
45°C	Continuous	As temperature rises, 3 min on; 7 min off
		As temperature falls, 1 min on; 16 min off
57°C	Continuous	Continuous

[a](°C × 1.8) + 32 = °F

During the first 24 hours that the mix is in the reactor, the compost temperature increases when the air supply increases. In the summer, the aeration system is set to introduce only enough air into the compost to maintain an oxygen level of at least 10 to 12 percent at all times. In the winter, because the air supply is colder, the oxygen level is increased to raise the compost temperature, thereby offsetting the cold incoming air. However, care is taken not to add so much cold air that the compost becomes chilled.

6.4.1.3 Oxygen Monitoring

Oxygen in the composting mass is measured manually using a lance-type probe and oxygen meter. Daily measurements are made during the first several days after a batch of mix is loaded into the reactor. The results are used to establish temperature setpoints or to override the temperature control of the blowers, if necessary. After the first few days, the biological activity of the compost mass diminishes, and the oxygen levels are measured less frequently.

6.4.1.4 Other Tests and Equipment

At the time of the site visit, the laboratory technician was experimenting with two stability tests. One was a pressure differential test that measures oxygen uptake by the change in pressure in a sealed vessel containing compost. In the second test, a compost sample is wetted to 60 percent moisture and placed in a beaker. A dissolved oxygen (DO) meter is then used to measure the oxygen content of the beaker atmosphere.

The stability test results had not been correlated with process parameters. The two tests did not always agree, and according to the tests, compost that is stable will reheat if placed in the reactors again. Since the preliminary data from these tests are inconclusive or misleading, they are not used for process control.

The design engineer developed a porosity test, which measures the bulk weight of the mix or compost using a standardized bucket. The operator compresses the material in the bucket by standing on a plywood disk placed on top the material, and measures the decrease in depth. From the bulk weight and change in height after compression, the "loose" and "compacted" porosities are calculated by the database computer program. The loose bulk weight is also checked against the measurements estimated by the nuclear scale (see Section 6.3.3.1).

Grab samples of the compost leaving the reactors are collected each day and stored in a refrigerator, and a composite sample is created once a month and sent to an outside laboratory for detailed analysis. Example data from three monthly composites are shown in Table 6.3. In addition, two grab samples per 9.1 t (10 ton) of product compost leaving the reactor are sent to the WWTP for analysis as a backup to the outside laboratory analysis.

Dry solids are measured in the dewatered sludge, the amendment, the mix as it is loaded into the reactor, and the compost (once during fluffing and again during discharge operations). The facility plans to obtain a micro-

Table 6.3 Compost Composition (Composites taken in period: February 2 to March 31, 1988)

Constituent	Concentration Range	Units[a]	
Total Solids	61-63.4	%	AR
Conductivity of 10% Solution	510-1,080	mhos/cm	—
pH of 10% Solution	6.8-8.5		—
Total Organic Carbon (TOC)	210,000-260,000	mg/kg	AR
Heat Content	4,000-4,532	Btu/lb[b]	"
Total Kjeldahl Nitrogen (TKN)	2,450-2,700	mg/kg	"
Organic - Nitrogen	520-800	"	"
Ammonia - Nitrogen	1,900-2,300	"	"
Nitrate - Nitrogen	0.14-88	"	"
Total - Phosphorus	2.7-4,400	"	"
Calcium	1,800-30,000	"	DW
Potassium	2.0-1,600	"	"
Arsenic	3.7-12	"	"
Cadmium	7.7-11	"	"
Chromium	0.2-54	"	"
Copper	190-230	"	"
Lead	130-160	"	"
Magnesium	470-530 (only two samples)	"	"
Mercury	0.46-0.51	"	"
Molybdenum	14 (only one sample)	"	"
Nickel	18-23	"	"
Selenium	1.0-<1.3	"	"
Zinc	110-900	"	"
Aldrin	<0.01-<0.1	"	AR
Benzene	<5	µg/kg	"
a-NHC	<0.01-<0.1	mg/kg	"
b-BHC	<0.01-<0.1	"	"
d-BHC	<0.01-<0.1	"	"
g-BHC (Lindane)	<0.01-<0.1	mg/kg	AR
Carbon Tetrachloride	<5	µg/kg	"
Chlorodane	<0.01-<0.1	mg/kg	"
Chloroform	4-20	µg/kg	"
Cyanide	1.2-87	mg/kg	"
4,4',-DDD	<0.01-<0.1	"	"
4,4',-DDE	<0.01-<0.1	"	"
4,4',-DDT	<0.01-<0.1	"	"
Dieldrin	<0.01-<0.1	"	"
Endosufan I	<0.01-<0.1	"	"
Endosulfan II	<0.01-<0.1	"	"
Endosulfan Sulfate	<0.01-<0.1	"	"
Endrin	<0.01-<0.1	"	"
Endrin Aldehyde	<0.01-<0.1	mg/kg	AR
Heptachlor	<0.01-<0.1	"	"
Heptachlor Epoxide	<0.1	"	"
Hexachlorobenzene	<4-<15	"	"
Hexachlorobutadiene	<4.5-<14	"	"
PCB 1016	<0.02-<0.2	"	"
PCB 1221	<0.02-<0.2	"	"
PCB 1232	<0.02-<0.2	"	"
PCB 1242	<0.02-<0.2	"	"
PCB 1248	<0.02-<0.2	"	"
PCB 1254	<0.02-<0.2	"	"
PCB 1260	1.7-2.9	"	"
Toxaphene	<0.1-<3	"	"
Trichloroethylene	<5	µg/kg	"
Vinyl Chloride	<5-<10	"	"

[a]DW = dry weight; AR = as received.
[b]Btu/lb × 2.326 = kJ/kg.

wave solids instrument because oven-drying is too slow. The metals content of the WWTP sludge is measured by the city.

6.4.1.5 Data Management

Temperature, oxygen, and porosity data are collected periodically for each batch of compost loaded into a reactor. Data are tabulated on a computerized spreadsheet and are used to decide whether a batch will be used as recycle or as product. The data are also used to diagnose process problems when a "bad" batch of compost is produced.

The data collection and storage methods have been easily understood by the operators, and have greatly aided in diagnosing process problems and in forecasting and maintaining product quality.

6.4.2 Product Quality

Ohio regulations define three classes of compost/sludge for reuse purposes. Table 6.4 shows the allowable uses and associated standards. Akron compost is a Class II product, primarily because it does not always meet the cadmium/zinc standard. The product is of proper quality for landscaping and other non-food chain uses.

No product is sold until after it has been cured/stored for a minimum of 3 months. Also, to enhance the appearance of the product and remove large particles, the product can be run through a shredder before being sold.

6.4.3 Mass Balance and Reactor Detention Time

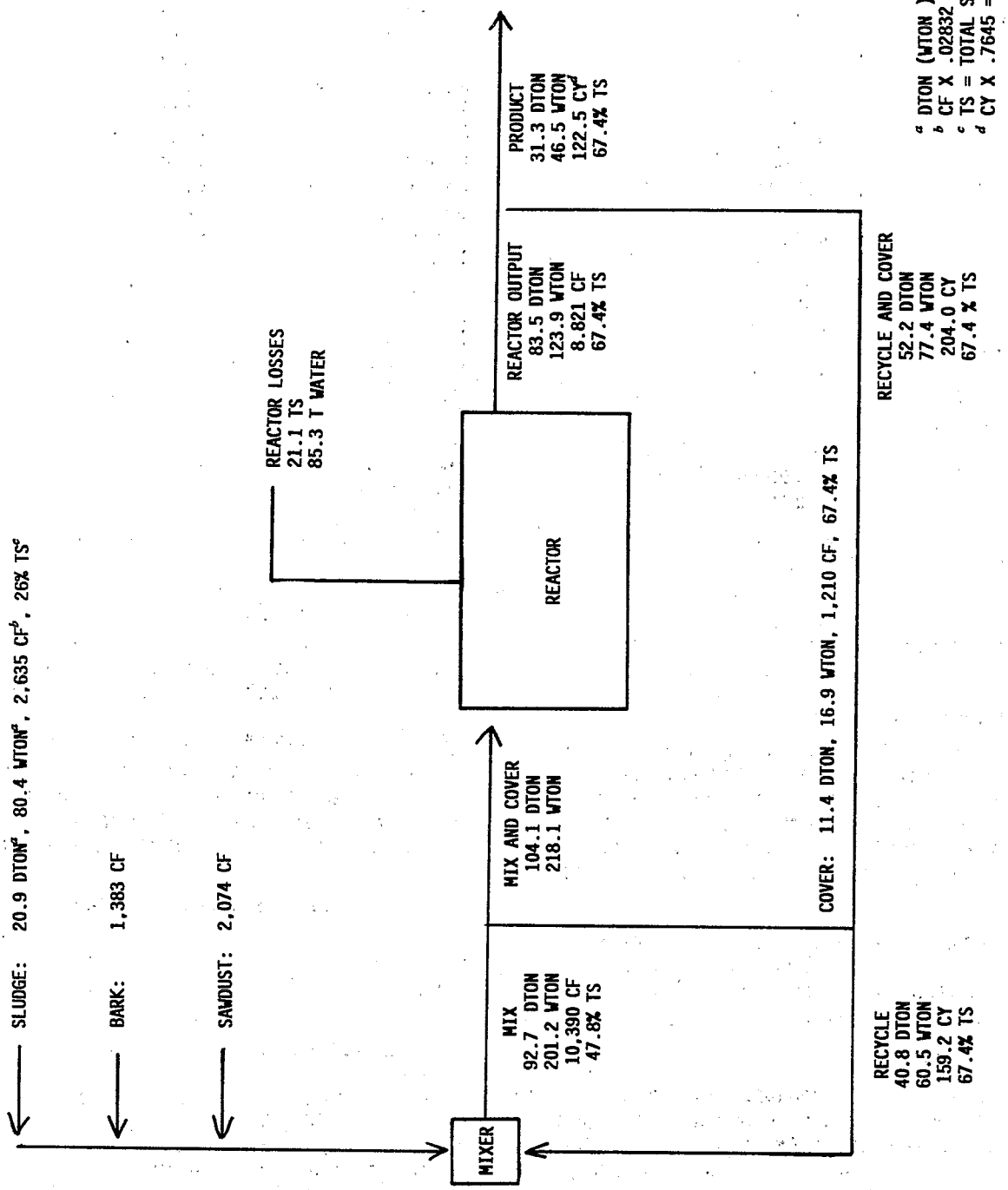
The mass balance for the Akron facility is shown in Figure 6.12. It was constructed based on loading data from February 1 to December 1, 1988, and on the corresponding discharge data from March 14 to December 20, 1988.

Table 6.4 Compost Use Regulations and Standards

Constituent	Compost Sludge Class I[a]	II[b]	III[c]
Cadmium	≤12.5	≤25	>25 mg/kg
Lead	≤500	≤1,000	>1,000 mg/kg
Polychlorinated Biphenyls (PCB)	≤5	≤10	>10 mg/kg
Cadmium/Zinc (ratio)	≤0.015	>0.015	>0.015

[a]Class I: No restrictions on use. Can be applied to food crops.
[b]Class II: Landscaping uses only. Can *not* be applied to food crops. Consumers must be warned of dangers and all sales must be logged.
[c]Class III: Used for landfill or strip mine reclamation only.

Figure 6.12 Akron, Ohio, Mass Balance
Average Daily Quantities, 2/1/88 to 12/1/88 (Based on 7-day/week)



[a] DTON (WTON) X 0.9072 = DT(WT)
[b] CF X .02832 = M^3
[c] TS = TOTAL SOLIDS
[d] CY X .7645 = M^3

The values shown in the figure are the daily averages calculated by dividing the aggregate values for the entire time period by the number of days (305 days between February 1 and December 1, 1988). The batches loaded during February 1 to December 1, 1988, remained in the reactor an average of 23 days with a range of 15 to 44 days.

Based on the values calculated in the mass balance, the reactor detention times and plant capacities at various mix ratios were calculated, as shown in Table 6.5. As indicated by the table, the greater the volume of mix/dt of sludge used, the shorter the detention time at the design capacity or the lower the capacity at the design detention time. Because the effective reactor volume has been decreased by adding a layer of compost on top of the compost bed for odor control, either the ultimate capacity of the plant will be limited or the detention time in the reactors at the design capacity will be shortened.

Table 6.5 Detention Times and Capacities at Various Mix Ratios

	Design Mix Ratio	Current Mix Ratio without Cover[a]	Current Mix Ratio with Cover
Mix volume per dry ton of sludge (ft^3/dton)	378[b]	504	561
Detention time at design capacity of 73 dt sludge/day	21	16	14
Plant capacity at a 21-day detention time (dton sludge/day)	73	55	50

[a]A layer of recycle is placed on top of the compost bed for odor control purposes.
[b]ft^3/dton × .0311 = m^3/dt.

6.5 Operations

6.5.1 Staffing

All staff are employees of the Fairfield Service Company rather than the city. Table 6.6 lists the staff in place at the time of the site visit, including the staff needed to operate the dewatering equipment. The table also includes an estimate of the staffing requirements for operating the plant at design capacity (i.e., a two-shift operation). The table does not reflect contracted services, such as night and weekend guards.

All staff work Monday to Friday. The operations staff works from 6:00 a.m. to 2:30 p.m. and the office staff works from 8:00 a.m. to 4:30 p.m. Sludge is processed four days per week, and the fifth day is used for maintenance and housekeeping.

At the time of the site visit, the general manager had 5 years of experience working at a solid waste and sludge composting facility. The operations manager is certified as a Class IV (highest in Ohio) wastewater treatment plant operator. The lab technician has a B.S. degree in chemistry. Other staff personnel generally have no prior compost or wastewater training. All staff members were trained on the job in both the principles of composting and the operation and maintenance of the equipment. Continuing education is provided on safety issues.

Table 6.6 Staff Requirements[a]

Position	No. Employed During Site Visit	No. Needed for Two-Shift (full capacity) Operation (estimated by manager)
General Manager	1	1
Operations Manager	1	1
Foreman	1	2
Lab Technician	1	1
Accountant	1	1
Secretary	1	1
Dewatering Operator	1	3
Dewatering Utility Worker	1	3
Loader Operator	2	4
Compost Operator	2	3
Maintenance Mechanic	2	3
Maintenance Helper	2	3
Utility Worker	2	4
Total	18	30

[a]The staff are employed by Fairfield. The city employs a full-time site superintendent in addition to the personnel listed above.

The city employs a full-time onsite superintendent to oversee the facility for the city. He is a registered engineer with a background in construction and was closely involved in the plant construction.

The city continues to retain Burgess and Niple, Limited, who at the time of the site visit, operated the odor control pilot facilities and coordinated the technical aspects of the planned M/R grant application.

6.5.2 Marketing and Distribution

The city completed a marketing study that identified topsoil producers and landscapers, including nursery operators, as the major potential users of the compost. Direct use by the general public is not expected, although the public is the end user for many landscaping applications.

In addition to its operating contract, the Fairfield Service Company has a 3-year marketing contract with the city. In the first year of marketing, Fairfield is responsible for product sales and receives all revenues from the sales after marketing expenses are reimbursed. In the second and third years, if revenues exceed marketing costs, the city will receive 75 percent of the profit.

The compost will be priced on a sliding scale, depending on the quantity ordered. For instance, a pickup truck-sized load will cost \$25/m^3 (\$19/cy), with larger orders

receiving lower unit prices. As a goodwill gesture, bagged compost is available to the general public for $1/bag.

As of July 1988, the onsite inventory of product was about 46,000 m^3 (60,000 cy). During the summer of 1988, 8,000 m^3 (10,000 cy) were sold to primary markets and 8,000 m^3 (10,000 cy) were sold to secondary markets.

Revenues generated were not available.

6.5.3 Operating Costs

The total annual operation and maintenance costs estimated in 1984 (postdesign) were $1,944,000, which includes the cost of sludge dewatering.

The individual cost categories are shown in Table 6.7 in both 1984 and 1987 dollars. In 1987, expenditures for the composting process were estimated to be $1,398,000.

Table 6.7 Operations and Maintenance Cost Estimates ($1,000)

	Preconstruction Estimate (73 dton/day sludge processing)[a]		Estimated Actual Expenditures (25 dton/day sludge processing)[a]
	1984 $[c]	1987 $[d]	1987 $[a]
Labor	528	564	390
Power and Fuel	337	360	187
Chemicals and Materials	816	871	318
Maintenance	263	281	50
Contracted Services	0	0	153
Subtotal	1,944	2,075	1,098
Management Fee	0	0	300
Total	1,944	2,075	1,398
$/dry ton	73[f]	78[g]	153

[a]7-day/week basis.
[b]dton/day × .9072 = dt/day.
[c]Includes dewatering.
[d]1984 costs updated by ratio of *Engineering News Record* cost indexes for January 1984 (4109) and June 1987 (4386).
[e]Excludes dewatering.
[f]Based on 73 dt/day, 365 days/year.
[g]Based on 25 dt/day, 365 days/year.

Comparisons of actual with estimated costs are difficult because the current plant budget includes the dewatering operation and the plant is running at only partial capacity. Power costs cannot be isolated to show the amounts spent for aeration, materials handling, and other uses.

Unexpected costs include the additional sawdust needed to dust the cleated conveyors, modifications made to the odor control system and reactor roof fans (to reduce noise), and the design of the plant modifications to provide aerated curing/storage. Cost estimates for these jobs were not available during the site visit.

6.6 Update

As of June 1989, no major changes had been made to the facility or operations since the site visit. The plant processed a total of 7,104 dry metric tons (7,825 dry tons) in 1988, or an average of 19.3 dry metric tons (21.3 dry tons) per day. The actual operating costs shown in Table 6.8 include dewatering costs, which are not kept separately.

Table 6.8 Operating Costs[a] (January 1 through December 31, 1988)

Item	Amount	% of Total
Labor	$ 595,977	29
Utilities	260,275	12
Amendments	410,022	20
Polymer	87,911	4
Other[b]	719,726	35
TOTAL	$2,073,911	

[a]Includes dewatering.
[b]Breakdown of these costs not given.

Akron plans to change the method of conveying sludge from the storage bin to the mixer, where sludge sticking to the existing cleated conveyor is a problem. At the time of the site visit, the plan was to add a sawdust bin to "dust" the conveyor prior to sludge placement. The current plan is to replace the cleated conveyor with a flat belt "pinch" conveyor, and rearrange the sludge feed to the belt to give the conveyor a flatter slope.

The city feels compost marketing is going well; 1989 sales to date already meet 1988's total sales. Also, as a promotion, bags of compost are being sold for one dollar per bag; eight to nine thousand bags were sold "in the past few weeks".

Chapter 7
Cape May, New Jersey

7.1 Introduction

The Cape May County, New Jersey, in-vessel composting plant is owned by the Cape May County Municipal Utilities Authority (CMCMUA). The facility uses a rectangular vertical system supplied by Purac Engineering, Inc. The original design capacity of the facility was 11.0 dt/day (12.1 dton/day), but its maximum capacity has since been increased to 18 dt/day (20 dton/day).

The facility is situated on a 20,000 m^2 (5-acre) fenced-in flat site, bordered by back bay waters leading to the Atlantic Ocean on the east and by a highway on the west. Homes are located on the far side of the highway, with the nearest residence to the plant about 305 m (1,000 ft) away. Some public office buildings are situated on the south side of the facility, and there is an open area to the north. Little room exists for expansion of the facility.

The site visit took place on June 22 and 23, 1988. Except as indicated, the information presented in this case study is representative of that time only.

7.2 History of the Plant

7.2.1 Procurement and Construction

The CMCMUA hired PQA Engineering Company as a consultant to evaluate in-vessel composting technologies and other methods of sludge disposal. The consultant recommended in-vessel, plug-flow composting because that method would allow the operators to have greater control over the composting process, including odor emissions. At the time the decision was made, the plug-flow method was well established in Europe. In addition, in-vessel sludge composting was estimated to cost less per dry ton ($341/dt [$310/dton]) than incinerating the sludge ($400/dt [$400/dton]) or shipping it to Pennsylvania for land application ($881/dt [$800/dt]).

The CMCMUA issued a prequalification RFP to which Taulman-Weiss and Purac both responded. Both submissions were judged to be acceptable, and the consulting engineer designed the Cape May facility based on these two systems. An advertisement was then issued for a construction contractor, from which several bids were received. Because the low bid exceeded the construction cost estimates (see below), the engineer redesigned the facility to lower the estimated costs, as follows:

- Deleted redundant conveyors and blowers, emergency generators, a shredded newspaper amendment system, a fire protection system for the amendment storage area, and an office building, which was to include the laboratory and lockers
- Incorporated additional drag chain conveyors and compound curve configurations into the conveyance system so that it would use less equipment
- Converted an amendment storage silo to open bins
- Reduced storage space
- Simplified instrumentation
- Minimized paving
- Reoriented the reactors to utilize less surface area

According to the chief of operations, some of the design modifications, such as those made to the original instrumentation system, eliminated overly complicated and unnecessary aspects of the system. Other changes, including the addition of drag chains, the minimized paving, and the reorientation of the reactors, have adversely impacted operations, as is described in the following sections.

After redesign, the project was advertised again and an adequately low bid was received from McElwee-Courbis Construction Co. Purac was hired as a subcontractor to the general contractor.

Purac's performance bond was still outstanding at the time of the site visit because the company had not met the amendment guarantee. The recycle, as specified, was not yet available on a regular basis.

7.2.2 Capital Costs

Construction costs were $8.4 million; 95 percent of the costs was paid for by an EPA Innovative/Alternative (I/A) Grant and the State. Approximately $3 million has been spent on modifications.

7.2.3 Operating History and Current Status

Regular operation began on April 29, 1985, and a permanent operating permit was issued in September 1987 by the New Jersey Department of Environmental Protection (DEP). Due to odor control problems and community complaints, the DEP issued a consent order that required the facility to reduce operations to a throughput that would not produce nuisance odors. In August 1986, the reactor exhaust system was redirected to a new two-stage scrubber.

Five fires have occurred at the facility: one in August 1985; three in November 1986; and one in December 1987. The 1985 and 1987 fires were not attributed to the composting process, but to poor fire prevention measures practiced by contractors working on site. The 1986 fires appeared to be caused by spontaneous combustion in the compost (see Section 7.3.4.3). The damage from the last fire in November 1986 put the plant out of operation until June 1987. Smoldering fires continue to occur in the outdoor curing/storage piles.

Several other aspects of the system were modified, including the aeration system, in mid-1987; and the conveyance, reactor, and external curing/storage systems, from the winter of 1987 through April 1988. After the modifications were completed, the facility was restarted in April 1988.

At the time of the site visit, the plant was limited to processing 11 dt/day (12.2 dton/day) of sludge, due to the DEP consent order. Based on the ongoing system modifications and odor control monitoring, the plant is gradually increasing its operating throughput. In general, the plant operates at a peak rate during summer the when it processes 18 dt/day (20 dton/day) of sludge. During the winter, the plant processes sludge at a low rate of 7.3 dt/day (8.0 dton/day).

7.3 Description of the Plant

7.3.1 Systems Overview

Figure 7.1 is a schematic of the Cape May composting facility. The plant is composed of a storage shed for dewatered sludge; storage bins for amendment and recycle; an operations and maintenance building, where the feed is conveyed and mixed in two mixers; a reactor building, which houses the two reactors and blowers; an open-air covered temporary holding area for the material from the reactor; and an uncovered curing/storage area. The sawdust and recycle storage bins are in adjacent bays outside the operations and maintenance building. Odor control scrubbers are outdoors.

Figure 7.2 shows the materials-handling train. Amendment and recycle are pre-mixed on the ground and transported by a front-end loader to an amendment/recycle mixture storage area. The sludge and amendment/recycle are then transported by truck to live-bottom bins in the operations and maintenance building. The materials are then carried via conveyors to the mixers.

In the reactor aeration system, inlet air enters the bottom of the compost mass in the reactor. Exhaust air is drawn from beneath the surface of the upper layer of the material and from the headspace above it. The exhaust air from the reactors is vented into a two-stage odor control scrubber. The operations and maintenance building is ventilated by an exhaust blower that pulls the air through a single-stage scrubber.

The mix is conveyed to the top of one of the reactors (see Figure 7.3). At the bottom of each reactor, a moving outfeed screw conveys material from the second reactor to a series of conveyors, which deposit it in a temporary pile outside the reactor building. A front-end loader moves the material from this pile to either the recycle storage bins or a concrete pad, which serves as the aerated curing/storage area.

7.3.2 Feed and Mix Characteristics

7.3.2.1 Sludge

The composting facility serves four wastewater treatment plants (WWTP) with a combined treatment capacity of 1.4 m^3/s (31 mgd). The treatment train for all of the WWTPs consists of the following stages: primary clarifiers (with about 50 mg/L of ferric chloride added at three of the facilities), rotating biological contactors, secondary clarifiers, gravity thickeners for combined primary and secondary sludges, and belt filter presses. While the sludge is not stabilized at any of these facilities, it must meet State regulations for land application before it can be composted, and metals and organics levels in the sludge must be tested before it can be sent to the composting plant.

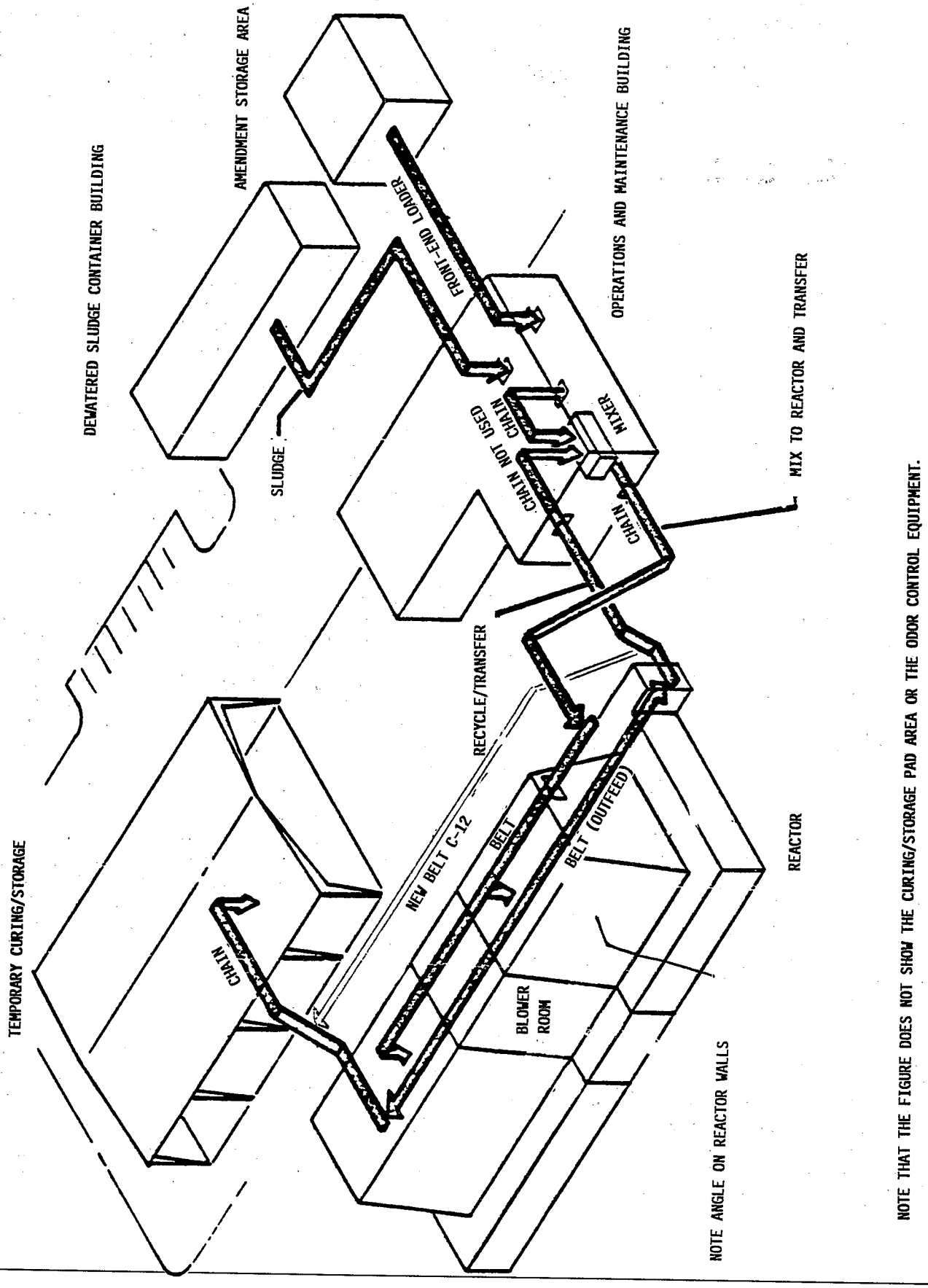
By design, the minimum dry solids content of the sludge cake is 20 percent. The actual dry solids content is 20 to 30 percent (23 percent average). The actual bulk weight is 740 kg/m^3 (46 lb/cf) average; 800 to 960 kg/m^3 (50 to 60 lb/cf), by design. Volatile solids in the sludge cake range from 70 to 80 percent, depending on the plant, the season, and the amount of ferric chloride added to the sludge. The greater the amount of ferric chloride, the lower the volatile solids content in the incoming sludge.

7.3.2.2 Amendment

The facility uses hogged wood waste, which is a very coarse sawdust or very fine woodchip, as amendment. According to the specifications, the shavings must be kiln-dried, the dry solids content must be 50 to 70 percent, and the bulk weight must be 260 to 350 kg/m^3 (16 to 22 lb/cf). The actual dry solids content is 65 to 70 percent, and the actual bulk weight is approximately 264 kg/m^3 (16.5 lb/cf).

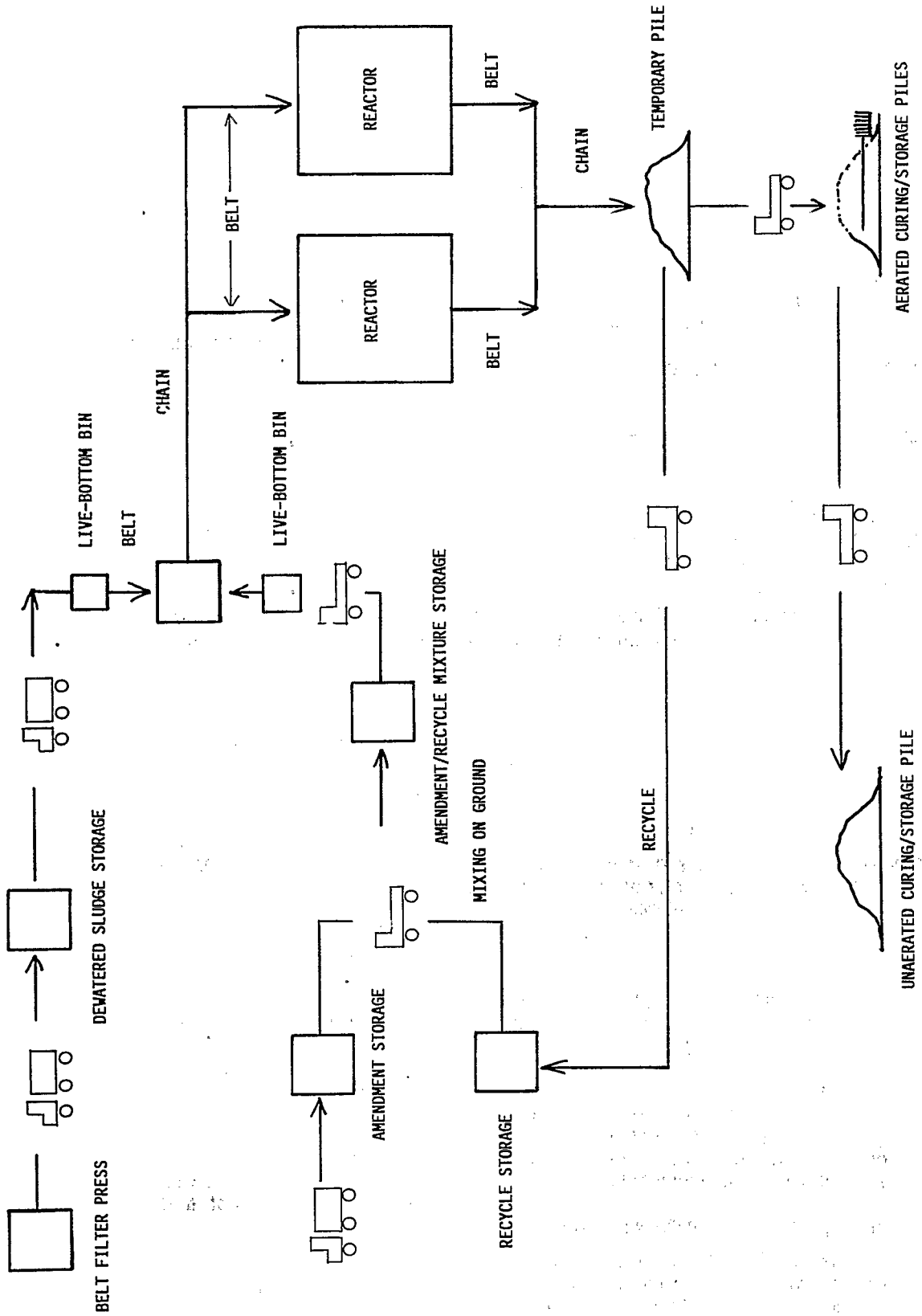
At least 80 percent of the shavings must be larger than 5 mm (5 mesh) and 98 percent must be smaller than 12.5 mm (150 mesh). The operators developed the size specification so that the particles would be large enough to maximize porosity in the mix, but small enough to eliminate the need to screen compost. In the past, wood "flour" in the amendment created a muddy consistency in the mix, which tended to jam the conveyors. Stringy materials such as bark also jammed the conveyors.

Figure 7.1 Cape May, New Jersey, Sludge Composting Process Train



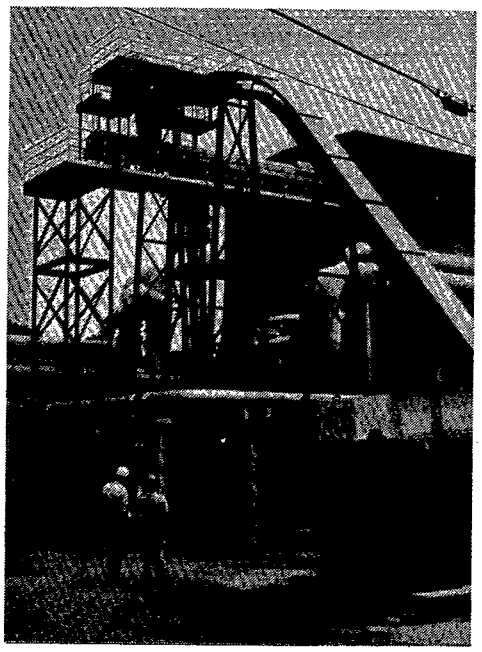
NOTE THAT THE FIGURE DOES NOT SHOW THE CURING/STORAGE PAD AREA OR THE ODOR CONTROL EQUIPMENT.

Figure 7.2 Cape May, New Jersey, Materials Handling System



Changing to a larger particle size in the amendment significantly increased the porosity of the mix and decreased the supply blower back pressures measured across the mass in the reactor (see Section 7.3.4.3). The operator of the facility has had some difficulty obtaining amendment that meets the size specifications, however, because there is no local lumber industry.

Figure 7.3 Drain Chain/Conveyor to Top of Reactor



7.3.2.3 Recycle

The dry solids content of recycle from the reactors is 53 to 65 percent. The bulk weight is 609 kg/m³ (38 lb/cf) (design); 480 to 640 kg/m³ (30 to 40 lb/cf) (actual, depending on the moisture content). Too many fine particles in the recycle create a sticky mix.

7.3.2.4 Mix

The design criteria for the mix is 40 percent dry solids; 705 kg/m³ (44 lb/cf). At the time of the site visit, the operating goal for the mix was 37 percent solids, or 401 kg/m³ (36 lb/cf). The operator wanted to increase the moisture content of the mix to maintain the moisture levels emerging from the reactor because the process appears to be moisture-limited during composting outside the reactor (see Section 7.3.5).

The overall design mix ratio by volume is 1/0.6/1, sludge to sawdust to recycle. Between May 18 and 27, 1988, the actual mix ratios were 1/0.72/0.57 by volume, 1/0.22/0.37 by wet weight, and 1/0.74/0.87 by dry weight. Since that time, a greater amount of recycle has been used. At the time of the site visit, the mix ratio was closer to the design ratio than it was during spring 1988. Table 7.1 summarizes mix properties present on June 22, 1988.

7.3.3 Materials Handling

All phases of the materials-handling process are controlled by computer from a single location. Conveyors are interlocked through the computer, and switches/indicators are located on all discharge chutes.

The sludge is delivered in 15 m³ (20-cy) roll-off containers, which are then stored in an enclosed loading dock designed to hold a maximum of six containers. Sludge is usually stored for less than 1 day. The containers are slid off the truck into the sludge bays, accessed through metal "garage" doors.

Table 7.1 Properties and Ratios of Sludge and Amendments (Based on mix sample, June 22, 1988)

	Wet lb/min	% Solids (input for batch materials)	Density (lb/cf)	Volume Ratio
Sludge	218[a]	24	52[b]	*1[c]*
Amendment/Recycle Mixture	*160*	63	24	*1.6*
Water[d]	40			*0.15*
Mix	418	37	36	

[a]lb/min × 7.56 10⁻³ = kg/s
[b]lb/cf × 16.02 = kg/m³
[c]Underlined values are those set by the operator.
[d]Water is added at the mixers.

A roll-off truck also dumps the sludge from the 15 m³ (20-cy) roll-off containers into a 51 m³ (1,800-cf) live-bottom bin containing six bottom screws and one collector screw. The screws then direct the sludge to a flat belt conveyor.

Amendment and recycle are stored in covered concrete bins that are open on one side so that the material can be moved with a front-end loader.

The recycle and amendment are pre-mixed on the ground with a front-end loader. The mixture is measured volumetrically by counting the "buckets" of recycle and amendment in the mixture. The solids content is measured before the material is fed into the system (see below).

The amendment/recycle mixture is dumped into and stored in a live-bottom bin located in a bay adjacent to the sludge bins and is accessed through a garage door. A vibrating screen was installed over the opening of the bin to remove large (0.03 to .04 m [1 to 1.5 in.]) chunks and trash and protect the equipment downstream of the bins. The bin contains four bottom screws and one cross collector screw.

The outfeed from the amendment/recycle mixture and sludge storage bins passes a weigh belt and the data are fed into the computer, which controls the feed rates. The amendment/recycle mixture feed rate is usually held constant; the sludge feed rate is varied.

The outfeed from each bin falls onto a separate flat belt conveyor housed in the basement of the operations and maintenance building. The belt conveyors feed drag chain conveyors that lead to the mixers on the ground floor of the building.

By design, the feed materials drop into the two mixers through sliding plate doors located in the housing of the conveyor. There is a separate door for each mixer. The

original intent was to use the mixers on an alternating basis. Because some of the mix sticks to the drag chain flights and does not completely discharge in one pass across an open door, however, both conveyor doors must be opened, requiring that both mixers operate at the same time. If both mixers are not run, feed materials that stick to the flights could accumulate in the drag chain housing and jam the conveyor. With the modified arrangement, about 90 percent of the feed materials are processed by one mixer and 10 percent by the other. The solids content of the mix is checked manually every 30 minutes during loading.

The two .01442 m^3/s (1,833 cf/hr) pugmill mixers contain interlocking paddles. Water is almost always added directly into the mixers to create the proper solids content. However, the mix sometimes becomes sticky when water is added, which can plug the chutes. To keep the mixer discharge chute clear, 58 of the original 116 mixer paddles were removed and the 58 remaining paddles were replaced with more effective custom paddles.

7.3.4 Reactors

7.3.4.1 Reactor Feed System

The mixers feed a drag chain conveyor that leads to the top of the reactors. The specifications called for a "positive-displacement" drag chain, which requires close tolerances between the flights and the housing of the chain. These close tolerances were created by building the system with a narrow flight housing for the feed side of the chain and a wide housing for the return side. (Customarily, the wide housing covers the feed side of the chain and the narrow housing covers the return side. The close tolerances and the absence of "wear bars" for the flights to rest on, however, have caused abrasion of the flights and the housing.

Another problem with the drag chain is that the mix can compact into dense masses capable of bending back the steel flights, and causing them to jam in the chain housing. The flights have been made smaller, but they still require extensive maintenance (1.5 people full-time) and about $100,000 per year to replace broken chains, flights, and worn housings.

The drag chain leads to a flat belt conveyor that runs along the length of the reactors. The flat belt conveyor drops the mix into a tripper car that contains another flat belt and movable plows. The car moves along the length of the top of the reactor, while the plows move across its width, so that all the material is pushed off the belt. Although the intent is to provide an even bed, the mix is not deposited evenly near the reactor walls; the depth of the bed near the walls is not as deep as in the middle of the reactor.

7.3.4.2 Configuration

In the original design, the reactors were operated in series. To increase the capacity of the facility to 18 dt/day (20 dton/day), the reactors were converted to parallel operation. By design, the original second reactor is a smaller version of the first reactor, with a volume of 850 m^3 (30,000 cf) as opposed to 1,050 m^3 (37,200 cf). They share the same infeed device, have identical outfeed conveyance systems, and have a composting mass height of 8.0 m (26 ft) (see Figure 7.4).

The walls of each reactor slope slightly outward from top to bottom (see Figure 7.1). The design intent was to prevent bridging of the compost. However, as the compost moves down through the reactor, it shrinks and separates from the walls, creating potential paths for the short-circuiting of the aeration system (see Section 7.3.4.3). Galvanized angles 0.2 by 0.2 by 0.01 m (8 by 8 by 0.5 in.) were bolted to the walls of the reactors to redirect the flow of air through the compost.

7.3.4.3 Reactor Aeration System

The aeration system has undergone two major modifications: the reactor exhaust was separated from the mixing building ventilation system and directed to a new two-stage scrubber; and additional supply and exhaust blowers, a headspace ventilation system, and the curing/storage pile aeration system were installed (see Section 7.3.6). Figure 7.5 shows the original and the modified systems.

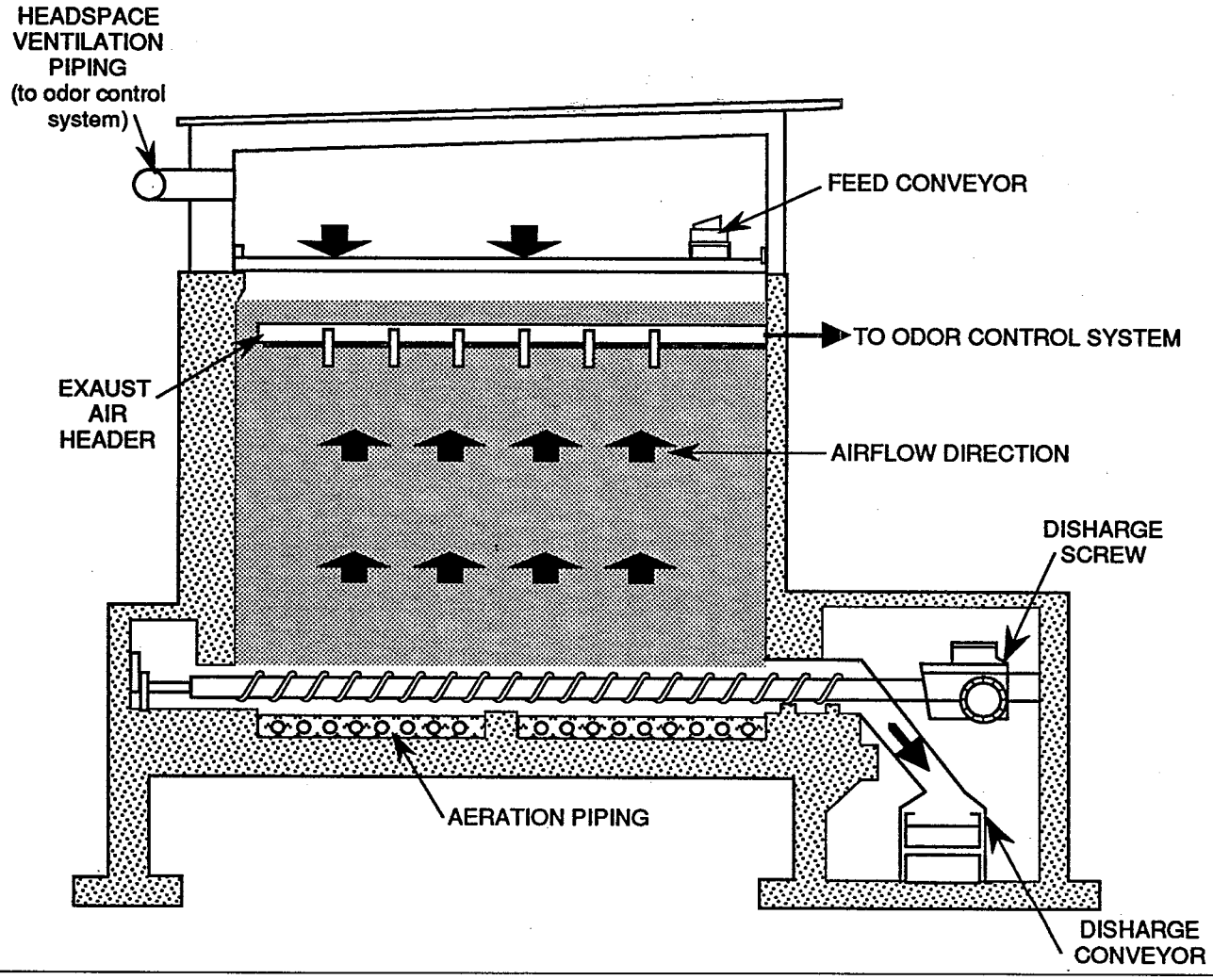
The modified aeration system uses 11 blowers: 5 to supply air to the bottom of the reactors, 5 to exhaust the air from beneath the surface at the top of the reactors, and 1 to exhaust air from the reactor headspace. Blower capacities are summarized in Table 7.2. The plant operates with a total back pressure of less than 6,897 Pa (1 psi) (3,448 Pa [0.5 psi] through the compost).

Each reactor contains three header pipes situated 2.8 m (9 ft) apart on the bottom of the reactor. Each header pipe has twenty-two 0.5-m (2-in.) PVC diffusers centered in a bed of gravel 0.838 m (2.75 ft) thick. The configuration creates three vertical aeration zones in each reactor. One valve per header pipe in the smaller reactor and two valves per header pipe in the larger reactor regulate the amount and rate of flow of air into each reactor.

A 0.6-m (2-ft) layer of wood chips lies above the gravel and beneath the compost and outfeed screw. The thickness of the chips was chosen to prevent creating a hardpan in the bottom of the reactor. Masonry walls 0.15 m (6-in.) thick separate the three aeration sections.

On one occasion during the first year of operation, a hardpan formed on top of the gravel layer. Aeration tests showed that air did not penetrate this layer, and picks and shovels were required to remove it. In addition, portions of the gravel layer were glued together by dried leachate. This layer did not allow passage of air either. The gravel layer was cleaned by filling it with caustic soda and turning on the aeration system for agitation. The problem has not recurred. The operators believe that leachate production is caused by improper aeration of the composting mass, and the modifications that have been made to ensure proper aeration have prevented the problem.

Figure 7.4 Purac Reactor, Cape May



Carbon steel air supply lines were originally installed. Due to corrosion, newly installed additional supply lines are stainless steel. The original exhaust piping was made of .05-m (2-in.) fiberglass, but these pipes broke, apparently because the flow of compost twisted them. Flexible joints, 0.15 m (6 in.) stainless steel stove pipes, and wire reinforced rubber hose replaced the broken exhaust pipes. At the time of the site visit, the facility planned to replace the exhaust piping once again, this time with 0.3-m (10-in.) stainless steel or galvanized pipes, and to build a sturdier support system.

In November 1986, when the reactors were still run in series, three fires occurred in the reactors. Two smoldering fires occurred in the bottom of the second reactor on November 6 and 7. Although the actual cause of the fires is not known, spontaneous combustion apparently took place in the compost.

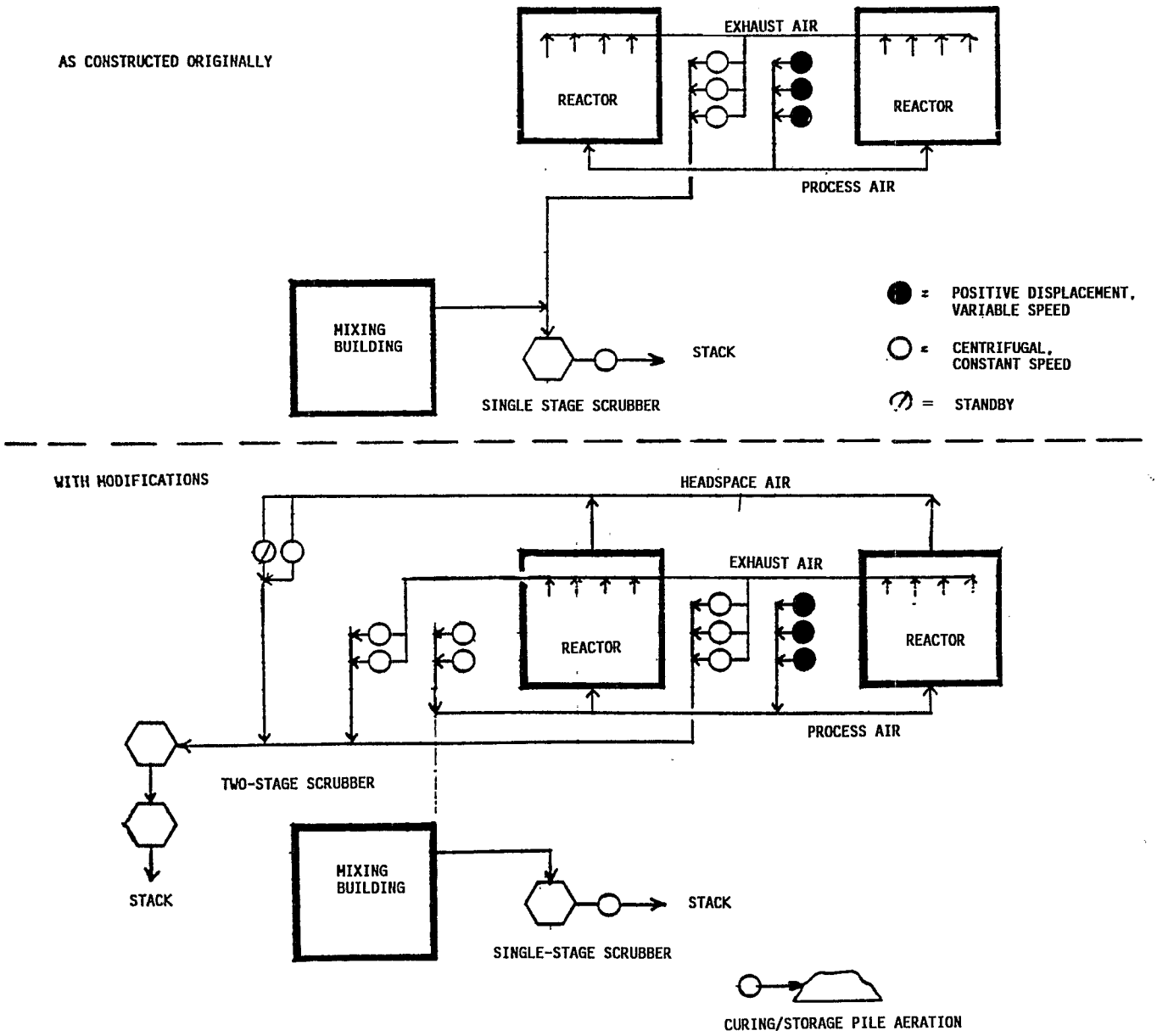
The fires caused moderate physical damage, including spalling of the concrete walls of the reactor. The fires were extinguished by emptying the reactor and thinly spreading out the hot material to allow it to cool.

A fire in the first reactor started several weeks later. There is disagreement over the specific cause of the fire, but overly long storage of material in the reactors lead to excessive drying, which was a contributing factor. The fire flared out the top of the reactor, causing extensive damage to the flat conveyor belt, the tripper car-conveyor, the movable plow, and the metal roof. The fire department was called in to extinguish the fire.

After the fire, a number of modifications were made to the system and new procedures were instituted, as follows:

- Compost will not remain in the reactor for an excessive amount of time (i.e., the reactor is no longer used to store compost).
- The mix is kept as wet as possible, consistent with proper materials handling and product quality.

Figure 7.5 Aeration and Ventilation Schematic



- Heat detectors and a sprinkler system were installed in the headspace area, firefighting hoses and standpipes were installed throughout the reactor building, and heat sensors were installed in the outfeed device tunnel. As a secondary means of fire protection, a high temperature 85°C (185°F) alarm was programmed into the computer.
- Equipment in the headspace, including the flat belt conveyors, was retrofit with fire-resistant material. To prevent potential fire damage, the tripper car is now stored over the blower room when not in use, rather than over the reactors.
- The materials-handling system now provides for material to be moved, if necessary, under any foreseeable circumstance and to avoid a situation where material must be stored in the reactor.
- State DEP approval of the compost distribution program eliminated the need to store large quantities of material on site.

7.3.4.4 Outfeed Device

The outfeed device, identical for both reactors, is a moving screw contained in a tunnel beneath the compost mass, which deposits the reactor product onto a belt conveyor. The screw is hard-surfaced with Triten steel. The taper and the size of the flights on the screw and the rotational and advance speeds of the outfeed device were selected to optimize the outfeed rate and volume.

Table 7.2 Blower Capacities

	Initial Construction				Units Now in Place			
	Number	cfm	Pressure	Horsepower	Number	cfm	Pressure	Horsepower
Supply to reactor	3	1,500[c]	6.7 psi[d]	75[e]	3 2	1,500 6,000	6.7 psi 4 psi	75 200
Exhaust from reactors[a]	3	2,000	10 in. W.C.[b]	20	3 2	2,000 7,000	10 in. W.C. 2 psi	20 150
Exhaust from headspace[a]	None				2 (1 is a standby)	9,000		
Exhaust from container building	1	3,500			1	3,500		

[a]Total exhaust from reactors and headspace is limited to 20,000 cfm by the capacity of the odor control scrubbers and other piping.
[b]W.C. = water column.
[c]cfm × 4.719 × 10^{-4} = m^3/s
[d]psi × 6,895 = Pa
[e]hp × 745.7 = W

An electronic control unit that senses pressure on the outfeed carriage and the torque of the screw automatically slow the speed of the carriage if preset limits are reached.

7.3.4.5 Leachate and Condensate

Leachate drains at the bottom of the reactors are connected to drip traps and a 6,250 L (1,650 gal) storage tank, which is pumped out periodically. Very little, if any, leachate is generated under current operations. A 1,140 L (300 gal) receiving tank at the suction end of the new exhaust blowers controls the accumulation of condensate in nonoperating blowers. The estimated volume of condensate is about 380 L/day (100 gal/day). Condensate is mixed with the leachate, sanitary waste, and scrubber blowdown water, all of which is pumped to the adjacent WWTP. The scrubber blowdown water and runoff from the curing/storage pad (see Section 7.3.5) are the major sources of wastewater.

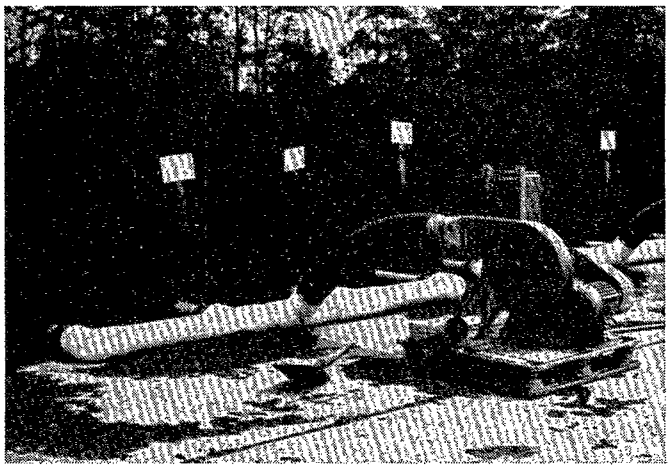
7.3.5 Exterior Curing/Storage

The plant was modified so that curing/storage takes place outside of the reactors in aerated piles. To accomplish this, the material on the outfeed belt conveyor is now transferred to a chain conveyor that deposits the material in a temporary covered holding area outdoors. A front-end loader or dump truck then moves the material to either the recycle storage area or an uncovered concrete pad where curing/storage takes place.

The working area of the uncovered pad is 49 by 110 m (160 by 360 ft). The dimensions of the extended piles are 14 m wide by 2 m high by 6 m long (47 by 6 by 150 ft) each. The area holds 90 days worth of unaerated product at summer (high) production plus 30 days of aerated curing/storage.

Each pile is aerated with an independently controlled centrifugal, positive-flow blower that has a 0.03 m^3/s (600 cfm) at 0.2 m (7 in.) water column (W.C.) capacity (see Figure 7.6). PVC piping is used for the four main header pipes in each pile; lateral pipes are polyethylene 0.1 m (4-in.) in diameter with two rows of perforations. These holes are 0.006 m (0.25 in.) in diameter on 0.15 m (6-in.) centers. There are no holes in the first 2 m (6 ft) of the lateral pipes.

Figure 7.6 Aerated Static Curing/Storage Pile



Thermocouples are buried in newly created aerated piles to measure temperature once per day. The goal is to maintain the temperature at between 45° and 50°C (113° and 131°F) by adjusting the blower operating schedule. The piles are aerated continuously for the first 1 to 3 days and intermittently thereafter (by an electric timer) for the duration of the 30-day minimum curing/storage time required by the permit. Aerated piles are not agitated, but unaerated piles are turned on a weekly basis.

The area is surrounded by a 9 m (30 ft) wide asphalt apron. Both the apron and the concrete pad are sloped 3 percent for drainage. The drainage is channeled to a holding pond that is periodically pumped to the adjacent treatment plant.

One fire occurred at the end of a curing/storage pile and smoldering fires occasionally occur. When the material gets too dry, the biological reactions stop. Rain on the pile can then restart the biological reactions without wetting the material enough to prevent combustion. A consultant recommended monitoring the moisture content in the piles and changing the aeration pipe configuration so that the perforated pipe extends the full length of the pile rather than stopping 2.4 to 3 m (8 to 10 ft) from the end.

7.3.6 Nonprocess Air Handling

The headspace of the reactors was originally vented by louvers only. In the modified system, ventilation of the

process building is part of the odor control system (see Section 7.3.7). Table 7.2 shows the size of the blowers used for ventilation.

Fogging in the headspace has been reduced by the new ventilation system but not completely eliminated during cool, damp days. A consultant to the CMCMUA suggested supplementing the capacity with an additional 4 m^3/s (9,000 cfm) blower capacity, to be used only when needed. Odor control for this intermittently operated system would be provided by a compost filter. Exhausts from the sludge container building and mixing building are also collected for treatment.

7.3.7 Odor

The plant began operating with two odor control systems: one system handled the exhaust from the reactors and the operations and maintenance building, while the other processed the exhaust from the sludge container building. Sodium hypochlorite was the only chemical used in both scrubbers. Reactor headspace air was vented directly into the atmosphere.

7.3.7.1 Odor Complaints

From the start of operations, individuals residing west of the plant complained about the odors. All confirmed complaints have been received when the winds were from the east and southeast.

As a result of the complaints, the DEP negotiated an administrative consent order with the CMCMUA. To comply, the plant had to shut down operations, modify its odor control equipment to eliminate the nuisance conditions (see Section 7.3.7.3), and then reinitiate operations in stages. At each level of increasing production, the facility must prove it can operate without producing nuisance odors before it is allowed to increase capacity. State and local evaluation teams judge the plant's performance.

7.3.7.2 Odor Sources and Characterization

The CMCMUA hired Roy F. Weston, Inc. to conduct three odor control studies, which investigated complaints, identified and characterized odor sources, measured air quality, conducted air dispersion modeling, and evaluated the newly installed equipment. The studies took place in September 1985, and in August and September, 1987.

The studies found that the major odors detected were from sulfur and nitrogen compounds. Analysis of the odor complaints identified the following sources:

- Air that escapes through the open doors of the sludge storage area and mixing building
- Sludge exposed to the atmosphere during transport
- Spilled sludge
- An overloaded single-stage scrubber that treats the reactor and operations and maintenance building
- Reactor headspace air
- Sodium hypochlorite that escapes from the scrubber stack
- Material from the reactors, exposed in transport from the outfeed area to the recycle storage bins, or while mixing with the amendment
- Compost piles that are incompletely stabilized in the reactors (identified before the exterior aerated curing/storage system was installed). (See Section 7.3.5.)
- Hydrogen sulfide that escapes from the mixers

During the site visit, a slightly "musty" odor was detected when curing/storage piles were opened. These odors were not detected off site. A "burnt" odor was noticed whenever recycle was handled, i.e., mixed with sawdust, loaded into the amendment/recycle mixture feed bin, loaded onto a truck for transport to the curing/storage area, etc. It is not known if this odor was detectable off site. Subsequent to the site visit, operators reported that the "burnt" odor disappeared after all the "old" compost was removed from the facility.

At the Cape May facility, unaerated curing/storage results in anaerobic pile centers and odor production, even after compost has met the regulatory requirements for time and temperature following 14 days in the reactors. In general, when the compost is properly conditioned in the reactors (i.e., correct detention time, aerobic conditions, proper temperatures), aerated curing/storage does not appear to be malodorous.

7.3.7.3 Odor Treatment

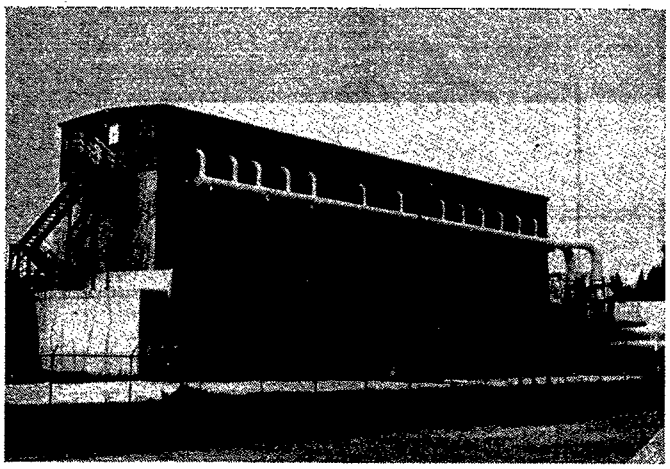
In summer, approximately 50 to 75 ppm of ferric chloride is added to the influent at the WWTPs to aid primary sedimentation. This has the additional benefit of greatly reducing the sulfides in the raw sludge. During the non-summer months, Chi-X is added to the mixer water to control odors emanating from sludge in the mixing area. The modifications to the reactor aeration system (see Section 7.3.4.3) included changes to the odor treatment system (see Figure 7.5). Three independent scrubber systems are used to treat exhaust from the sludge container building, the operations and maintenance building, and the reactor and headspace.

Exhaust from the sludge container building is drawn through a single-stage wet scrubber containing a solution of sodium hypochlorite and sodium hydroxide. Nonprocess air from the operations and maintenance building, including the sawdust room, sludge room, mixer, and basement, is treated in a single-stage scrubber with sodium hypochlorite and sodium hydroxide. This

scrubber system originally treated the air from the reactor, as well as from the operations and maintenance building.

With the modified system, all the louvers that originally vented the reactor headspace air, except for one on the west end of the building, have been closed; the reactor and headspace exhausts (see Figure 7.7) are now treated with a condenser and a two-stage scrubber. The scrubbing chemicals are sodium hydroxide and sodium hypochlorite in the first stage, and sulfuric acid in the second stage.

Figure 7.7 Reactor Building Showing Headspace Exhaust System



7.3.7.4 Odor Control Monitoring and Performance

Sampling ports have been installed at several locations in the odor control treatment train so that the operator can spot check the odor levels by sniffing. In addition, detailed checklists of system operations are completed each day and in the event of an odor complaint.

Odor control consultants judged that the removal efficiencies for sulfur and nitrogen compounds from the two-stage reactor scrubber were sufficient to avoid affecting neighbors. Removal efficiencies for organic compounds were not as successful, but these compounds are not considered to be major causes of odor. When the odor control consultants conducted their sampling, sulfuric acid was used in the first stage and sodium hypochlorite with sodium hydroxide was used in the second stage. During subsequent experimentation by the operator, the reverse sequence (sodium hypochlorite and sodium hydroxide in the first stage and sulfuric acid [pH of 4] in the second stage) was judged to be more effective in controlling odors. At the time of the site visit, the operator was investigating techniques to increase the efficiency of the system, including using soil or compost biofilters as polishing devices, refrigerating part of the system to condense organics, and/or adding surfactants to increase the solubility of organics.

Table 7.3 shows the results of a test that measured the odors emitted from the first reactor, mixing building, and sludge storage building scrubbers. Dispersion modeling tests were also conducted to estimate the maximum 1-hour ground-level concentrations of a number of compounds and their distances from the two-stage odor scrubber stack. The results indicated that the maximum impact of the modified system occurs 270 m (870 ft) away from the stack and that no odors exist at the property boundary.

During the site visit, odors from the treated airstreams were not detectable when the plant operated at reduced capacity. The operators expected to receive approval to increase the loading rate at that time, but odor complaints were still being received. According to a monitoring team's followup reports, the odors were mostly transitory and not very strong. Since the odor control system has been modified and odors reduced, some question exists as to whether the complaint-causing odors originated from the composting plant or the adjacent WWTP.

7.3.8 Support Facilities

The primary support facilities are the laboratory area located in the mixing building and two trailers, which were added after construction and serve as the office for the supervisor and operators, a meeting room, and a lunchroom. The clerk's office is located in the maintenance building, which consists of a two-bay garage space and a storage area for spare parts. Spare parts are also stored in two old tractor-trailers parked on the edge of the site. A shower, located in the operations and maintenance building, serves the whole facility.

7.4 Monitoring and Performance

7.4.1 Reactor Control Strategy

7.4.1.1 Temperature Monitoring and Control

The facility aims to attain the EPA pathogen-reduction temperature criterion of 55°C (131°F) for 3 consecutive days.

Temperatures are recorded at different depths using different length stainless steel probes that are sealed on the bottom. Each of the three vertical zones, created by the aeration system pipes, contains five temperature probes. A thermistor (electronic temperature measuring device) sits in a pool of glycerine in each probe.

7.4.1.2 Aeration Quantities and Rates

The quantity of air fed to the reactor is modulated by blower output and the air feed valve schedule. The blower speed (for positive displacement blowers) or suction valves (for centrifugal blowers) is automatically regulated to maintain about a 58°C (136°F) average temperature in the area 2 to 4 m (6 to 12 ft) down from the top surface of the compost. This is the so-called "hot

Table 7.3 Air Quality Measurements and Scrubber Removal Efficiencies (Data taken from September, 1987, odor control report prepared by Roy F. Weston, Inc.)[a]

	Reactor Scrubber (two-stage)			Mixing Building Scrubber (one-stage)			Sludge Storage Building Scrubber (one-stage)		
Constituent (ppm/v)	In	Out	Removed %	In	Out	Removed %	In	Out	Removed %
Total Reduced Sulfur, S	8.4	0.38	96	9.6	>0.11	>99[b]	0.88	0.11	88
Total Nitrogen, N	11.7	0.06	99	0.27	0.13	52	0.43	0.05	88
Ammonia, NH_3	10.2	0.04	>99	0.27	<0.04	>85	0.42	<0.04	>90
Total Aldehydes	25.0	12.4	50	—[c]	—	—	—	—	—
Total Volatile Organics	>2.387[d] >3.443[e]	>3.212 >2.171	—	>3.357 >0.694	>2.073 >0.207	—	0.377 0.21	0.135 0.054	64 74

[a]Single tests were conducted for all but the volatile organics for which duplicate tests were conducted. Individual organic compounds reported include acetone, chloroform, 1,2-dichloroethane, toluene, xylene, 1,2-dichlorobenzene, trichlorofluoromethane, dimethyl disulfide, C9/C10 hydrocarbons, aldehydes, methylene chloride, acetone, carbon disulfide, 2-butanone, 1,1,1-trichloroethane, styrene, C4/C5 hydrocarbons.
[b]Test results reported as ">" indicate tests where the mass spectrometer detector response capabilities were exceeded.
[c]"—" indicates that no data were analyzed for these chemicals.
[d]Measurements on first line taken while mixing an "odorous" sludge.
[e]Measurements on second line taken while mixing a "normal" sludge.

zone" in the Cape May reactors. The average temperature of each aeration section controls the valve schedule, with the valves opened for a minimum of 5 minutes out of each 15-minute cycle. Aeration to each zone is set in proportion to the amount the average temperature in the zone is cooler than the hottest zone. The valves in the hottest zone are open the full 15 minutes of each cycle.

The total air fed to each reactor is measured and recorded daily. In addition, the computer displays all temperatures in the reactor every 30 minutes. Although the frequency of the temperature readings controls temperatures to a relatively close tolerance, the bed does not always appear to meet the EPA time-temperature criterion. But, in general, the reactor produces a compost that meets the criterion and has an acceptably low moisture content (see Section 7.4.3).

7.4.1.3 Other Tests and Equipment

Carbon dioxide (CO2) is continuously measured in the exhaust gas and recorded once per day. Based on low CO2 values, the air needed for cooling is significantly greater than the amount of air needed for biological reactions.

A solids test was developed on site using a kitchen microwave oven calibrated against the Standard Method. Operators prefer using the kitchen microwave oven over a microwave unit engineered for WWTP operations because the kitchen oven is less expensive and can handle larger samples.

Testing for chlorine residuals and pH in the scrubbers and screening the particle-size of wood shavings are also done on site. Metals are tested in the aerated piles by taking three grab samples per pile. A monthly composite is then made from the samples. The composite is sent to an independent laboratory for analysis.

7.4.1.4 Data Management

The computer monitors the temperature probes and is capable of printing out either instantaneous or 24-hr average temperature reports. Outfeed batch quantities are also printed out. Characteristics of each batch of mix are printed out by the computer after the batch is fed into the reactors. The operators keep this information in a computerized data base.

The data are used to determine if a particular batch will be used as recycle or sent to curing/storage. A batch will be used as recycle if its temperature exceeds 75°C (167°F) (the in-house criterion for a "bad" batch), or if it does not reach 55°C (131°F) for 3 days (the EPA pathogen-reduction criterion).

The amount of sludge processed and the data on metals content are reported to the State on a regular basis as a condition of the permit. Temperature profiles are maintained as proof of significant pathogen reduction.

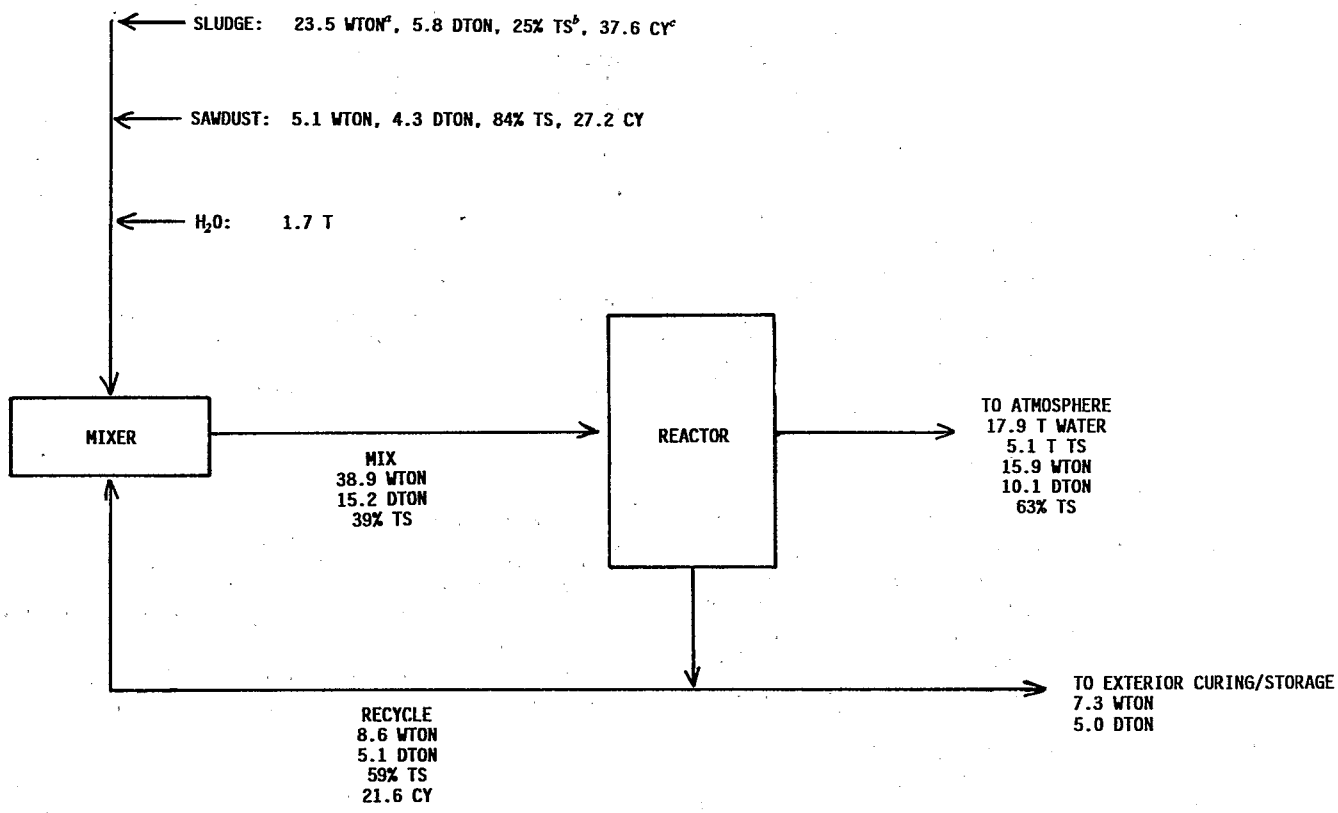
7.4.2 Mass Balance and Reactor Detention Time

A mass balance for the plant during May 16 to 27, 1988, is illustrated in Figure 7.8.

As specified in the operating permit, the minimum plug-flow detention time in the reactors is 14 days. The actual plug-flow detention time, based on the bulk weight of the mix and the total feed volume, is estimated to be 17 days when using both reactors at 18 dt/day (20 dton/day). The operator believes that 9 to 10 days would probably produce a material acceptable for aerated curing/storage. Based on the loading rate at the time of the site visit, when only the larger reactor was used, the plug-flow detention time was 17 days.

At the time of the site visit, the detention time in the reactor was not sufficient to stabilize the compost so that it could be cured/stored without aeration.

Figure 7.8 Cape May, New Jersey, Mass Balance Average Daily Quantities, May 16 to 27, 1988



[a] WTON (DTON) X 0.9072 = WT(DT)
[b] TS = TOTAL SOLIDS
[c] CY X .765 = M^3

7.4.3 Product Quality

Project specifications require that the finished compost have the following characteristics:

- Brown color
- Medium coarse to fine texture
- Friable
- Maximum of 10-mm particle size
- Minimum solids content of 40 percent
- Minimum volatile solids reduction of 40 percent
- Maximum of two odor units (ASTM D-1391-1978)

The product produced at the time of the site visit met color, texture, solids content, and volatile solids reduction specifications. It did not, however, meet the maximum particle-size criterion because of the kind of sawdust used. (The ASTM odor specification applies to gases and has no provision for odors from solid materials; therefore, it cannot be applied to the compost.) At full capacity, the plant should produce about 5,700 m^3/year (7,500 cy/year) (2,700 to 3,600 dt/year [3,000 to 4,000 dton/year]) of product.

Salmonella testing, conducted during plant startup, showed that pathogens were significantly reduced as long as the average "hot zone" temperature was greater than 55°C (131°F). After 2.5 years of testing, the DEP now accepts average "hot zone" temperatures as demonstration that the process meets EPA's criteria for PFRP (Process to Further Reduce Pathogens).

Testing for metals is done by an outside laboratory. Table 7.4 lists the metals content of a sample pile, along with the New Jersey criteria for metals in sludge.

New Jersey State restrictions on the use of the compost are as follows:

- No sludge-derived product can be used on food crops.
- Distribution to homeowners or the general public is prohibited without DEP approval (see Section 7.5.2).
- Compost cannot be applied during the winter (mid November through March 1).

Thirty dt/year/acre or less can be applied to nonfood crops if the nitrogen requirement of the crop and the metals-loading criteria are less than the levels listed in "State Guidelines for Land Application of Residuals" or Federal Regulations 30 CFR, Part 257, Sec 257.3-5. Any application greater than 27 dt/year/acre (30 dton/year/acre) or 45 dt/acre (50 dton/acre) over the life of the site requires a DEP permit. In addition, any project utilizing more than 100 cy of compost requires a permit.

Table 7.4 Heavy Metals Content After Curing (ppm, dry weight basis)

Metal	Minimum	Maximum	Average	NJDEP[a] Sludge Quality Criteria for Land Application
Arsenic, As	0.5	9.4	2.5	10
Cadmium, Cd	0.6	7.6	3.0	40
Chromium, Cr	11.0	257.0	89.7	1,000
Copper, Cu	155.7	870.0	416.0	1,200
Lead, Pb	22.9	160.0	97.9	4,800
Mercury, Hg	0.2	3.5	1.7	10
Nickel, Ni	6.2	45.0	16.8	1,250
Zinc, Zn	190.9	1,030.0	743.1	2,400

[a]New Jersey Department of Environmental Protection.

7.5 Operations

7.5.1 Staffing

Fourteen people are employed year-round by the Cape May facility:

- 1 superintendent
- 1 foreman
- 2 operators
- 6 utility people
- 1 mechanic
- 1 assistant mechanic
- 1 electrician
- 1 clerk

In addition, there are five summer employees.

At the time of the site visit, the supervisor had just been promoted from the foreman position. (Promotions are generally made from within the organization.)

He had worked at the plant for 1.5 years, but had no prior experience in composting or wastewater treatment operations. The two operators were studying for the entry level WWTP operator State certification; there is no compost handling certification in New Jersey.

The system supplier provided "hands-on" training during startup. In addition, the previous supervisor initiated monthly training meetings that covered both composting theory and operations. These monthly meetings were still being held at the time of the site visit. The plant electrician received special training on the use and maintenance of the computer system. In addition, the staff are trained to operate all phases of the system, although each operator is generally assigned to operate the same equipment on a regular basis.

The plant is operated 5 days per week according to the following schedule:

Maintenance shift	— 5:00 a.m. to 1:30 p.m.
Operations I	— 11:00 a.m. to 7:30 p.m.
Operations II	— 7:00 p.m. to 3:00 a.m.
Supervisory personnel	— 7:00 a.m. to 3:30 p.m.

The maintenance shift operates during the day so that the staff can procure supplies and parts. Mixing and loading operations are done at night to minimize odor complaints and avoid interruptions due to daytime activities such as maintenance or construction. The shifts overlap to maintain continuity of operations. The facility has instituted the two shift operation shown above in anticipation of time required to load and process the 20 dt/day (18 dton) that will eventually be fed into the system.

7.5.2 Marketing and Distribution

No marketing study has been conducted except to ascertain that the product is marketable. The costs associated with composting (see Section 7.3.3) have influenced the CMCMUA's approach to marketing, however. The facility intends to keep a price for the compost so that it is not considered to be "waste" product; nevertheless, the CMCMUA claims to have no illusions about making money with the product. The compost sells for $2.6/m^3 ($2/cy), $5.5/dt ($5/dton).

In accordance with State regulations, the compost can be sold in bulk only to "qualified" customers. "Qualified" is an undefined term that implies that the State wants to ensure that the customer will follow instructions about allowable uses. All members of the New Jersey Nurseryman's Association are "qualified," for example.

The plant received its license to distribute compost in April 1988. Before that time, only a State-approved compost blender and distributer could dispose of the compost. Under such stipulations, the plant had to inventory 1 year's production of compost. Since April 1988, however, all compost produced has been sold and the facility is not concerned about flooding the market.

At the time of the site visit, most compost had been sold as soil amendment to cover and promote revegetation of a 65,000 m^2 (16-acre) local landfill that was being closed. This was a short-term, high-volume demand. Other major users and uses of the compost include:

- Sand and gravel companies — topsoil component for highway revegetation projects
- Municipalities — parks
- Earthlife (State-approved company) — compost blending and distribution

Table 7.5 Operations and Maintenance Costs

Category	Estimate at Startup (1,372 dry tons of sludge processed)[abd] (1985 $)	%	(FY 1989 $)[b]	%	Budget Estimate (4,840 dry tons of sludge processed) FY 1989	%
Labor (number of employees)	105,000(4)	23.7	114,200(4)	23.7	418,074(15)	35.6
Power	135,000	30.5	146,800	30.5	175,000	14.9
Sawdust, Chemicals, and Supplies	100,000	22.6	108,700	22.6	215,000[c]	18.3
Other[e]	40,000	9.0	43,500	9.0	230,325	19.6
Repetitive Repair and Replacement (sinking fund reserve)	63,000	14.2	68,500	14.2	136,000	11.5
Total	443,000 ($323/ton)	100.0	481,700 ($351/ton)	100.0	1,174,000 ($243/ton)	100.0

[a]The number of tons processed is artifically low and the price per ton is high because the figures reflect a combination of startup and routine operation.
[b]1985 costs escalated by the ratio of Engineering News Record (4568/4201) construction cost indices for December, 1988, and June, 1985.
[c]Chi-X masking agent costs about $8.60 per liter ($1,800 per 55 gallon). Amendment is $18.64/m3 ($14.25/cy).
[d]dtons × .9072 = dt
[e]This category is a "catch all," and items included in the startup and budget estimates are not necessarily the same.

The operators would prefer to distribute all of the material locally, if possible, because local residents are subsidizing the manufacture of the compost.

7.5.3 Operating Costs

Table 7.5 shows the expected operations and maintenance costs for 1985 which were estimated at startup and updated to 1989, as well as the 1989 budget estimate.

Through September 1988, the operations and maintenance costs to process 1,090 dt (1,200 dton) of sludge were $474,150 ($435/dt) ($474,000 [$395/dton]). The tonnage processed in this time period was limited by the DEP order.

7.6 Update

As of June 1989, the plant had been running at full capacity, 18 dt (20 dton) per day, since the end of the summer, 1988. Because there has been only one odor complaint since March 1988, the State has given the plant permission to operate at full capacity all year. Actual amounts of materials processed and operating costs are shown in Tables 7.6 and 7.7.

The plant is temporarily running at half capacity now, due to a broken outfeed device (screw) in the center of one reactor. A new screw is being fabricated locally, and will be used to dig out the broken screw. The plant should be back at full capacity by July 1. It is not known why the screw broke; no problems were seen at the last annual inspection.

Cape May has spent a great deal of time in the past year fine-tuning the odor treatment process. Sulfuric acid is used in the first stage of the two-stage, packed tower wet scrubbers. Hydrogen peroxide will be used instead of the current hypochlorite in the second stage. Cape May will be testing corn syrup as a surfactant in the first stage to make aldehyde compounds more water soluble.

Table 7.6 Materials Processed (April 1 through December 31, 1988)

Material	Amount Processed[a]	Percent Average	Solids Range	Mix Ratio
Sludge	1,982[b]	27.3	24-32	1
Amendment	1,594	81.9	76-90	0.84
Recycle	2,020	58.9	54-66	0.81
Compost Product	2,394[c]	52.8	47-63	

[a]Total dton (dton × 0.9078 = dt)
[b]Processing rate was limited during the summer due to an agreement with State concerning odors.
[c]100 percent of the product was sold.

Table 7.7 Operating Costs (April 1 through December 31, 1988)

Item	Amount	% of Total
Labor (operations)	$194,127[a]	25
Labor (maintenance)	129,419[a]	17
Power and Fuel	130,750	17
Amendment	123,686	16
Maintenance Materials	93,646	12
Odor Control[b]	36,218	5
Contracted Repairs	29,195	3
Other[c]	39,866	5
TOTAL	$776,907	
Revenues	19,038	
Product Disposal Costs	0	

[a]Includes 35 percent fringes.
[b]Cost of city water and chemicals.
[c]Breakdown of these costs not given.

Chapter 8
Clayton County, Georgia

8.1 Introduction

The Clayton County in-vessel composting facility is owned by the Clayton County Water Authority (the Authority). It is located on the same site as the Northeast Clayton County Water Pollution Control Plant in Rex, Georgia, about 48 km (30 miles) southeast of Atlanta. The composting facility, designed by Taulman Compost Systems (Taulman), has two reactors in series. It is a second generation Taulman system and has a design capacity of 2.6 dt/day (2.9 dton/day) sludge on a 7-day basis.

The composting facility is situated in a rural area between a creek and a county road. The nearest homes are on the other side of the road, 183 m (200 yd) uphill from the plant. There are also homes on the far side of the creek, about 366 m (400 yd) from the plant.

The site visit took place on July 26 and 27, 1988. Except as indicated, all the information presented in this case study is representative of that time only.

8.2 History of the Plant

8.2.1 Procurement and Construction

In 1982, the Authority, which is a quasi-governmental special services agency, considered a number of sludge management alternatives: landfilling, incineration, pelletizing, and composting. The Authority chose in-vessel composting primarily to maximize odor control (the Authority's existing pelletizing plant experienced many odor problems at the time). The Authority also wanted to produce a consistently high-quality product and felt that keeping the compost system out of the weather (as compared to outside static pile composting) would be a key factor in achieving this goal.

The Authority solicited proposals from two equipment suppliers who they felt had the most experience with in-vessel composting. In choosing between the proposals, the Authority gave the greatest weight to the suppliers' experience and willingness to buy the product; cost was a secondary consideration. The Authority chose the Taulman in-vessel composting system. Although the competitor protested (Taulman had projected a 20-year cost about a million dollars higher than the competitor), the Authority ultimately chose Taulman because of its superior experience and willingness to purchase the compost product.

The engineering firm of Robert and Company designed the plant using the Taulman technology. The general manager of the Authority described the process as a "joint design" in which the supplier and the engineer specified the equipment. These equipment specifications (and their associated costs) were included in the bid documents, which made it easier for the Authority to compare construction bids.

The general manager was satisfied with the procurement process and results. He found that having an engineering firm was an asset because of its expertise and objectivity, especially in the prequalification stage. In addition, he felt that the criteria used by the Authority in choosing an in-vessel system-supplier experience and willingness to buy the product — worked well.

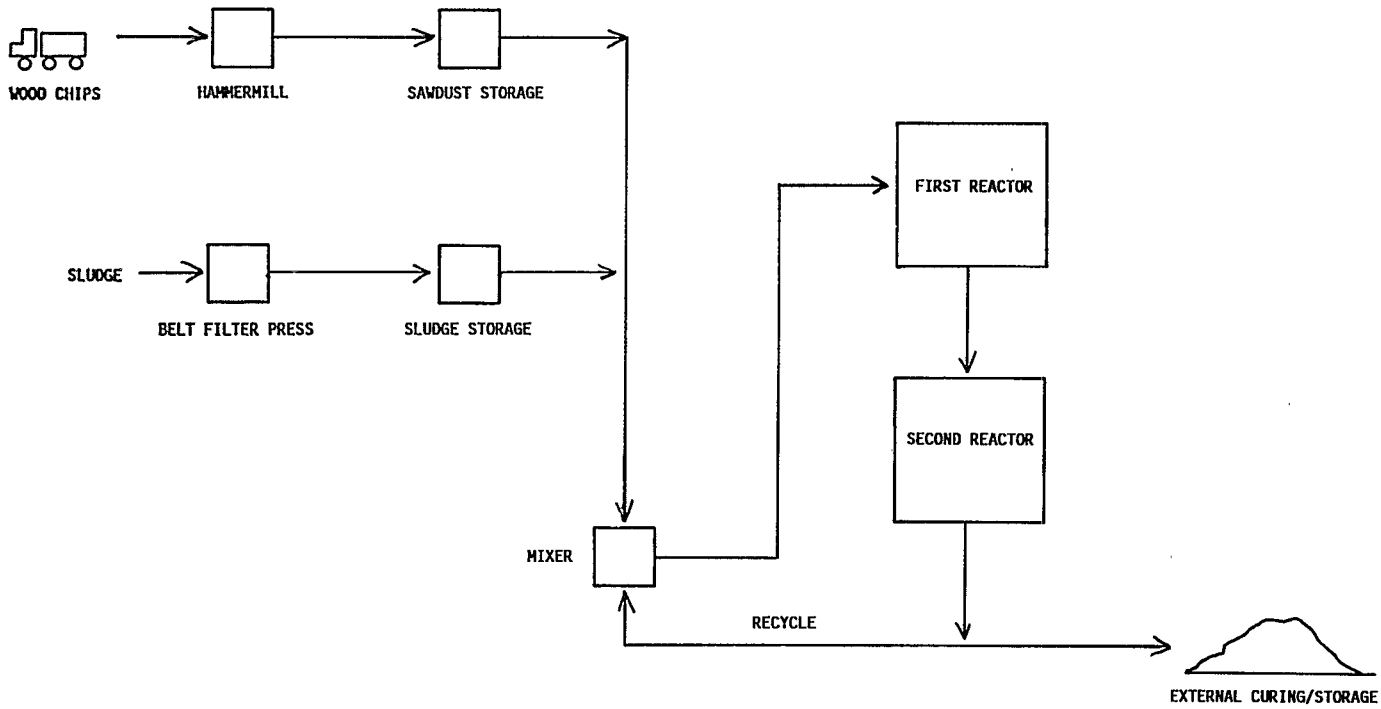
8.2.2 Capital Costs

In November 1984, the design engineering firm estimated that the capital costs for the facility would be $2,756,300. The actual capital costs were $2,434,243 (after subtracting a $90,000 change order in the Authority's favor). Although this value is very close to the 1984 estimate, the scope of the final project was smaller than that envisioned in 1984. Since the Authority had a fixed budget (a reserve bond issue), it trimmed a number of items from the construction contract (including a covered product storage building, spare parts storage, an employee restroom, and an automatic sprinkler system) in order to stay within the budget. As money becomes available, some of these items are being constructed. The product and equipment storage building, one of the items deleted from the original scope, has since been built at an additional cost of $80,000. A compost storage building (30 m x 12 m [100 ft x 40 ft]) has also been constructed.

8.2.3 Operating History and Current Status

The construction of the plant went well and the plant began operating in August 1986. Both reactors were full by December 1986, and, since then, the plant has been operating continuously. In February 1987, the facility began to use output from the second reactor for recycle. As of July 1988, the plant was processing all of the

Figure 8.1 Clayton County, Georgia, Composting Process Train



treatment plant's sludge; 1.2 dt/day (1.3 dton/day) on a 7-day basis (averaged from January to June 1988).

8.3 Description of the Plant

8.3.1 Systems Overview

The plant has two reactors in series; both are cylindrical vertical reactors. The mix ratio is visually controlled and the speed of the sawdust conveyor is varied to achieve the proper mix. The mix is transported by conveyors to the mixer, then dropped into the first reactor. The compost is removed from the first reactor by a screw conveyor, and transported to the second reactor. After the compost is removed from the second reactor, some of it is used as recycle, the remainder is cured/stored in a curing/storage building. The process is shown in Figure 8.1. Because the plant is small with essentially a single process train, there is no redundancy on most major process components. Figure 8.2 provides an overview of the existing facilities.

While in the reactors, the compost is aerated by diffusers located in the reactor bottom. The air is exhausted from the top of the reactors and directed to the WWTP, where it is bubbled through the wastewater emergency bypass holding pond.

8.3.2 Feed and Mix Characteristics

8.3.2.1 Sludge

The facility composts waste-activated sludge (WAS) from a 0.18 m^3/s (4 mgd) wastewater treatment plant (WWTP) where ammonia, nitrates, and phosphorus are removed from the sludge. Dissolved air flotation (DAF) units receive the wastewater, which contains 0.75 to 1 percent solids, and concentrate it to about 4 percent solids.

When the sludge enters the composting facility, it is dewatered on a belt filter press. (Although the plant was designed to have two belt presses, only one belt press was installed during construction. There is space in the building for another press to be added in the future.) The dewatering operation is run 4 to 5 hours a day, 5 days a week. An average 8.4 dt/week (9.2 dton/week) were dewatered from January to June 1988.

Although the dewatering system is designed to increase the solids content to a minimum of 18 percent (average 20 percent) solids, it has not been able to meet the 18 percent minimum consistently. In 1987, the solids content ranged from 16.0 to 18.5 percent and averaged 17.7 percent. In the first 6 months of 1988, the solids content averaged 16.3 percent, ranging from 15.3 to 16.7 percent. At 17 percent solids, the volatile solids of the dewatered sludge range from 68 to 79 percent and the bulk density ranges from 880 to 960 kg/m^3 (55 to 60 lb/cf).

A screw conveyor collects the sludge from the belt press and conveys it to the sludge hopper. The sludge hopper is open-topped and has a capacity of 26 m^3 (920 cf). The sludge is removed from the hopper by a live-bottom, integral drag chain conveyor.

8.3.2.2 Amendment

Sawdust made on site in a hammermill from wood chips (60 percent pine and 40 percent hardwood) is used as an

amendment. The pine chips are produced from timber grown on Authority land irrigated with treatment plant effluent, while the hardwood chips are purchased from a local supplier. There are only verbal quality control specifications, and sometimes the supplier delivers hardwood chips contaminated by metals and other trash. The bulk density of the wood chip mix is 260 kg/m³ (16 lb/cf); it contains 56 percent solids.

The operators found that green chips were hard to grind and move pneumatically. Now, the operators dry the chips for 1 to 1.5 weeks on site before trucking them to a live-bottom hopper. A dual screw conveyor takes the chips to the hammermill, where they are made into sawdust. According to the design specifications, 90 percent of the sawdust must be smaller than 0.006 m (0.25 in.). The solids content of the sawdust averages 60 percent, and ranges from 52 to 66 percent. The sawdust is pneumatically transported to a silo with an effective volume of 200 m³ (7,000 cf). An outfeed screw conveyor with an adjustable feed rate removes the sawdust from the silo.

8.3.2.3 Recycle

The recycle comes from the second reactor. It has an average solids content of 50 percent and an average bulk weight of 590 kg/m³ (37 lb/cf).

If the facility is inoperable, the DAF units can store 1-day's production of sludge. Additional storage is available in the WWTP's aeration tanks. Under Georgia Environmental Protection Department regulations, in emergency situations the Authority can land-apply dewatered sludge at one of its land treatment facilities.

8.3.2.4 Mix Ratio

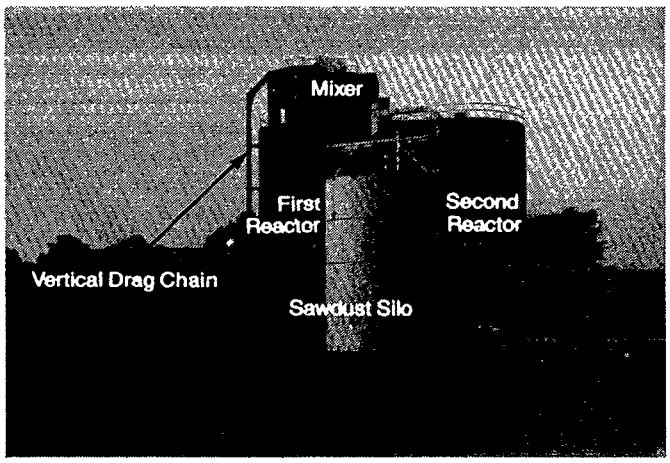
Because the sludge is wetter than anticipated, 40 percent more amendment and recycle are used than planned for in the design. The design mix ratio is 1/1/1 sludge to sawdust to recycle (by volume). In 1987, the actual mix ratio was 1/1.4/1 sludge to sawdust to recycle (by volume); 1/3/1.7 (by dry weight). In 1988, when more recycle was added due to the increased water content of the sludge, the ratio changed to 1/1.4/1.4 (by volume). The solids content of the mix is 34 to 35 percent and the kind of sawdust (pine or hardwood) used does not affect the mix performance. The porosity and bulk density are not measured nor are they used as control parameters.

8.3.3 Materials Handling

A schematic of the materials handling system is shown in Figure 8.3. First, the feed materials are conveyed to an elevator conveyor (a vertical drag chain). The sludge and recycle feed rates are constant; the sawdust feed rate is adjusted to achieve the desired mix solids content.

The vertical drag chain conveyor then takes the materials to an accumulator, a type of reversible screw conveyor. When operated in one direction, materials are fed from the accumulator into the mixer. When operated in the other direction, the mixer is bypassed and the materials go directly to the reversing drag chain conveyor for transfer to the top of the second reactor.

Figure 8.2 Overview of Facilities at Clayton County Plant



In general, the materials handling system works well. The drag chains have lost only one flight in 2 years of operation.

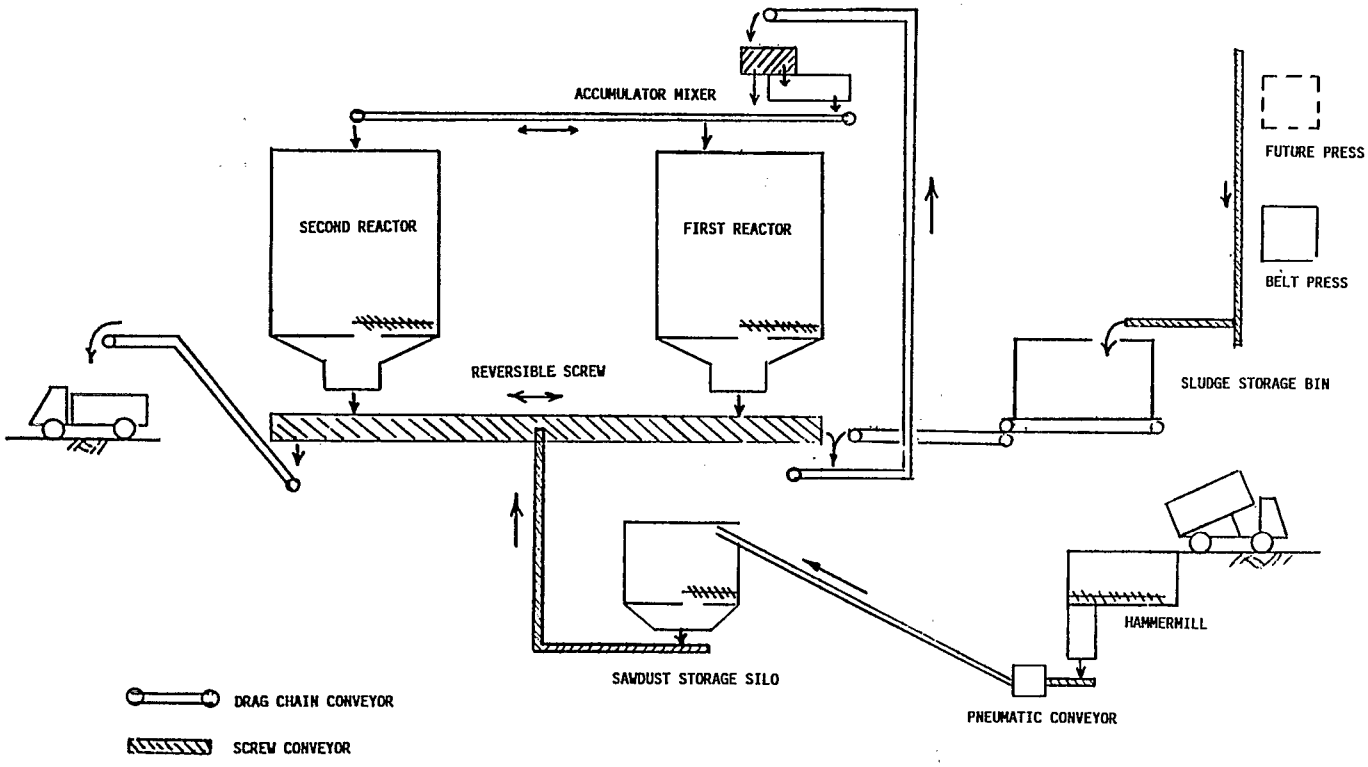
Some conveyance devices, however, cannot handle the capacity of their upstream feed devices and thus become chokepoints. One example is the sludge outfeed conveyor. When the sludge is wet, the discharge rate from the full hopper exceeds the capacity of the downstream elevator drag chain, overloading its motor. To correct this problem, the operators have requested a variable speed sludge bin outfeed device. In the meantime, the operators must sometimes limit the depth of sludge in the storage hopper to 50 to 60 percent of the maximum depth available.

Another example of improperly matched conveyance devices is the discharge drag chain conveyor (to outside the plant), which is too small relative to the upstream screw. This chokepoint wastes the time of the truck driver taking the compost delivery, because he or she must wait until all the compost has been conveyed. In addition, material built up on the drag chain conveyor housing. The operator installed ultra-high molecular weight (UHMW) plastic lining, which has eliminated the latter problem.

Some of the chutes have jammed, also. To overcome this problem, the operators have installed additional inspection hatches on many of the transition chutes so that they can inspect them periodically during the day.

A Littleford plow-type mixer is mounted on top of the first reactor. The mixer works well; however, its location (and that of the accumulator) is problematic for the operators, who depend on the mix appearance for quality control.

Figure 8.3 Schematic of Materials Handling System



Operators are based in the ground-level control room where they cannot see the accumulator or the mixer, and have to climb exterior stairs periodically to check the mix. The mixer and accumulator are also difficult to service since there is no elevator and the operators have to climb exterior stairs to reach this equipment.

8.3.4 Reactors

8.3.4.1 Reactor Feed System

The materials from the mixer are conveyed by a drag chain conveyor to the first reactor. There, the feed materials are dropped onto a rotating conical distributor (a "slinger") located in the apex of the reactor. This slinger distributes the material uniformly only when it falls into the center of the cone. Uneven distribution has been a problem and the operator is considering building a funnel to direct the feed to the center of the slinger.

8.3.4.2 Configuration

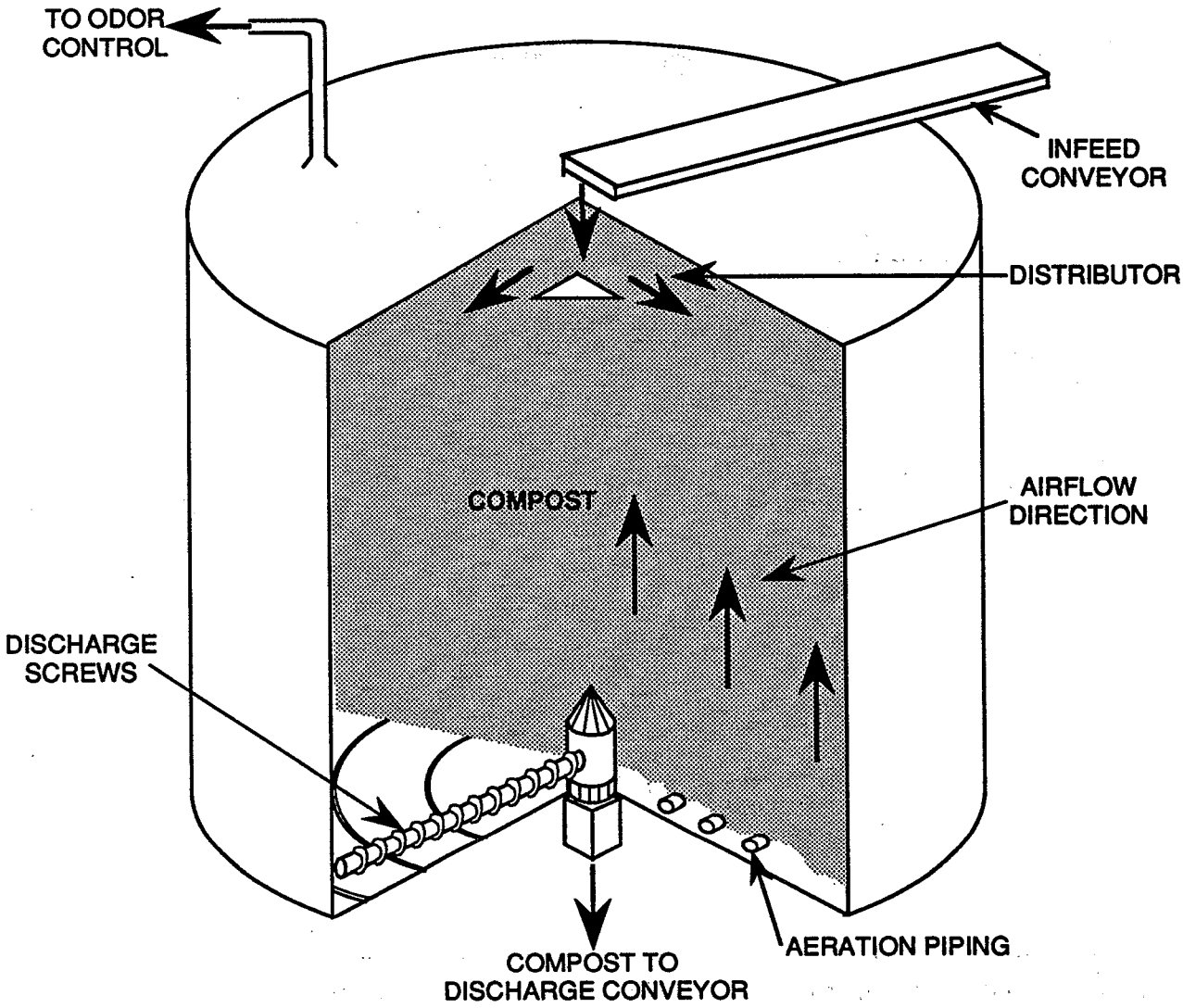
Both reactors are vertical cylinders made from insulated steel and have steel bases; the inside walls are epoxy-coated. The reactors are 8.8 m (29 ft) tall, and have 7.6 m (25 ft) diameters and 400 m^3 (14,125 cf) volumes (see Figure 8.4). There is no fire protection system.

The composting mass is 8.2 m (27 ft) deep; the depth is determined by a mechanical level indicator. Because the surface of the compost is uneven, the depth reading is sometimes incorrect, so the operators periodically check the depth visually when charging the reactor in order to determine when it is full.

8.3.4.3 Reactor Aeration System

The reactors are aerated by three positive displacement blowers located in the process building. There is one supply blower for each reactor plus a backup blower that can feed either reactor. Each blower is rated at 0.09 to 0.3

Figure 8.4 Taulman Composting System Reactor

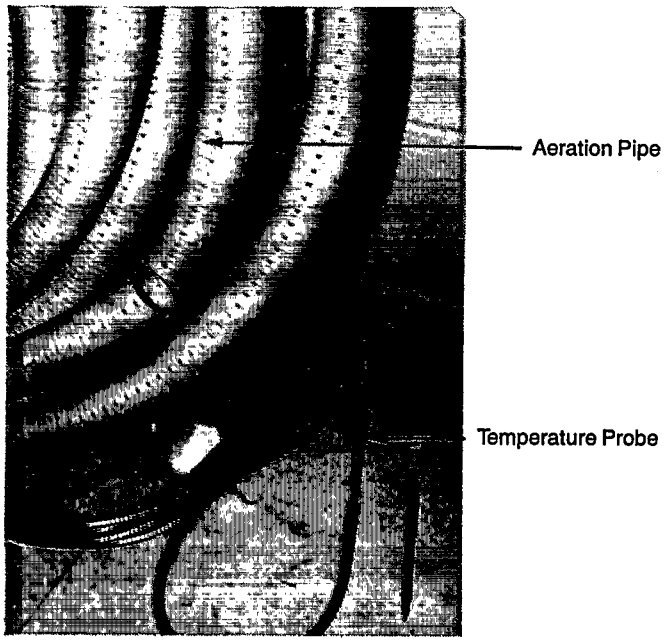


m^3/s (200 to 700 cfm). Normally, the blower for the first reactor runs between 0.2 to 0.28 m^3/s (500 to 600 cfm) and the blower for the second reactor runs at 0.18 to 0.2 m^3/s (400 to 500 cfm) with a 10,340 Pa (1.5 psi) back pressure.

The aeration system is divided into quadrants inside the reactor, with no walls between the quadrants to prevent the air from short-circuiting. The blowers pull in air from the outside and heat it (by compression). Then the blowers direct the air through carbon steel pipes to a header that distributes it into the quadrant-specific pipes that feed the perforated plastic pipes in the bottom of the reactor. The 50-mm (2 in.) diameter plastic piping is perforated and corrugated. The pipe is laid on top of 0.5 m (2 in.) of 0.02 m (0.75-in.) gravel in a 0.2-m (8-in.) deep plenum, with 0.15 m (6 in.) of gravel covering it. Figure 8.5 shows a section of reactor aeration piping with temperature probes.

Originally, the aeration piping was mounted with no support between the span of the aeration headers, except the gravel underneath, and covered with a 0.2 m (6-in.) layer of 0.01 m (0.5 in.) gravel. This allowed the piping to settle in the gravel (upon installation), rather than keep the pipes level. During the annual inspection of the first reactor, operators found leachate in the low areas where the piping had settled, close to the floor of the reactor. Also, during the annual inspection of the first reactor interior, operators found a compressed, "hardpan-like" material on top of the gravel layer. No back pressure problems had been noticed, so they assumed that air had

Figure 8.5 Section of Reactor Aeration Piping with Temperature Probe



been penetrating this layer. The lowest portion of the gravel had been covered with a layer of dried leachate that started to cement the gravel particles together and plug the holes in the aeration piping.

As a result of these findings, the aeration piping in the first reactor was modified. The gravel was replaced with 0.02 m (0.75 in.) washed round river rock, and the aeration piping was remounted on pressure-treated hardwood boards located in the middle (rather than bottom) of the gravel layer. In this way, the aeration piping was separated from the collected leachate. The piping in the second reactor had not been modified yet, but the Authority planned to do so during the next inspection.

When either reactor discharges material, its aeration system must be deactivated or material and air will be blown from the discharge area. Originally, the aeration system was arranged so that anytime a reactor was loaded or discharged from, the aeration system (not exhaust) was shut down. As a result, the operators could not aerate either reactor while loading. In the case of the second reactor, substantial amounts of leachate were drained from the bottom of the reactor on a daily basis. The aeration systems have since been wired differently, so that both reactors can be aerated while being loaded, but not while discharging. In response, leachate in the second reactor has been virtually eliminated.

8.3.4.4 Outfeed Device

The outfeed device is a radial screw (Weiss type AS7) that is fixed at a center pivot and rotates around the reactor while turning on its axis. As the screw turns, it draws compost into the center of the reactor, where the compost is dropped onto a reversible screw conveyor. The screw drives are housed in the center pivot, and the screw is turned on its axis by a hydraulic motor and is rotated through the compost by a hydraulic piston. By adjusting the gearing and hydraulic power system, the screw can be turned at any speed. To date, the hydraulic system has worked well.

The screw has never been trapped in the composting mass, although sometimes the operator must use the screw to break the crust that forms around it. The outfeed screw is epoxy-coated and is not hard-surfaced. Excessive wear has not been a problem.

Beneath the outfeed device, a funnel conveys the compost to a reversible screw. In the first reactor, this funnel has become blocked with compost that backs up into the center pivot. On one occasion, the blockage or a dump gate that failed to open pushed the screw off the splined gear on the gearbox and into the wall of the reactor. To remedy the situation, a hole was cut into the steel outer wall of the reactor and "porta-power" units were used to remount the screw. A detector has been installed in the funnel to detect blockages, which are removed by hand through an access door.

Because the reversible screw conveyor connecting the outfeed ends of the two reactors serves two functions (loading recycle to the reactor and discharging the compost), the operator cannot simultaneously load the first reactor and discharge material from the plant (see Figure 8.3). The typical daily loading schedule from March to July, 1988, was 1.7 hours of discharge from the second reactor, 2.6 hours of transfer from the first reactor to the second reactor, and 3.5 hours of first reactor fill. Typically, the system operates 8 hours/day.

8.3.4.5 Leachate/Condensate

Leachate is collected from each quadrant, which the operators check each morning. If the operators notice excess leachate in any quadrant over a period of time, they increase the aeration rate or time to that quadrant. The quadrants are aerated in sequence, with each quadrant normally aerated for 6 minutes. Four and a half minutes into the cycle, aeration in the next quadrant is initiated, so that the aeration of adjacent quadrants overlaps by 1.5 minutes. Since the operators changed the aeration piping and gravel in the first reactor, excessive leachate has not been a problem.

8.3.5 Exterior Curing/Storage

A drag chain conveyor takes the compost from the second reactor to the exterior of the building, after which it is loaded into trucks and taken to the storage building (372 m^2 [4,000 cf]) where compost and wood chips are stored. This covered, open-sided building can hold a maximum 612 m (800 cy) of compost, or 5 to 7 weeks of compost, depending on how much space is utilized for wood chip storage. After storage (no minimum time required), a front-end loader moves the compost onto trucks for transport off site.

A trench aeration system was built into the concrete floor of the compost storage building. The operators, however, found that the system would not pull air through the compost, probably because of the complex configuration of the system's 0.15 m (6 in.) tubing. Alternatively (or additionally), compost fines may be infiltrating the aeration trenches and limiting their aeration capacity. The aeration system is presently used for drying wood chips.

8.3.6 Nonprocess Air Handling

All nonprocess air is vented directly to the atmosphere by three roof fans. There are additional exhaust fans (that also vent directly to the atmosphere) in the exhaust blower room, the polymer room, the hammermill room, and the dewatering room. Often the "garage" doors in the dewatering area are left open to increase the airflow through the process building.

8.3.7 Odor

The process air is exhausted from the reactors by two exhaust blowers located just inside the building. The blowers are ducted so that one exhaust blower can pull from both reactors. This air is directed to the wastewater emergency bypass holding pond, where it enters a perforated plastic pipe (0.02 m [0.75 in.] holes) and is released into the water 0.71 m (28 in.) deep. After diffusing through the water, the process air is released at ground level.

The process air was originally diffused into a sludge storage tank located following the DAF units. This configuration was changed due to splashing of the sludge out of the tank and an adverse effect on sludge dewaterability.

Odors from the plant are not excessive despite the relatively simple odor control system. In the 8 months prior to the site visit, there were 12 odor complaints from local residents. The odors are worse at night and early morning when the air is relatively still. When the plant is operating normally, the odors do not correlate with plant activities, but whenever the reactor vessel must be cleaned out for inspection or repair, the composting sludge must be stored outside, thereby generating odors and complaints. The storage site for material removed from the reactor during maintenance is closer (91 to 137 m [100 to 150 yd]) to the neighbors than the plant itself, exacerbating the problem.

Neighbors who were brought on site to help locate sources of odors identified the dewatering room, the process air diffuser, and the curing pile as odor sources. The odors at both the air diffuser and the curing piles were verified by the survey team, who reported a musty odor while standing on the edge of the pond near the process air discharge and both musty and sickly-sweet odors from the compost piles when they were moved.

Although there is no formal monitoring program, MacMillan Research Limited tested the process air, which was sampled before and after it was bubbled through the holding pond. The results are shown in Table 8.1.

Table 8.1 Process Air Constituents

Constituent	Concentration (ppm) Reactor Air	Diffuser Air
Methane	<1 ppm	<1 ppm
Total Hydrocarbon	<1	<1
Hydrogen Sulfide	<1	<1
Carbon Monoxide	9.7	4.5
Sulfur Monoxide	<0.1	<0.1

There are no plans to modify the odor control system.

8.3.8 Support Facilities

The process building, which is a one-story building wrapped around the bottom of the reactors, houses the control room, laboratory, and restroom. Solids testing is done in the laboratory; all other testing is done at the Authority's offsite central laboratory. The operators' "office" is a desk in the control room. The operators desire a separate, quiet office suitable for meetings.

8.4 Monitoring and Performance

8.4.1 Reactor Control Strategy

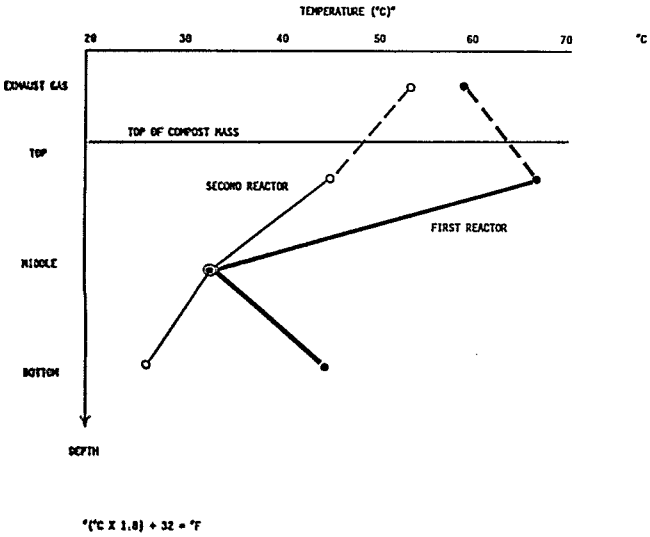
At the time of the site visit, State regulations were not yet in effect. The plant is operated to meet the EPA 3-day 55°C (131°F) criterion for pathogen reduction. In addition, the operators aim for 60°C (140°F) at the top of the first reactor. Strip chart recorders document the temperatures of the compost in the reactors and the exhaust gas from the reactors. Reactor temperatures are not currently being monitored by the State Environmental Protection Department. A single daily value taken at the beginning of the workday is recorded in the daily log sheet. This value is the primary basis for deciding whether or not to change airflow rates.

The temperatures are measured inside the reactors by probes, which are stainless steel thermocouples contained in 0.02 m (0.75 in.) diameter stainless steel pipes filled with lightweight oil. Each reactor has three probes placed in three different locations: 2 m (6 ft) off the bottom; 1.2 to 1.5 m (4 to 5 ft) into the compost from the top, and at the midpoint of the compost. The temperature profile in the first reactor shows an unexpected pattern: the middle temperature probe records the lowest temperature in the reactor (see Figure 8.6). This pattern is reportedly stable.

The operators control the temperatures by manually changing the airflow rates. Typically, the airflow rates are 0.24 to 0.28 m^3/s (500 to 600 cfm) per reactor. When the flow rate is 0.28 m^3/s (600 cfm), decreasing the airflow increases the temperature. If the flow is near 0.24 m^3/s (500 cfm), decreasing the airflow depresses the temperature. When the plant first started up and discharge from the first reactor was used as recycle, the temperature

was increased by decreasing the airflow and vice versa. Now that discharge from the second reactor is used as recycle, the first reactor does not operate as predictably: the temperature at the top of the reactor changes most in response to changes in airflow, the middle temperature is the least sensitive, and the bottom temperature is intermediately sensitive.

Figure 8.6 Typical Temperature Profile (Average of Daily Readings for May 1987)



To further complicate temperature control, changes in airflow rates do not immediately affect reactor temperatures. Usually the temperature changes 8 to 24 hours after the airflow rates have been adjusted. To date, temperature variations have not had a noticeable impact on product moisture content.

There is no specific temperature goal set for the second reactor. The aeration system is set at the maximum rate possible without cooling the reactor to below 35° to 40°C (95° to 104°F).

An oxygen feedback system was built into the control system, but is not used because the operators have successfully run the facility without it and the variation in oxygen content is minimal. Typical concentrations in the past have been 18 to 19 percent in the exhaust gas stream.

A solids test is performed on each batch of sludge going to the belt press, dewatered sludge, feed mix going to the first reactor, material transferred from the first reactor to the second reactor, material discharged from the second reactor, and sawdust used in the mix.

Daily log sheets are kept by the operators, who also prepare monthly summaries. There is no computer logging capability yet, but the Authority is planning to purchase some software. Computerized data storage and manipulation capabilities will save operators a significant amount of time and facilitate long-term process monitoring.

8.4.2 Mass Balance and Reactor Detention Time

A materials flow diagram, constructed from plant records for July 1987 to June 1988 is shown in Figure 8.7. A mass balance is not shown because for unknown reasons, the calculations to close the balance yielded negative volatile solids destruction in the reactors.

At the design mix ratio and average bulk density values, the plug-flow detention time in the first reactor is 16 days. At the current mix ratio (1/1.4/1.4), the actual plug-flow detention time in the first reactor is only 12.6 days.

In the second reactor, the plug-flow time is 15 to 18 days under design conditions. Under actual conditions, the material takes 19 to 21 days to pass through the second reactor.

8.4.3 Product Quality

The final product contains 50 percent solids. Typical metals data from an April 1988 laboratory report are shown in Table 8.2. There are no restrictions on the use of the compost.

Table 8.2 Heavy Metal Concentrations in Compost

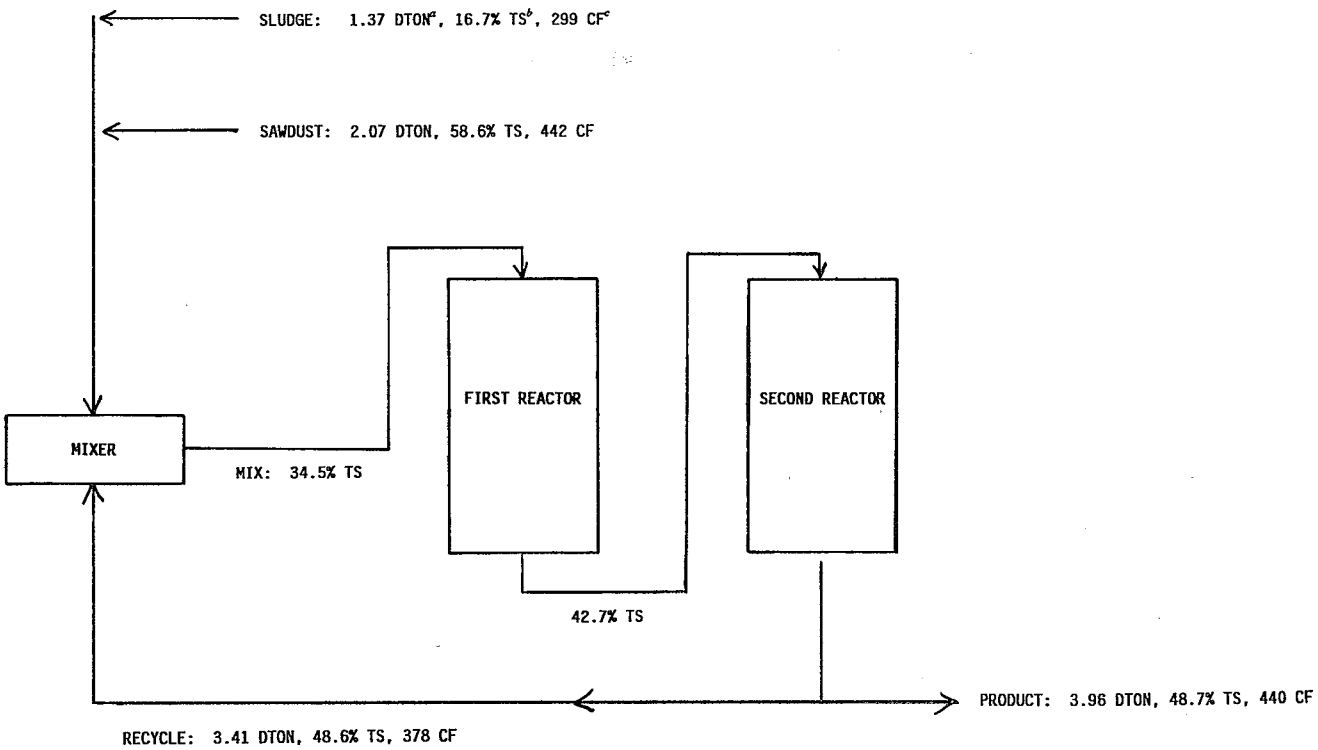
	Concentration (mg/kg)		
Metal	Sludge Cake	Fresh Compost	Cured Compost
Cadmium	3	2	2
Chromium	80	30	30
Copper	150	68	95
Iron	16,500	6,700	7,100
Manganese	650	400	410
Nickel	28	20	19
Lead	3.4	0.50	1.0
Silver	1.5	1.6	2.3
Zinc	590	300	560

8.5 Operations

8.5.1 Staffing

The plant is staffed 5 days/week, 10 hours/day by three staff members assigned exclusively to the dewatering/composting facility: a supervisor, a foreman, and an operator. The control system alarms are tied into the WWTP board so that during the second and third shifts, when the compost operators are not working, WWTP operators can monitor the compost plant. These operators, however, are not trained in the operation of the composting plant. As a result, the composting supervisor must be

Figure 8.7 Clayton County, Georgia, Materials Flow July 1987 to June 1988



[a] DTON (WTON) X 0.9072 = DT(WT)
[b] TS = TOTAL SOLIDS
[c] CF X .02832 = M^3

called whenever a problem occurs during the second or third shift or on weekends.

The operating staff performs preventive maintenance duties. Maintenance personnel supplied by the WWTP staff or the central Authority are used whenever manpower or knowledge limitations make the work impossible for the operating staff to conduct. The intermittent use of maintenance personnel has not caused any problems, but it was impossible to estimate their hours. The plant is too small and is working too well to justify assigning a full-time maintenance person to the staff.

When drawing maintenance personnel from the treatment plant or central Authority staff, the priority given to compost plant needs compared with other needs is determined on a case-by-case basis. The operator feels that the Authority management has a good understanding of the operations at the compost plant. The plant has never been idle for lack of maintenance.

The compost supervisor is a Class 2 wastewater operator. (Georgia has a 3-class licensing system.) He has 6 years of WWTP experience and some junior college education. The foreman is also a Class 2 operator with 6 to 7 years WWTP experience. He is a high school graduate. The operator is a high school graduate and has no certification.

None of the operators had prior experience working at a composting plant. Initial training by Taulman emphasized the mechanical aspects of the plant. Although some process questions were addressed during startup, the plant supervisor would have preferred that more emphasis had been given to composting process principles at the beginning so that the operators would have been aware of potential problems.

The plant supervisor has hosted other Taulman plant operators, who visited Clayton County for orientation prior to their own plant startups. The Clayton County supervisor would have liked to have had an orientation similar to this before starting up his own plant.

8.5.2 Marketing and Distribution

North American Soils (NAS) is committed to buying all of the plant product at $7.67/m³ ($5.75/cy). The compost's primary users are landscapers and public agencies. In addition, the Authority uses some compost for its own facilities. Approximately 90 to 95 percent of the compost produced is sold to NAS; 5 to 10 percent is used "in-house." The product distribution system is working well, with compost going directly to end users on a regular basis.

8.5.3 Operating Costs

A design cost estimate by Taulman in 1982 projected operating and maintenance costs of $33/wt ($30/wton) compost and revenues of $22/t ($20/ton). At 590 kg/m³ (1,000 lb/cy), these values would be $20/m³ and $13/m³ ($15/cy and $10/cy, respectively.) The following estimates of annual costs (presented in 1988 dollars) were adapted from the 1984 evaluation report by Robert and Company:

Power:	$27,000
Amendment:	49,800
Subtotal:	$76,800
Revenues from product sale:	47,400
Net:	$29,400

Expenses for fiscal year 1988 (May 1987 to April 1988) are summarized in Table 8-3. The actual amendment and power costs were higher than predicted due to wetter sludge cake; the revenues were lower than predicted. The operations and maintenance costs are reasonably close to those expected.

Table 8.3 Expenses and Revenues for Fiscal Year 1988 (May 1987 to April 1988)

	Annual Total	$/cy Sold (6,366 cy[d] Sold)	$/dton Processed (503.1 dton[e] Processed)
Operating Expenses:			
Direct Labor and Benefits	59,482	9.34[b]	118.23[c]
Electricity	37,610	5.91	74.76
Other Utilities	607	0.10	1.21
Wood Chips	13,307	2.09	26.45
Chemicals (for Dewatering)	9,884	1.55	19.65
Supplies	5,820	0.91	11.57
Outside Services	1,370	0.22	2.72
Maintenance and Repairs	17,467	2.74	34.72
Miscellaneous and Overhead	3,051	0.48	6.06
Total Operating Expenses	148,598	23.34	295.37
Interest on Bond and Depreciation of Plant[a]	279,081	43.84	554.72
Total Expenses	427,679	67.18	850.09
Revenue (sales):	36,604	5.75	72.76
Net Income/(Loss)	(391,075)	(61.43)	(777.33)

[a]Compost plant assets total $2,268,300. All assets depreciated on the straight line method with 30-year life.
[b]$/cy × 1.31 = $/m³
[c]$/dton × 1.102 = $1/dt
[d]cy × .7646 = m³
[e]dton × .9702 = dt

It costs the Authority $4.46 to produce and transport 1 wet ton of pine chips to the composting plant from its land treatment operation. Since pine chips are supplied "free," there is little economic pressure to reduce sawdust use. The wood chips from the land treatment system also power the Authority's sludge pelletizing operation. Therefore, the Authority must supplement its supply for the composting plant by buying hardwood chips from local sources for $12 to $13/wt ($11 to $12/wton.)

The operators have made a number of equipment modifications, all of which were unexpected costs. These modifications included lining the discharge drag chain conveyor with UHMW plastic and installing inspection hatches on chutes. The aggregate cost for these modifications was not available during the site visit.

8.6 Update

In March 1989, the survey team received the following information by phone from the facility. Since the site visit, one gearbox that transfers rotational power to the outfeed auger failed when the operators misread the sight glass and did not recognize that the fluid level was too low. (The fluid level sight glass was difficult to inspect and had to be read in an awkward position using a mirror and flashlight.) The operators had the gearbox rebuilt and moved the fluid level indicator to a more accessible location.

Another problem occurred when the outfeed auger got stuck in the compost. The screw would turn, but it would not advance. The mix and compost characteristics were not unusual and the screw had not been stationary for an unusual length of time. Thinking that a temperature probe may have become entangled in the auger, the operators cut a hole in the outer wall of the reactor to inspect the auger. The inspection did not reveal any obvious cause for the hang-up. Subsequently, the operators changed the angle of the hydraulic piston that turns the central pivot of the auger and had the hydraulic motor powering the piston rebuilt. Although these two modifications solved the problem, both reactors will be retrofitted with a second advance mechanism (mirror image to the existing one) to better distribute the torsional forces. The system supplier has also observed problems with this mechanism at European facilities.

During the annual inspection of the first reactor (the second reactor has not been inspected yet), the following conditions were noted and addressed as indicated:

- The epoxy coating on the walls was blistered; the spots were recoated.
- The outfeed screw was minimally worn, so resurfacing was not required.
- The rubber air seal between the reactor and the building was replaced.

As of June 1989, the faciity had no further changes to the plant or operations to report.

Chapter 9
Newberg, Oregon

9.1 Introduction

The city of Newberg, Oregon, owns and operates an in-vessel composting facility located on the same site as the city's wastewater treatment plant (WWTP). The WWTP pumps sludge to the facility, where it is composted in two reactors that were designed and constructed by Ashbrook-Simon-Hartley (Ashbrook). This plant is the first of its kind in the United States, although there is a comparable plant that composts solid waste in Germany. The design capacity of the system is 3.2 dt/day (3.5 dtons/day). At the time of the site visit, the facility was processing 0.9 to 1.4 dt/day (1.0 to 1.5 dton/day).

The facility is located outside the city limits in a rural area on a plateau approximately 30 m (100 ft) above the Willamette River valley. There are a few homes located within a one-half mile radius. Adjacent to the plant are a small airport, a solid waste transfer station, an orchard, and a large papermaking company.

The site visit took place on July 11 and 12, 1988. Except as indicated, the equipment, processes, data, and issues described in this case study are representative only of that time.

9.2 History of the Plant

9.2.1 Procurement

Planning for the Newberg WWTP began in 1983. Initially, the city's sludge management plan specified the use of either land application or landfilling. But when the Oregon Department of Environmental Quality gave the Newberg plant low priority on the construction grant priority list, the city investigated Innovative/Alternative (I/A) technologies as a means of enhancing its position on the State's priority list. The city selected in-vessel composting, an I/A technology, and was then given a high priority for construction grants. The EPA subsequently funded 75 percent of the wastewater treatment plant and 85 percent of the composting facility.

The city's consultant, Kramer, Chin and Mayo, Inc., evaluated several in-vessel composting technologies and specified Taulman-Weiss, Purac, or an equal. On October 18, 1985, the city received bids from Taulman-Weiss, Purac, and Ashbrook. The specifications required that the bids separate capital costs from operating costs (e.g., electric power, power demand, sawdust, downtime, and chemical costs). The city then added the capital and operating costs to obtain total life-cycle costs and used these figures to compare bids.

9.2.2 Capital Costs

Ashbrook was the low bidder at $3.3 million, followed by Purac at $4.6 million, and Taulman-Weiss at $5.1 million. After evaluation by the city, the engineer, and the State, the Ashbrook system was accepted as an equal. (See Table 9.1 for a breakdown of Ashbrook's bid.) At the time of the site visit, a change order for minor modifications had resulted in the expenditure of an additional $15,000 by the city.

Table 9.1 Bid Results (Present Worth Costs) October 18, 1985

Item	Ashbrook Estimate	Ashbrook Cost ($)
1. Composting Facilities	Contract Price (lump sum)	$2,824,000
2. Electric Power (@ $950,000/ kWh/lb dry solids)	0.366 kWh/lb[a]	347,700
3. Power Demand (@ $600/kW)	84 kW	50,400
4. Sawdust (lb dry solids/ lb dry solids @ $260,000)	0.35 lb/lb[b]	91,000
5. Downtime (@ $5,000/day/ year)	0 day/yr	0
6. Chemicals (@ $/16,000,000 lb dry solids)	0	0
Total Life-Cycle Costs		$3,313,100

[a]KWh/lb x 7.936 x 10^{-3} = kJ/kg.
[b]lb x .4536 = kg.

The contract between the city and Ashbrook requires Ashbrook to indemnify the city if the life-cycle costs exceed those presented in the bid. The city will evaluate how well the Ashbrook bid compares to the facility's steady-state performance after the performance test is conducted. If the calculated total life-cycle costs are less than the bid, there will be no payments. If the costs

exceed the bid by up to 30 percent, Ashbrook will pay the difference to the city in a lump sum payment prior to the release of the performance bond by the city. If the calculated life-cycle costs exceed the bid by 30 percent or more, the facility will be considered unacceptable and the composting process will be revised or replaced.

9.2.3 Operating History and Current Status

The in-vessel composting facility was built at the same time as the new wastewater treatment facility. Construction of both started in October 1985 and the composting facility began operating in August 1987. Until February 1988, the plant composted sludge from the nearby Hillsboro wastewater treatment plant on an intermittent basis, because sludge was not yet produced by the new plant. From February to May 1988, the facility processed nearly all sludge produced by the new treatment plant (approximately 0.9 to 1.4 dt/day [1 to 1.5 dton/day]). Since May 1988, some of the sludge produced by the plant has been applied to farm land owned by the plant manager.

In May 1988, the interior wall of one of the reactors buckled, causing structural damage. The reactor wall was repaired and the reactor went back into operation in August 1988. Then, in November 1988, the exterior sidewall of the same reactor cracked. The reasons for these failures are not known, although both were associated with unusually wet sludge and, at least in the first instance, increased door pressures shortly before the incident.

At the time of the site visit, the composting facility was still in the start-up mode. A performance test was initiated in August 1988 but suspended in November 1988 when the second wall section of the reactor buckled. As of December 1988, Ashbrook was studying the reactor's structural design and was planning to repair the damage and repeat the performance test.

9.3 Description of the Plant

9.3.1 Systems Overview

The Newberg composting facility consists of two buildings: the dewatering building and the composting building. The composting building, which measures 24 by 30 m (80 by 100 ft), houses two reactors; a blower room; a control room; and the conveyance systems for sludge, sawdust, and recycled compost. Feed materials are conveyed into a mixer, and the mix is conveyed to the reactors, which are operated in parallel. The compost is pushed through and out of the reactors with a hydraulic ram, and conveyed outside, where composting is completed in aerated piles. The reactors are aerated by air supplied by equipment in the blower room, located between the two reactors. The air is exhausted by equipment in the blower room and directed to the oxidation ditches at the WWTP. This entire process is controlled by a computer that is capable of running the plant automatically. Figure 9.1 is a schematic of the process.

9.3.2 Feed and Mix Characteristics

Average dry weather flows of wastewater to the WWTP range from 0.07 to 0.09 m^3/s (1.5 to 2.0 mgd). The WWTP generates between 0.9 to 1.9 dt (1 to 1.5 dton) of waste sludge per day with 1 percent solids and 75 percent volatile solids. This sludge is stored for about a week at the WWTP in two aerated, uncovered tanks, each with a 303,000 L (80,000-gallon) capacity. Then the sludge is pumped to the dewatering building, where it is polymer-conditioned and thickened in two dissolved air flotation (DAF) thickeners. After thickening, the waste-activated sludge (WAS) contains 3 to 4 percent solids.

Next, the sludge is dewatered in two Ashbrook belt filter presses where more polymer is added. Since startup, cake solids have ranged from 12 to 20 percent dry solids with an average of 16 to 18 percent; bulk density has been approximately 880 kg/m^3 (55 lb/cf).

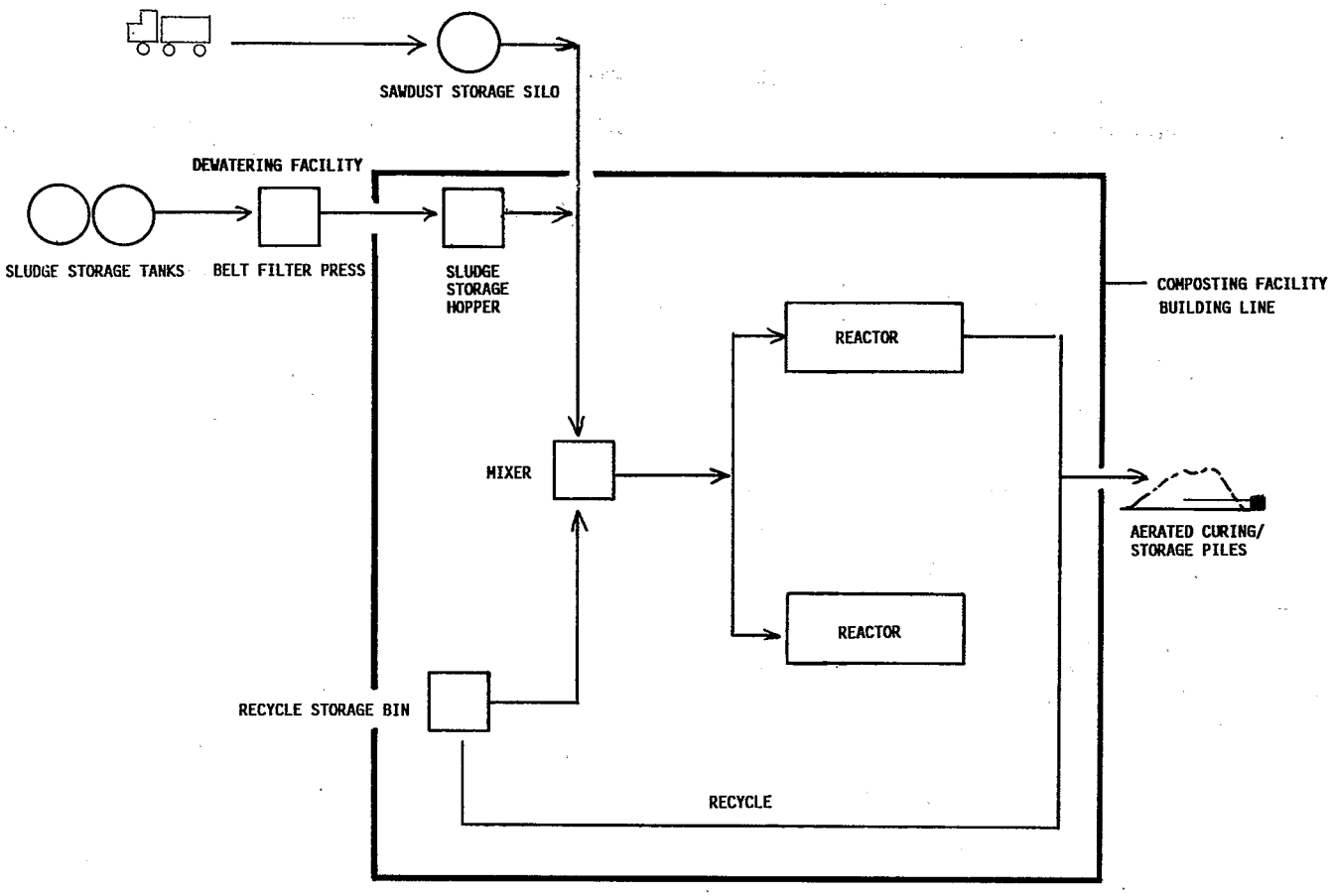
Sawdust is added to the dewatered sludge as an amendment. The contract specifications for the sawdust call for a minimum solids content of 50 percent (60 percent weekly average); a product clean and free from dust, rot, burned material, sand, grit, or other objectionable material; a maximum particle size of 0.006 m (1/4 in.); untreated softwood (no more than 15 percent hardwood); and no more than 50 percent bark (by volume). Initially, the sawdust used at the plant was frequently contaminated with rocks, bark, and oversized material that jammed the amendment storage pneumatic loading system. Subsequently, the city found a more reliable supplier. The amendment used now has a dry solids content of 90 percent and has a bulk density of approximately 176 kg/m^3 (11 lb/cf).

Recycle directly from the reactor output is also added to the mix. The solids content of the recycle ranges between 35 and 45 percent; bulk density is 721 kg/m^3 (45 lb/cf). Recycle is stored in a 25-m^3 (900-cf) steel bin equipped with a drag chain outfeed device.

The design specifications required a mix ratio appropriate for the Taulman system. After Ashbrook was selected as the supplier, its engineers changed the specified mix ratio to one consistent with their process: 1.0/0.35/5.0 sludge to sawdust to recycle (by volume). During early July 1988, the volumetric mix ratio was approximately 1.0/0.5/10 sludge to sawdust to recycle. Thus, both sawdust and recycle usage is higher than originally anticipated.

Although Ashbrook recommended that the mix contain 38 percent solids with a minimum of 35 percent, actual solids in the mix have ranged from 30 to 40 percent; the bulk density is approximately 400 kg/m^3 (25 lb/cf). Within the reactor, the bulk density increases to approximately 880 to 1,040 kg/m^3 (55 to 65 lb/cf) (based on limited testing). At the reactor discharge, the solids content ranges from 35 to 45 percent.

Figure 9.1 Newberg, Oregon, Composting Process Train



9.3.3 Materials Handling

The feed systems for sludge, sawdust, and recycle differ (see Figure 9.2 for a diagram of the entire conveyor system). The dewatered sludge is transported on belt conveyors from the dewatering building to an enclosed, vented storage overhead hopper in the composting building. The storage hopper is a live-bottom steel bin with a 34 m^3 1,200-cf capacity; the outfeed device is a variable speed screw conveyor.

Sawdust is received on an open pad, then transferred to a 156 m^3 (5,500 cf) glass-lined steel storage silo. The specifications require that suppliers dump the sawdust next to the building and the operators use a suction hose to "manually" transfer the sawdust into the storage silo. Using this method, operators took 4 hours to transfer one truckload. The city has recently constructed a temporary 1.5-m^3 (2-cy) wooden receiving hopper to facilitate the pneumatic transfer of sawdust to the silo. A permanent receiving hopper is being planned. The sawdust outfeed device is a rotating chain with a capacity of 0.0006 to 0.008 m^3/s (80 to 1,100 cf/hr). An enclosed screw conveyor meters sawdust to the mixer infeed device, an enclosed drag chain conveyor.

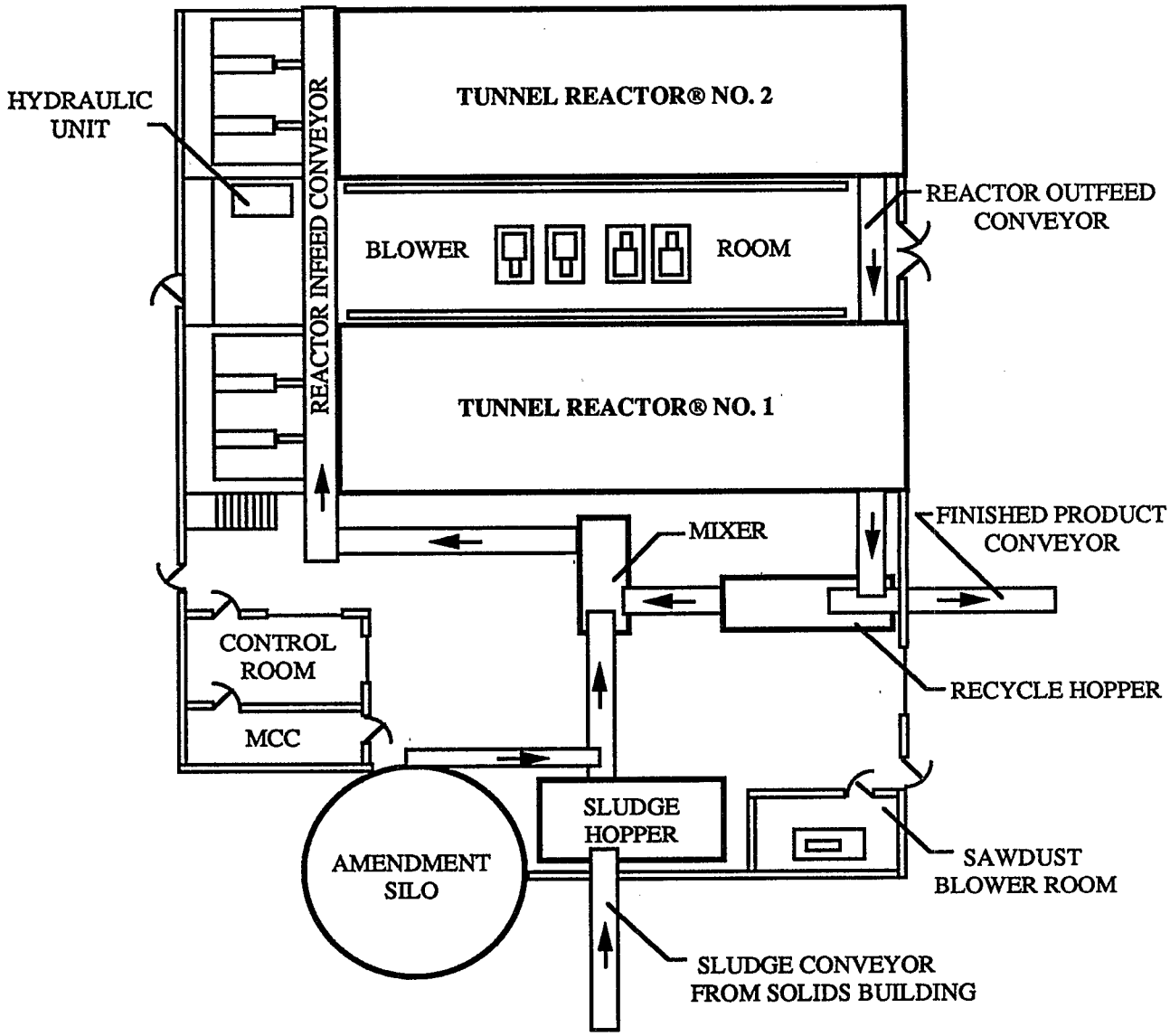
The sludge and amendment are both taken to the mixer by the drag chain conveyor. Recycle is discharged from the recycle bin by drag chain conveyor directly to the mixer. All other drag chain conveyors are constructed of a high strength alloy and have galvanized steel housings.

The mix ratio is controlled by a computer, based on information supplied by the operators. Every time the operators load mix into the reactor, they record the percent solids in the reactor infeed and outfeed and then supply the computer with the solids content and required volume. The computer adjusts the mixture ratio for the next reactor charge by setting the speed of the conveyors, and hence, the feed rates of sludge, sawdust, and recycle. Weight scales were not specified by the engineer, so there are none.

The pugmill mixer is operated at constant speed. The mix discharges to an inclined drag chain conveyor, and then to a horizontal reactor infeed drag chain conveyor that loads either of the two reactors in the order designated by the operator.

Several of the drag chain conveyors have been modified to reduce compaction of material and motor overload. The flights on the compost outfeed conveyor were reduced in height from 0.1 m to 0.04 m (4 in. to 1.5 in.), allowing more room between the flights and the conveyor

Figure 9.2 Newberg, Oregon, Materials Handling System



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housing. At the time of the site visit, occasional breaking of flights and jamming of conveyors still occurred.

9.3.4 Reactor

9.3.4.1 Reactor Feed System

Each reactor has a hydraulically activated steel door measuring 5.5 m wide by 3.7 m high (18-ft wide by 12-ft high). To charge the reactor, the doors are retracted 0.76 m (30 in.) for approximately 15 minutes while the void created by the retracted door is filled with mix from the infeed conveyor. When a level probe, located at the door, indicates that the void is filled, the door automatically closes. During the performance test period, the probes became fouled, causing the door to close prematurely. Daily (or more frequent) probe cleaning has since solved the problem.

Approximately 15 m (540 cf) of mixture is fed to the reactor in one charge. After filling, the door closes, compressing the infeed to approximately a 0.25 m (10-in.) thickness. The entire contents of the reactor (about 363 t [400 tons]) then move forward and 0.25 m (10 in.) of compost are pushed out at the discharge end.

While the reactor is charged, air is blown into the bottom of the reactor to reduce the friction of the compost moving along the reactor floor. During this time (40 seconds),

each reactor receives 1.18 m³/s (2,500 cfm) of air at a pressure of about 20,700 Pa (3 psi). As a result of this pressurization, the door has to overcome only 8,074 Pa (1,200 psi) instead of 13,790,000 Pa (2,000 psi) in order to close.

9.3.4.2 Configuration

There are two totally enclosed plug-flow composting reactors. Each unit is a large reinforced concrete chamber with a volume of approximately 885 m³ (13,600 cf) and inside dimensions of 5.5 m wide by 2.7 m high by 19 m long (18 ft wide by 12 ft high by 63 ft long). The walls are 0.23 m (9 in.) thick. Aeration diffusers are embedded in the floor of the reactor (see Section 9.3.4.3). Two meters (6 ft) in front of the discharge door, the reactor floor slopes 45 degrees to the outfeed conveyor, which is located 2 m (6 ft) below the reactor floor (see Figure 9.3). Figure 9.4 shows the interior of the reactor.

Figure 9.3 Ashbrook Composting System

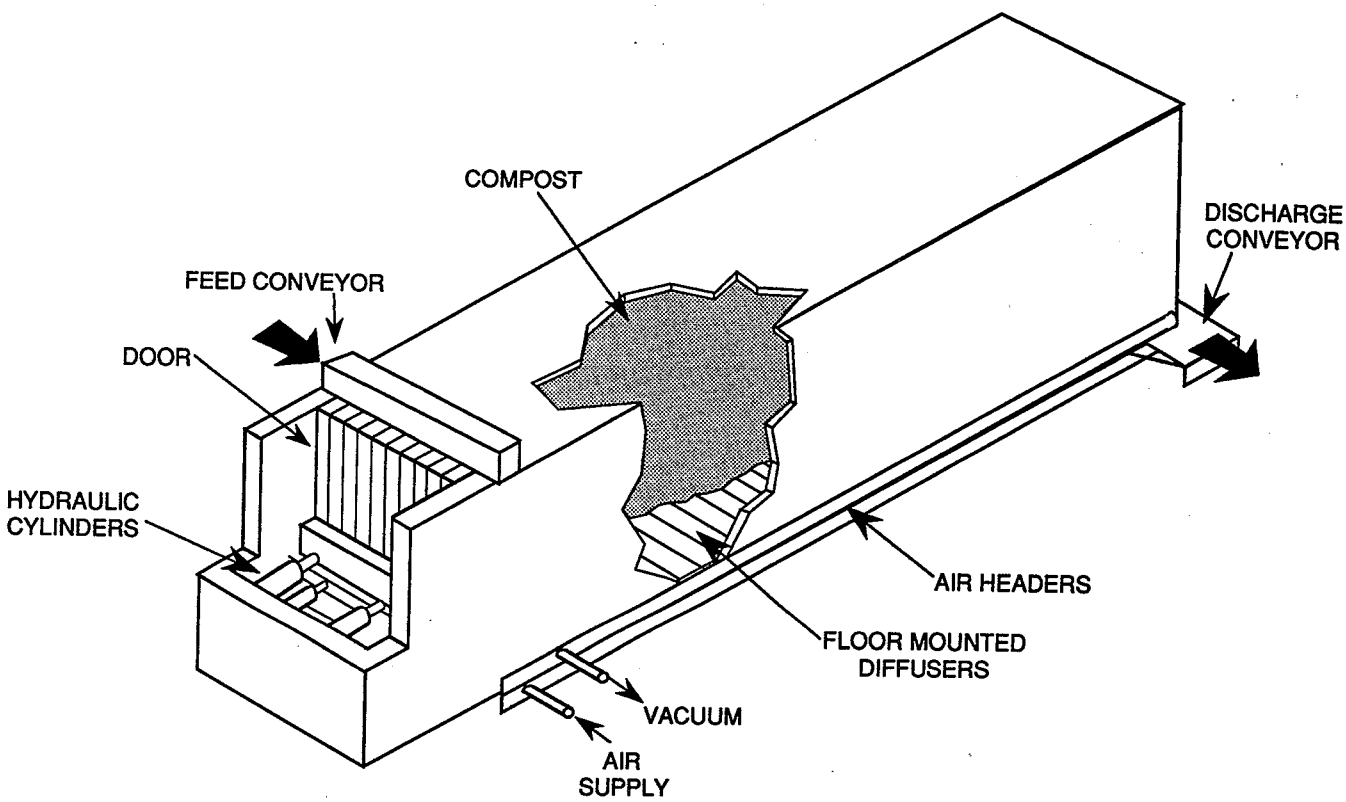
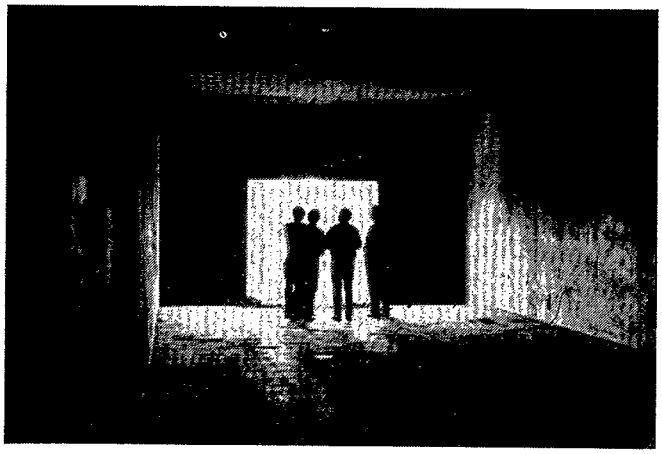


Figure 9.4 Interior of Tunnel Reactor, Facing Discharge End

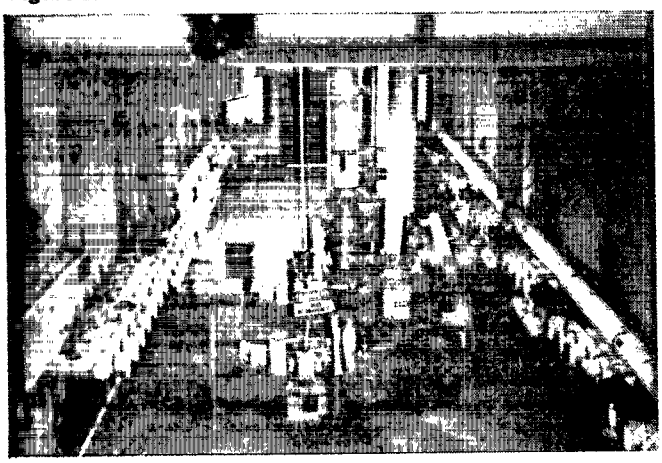


9.3.4.3 Reactor Aeration System

The reactors are aerated by air supplied to and withdrawn from the bottom of the reactor. The air is moved by blowers that are housed in the blower room, which is located between the two reactors (see Figure 9.5). The air is supplied by two 30,000 W (40 hp) variable speed rotary positive displacement pressure blowers with cast iron lobes. Each unit has a capacity of 1.18 m³/s (2,500 cfm) at 20,700 Pa (3 psi). The system was designed to supply 0.6 m³/s (1,250 cfm) to each reactor, with one unit supplying both reactors; the second unit was included as a standby. Both units can be operated simultaneously, however, so that one reactor theoretically can be supplied with up to 2.4 m³/s (5,000 cfm).

The aeration system was designed to supply 0.001 m³/s per 1,000 m³ (90 cfm per 1,000 cf) of reactor volume,

Figure 9.5 Air Blower Room Between the Two Reactors



which is equivalent to about 0.56 m^3/s (1,200 cfm) per reactor or 5.3 air changes per hour (empty-bed basis). Typical rates are approximately 0.38 to 0.47 m^3/s (800 to 1,000 cfm) per reactor at 10,340 Pa (1.5 psi). During mid-1988, with one reactor in operation, the rate was increased to 1.18 m^3/s (2,500 cfm).

Air is supplied to or withdrawn from each reactor through seven independent aeration zones. Each zone consists of six diffuser channels in the floor of the reactor. The diffusers consist of a 0.0009 m (3/8-in.) wide slot that connects an embedded 0.08 m (3-in.) diameter stainless steel pipe to the floor surface. The pipes run the 5.5 m (18-ft) width of the reactor and are spaced about 0.46 m (18 in.) apart. The seven aeration zones are valved and connected to two 0.15 m (6-in.) diameter steel headers: one is valved to the pressure blowers; the other to the exhaust blowers. The seven aeration zones can be operated in any combination of positive pressure and vacuum to regulate temperature and airflow in the reactor. Normally, of the seven aeration zones in each reactor, three or four are in the vacuum mode.

Two 30,000 W (40 hp) constant speed centrifugal exhaust blowers direct the air to the odor control system. Each blower was originally sized for 1.18 m^3/s (2,500 cfm), 0.6 m^3/s (1,250 cfm) per reactor. However, the discharge pressure to the odor control system exceeded expectations and the two exhaust blowers are now operated in series to obtain a total airflow of 1.18 m^3/s (2,500 cfm) at 14,000 Pa (2 psi). Under existing conditions there is no standby unit.

9.3.4.4 Outfeed Device

Both reactors are serviced by a single drag chain outfeed conveyor rated at 0.0007 to 0.001 m^3/s (100 to 200 cf/hr). This outfeed conveyor discharges to an elevated drag chain conveyor, which in turn discharges to a reversible drag chain conveyor that either transfers compost to the recycle bin or discharges compost outside the building.

9.3.4.5 Leachate/Condensate

Condensate and reactor leachate are collected in a modified in-line moisture trap in the suction line of the exhaust blowers. The trap discharges into a dry sump in the center of the aeration gallery that empties into the plant drainage system. Nineteen to 38 L/day (5 to 10 gal/day) of condensate and leachate are discharged by the blower room sump. Condensate is also collected at the discharge of the 0.46 m (18-in.) odor control line that runs to the two oxidation ditches.

9.3.5 Exterior Curing/Storage

As designed, the material from the reactors would be placed outside on a concrete pad, which measures 27 by 21 m (90 by 70 ft). This curing/storage area is approximately 2,800 m^2 (30,000 ft^2). At the time of the site visit, nearly all the material produced since startup, 1,530 m to 1,900 m^3 (approximately 2,000 to 2,500 cy), was stored at the conveyor drop point on the ground in 2.4- to 3.7-m (8- to 12-ft) high piles. Using a front-end loader (delivered during the site visit), the facility plans to move the compost to the concrete pad, which is intended to accommodate two 450 m^3 (16,000-cf) piles of compost. The piles will be aerated with four 52,000 W (7.5 hp), 0.47 m^3/s (1,000 cfm) portable blowers operated in the suction mode and regulated by timers. Exhaust from the piles will be discharged to the oxidation ditch or to a second pile of older, "finished" compost. Ashbrook engineers believe that the odor control pile will be adequate and that the oxidation ditch discharge system will not be required. Condensate, leachate, and stormwater runoff are collected from the curing/storage area and returned to the wastewater treatment facility.

The plant may be operated without aerated piles because the actual sludge quantities are less than anticipated, which increases reactor detention time, and because the currently unaerated piles do not appear to present odor problems.

9.3.6 Nonprocess Air Handling

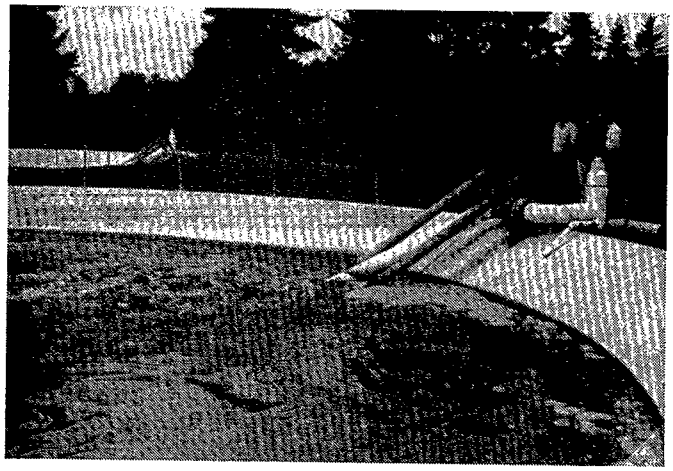
The dewatering building air is vented to the atmosphere with roof fans rated at 0.71 m^3/s (1,500 cfm), which provide five air changes per hour. In the mixing room area, two roof fans rated at 2.3 m^3/s (4,800 cfm) discharge to the atmosphere and provide 24 air changes per hour. The DAF units (which are outdoors, but covered), dewatered sludge hopper, and enclosed conveyors are vented to the inlet of the blowers that supply air to the reactors. These supply blowers are also valved to allow the intake of fresh air from the blower room. The reactor feed area, where the reactor doors and their hydraulic mechanisms are located, is vented to the atmosphere with two roof fans rated at 2.3 m^3/s (800 cfm). The fans provide 24 air changes per hour.

9.3.7 Odor

To control odors, blowers discharge the air from the reactors to the oxidation ditches through a 0.46-m (18-in.) diameter pipe, 610 m (2,000 ft) in length. At each oxidation ditch, the airstream is bubbled through approxi-

mately 0.9 m (3 ft) of mixed liquor using coarse-bubble diffusers (see Figure 9.6). No apparent "composting" or ammonia odors are discernible, although there is a slight musty odor characteristic of an activated sludge system. As a standby measure, the exhaust blowers can be vented to the cure piles.

Figure 9.6 Reactor Air Being Discharged from 18-in. Diameter Exhaust Pipe into Oxidation Ditches



The odor control system appears to be effective, although at the time of the site visit, slight ammonia odors were noticeable at the sludge storage bin, at the discharge end of the reactor, and in the curing/storage area when a 1-month-old pile was disturbed. There were no compost odors in the mixing room or around the plant grounds. Several factors may be contributing to the good odor record: the plant is surrounded by a large buffer zone, the sludge production is only about 0.9 to 1.4 dt/day (1 to 1.5 dtons/day) (30 percent of design), and the sludge itself may be partially stabilized in the underloaded oxidation ditch before it is dewatered. (Approximately 50 percent of the wastewater is highly biodegradable food process wastes.) No odor characterization studies have been conducted.

9.3.8 Support Facilities

The mixing area has an enclosed control room separate from the motor control center (MCC) with sufficient area for the computer and a desk (see Figure 9-2). A separate multipoint strip chart shows reactor temperatures, door pressures, and pressure in the charging zone. In the future, the pressure-sensing capability will be increased to show wall pressures near the charging door.

The central WWTP control building is located near the composting building. It contains administrative facilities, a classroom, a laboratory, and a shop and vehicle maintenance area. All facilities appear to be adequate.

9.4 Monitoring and Performance

9.4.1 Reactor Control Strategy

Newberg's composting goal is to produce a pathogenically safe, marketable product. The system was designed for a 14-day reactor plug-flow detention time, followed by exterior aerated curing/storage. Because the plant has not operated consistently due to varying sludge solids contents and quantities and reactor structural problems, it has not been possible to compare performance with design objectives.

9.4.1.1 Temperature Monitoring and Control

Wall-mounted temperature probes were supplied with the system, but they were removed after numerous failures. Each reactor was also fitted with a 15 m (50-ft) long temperature probe that was installed along the length of the reactor core (about 2 m [6 ft] from the floor and 2.7 m [9 ft] from the reactor walls). The probes were pushed into the composting mass after the units were initially filled, and attached to the charging door. As a consequence of their location, the probes moved 0.76 m (30 in.) back and forth every time the reactor was charged. This movement broke the probes and, at the time of the site visit, they had not yet been replaced.

New probes planned for the system will also be placed longitudinally through the core of the reactor. They will, however, be anchored to an outside wall approximately 3 m (10 ft) in back of the door. The door will have a hole and gasket system so that the probe will not move with it. The probe will be equipped with seven sets of thermocouples that take three temperature readings in the same location every 2.4 m (8 ft) along the reactor length. A computer will then average the three readings, disregarding any outliers.

The reactor is also equipped with ports for manually recording temperatures: each of the seven aeration zones has three ports along the sides at different elevations and two roof ports, for a total of 35 ports. (These ports can also be used for sampling.) All of the ports are accessed from the exterior of the reactor. During the site visit, the automatic temperature probes were inoperable, so a 0.9-m (3-ft) temperature probe was used to record temperatures manually from the roof ports.

The roof of each compost reactor has been equipped with temperature probes set for 85°C (185°F) to act as fire indicators. According to Ashbrook, in the event of fire, the sampling ports can be used for injection of water or chemical retardants. Shutting the closed loop aeration system might also be effective.

9.4.1.2 Aeration Quantities and Rates

The operator can control the temperature of the compost by setting the airflow rate (0 to 0.6 m^3/s [0 to 1,250 cfm]) per reactor and airflow direction (pressure or vacuum) for each of a reactor's seven aeration zones. If temperatures in the first two or three zones are cool 30° to 50°C (86° to 122°F), the aeration system is set in the vacuum mode. If the temperatures exceed 60° to 70°C (140° to 158°F), either pressure is applied to cool the material or the zone is kept in the vacuum mode and the airflow is increased.

In the sixth and seventh aeration zones, the temperature is allowed to drop below 50°C (122°F) to enhance drying, provided that the EPA time and temperature criteria have been met. The adequacy of the aeration system could not be judged due to the lack of reliable temperature data, but operators report that the system is aerobic and generally meets EPA pathogen reduction requirements.

Oxygen meters, installed on exhaust lines from each reactor were required in the specifications, but are not in use and the operators have no plans to activate them. Ashbrook supplied the equipment but believes that such monitoring does not assure aerobic conditions in all zones, since it is possible to have anaerobic pockets that are undetectable. Furthermore, oxygen is rarely a limiting factor in in-vessel composting systems.

9.4.1.3 Mix Ratio Control

The computer system controls the mix ratio by setting the speed of the conveyors, based on information entered by the operators.

9.4.1.4 Data Management

The computer system has a data logger for airflow, temperature, and materials quantities. No further information is available due to the status of the facility.

9.4.2 Mass Balance

A mass balance is not available since the plant is still in the startup phase.

9.4.3 Product Quality

The recommended and actual mix ratios both have an unusually small proportion of sawdust and a very large proportion of recycle (see Section 3.2). A low solids content in the mix could be corrected by adding less sawdust than recycle, since the solids content of the sawdust (90 percent) is higher than the recycle (35 to 45 percent). Because of the nature of their contract with the city, however, Ashbrook cannot dramatically alter the percent of sawdust required in the mix without risking monetary penalties. As a result, they use large quantities of recycle to improve the solids content of the mix. Because of the large volumes of recycle, the reactor detention time has been reduced. However, these ratios change weekly and are not indicative of the potential performance of the facility.

Compost quality is shown in Table 9.2. The compost meets all of the State standards for application to agricultural land. Analyses performed during the initial performance test period showed no salmonella and approximately 130 fecal coliform bacteria per gram of dry solids.

Table 9.2 Oregon Administrative Rules for Acceptable Levels of Metal Content of Sludge for General Application to Agricultural Land

Element	Grab Sample Concentration[a] (mg/kg)	State Standard (mg/kg)
Cadmium	0.8	25
Chromium	4.9	—
Copper	84	800
Lead	1.6	1,000
Mercury	0.3	—
Nickel	4.7	100
Zinc	240	2,000

[a]May 1988.

9.5 Operations

9.5.1 Staffing

The wastewater treatment facility has a staff of six operators including the manager. They all work the day shift, 5 days per week. At the time of the site visit, one operator was assigned to the sludge conditioning and dewatering process and another to the composting process. The city plans to assign a second person to the composting process for 20 hours per week. During the site visit, Ashbrook had a full-time process engineer on site.

The composting operators have a high school education, wastewater treatment experience, and State wastewater treatment certification. The State does not have a composting operator certification program.

Ashbrook provided a combination of classroom and hands-on training for the manager and selected operators. The topics covered in these sessions included the composting process, operational control, and equipment operation and maintenance.

9.5.2 Marketing and Distribution

Very little of the product has been utilized to date, although some has been used by the city at the plant and at a public library. A 1987 marketing study recommended that the city sell the product in bulk to a single end user (nursery, landscaper, or broker). City officials have also discussed a potential giveaway program to city residents.

9.5.3 Operating Costs

Prior to operation of the facility, the operator did not have a complete estimate of operations and maintenance costs. Ashbrook made the following estimates in its bid:

- Sawdust 0.16 kg/kg (0.35 lb/lb) sludge
- Labor (one and one-half operators, 5 days/week)
- Power 0.003 kJ/kg (0.37 kWh/lb) dry solids and 84 kW peak power demand)

The current sawdust usage is somewhat higher than anticipated (it varies from 0.18 to 0.4 kg/kg [0.4 to 0.8 lb/lb] sludge), even though the dry solids content is 90 percent as compared to the 60 percent specified.

An approximate first-year budget was developed during the site visit with the assistance of the WWTP manager.

He estimated that the annual operating costs were $75,000 for the first year (August 1987 to August 1988). (See Table 9.3.) There have been no unexpected costs (except for the $15,000 change order), as Ashbrook has made all the necessary repairs and modifications at their own expense.

9.6 Jpdate

The plant was not operating as of June 1989. In November 1988, the exterior wall cracked for the same reactor whose interior wall had buckled in May. The performance test which was begun in August was suspended. It is suspected, but not known, that the exterior wall was also damaged in May, and the problems did not surface until November. The system supplier is currently rebuilding the reactor, and strengthening the walls of the other reactor. The plant should be back in operation in September 1989.

Table 9.3 Estimated First Year Operations and Maintenance Costs

Component	Cost ($)	Basis
Labor	$42,000	60 hours/week[a], $28,000/year/operator
Sawdust	3,000	0.35 lb/lb[b] sludge, 300 lb/cy[c] $3/cy, 1 dt/day sludge
Power	25,000	Two exhaust blowers, continuous draw; one aeration blower, 50% draw; $0.04/kWh
		Materials handling and lighting additional 20%
Maintenance	5,000	First year, includes front-end loader fuel
Total	$75,000	

[a]Represents 1.5 operators each working 40 hours/week at the composting facility (dewatering facility operator labor not included).
[b]lb × 0.4336 = kg.
[c]lb/cy × 0.5933 = kg/m³.

Chapter 10
Plattsburgh, New York

10.1 Introduction

The Clinton County in-vessel composting facility is located in Plattsburgh, New York. Although owned by the county, the facility is operated by the City of Plattsburgh under an intermunicipal agreement whereby the city assumes responsibility for all costs and operations. The Water Pollution Control Plant (WPCP) in Plattsburgh delivers dewatered sludge to the facility. The Plattsburgh WPCP is an activated sludge plant that is jointly owned by the city and three paper mills. In 1987, the paper mills contributed 56 percent of the plant flow and 91 percent of the biological oxygen demand (BOD); the mills pay their share of annual operating costs through user charges.

The dewatered sludge is composted using a Fairfield circular agitated bin process. The Clinton County plant is the first Fairfield in-vessel sludge composting facility in the United States designed for only municipal wastewater sludge. There is an older facility that co-composts sludge and solid waste in Wilmington, Delaware. The design capacity of the system is 31 dt/day (34 dton/day) of sludge. At the time of the site visit, the facility was processing all of the city's sludge, an average 25 dt/day (28 dton/day).

The site visit took place on April 27 and 28, 1988. Except as indicated, the equipment, processes, data, and issues described in this case study are representive of that time only.

10.2 History of the Plant

10.2.1 Procurement and Construction

Before the in-vessel facility was constructed, dewatered sludge from the WPCP was trucked to a landfill site some 12 miles away. However, when it became clear that the landfill would be full by mid-1986, the city investigated other methods of sludge management. At first, the city elected to co-incinerate the sludge with the county solid waste. But when the solid waste incinerator was not funded, the city quickly chose an alternative in order to obtain funding as part of an upgrade of the WPCP.

The city chose in-vessel composting over static pile composting for two reasons: to better contain and control odors and to more effectively stabilize the sludge in winter. System suppliers were invited to make presentations before city officials. Two reasons influenced the city's choice of in-vessel system. First, the city's sludge is coarse and fibrous. (Due to the paper mill waste, the city was concerned about compaction and loss of porosity in the reactor.) The shallow depth and mechanical mixing of an agitated bin system appeared to ensure that the sludge would be completely mixed and aerated. Second, the capability to simultaneously load and unload material from the reactor appeared to provide more operational flexibility. After comparing the costs associated with rectangular and circular agitated bin systems, the city chose the Fairfield process.

The city hired the engineering firm of Metcalf and Eddy to prepare the contract specifications and put them out for bid. The specifications, which were based on the Fairfield process, called for the Fairfield process or "an equal." Fairfield was the low bidder and, in June 1984, the contract was awarded to Fairfield.

10.2.2 Capital Costs

The projected capital cost of the facility was $10,340,000 (201 Wastewater Facilities Plan Amendment, February 1983). Construction costs (1985-86) were $12,086,000, plus $530,000 for engineering and change orders totaling $451,000.

10.2.3 Operating History and Current Status

The plant started up in April 1986. The plant operators and Fairfield Service Company conducted the performance test during July and August, 1986; the plant met the specifications. Once the performance test was successfully completed, the supplier's engineer left the site and the plant initiated "commercial" operations in August 1986. The facility, however, operated throughout 1987 at reduced capacity, primarily due to severe odor problems (see Section 10.3.7).

There have been other problems, too. In August 1987, plant operators discovered that the layer of wood chips in the bottom of the reactor had turned into "hardpan," preventing air from flowing up into the compost bed. (The aeration system is described in detail in Section 10.3.4.3.) The plant was taken out of service while the hardpan was dug out by hand (reactor 1: August to November 1988; reactor 2: November to January 1988).

In January 1988, the hangers holding up the exhaust air plenum in reactor 1 failed and the plenum fell into the reactor. (See Section 10.3.6 for a complete description of the ventilation system.) The plenum was removed and the reactor returned to operation. Since February 5, 1988, both reactors have been running continuously, composting all of the WPCP's sludge. (In March 1988, the New York Department of Conservation [DEC] prohibited further landfilling of sludge except when a "dire mechanical emergency exists whereby sludge cannot be transferred through the system.") At the time of the site visit, the plant was processing an average 25 dt/day (28 dton/day) of sludge.

10.3 Description of the Plant

10.3.1 Systems Overview

The plant consists of four buildings: two reactors operating in parallel, the air pollution control building, and the administrative/mixing room building. The feed (sludge, amendment, and recycle) is dumped into bins located on one side of the mixing room building and conveyed down into the mixing room. Conveyors also transfer mix to the reactors and material from the reactors to the curing/storage area. The air from the reactors is usually exhausted through a duct to the air pollution control building, where it is treated and released. Air can also be released directly from each vessel into the atmosphere. This process is shown schematically in Figure 10.1.

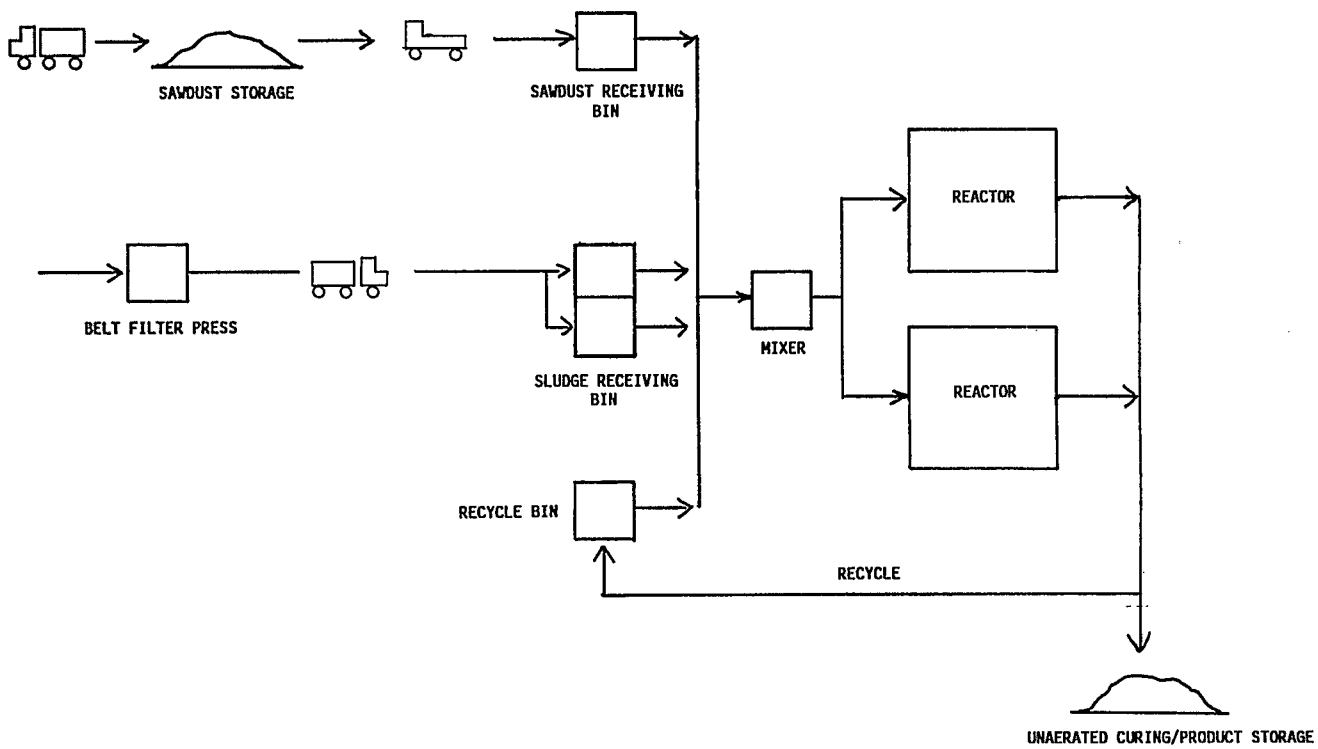
10.3.2 Feed and Mix Characteristics

The sludge from the WPCP is a mixture of primary sludge and waste-activated sludge (WAS) that has been thickened, then dewatered in belt filter presses at the WPCP. In early 1988, the average solids content was 20 to 25 percent. (The bulk density was typically 880 kg/m^3 [55 lb/cf].) To control odors, the WPCP adds potassium permanganate to the sludge. This treatment keeps sludge odors under control for several hours, usually more than enough time to put the sludge into containers, truck it to the composting facility, mix it, and convey it into the reactor.

When the sludge arrives at the composting facility, it is dumped from the trucks into two of four live-bottom feed bins. Each of the four feed bins holds 31 m (40 cy) and has nine 0.3 m (12-in.) diameter screw conveyors spanning the bottom. Figure 10.2 shows the sawdust bins with their screw conveyors. The bins are below grade and covered by a set of double doors, which are at grade.

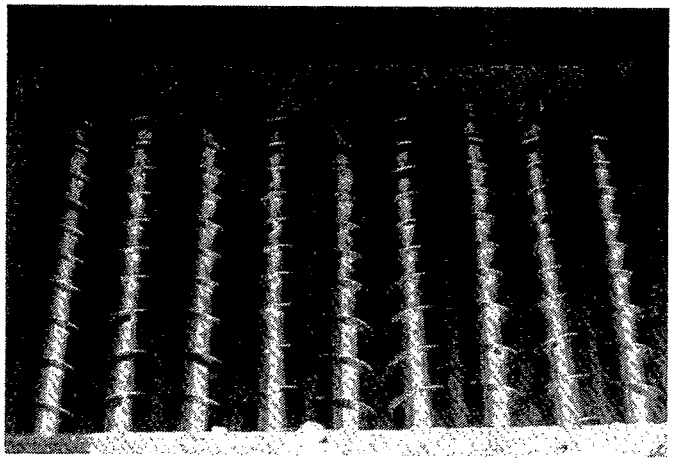
Sawdust is added as an amendment to increase the solids content of the sludge and make it easier to handle. The sawdust specifications require a solids content greater than 50 percent; a product free from ice, dirt, sand, stones, and other foreign materials; and a product that can be moved by the existing screw conveyors.

Figure 10.1 Plattsburgh, New York, Composting Process Train



"Thin wood shavings" can be mixed with the sawdust up to 50 percent by volume. The sawdust used at Plattsburgh has worked well and has been an important factor in the success of the operation. The sawdust is procured by an annual bidding procedure.

Figure 10.2 Sawdust Bins with Screw Conveyors



Currently, the sawdust supply, consisting mostly of softwoods, has a solids content of about 60 percent (the typical bulk density is 240 kg/m³ [15 lb/cf]). The solids content of each truckload is measured when it is delivered; the solids content of the material stored on site is measured daily.

The sawdust is stored on a concrete pad in a fiberglass shelter that is open on one side. A continuous roof vent and open areas about 1.2 m (4 ft) high at the bottom of the walls were provided to allow release of moist air. In practice, the openings allowed the wind to scatter the sawdust, so the operators covered them with plywood. The sawdust is transferred from the shelter to one of the feed bins by front-end loader.

The third feed material, recycle, comes directly from the reactor output to one of the feed bins. Recycle from the curing/storage area can also be loaded in the bin by front-end loader. Its solids content varies from about 43 percent in the winter to about 55 percent in the summer. The bulk density typically ranges from 400 to 481 kg/m³ (25 to 30 lb/cf).

10.3.3 Materials Handling

The feed systems for sludge, sawdust, and recycle are identical. At the end of each feed bin is a pair of twin 0.41 m (16-in.) diameter screw cross-conveyors that move the materials to individual feed conveyor belts. (The feed conveyor system is depicted in Figure 10.3.)

The four individual belts carry the sludge, sawdust, and recycle to a reversible mixer feed belt that is set up to feed either of the two pugmill mixers. The feed conveyors and mixers are located in an underground mixing room that is adjacent to the feed bins. In the past, the mixers have experienced some plugging problems, which the operators attribute to overly wet sludge. As the solids content of the sludge has increased, mixer problems have decreased and are now infrequent.

The sludge, sawdust, and recycle are mixed in the proper ratios to achieve a solids content of 40 percent and a bulk density of approximately 450 kg/m³ (28 lb/cf). Table 10.1 summarizes the design and actual mix ratios. As these figures indicate, the actual mix contains more sawdust and recycle than anticipated in the design.

Table 10.1 Mix Ratios

	Design	Actual
	Sludge/Sawdust/Recycle	Sludge/Sawdust/Recycle
Dry Weight	1/0.68/2.68	1/1/3.4
Wet Weight	1/0.23/0.97	1/0.4/1.7
Volume	1/0.69/1.67	1/1.5/3.3

The mix is controlled by a computer linked to belt scales. The solids contents and bulk densities of the mix constituents are measured several times during a shift. This information is manually fed into the computer, which adjusts the speeds of the feed conveyors to achieve the proper mix. The solids content of the mix is also measured several times during each shift. The system is able to consistently meet its solids content goal within a few percentage points.

The computer system has worked well except for the belt scales. These electronic devices quit frequently during the first year of operation and were difficult to repair because of a lack of local service support. When the scales are inoperable, the conveyor speeds must be determined by trial-and-error, a time-consuming task. Once the electronics in the system were repaired and the system was sealed better, the reliability of the belt scales improved substantially.

The mix is discharged through a funnel chute to a conveyor belt. Even though the funnel is nearly vertical, it sometimes plugs. Since there is no flow or plug indicator, the operators are not aware of the problem until the funnel is completely jammed.

The conveyor belt goes from the underground mixing room to an outside reactor feed conveyor. This conveyor is reversible and can feed either reactor, one at a time. The reactors are loaded 7 days/week, 10 p.m. to 8 a.m., to take advantage of offpeak power rates.

10.3.4 Reactors

10.3.4.1 Reactor Feed System

The reactor feed conveyor drops the mix into a hopper in the center of the rotating reactor bridge (see Section 10.3.4.2). The hopper then dumps the feed onto a conveyor belt on the bridge that takes the mix to the perimeter of the reactor, where it is discharged onto the top of the composting bed as the bridge rotates.

10.3.4.2 Configuration

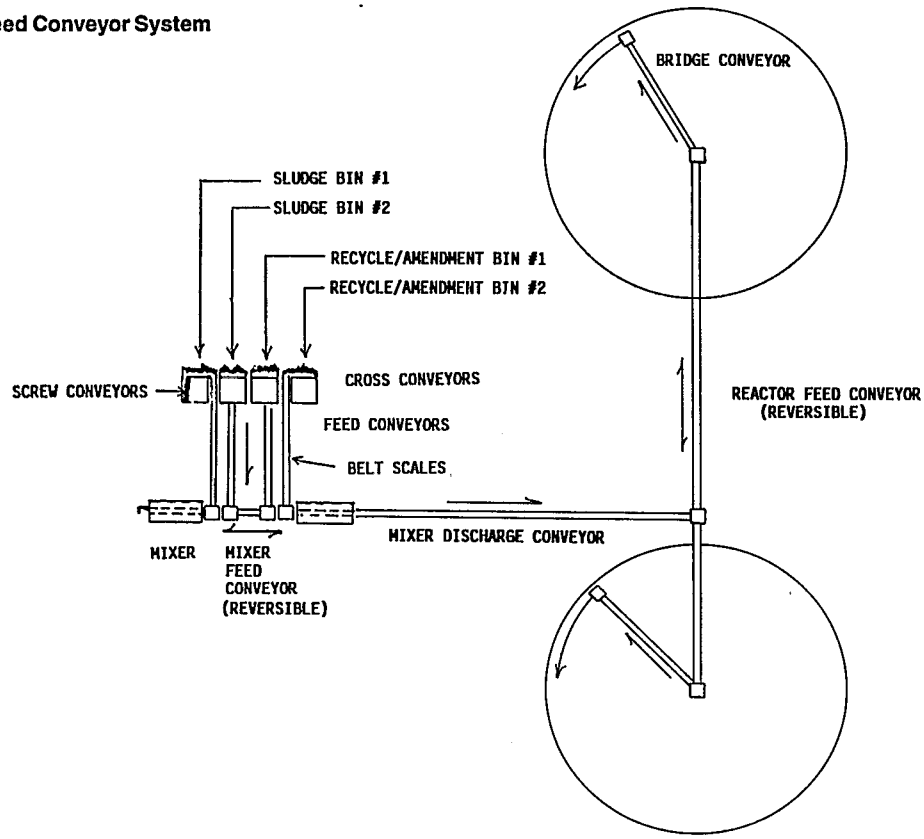
The plant has two reactors that operate in parallel. Each reactor is a 35.4-m (116-ft) diameter concrete cylinder placed below grade and covered with an aluminum geodesic dome. There is no fire protection system in the reactors. There also are no railings separating the perimeter walkway from the compost bed below.

The unique feature of the Fairfield system is its rotating bridge agitation system. (Figure 10.4 shows a cross section of a reactor.) A rotating bridge spans the compost bed and rides on a rail circling the bed. Twenty-seven augers (each 0.51 [20 in.] in diameter) are mounted on one half of the bridge, extending to above the bottom of the compost bed. Each auger is made from steel; the carrying side of the flights (the spirally arranged ridges on an auger) are hard-faced on both the edge and the outside 0.08 m (3 in.).

The top of the augers are angled towards the center of the reactor so that as the compost is mixed, it moves gradually from the perimeter to the center of the reactor. As the augers mix the compost, they maintain its porosity and create circular windrow-like piles on top of the bed. It was discovered that if the bed is 10 ft deep (as designed), these piles interfere with the bridge movement at the present rotational speed of one turn per 2 hours (as designed). Consequently, the bed depth is kept at 2.4 to 2.7 m (8 to 9 ft.).

The flights are wearing down to a "knife-edge" faster than expected (their design service life is 3 to 5 years). At the time of the site visit, eight augers had been replaced because of flight wear or broken or split shafts and an additional 18 needed replacement due to flight wear. In 1988 to 1989, the city planned to rebuild six augers and possibly buy six new ones. The replacement augers have thicker flights (0.01 m [0.5 in.] thick on the outside edge).

Figure 10.3 Feed Conveyor System



10.3.4.3 Reactor Aeration System

System Configuration

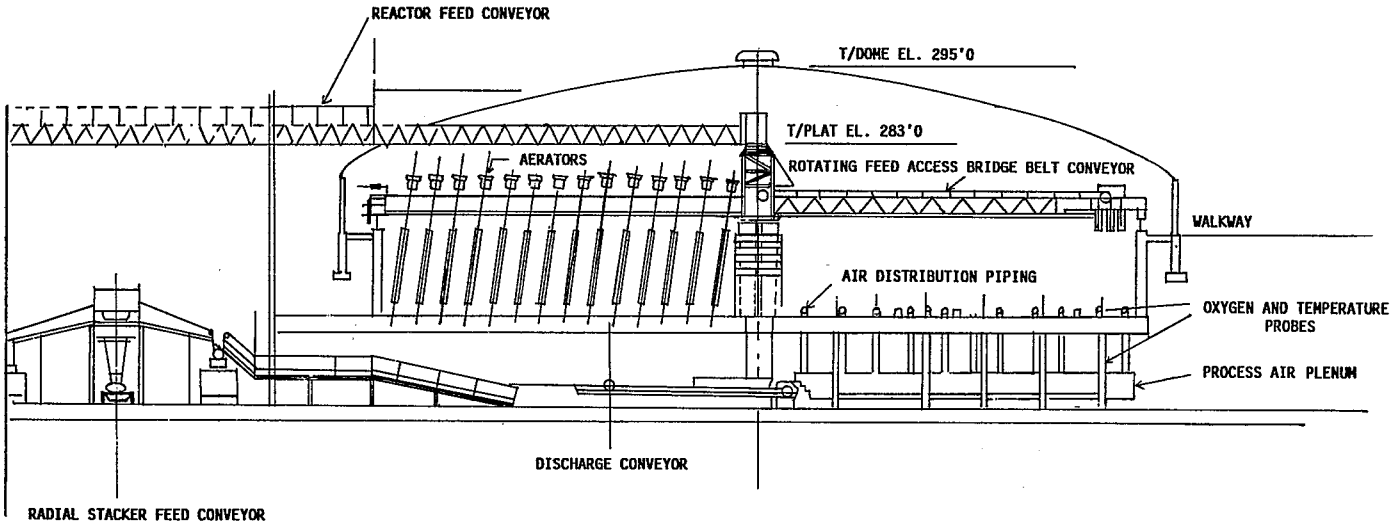
The compost is aerated by pressurized air introduced at the bottom of the reactor. This air is drawn from the mixing room, blown into the plenum underneath the reactor, and then distributed through perforated 0.25-m (10-in.) diameter PVC pipes. The pipes are arranged in a circular pattern, concentric to the reactor wall. These pipes are separated from the compost by a layer of 0.03-m (1-in.) diameter gravel, which in turn is covered with a layer of #1 stone (formerly wood chips, see discussion below). These layers are designed to prevent the compost from falling into the pipes.

A maximum of 7.6 m^3/s (16,000 cfm) of air are pumped through the compost in each reactor, and divided among five concentric aeration zones according to temperature. The amount of air going to each zone cannot be measured. Additional air enters the headspace of the reactor (the space between the top of the compost and the underside of the dome) through the side vents. These vents are permanently open to the outside and are located above the level of the compost. The air drawn in through these vents dilutes the odorous process air. A positive displacement blower exhausts a total of 28 m^3/s (60,000 cfm) from each reactor through a large doughnut-shaped duct which hangs from the dome (see discussion below). This air is directed to the odor control system in a separate building (see Figure 10.5). Figure 10.6 is a diagram of the air handling system.

Aeration Problems

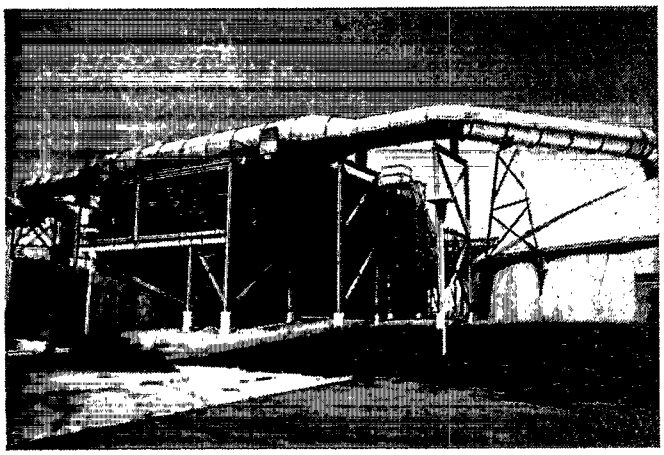
In August 1987, plant operators noticed that air was flowing up through the floor drains into the pipe gallery below the reactors, blowing leachate onto the walls and ceiling. When the operators bored a pilot hole into the compost bed, they discovered that the layer of wood chips, which

Figure 10.4 Cross Section of a Fairfield Reactor



was on top of the gravel base, had turned into "hardpan." The hardpan prevented the air from flowing up into the compost bed. Consequently, the air was flowing into the leachate drain system, pressurizing it. The plant was shut down for 2 months and ran at one half of its capacity for an additional 4 months while the hardpan was dug out by hand, and the wood chips were replaced with #1 stone.

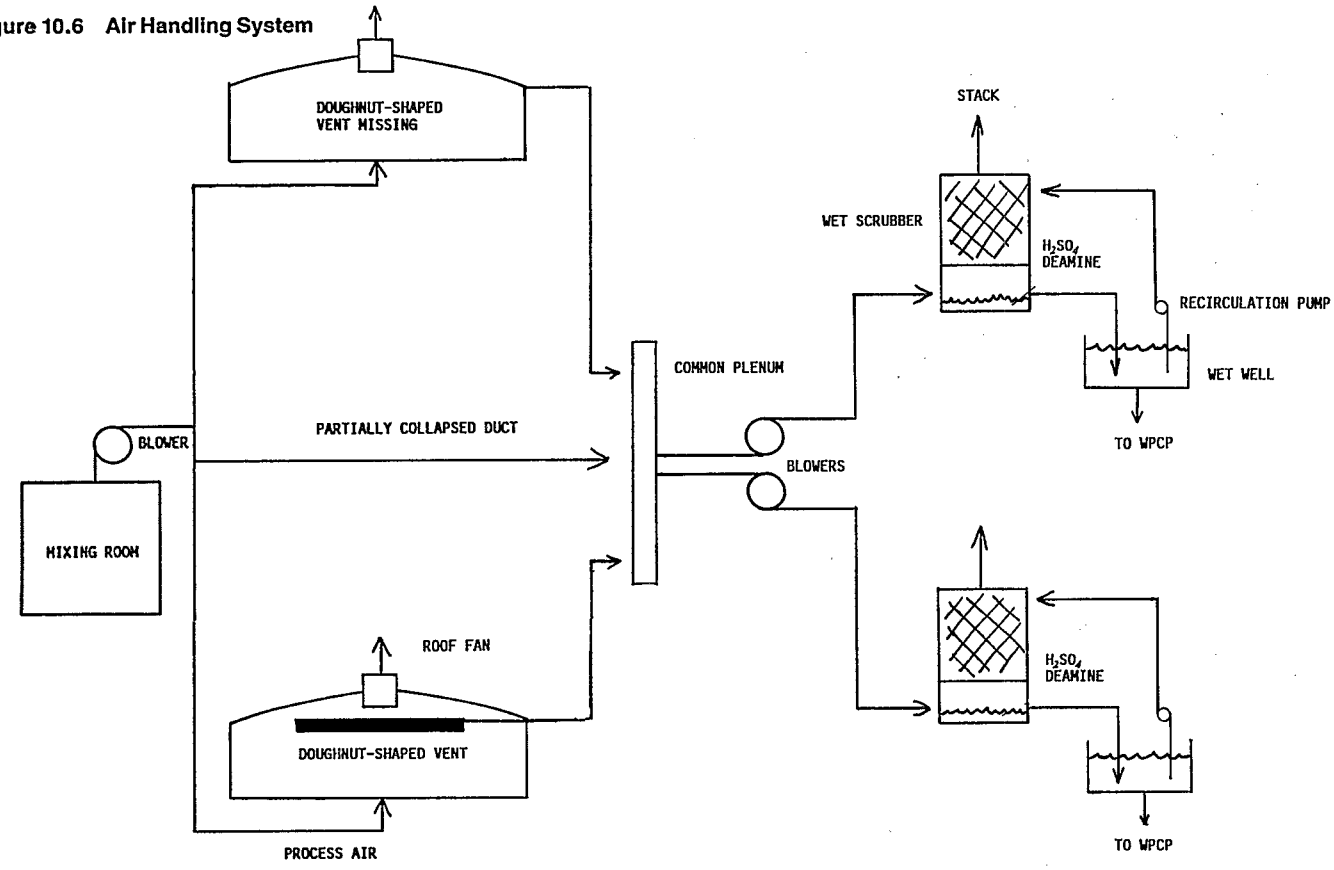
Figure 10.5 Ventilation Duct Taking Air from the Reactors (on extreme right and left) to the Odor Control Building (in the middle)



The reactors have also been plagued by excessive amounts of moist air, which condenses when the outside air temperature drops below about 10°C (50°F). This problem is exacerbated by the absence of any insulation in the domes. The excessive moisture is caused by too much cold air coming in through the side vents; cold air doesn't remove moisture, thus, fog and ammonia build up. At even colder temperatures, the moisture freezes on the equipment. In January 1988, the drain line for the doughnut-shaped exhaust duct froze in reactor 1, causing ice and water to accumulate in the duct until it was so heavy that the aluminum straps holding it to the dome gave way and the duct fell into the reactor. The duct was removed and the reactor returned to operation the following month.

The excessive moisture has also increased the corrosion of the auger drives and motors, the conveyor system, electrical contacts, and other electrical equipment in the reactor buildings. In addition, the condensation of moisture reduces the rate of moisture removal from the compost because the condensed vapor falls back onto the material. Consequently, more amendment must be added, reducing the detention time and increasing costs.

Figure 10.6 Air Handling System



Other problems are also caused by the high moisture levels inside the reactors. Ammonia builds up to potentially unsafe levels and fog reduces visibility. As a result, before maintenance work or manual temperature readings can be conducted, the reactor must be aired out for several hours by a roof fan. Supply air to the reactor is shut off while the reactor air is cleared. Since the ventilation system does not have the capacity to process all this air in a timely fashion, the air is vented directly to the atmosphere. This action results in odor complaints from neighbors. At the present time, the operators load only one reactor per night so that the other reactor is aerated for all but the 1 to 2 hours it takes to clear the fog and take temperature measurements.

System Modifications

To solve moisture related problems, the city is planning to install a rotating cover in each reactor. The cover will be mounted on the underside of the reactor bridge a few feet above the compost but below the side vents, so there will be no cold air pouring in through the side vents and much less process air to remove and treat. A similar rotating cover has been installed successfully at a full-scale Fairfield facility in Toronto. In Plattsburgh, the cover would have to be accompanied by modifications in the ductwork so that moisture-laden process air from the reactors could be separated from the air between the rotating cover and the dome, and sent directly to the odor control system. The air between the cover and the dome, which should be relatively odorless, could then be diluted with the air drawn in through the side vents and vented directly to the atmosphere by the roof fan. The fog would be eliminated and the decrease in the air volume handled by the odor control system would increase the residence time in the scrubbers, thereby decreasing the odor level of the exhausted air.

Funds for installing the reactor covers were requested under the modification/replacement provisions of the EPA I/A grant program, but DEC and EPA did not approve this request. In the opinion of these agencies, this situation represents a design failure rather than a technology failure. The city intends to proceed with the upgrade using its own funds.

10.3.4.4 Outfeed Device

The innermost auger moves the compost from the reactor over a weir and into a discharge chute (see Figure 10.4). The compost then falls onto a horizontal belt conveyor and is transferred to a common discharge conveyor, which takes the compost to a diverter gate. Some compost is diverted to the recycle feed bin; the remainder is diverted outside for long-term curing/storage.

10.3.4.5 Leachate/Condensate

The leachate from the reactors drains down through the #1 stone and gravel to the concrete pad below, where it is collected in drains. All leachate from the curing/storage piles is captured and directed to the WPCP; there is no leachate from the piles except when it rains.

10.3.5 Exterior Curing/Storage

Outside, a radial stacker conveyor with a 150-degree swing arc deposits compost, which is then moved by a front-end loader to the curing/storage yard, a 11,300 m^2 (2.8 acre) asphalt pad. The compost is cured/stored in unaerated piles a minimum of 30 days, although no minimum time is specified in the operating permit. Since demand for compost is low at the present time, curing/storage times are typically much longer. The piles are not odorous when undisturbed, but can emit strong odors if moved.

10.3.6 Nonprocess Air Handling

Mixing room air is ventilated at the rate of 0.76 m^3/s (16,000 cfm), representing four air changes per hour. There is a supplemental roof fan that vents to the atmosphere, but it is seldom used. Instead, the air is exhausted into the plenum beneath the reactor and is used as process air. When the reactors are not being aerated, the air from the mixing room bypasses the reactors and goes directly to the odor control system. The facility's designers anticipated that the odors in the mixing room would be elevated, but the odor level has not been problematic.

10.3.7 Odor

10.3.7.1 Odor Characteristics and Treatment

Because air exhausted from the reactor was anticipated to have a very low odor level, the facility was designed to vent most of the reactor air directly to the atmosphere, although a backup scrubber system was also provided. Once the facility came on line, however, it became immediately obvious that odor produced in the reactors was a major problem. To reduce odors, sludge inputs to the plant were severely restricted during the first year of operation.

For each reactor, there is a single-stage packed-bed wet scrubber in the odor control building. The original odor scrubbing system was designed to treat hydrogen sulfide and utilized a combination of sodium hydroxide and sodium hypochlorite. However, these chemicals were ineffective against ammonia and other compost-generated odors, so they were replaced with sulfuric acid and DeAmine, a proprietary chemical. The empty-bed air retention time in the scrubber is about 2.3 seconds. Before exiting, the exhaust goes through a mist eliminator into a short stack that protrudes about 1.5 m (5 ft) above the roof of the odor control building.

10.3.7.2 Odor Complaints

Odor complaints are recorded in the city engineer's office. In addition, an Odor Report Form is included in every homeowner's city electricity bill. In spite of the revamped odor control system, 29 odor reports were received in November and December of 1987. The odors were described as being "fecal and pungent (acidic)" and smelling like "garbage, dead animals, dead fish, and

ammonia." Most complaints were multiple reports of the same incidents (i.e., 24 reports covered only 13 incidents). During February and March 1988, 78 odor reports were received for 11 major odor incidents. Although the closest residence is 910 m (3,000 ft) away, odor complaints have originated from residential neighborhoods an average of 1,500 m (5,000 ft) away, and some complaints have come from residences more than 2.6 km (1.6 miles) away.

Correlation of complaints with plant activities, time of day, and weather show that odor incidents occur almost exclusively between 7:30 and 12:00 p.m., and between 6:00 and 8:00 a.m., when the process air is off and the headspace air is being vented directly to the atmosphere. Unfortunately, because of the fog problem, this situation occurs whenever maintenance work is required under the dome. Maintenance activities are needed frequently (almost daily) and, in general, cannot be scheduled in advance. Odors also correlate with wind direction when the wind speed is less than 2 knots. (The plant does not record meteorological conditions, but the nearby Air Force base and Plattsburgh airport do.) When the wind is greater than 2 knots, odor complaints drop, presumably because of dilution. Odors are worst in the late summer and early fall, when local overnight inversions trap emissions. Winter odors are thought to result from valley-wide stagnant air under high pressure conditions.

To date, limited air quality monitoring has been performed. In November 1987, Environment One Testing Laboratory from Albany, New York, measured 0.3 to 1.5 ppm of ammonia in the scrubber exhaust. The operators measured 100 to 200 ppm of ammonia under the dome.

Nearly all sludge composting processes generate some ammonia, but the concentrations documented at Plattsburgh are higher than those found at other facilities. The system supplier believes that much of the ammonia released in the reactors is derived from the urea added to the paper mill waste when it is treated at the WPCP. Because paper waste is nitrogen deficient, sludge bulking occurs unless nitrogen in the form of urea is added. As a result of the urea addition, the sludge contains nitrogen forms that are easily ammonified.

10.3.7.3 Odor Treatment

Funds for upgrading the odor control system were requested under the modification/replacement provisions of the EPA I/A grant program. This request was approved by DEC and EPA. The upgrade may add aerosol scrubbers in front of the existing scrubbers, forming a two-stage system: sulfuric acid and DeAmine may be used in the first stage; sodium hypochlorite and caustic soda may be used in the second.

There are no odor control measures for the curing/storage piles. The piles are not odorous when stationary. However, if they are opened or moved for any reason, they can emit strong odors.

10.3.8 Support Facilities

The maintenance facility is located in the administrative building and consists of a two-bay, two-story garage space. The facility is meant to serve as both a workshop and a garage, but there is no room to work when vehicles are inside. There is also very little space available, particularly on the ground floor, for storing heavy spare parts. The operators expressed a desire for chemical storage space in or near the scrubber building. The current practice of storing barrels of DeAmine on the working floor is not desirable, since they take up work space and restrict movement.

Additional facilities at the plant include an office, control room, lunch room, and locker rooms. The onsite laboratory has a microwave total solids instrument that measures the solids and water content of the sludge and compost in about 20 minutes. All chemical determinations are done at the WPCP laboratory or an outside laboratory.

10.4 Monitoring and Performance

10.4.1 Reactor Control Strategy

Five temperature probes, one for each aeration zone, are exhausted in lances that enter the reactor from below and extend about 1.5 m (5 ft) into the compost bed. They are tied into an electronic controller that opens or closes the motorized valves on the air supply lines to the five zones. If the temperature rises above the set range, the valves open. The temperature control range for the outer three concentric zones, Zones 3 to 5, is 52° to 60°C (125° to 140°F). The range for Zone 2 is 49° to 57°C (120° to 135°F); for Zone 1 (the innermost zone), it is 49° to 54°C (120° to 130°F).

The system is operated to meet DEC regulations, which require that the compost be maintained above 55°C (131°F) for 3 consecutive days. To ensure that these requirements are met, the DEC requires the facility to measure the temperature at six locations along the path of the compost motion (i.e., radially in the reactor). The operators take these readings manually twice a day with a temperature probe mounted on a pole.

Oxygen content data are used as backup to the temperature data for control purposes. The system is operated to maintain oxygen levels in the range of 12 to 18 percent. The same lances that hold the temperature probes can remove gas samples and direct them to an oxygen analyzer. Analyzing one gas sample at a time, all five zones are sampled over the space of an hour and the data are recorded on strip charts. Maximum and minimum oxygen contents are recorded daily. Porosity is not measured on a regular basis. A test column used during startup established that the proposed mix ratio would allow passage of the proper amount of air, as long as the mix density was less than 48.1 kg/m^3 (30 lb/cf). A similar test will be performed whenever drastic amendment changes are proposed.

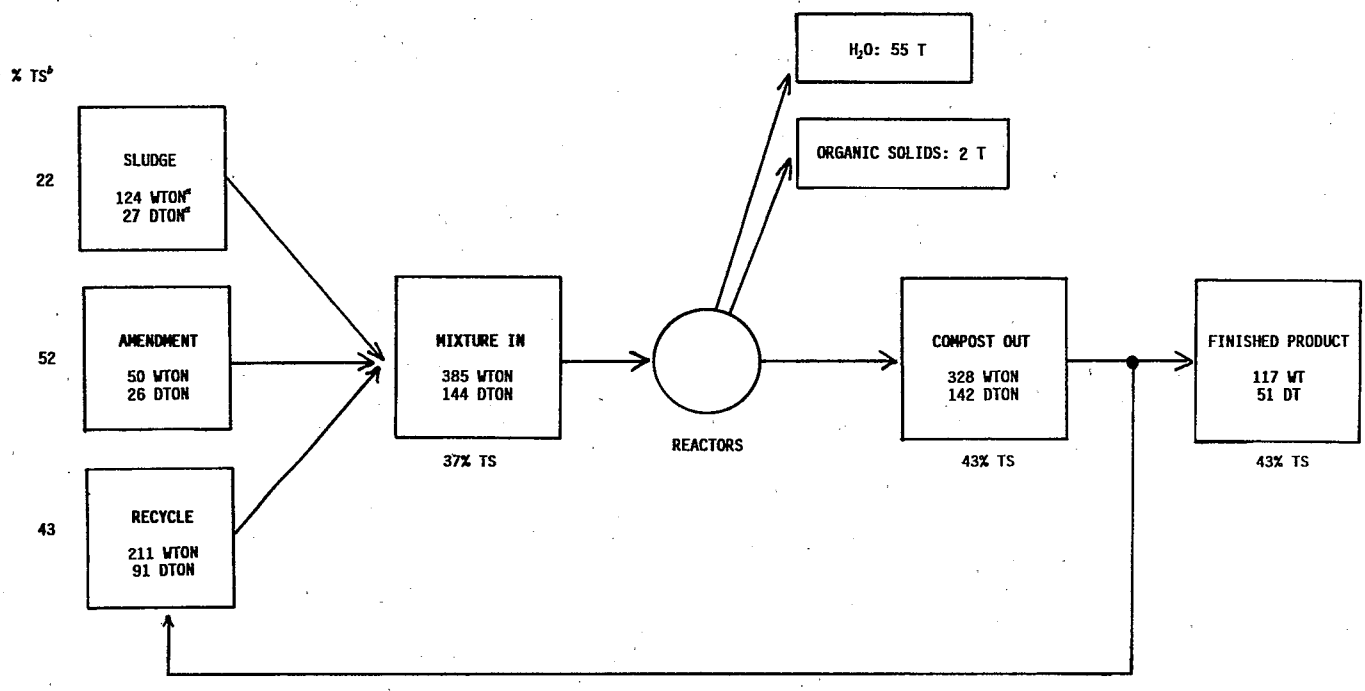
Monthly summaries of daily log sheets are prepared manually by the operator.

10.4.2 Mass Balance and Reactor Detention Time

The mass balances for average daily quantities taken from February 5 through April 4 are shown in Figure 10.7.

Since the facility must take all of the sludge generated at the WPCP, there is no operator control over the detention time. Current detention times range from 7 days in the winter to 10 days in the summer. The design detention time is 14 days.

Figure 10.7 Plattsburgh, New York, Mass Balance Average Daily Quantities, 2/5/88 to 4/28/88



[a] DTON (WTON) X 0.9072 = DT(WT)
[b] TS = TOTAL SOLIDS

10.4.3 Product Quality

The design values for product bulk density and product solids content are 561 kg/m³ (35 lb/cf) and 55 percent, respectively. The actual value for product solids content is 43 percent; the actual value for bulk density was unavailable. The State requires the city to monitor metals and polychlorinated biphenyls (PCBs) on a regular basis, with the frequency dependent on the production rate of compost. The city analyzes both the sludge and compost from the reactor for solids, nitrogen, and metals on a weekly basis. The weekly composite is created from three grab samples taken during the week. The concentrations of PCBs, phosphorus, and potassium are measured periodically. Stability and phytotoxicity are not tested. New York State standards and average product quality values for the characteristics measured (July to December 1987) are shown in Table 10.2.

During the first several months of operation, the compost was tested after curing/storage, in addition to being tested after leaving the reactor. The testing revealed that little or no changes occurred during curing/storage so this testing was discontinued. The compost is classified as a Class I product, meaning that it can be used in all applications except where food crops are grown. New York State policy prohibits the application of sludge or sludge-derived materials to any food crops.

10.5 Operations

10.5.1 Staffing

The plant is staffed by eight individuals: one supervisor, three operators, three maintenance personnel, and one laborer. Contract labor includes a New York State-certified electrician and truck drivers. Processing the nightly load of sludge regularly takes longer than the one shift allocated.

The plant supervisor has a B.S. in geology; 15 years experience in wastewater treatment, including 6 years at the Plattsburgh WPCP; and is a certified Grade 1A (highest) operator. He has been associated with the composting facility since the start of construction. The operators are certified Grade 2A WPCP operators. Maintenance personnel and laborers are not certified, but maintenance personnel are required to be high school graduates. Staff was trained initially by "looking over the shoulder" of the Fairfield personnel during startup (4 to 5 weeks) and making an extended visit to the Fairfield System in Wilmington, Delaware. There is no continuing training program. When the plant started up, staff rotated between the composting facility and the WPCP (3 weeks at the WPCP; 1 week at the composting plant). However, this practice was deemed inefficient since it took staff 2 or 3 days to reacquaint themselves with the plant at the start of each rotation. At the time of the site visit, the staff at the composting plant was assigned there permanently, although for administrative purposes they are still considered part of the WPCP staff.

10.5.2 Marketing and Distribution

The city has attempted to negotiate sales/disposal agreements. Unfortunately, these have fallen through either because the terms offered were not attractive to the city or because the other party experienced materials-handling problems. The compost has been marketed primarily by word of mouth. The city engineer has attempted to increase interest by mailing a series of flyers to landscapers, nurseries, golf courses, local governmental bodies, and people holding gravel mining permits. At the time of the site visit, the city was about to initiate a public giveaway program. DEC requires the plant to record all customers taking more than 23 m³ per load (30 cy/per load) or 110 t/year (100 ton/year). In 1987, about 3,600 t (4,000 ton) were sold to customers; total

Table 10.2 Sludge and Compost Constituents

Component	New York State Standard[a]	Sludge[b]	Compost[b]	Remarks
Total Solids — TS (%)	—	17	50	
Volatile Solids — VS (%)	—	85	82	
TKN[d] (%)	—	4.3	2.5	
NH N[e] (%)	—	0.11	0.59	
Chromium (µg/g)	1,000	17	17	
Cadmium (µg/g)	10	3.1	1.6	
Copper (µg/g)	1,000	182	167	
Nickel (µg/g)	200	17	11	
Lead (µg/g)	250	36	26	
Zinc (µg/g)	2,500	159	156	
Mercury (µg/g)	10	0.36	0.36	
PCBs[c] (µg/g)	1	0.81	<0.17	Week of 12/1/87 only
Phosphorus (µg/g)	—	—	2,700	Measured 11/24–12/22 only
Potassium (µg/g)	—	—	1,000	

[a]Maximum contaminant concentrations for Class 1 distribution (i.e., restricted only from soils growing edible crops).
[b]Average of weekly composites taken in the second half of 1987.
[c]Polychlorinated biphenyls.
[d]Total Kjeldahl nitrogen — organic nitrogen plus ammonia.
[e]Nitrogen in the form of ammonia.

revenues were $1,120 (some of the 3,600 t [4,000 tons] removed were taken by government agencies who were not charged). That year, the city paid $20,000 to dispose of 9,080 t (10,000 ton) of surplus product which was mainly used as landfill cover. Even though revenues were expected to increase to between $5,000 and $10,000 in 1988, an additional $20,000 (for a total of $40,000) was budgeted for the removal of surplus product.

10.5.3 Operating Costs

The total 1988 budget was $1,060,000; the Facilities Plan and the 1988 budget are summarized in Table 10.3. Current unit costs are:

Sawdust	= $24/wt ($22/wet ton) delivered
Electricity	= $0.07/kWh onpeak
	$0.04/kWh offpeak
	$7.11/kW demand charge
	($0.02/kWh estimated in Facilities Plan)
Sulfuric acid	= $0.14/L ($0.54/gal) (75 percent solution)
DeAmine	= $7/L ($26/gal)

Table 10.3 Operations and Maintenance Costs ($1,000's)

Cost Item	1983 Facilities Plan Estimate	Facilities Plan Estimate in 1988 Dollars[a]	1988 Plant Budget	Percent of 1988 Budget
Labor	122	139	125[b]	12
Power	60	68	250	24
Amendment and Chemicals	173	198		
Sawdust			225	21
Odor Control Chemicals			120	12
Maintenance	45	51	140	13
Miscellaneous	20	23		
Water and Sewer			60	6
Sludge Hauling[c]			100[b]	9
Excess Product Disposal Costs[c]			40	4
TOTAL	420	479	1,060	100

[a]Inflated by ratio of ENR cost indices (Facilities Plan: 3900, January 1988; 4456).
[b]Estimate by city.
[c]Not anticipated in Facilities Plan.

Operations costs have been higher than projected in all areas. The unit costs of power have been approximately four times greater than projected. As a result, the plant's operating schedule was changed to take advantage of offpeak rates; this is expected to save $60,000 per year in electricity costs. Maintenance costs have also been greater than expected due to corrosion problems inside the reactor. Sawdust costs are greater because the recycle has been wetter than expected.

10.6 Update

The facility was called in June 1989, to determine if there had been any major changes to the plant or operations since the site visit. The plant has operated continuously since February 1988, processing all of the sludge from the WWPT.

A hardpan was discovered again in February 1989, and had to be dug out.

The facility is in the process of enclosing the electrical system in the reactors to alleviate the problems due to the excessive flog.

The actual amounts of materials processed from January 1 to December 31, 1988 and operating costs are shown in Tables 10.4 and 10.5.

Table 10.4 Materials Processed (January 1 through December 31, 1988)

Material	Amount Processed[a]	Percent Average	Solids Range	Mix Ratio
Sludge	33,454[b]	21.2	21–23	1
Amendment	11,940	54	45–64	1.4
Recycle	45,652	48	43–55	2.67
Compost Product	25,415[c]		43–55	

[a]Total wton × 0.9078 = wt.
[b]Equal to 6,664 dt (7,319 dton).
[c]About 25 percent of the product was sold.

Table 10.5 Operating Costs (January 1 through December 31, 1988)

Item	Amount	Percent of Total
Labor	$ 241,444[a]	23
Power and Fuel	255,479[b]	25
Amendment	246,957	24
Maintenance Materials	97,476	9
Chemicals	81,151	8
Electrical Repair Service	22,670	2
Water and Sewer	35,781	3
Other[c]	50,378	5
TOTAL	$1,031,336	
Revenues	13,219	
Product Disposal Costs	8,522	

[a]Comes from WPCP budget.
[b]Power = $252,565; fuel = $2,914.
[c]Breakdown of these costs not given.

Chapter 11
Portland, Oregon

11.1 Introduction

The Portland, Oregon, in-vessel composting facility is owned by the City of Portland. The facility, designed by Taulman Composting Systems (Taulman), has two trains; each consists of three cylindrical vertical reactors, two "first-step" reactors, and a "second-step" reactor. It is the first Taulman system in the United States, and design improvements and modifications resulting from the experience at Portland have been incorporated into subsequent projects. The design capacity of the facility is 54 dt/day (60 dton/day) of sludge. At the time of the site visit, the plant was processing 18 dt/day (20 dton/day) of sludge.

The composting facility is situated in an urban area in the Columbia River valley on a flat, 20,200 m^2 (5-acre) site it shares with the wastewater treatment plant (WWTP). The total building area (including vehicular access) is 3,035 m^2 (0.75 acres). The plant is bounded by the river on the north, a boulevard on the south, and manufacturing plants on the east and west.

The site visit took place on July 12 and 13, 1988. Except as indicated, the equipment, processes, data, and issues described in this case study are representative of that time only.

11.2 History of the Plant

11.2.1 Procurement and Construction

In response to Portland's RFP, the city received proposals for a variety of sludge disposal systems. In May 1982, the city judged that Taulman's in-vessel composting proposal was technically and economically superior to the other proposals. In June 1982, a consulting engineer confirmed the city's analysis. The city's primary reasons for choosing an in-vessel system were the relatively small size of the site (the plant had to be built at the existing WWTP) and odor control. Taulman's guaranteed purchase of the compost for 20 years (four 5-year agreements) was another important factor.

The city awarded a turn-key contract to Taulman, who designed and built the facility. The following performance criteria were defined in the contract: product characteristics (color, texture, odor, pH, solids content, germination, and pathogen content); mix ratio; electrical usage; and staff requirements for normal operations.

The performance test, however, was not well-defined and became a matter of negotiation between Taulman and the city. They agreed that during the performance test, the city would operate only one train for 3 months and cannibalize the other train for the parts necessary to keep the first train operational. For the most part, the city was satisfied with the turn-key approach but, in retrospect, the city would write tighter specifications, particularly regarding the design and equipment.

11.2.2 Capital Costs

In their bid, Taulman proposed a capital cost of $10,900,000. After negotiating for additional items, the city issued the contract in October 1982 for $11,397,000. These construction costs were paid by 20-year bonds issued by the city.

In addition, there were four change orders in which the costs were split between the city and Taulman. The city's portion of these costs were:

Redesign of amendment-receiving facility to enable it to utilize shredded newspaper in the future	$ 48,000
Upgrading exterior and interior finishes	38,000
Dust control at amendment-receiving facility	63,000
Miscellaneous	17,000
Total	186,000

Taulman spent $55,000 for the dust control system at the amendment-receiving facility and an unknown amount for changes to the outfeed device and conveyor system. Taulman spent an additional $150,000 for warranty repair or modifications to equipment to gain plant acceptance.

11.2.3 Operating History and Current Status

Facility construction began in February 1983; it began operating in September 1984. In March 1985, the first compost produced by the facility was sold to North American Soils (NAS), a wholly-owned subsidiary of Taulman.

The actual capacity of the facility is less than design capacity, primarily due to increased sawdust usage and mechanical maintenance/repair problems. As of July 1988, only two first-step reactors (out of four) normally operated at any one time. Each reactor processed about 9.1 dt/day (10 dton/day) sludge. At the time, the WWTP was producing slightly more than 18 dt/day (20 dton/day) sludge; the excess was stored in the adjacent lagoon until it became full in July 1988. In July-August 1988, the plant was shut down for 4 weeks to remove sludge from the lagoon (under a temporary land application permit) and to perform some maintenance tasks.

The operating goal is to maintain the current loading rate of 9.1 dton/day (10 dton/day) per reactor and expand the operating capacity to 27 dton/day (30 dton/day) by operating another first-step reactor. This capacity is expected to be adequate for sludge production in the short-term future.

11.3 Description of the Plant

11.3.1 Systems Overview

The plant has two independent trains, each with three reactors; two reactors operate in parallel (first-step) and are followed by a reactor in series (second-step). The sludge, sawdust, and recycle requirements are computer controlled; the speed of their respective conveyor belts is set by the computer to achieve the proper mix. For each train, the mix is transported on a vertical drag chain up to the accumulator (a reversible screw) and then down into the mixer. Once mixed, the material can be conveyed to either first-step reactor. The compost is removed from the first-step reactors by an outfeed device; some of it to be used as recycle, the rest to be conveyed to the second-step reactor. After removal from this reactor, the compost is cured/stored outside. Figure 11.1 illustrates materials flow for both process trains. An overview of the facilities for one train is shown in Figure 11.2.

Figure 11.1 Portland, Oregon, Composting Process Train

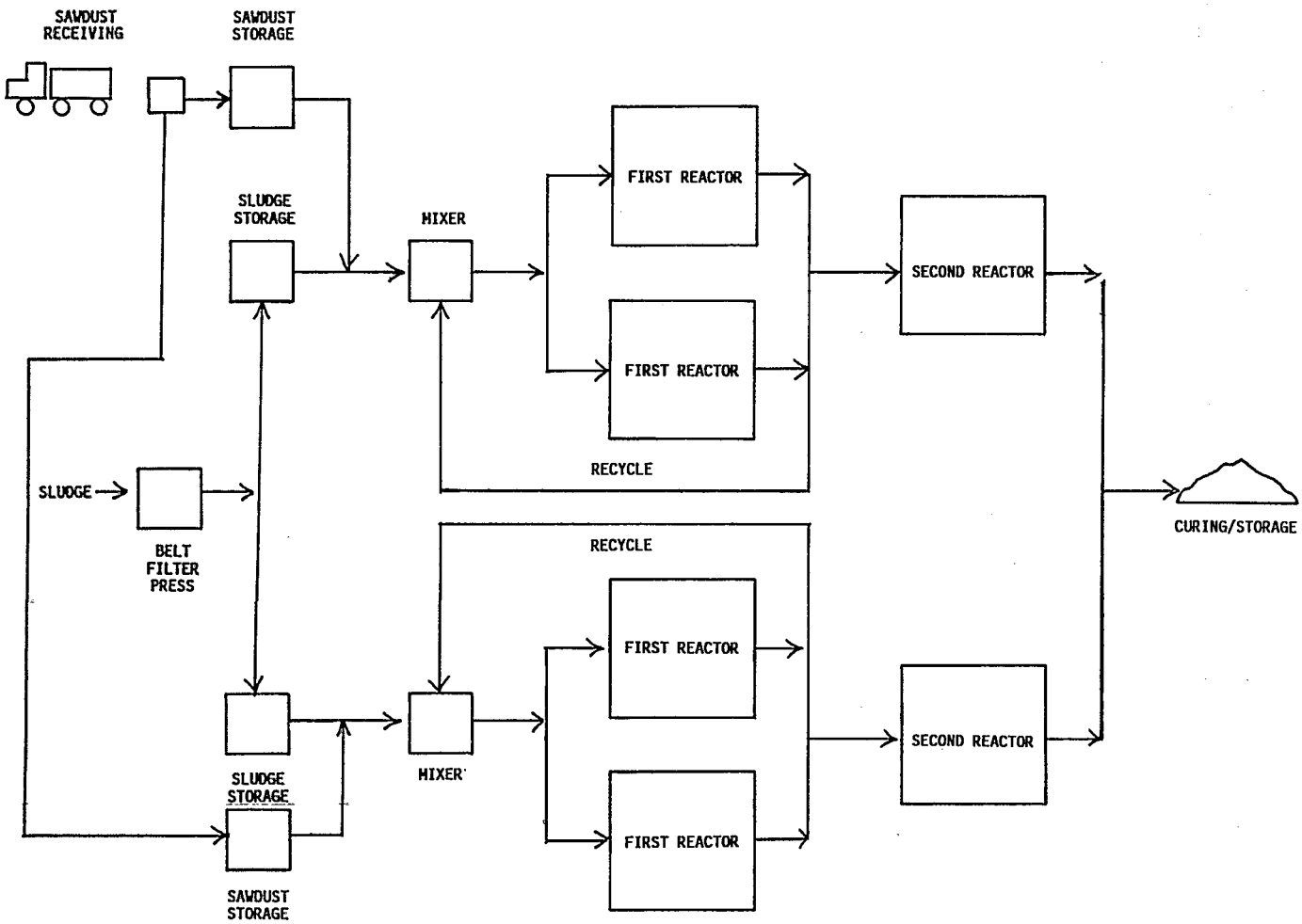
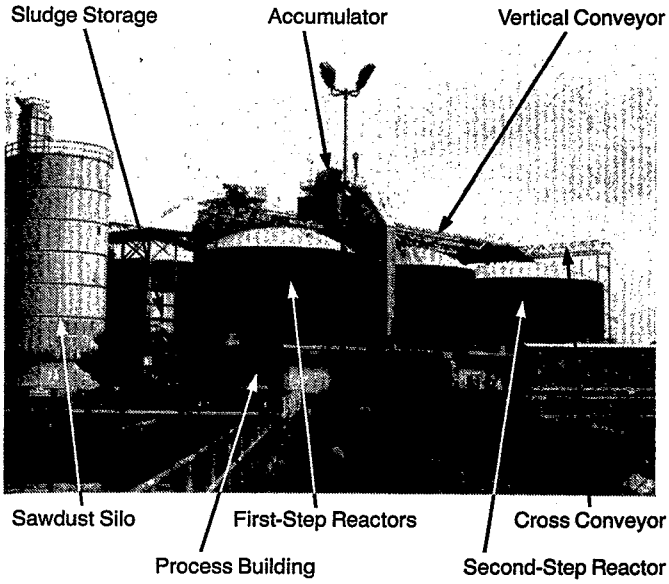


Figure 11.2 Portland, Oregon, Sludge Composting Process Train



While in a reactor, the compost is aerated by air supply piping located in the bottom of the reactor. The air is exhausted from the top of the reactor and directed to the WWTP, where it is bubbled up through the primary effluent collection channel.

There are no sprinkler systems for fire protection in the compost plant.

11.3.2 Feed and Mix Characteristics

11.3.2.1 Sludge

In the feed process, anaerobically digested primary sludge is blended with anaerobically digested waste-activated sludge (WAS) that has been stored in a lagoon. The volatile solids of the sludge range from 35 to 50 percent. Next, the sludge is dewatered in a belt filter press to achieve a total solids content ranging from 23 to 28 percent, with an average of 25 percent. The bulk weight ranges from 800 to 1,060 kg/m^3 (55 to 66 lb/cf). The dewatered sludge is stored in rectangular steel storage bins, one per train. Each bin has a working capacity of 76 m^3 (2,692 cf).

11.3.2.2 Amendment

Sawdust is used as an amendment. The total solids content of the sawdust varies from 60 to 95 percent, averaging 86 percent between June 15 and 30, 1988. The bulk weight ranges from 128 to 224 kg/m^3 (8 to 14 lb/cf).

The city awards the sawdust contract based on the lowest price for the sawdust needed to create a 37 percent solids mixture when mixed with sludge containing 25 percent solids. The advantage of using this criteria is that the city pays less for sawdust with a higher moisture content (50 to 60 percent solids) than it does for sawdust with a lower moisture content (greater than 60 percent solids). The major drawback of this approach, however, is that it does not encourage minimization of the sawdust volume. Excess sawdust aggravates materials-handling problems and shortens the plug-flow detention time in the reactors.

Originally, the sawdust specification allowed up to 15 percent hardwoods, a maximum particle size of 0.006 m (1/4 in.), and a maximum moisture content of 50 percent. The sawdust may also contain up to 50 percent bark by volume. However, the operators could not distinguish hardwood sawdust from softwood sawdust, so the hardwood specification was deleted. In addition, the maximum particle size was reduced to 0.002 m (1/16 in.) to eliminate wood shavings that did not mix well.

There is one sawdust storage silo for each train, from which sawdust is removed by a center pivot outfeed screw. Each silo holds 66 m^3 (23,556 cf). Almost every year over the December holidays, short-term closures of lumber mills and the consequent cessation of sawdust production shut down the plant for 2 weeks. Additional amendment storage space would help carry the plant through these periods.

Originally, the sawdust operation created a great deal of airborne dust, which was a safety hazard. To remedy the situation, the sawdust delivery system was retrofitted with a ventilation system that captures the sawdust at the delivery hopper, conveyor belt transfer points, and storage silo outfeeds; then directs the dust to a baghouse. (See Figure 11.3.)

Figure 11.3 Sawdust Receiving Bin and Sawdust Silo with Dust Control Ventilation System

11.3.2.3 Recycle

The recycle, which has a dry solids content of 38 to 40 percent, comes directly from either first-step reactor.

11.3.2.4 Mix

The design mix ratio is 1/0.4/0.6 sludge to sawdust to recycle (by volume), a ratio that assumes a sludge solids content of 25 percent, an amendment solids content of 60 percent, and a recycle solids content of at least 40 percent. Solids content of the mix was not given at design, other than as specified by the design mix ratio and solids content of the mix ingredients. The actual mix ratio during the site visit was 1/1.6/0.6 sludge to sawdust to recycle (by volume). The solids content of the sludge and the recycle were very close to the design values, but the sawdust used actually contained more solids than anticipated. Nevertheless, the actual mix uses about four times as much sawdust as the design primarily due to materials-handling problems, especially "oozing" (see Section 11.3.4.4).

The operators report that the optimal solids content of the mix is 35 to 50 percent. The current operational goal is 37 percent, which the plant has been able to meet consistently.

11.3.3 Materials Handling

Each train has its own highly automated materials handling system (see Figure 11.4). Normal operations are preprogrammed and the various conveying devices are electrically interlocked. If necessary, however, the operators can run the system manually.

The feed materials are conveyed on a trough belt conveyor to a vertical drag chain that moves the material up about 18 m (60 ft) into the accumulator, which is located on the roof of the mixer shed. The accumulator accepts materials from the drag chain conveyor and directs them, via a feed funnel, into the mixer.

Both the accumulator and the vertical drag chains have been problematic. The accumulator originally used double screw augers, but they wore out in less than 2 years and were unable to move material fast enough, thereby plugging the feed funnel. To correct these problems, the accumulator was modified to a one-screw system, which appears to be working reliably. Bearing failures caused by dust from the mix, however, are a continuing problem.

The vertical drag chains have had a number of problems including erosion and bent chain flights (due to material jamming, particularly on the curves). To correct these problems, the housings were rebuilt with abrasion-resistant steel, half of the flights were removed, and the remaining flights were trimmed so that they now block only 25 percent of the housing cross section (the original flights covered it almost completely). Every 4.6 m (15 ft) along the chain, a reinforced steel scraper flight slightly larger than the original flights has been installed. Since these modifications were made, few problems have occurred.

Nonetheless, the drag chains are wearing out faster than expected. The chains and flights must be replaced every year and the housings will probably have to be replaced every 3 years.

There is one Littleford plow-type mixer per train, both of which have had only minor problems. However, their location complicates operations because the operators, who depend heavily on mix appearance for quality control, are situated in the ground-level control room where they cannot see the accumulators or the mixers. The accumulators and mixers are also difficult to service since there are no elevators, and the operators have to climb a steel stair tower (sometimes covered with ice in winter) to reach them.

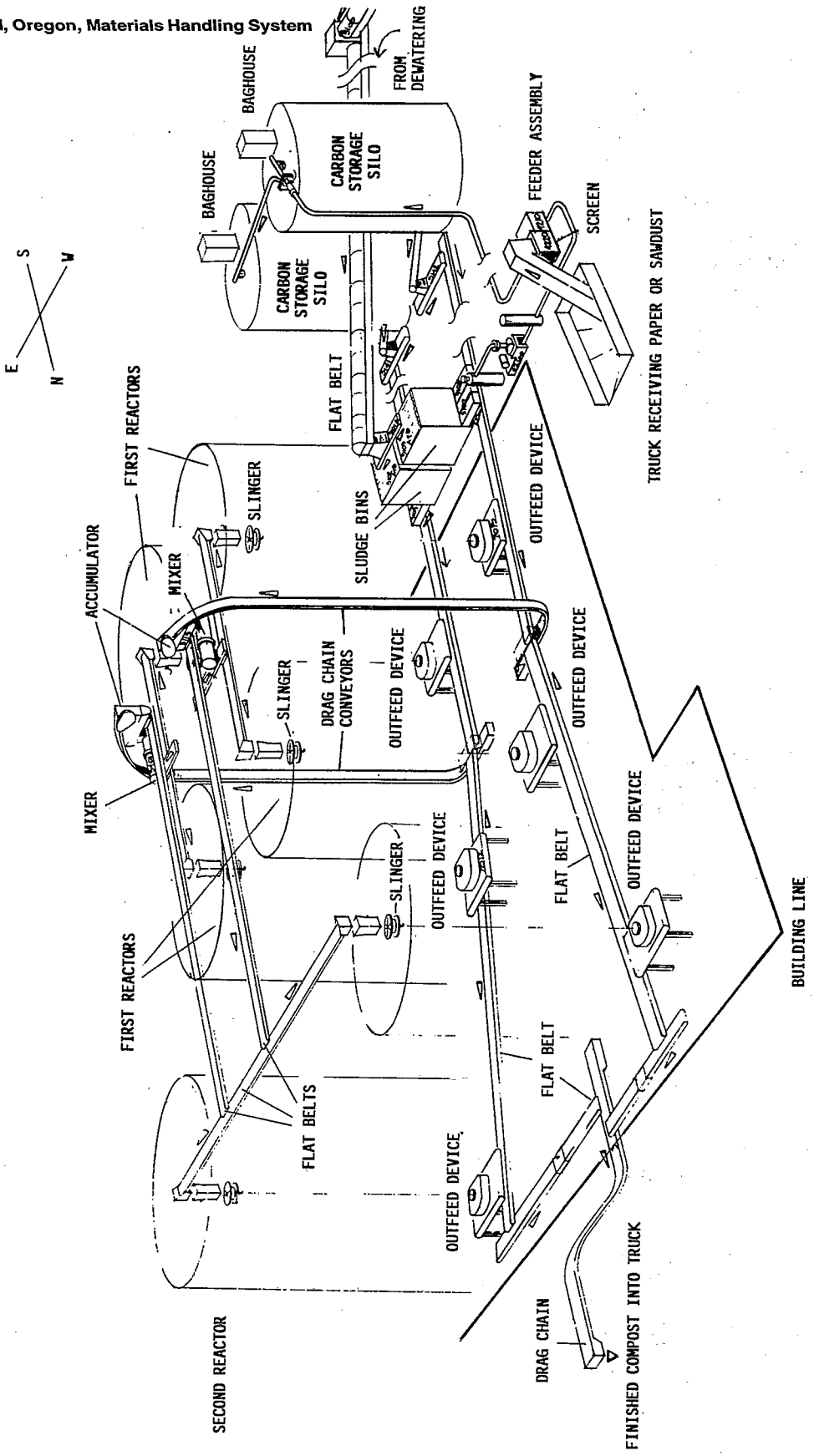
11.3.4 Reactors

11.3.4.1 Reactor Feed System

The mix is conveyed to the reactors on enclosed belt conveyors. (See Figure 11.5.) The feed materials enter either first-step reactor from the belts through "slingers", funnel-shaped devices that distribute the mix. In order to evenly distribute the mix, the slingers have been modified to spin in opposite directions for equal lengths of time. The slingers work well mechanically.

Repairing the slinger, however, is very difficult. To repair the top of the slinger or unjam the feed conveyor, the operator must access the top of the reactor on the outside of the building by climbing the stair tower to a narrow catwalk. From the catwalk, which is about 0.6 m (2 ft) above the top of the reactor, the operator must reach down into the top of the reactor to the slinger, an awkward position for the operator. In addition, there is no working space on the catwalk and the slinger cannot be removed from the top because there is no hoist. The operator is usually forced to repair the slinger by accessing the bottom of the slinger from inside the reactor dome. To do this, the operator must approach the slinger by walking across the surface of the composting mass.

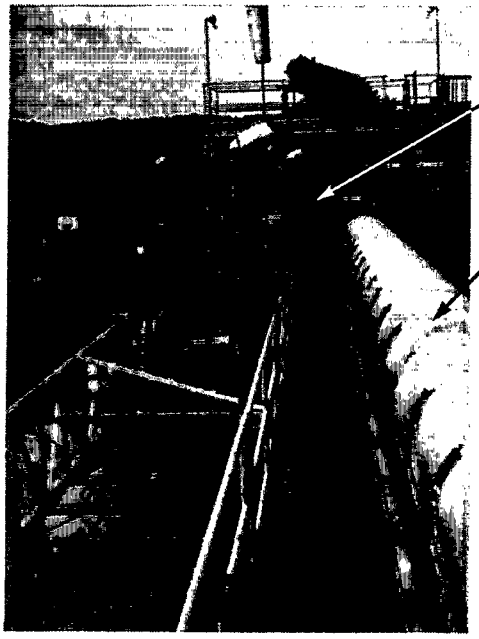
Figure 11.4 Portland, Oregon, Materials Handling System



The feed system is configured so that only one first-step reactor per train can be fed at a time. To make room for feed material in the reactor, some of the existing material in the reactor must first be removed. A typical loading cycle starts with 3 hours of unloading compost from the reactor and moving it to the second-step reactor. This is followed by 4 hours of unloading material from the first reactor and immediately recycling it as part of the fresh mix for the same reactor.

Currently, there is no way to move material from one feed train to the other until it is discharged from the first reactor (i.e., the mixer on one train cannot service the reactors on the other train). However, material from any of the first-step reactors can be moved to either second-step reactor. To give the facility more flexibility, adding a conveyor to connect the two trains at a location downstream of the mixers is being contemplated.

Figure 11.5 Side View of Vertical Drag Conveyor, Mixer Building, and Enclosed Belt Conveyor



11.3.4.2 Configuration

There are two cylindrical vertical first-step reactors per train, operated in parallel. Each one is 8.8 m (29 ft) tall and 13.0 m (42.5) ft in diameter with an average compost depth of 7.0 m (23 ft). The first-step reactors are constructed of steel and have concrete bases (see Figure 11.6).

There is one second-step reactor per train. Its construction is similar to the first reactors and it has the same height, 8.8 m (29 ft), but it has a larger diameter, 16 m (59 ft). Each cure reactor has a volume of 1,800 m^3 (63,200 cf). The second reactors are operated like the first reactors. After leaving the second-step reactor, the compost contains about 40 to 42 percent solids, and may contain up to 45 percent solids if the mix contains 40 percent solids.

11.3.4.3 Reactor Aeration System

Each of the six reactors is aerated by a positive displacement blower rated at 0.66 m^3/s (1,400 cfm) at 69,000 Pa (10 psi), 75,000 W (100 hp) variable speed. In addition, two auxiliary fixed speed blowers (one per train), each 0.33 m^3/s (700 cfm) at 69,000 Pa (10 psi); and 30,000 W (40 hp), can supply any of the four first-step reactors. The supply piping consists of 0.15 m (6-in) diameter PVC headers feeding 0.03 m (1.25-in) perforated PVC tubing laid beneath a 0.03 m (12-in) layer of 0.02 to 0.04 m (0.75- to 1.5-in.) washed river gravel. The piping is divided into four independent quadrants that are controlled by a programmable sequencer. There are no dividing walls in the gravel bed to prevent short-circuiting between the quadrants. The blowers for the first-step reactors usually run at 90 percent capacity for 20 hours per day (there is no aeration during reactor loading). The sequence for each quadrant in the second-step reactors is 2 to 3 minutes "on" followed by 6 minutes "off."

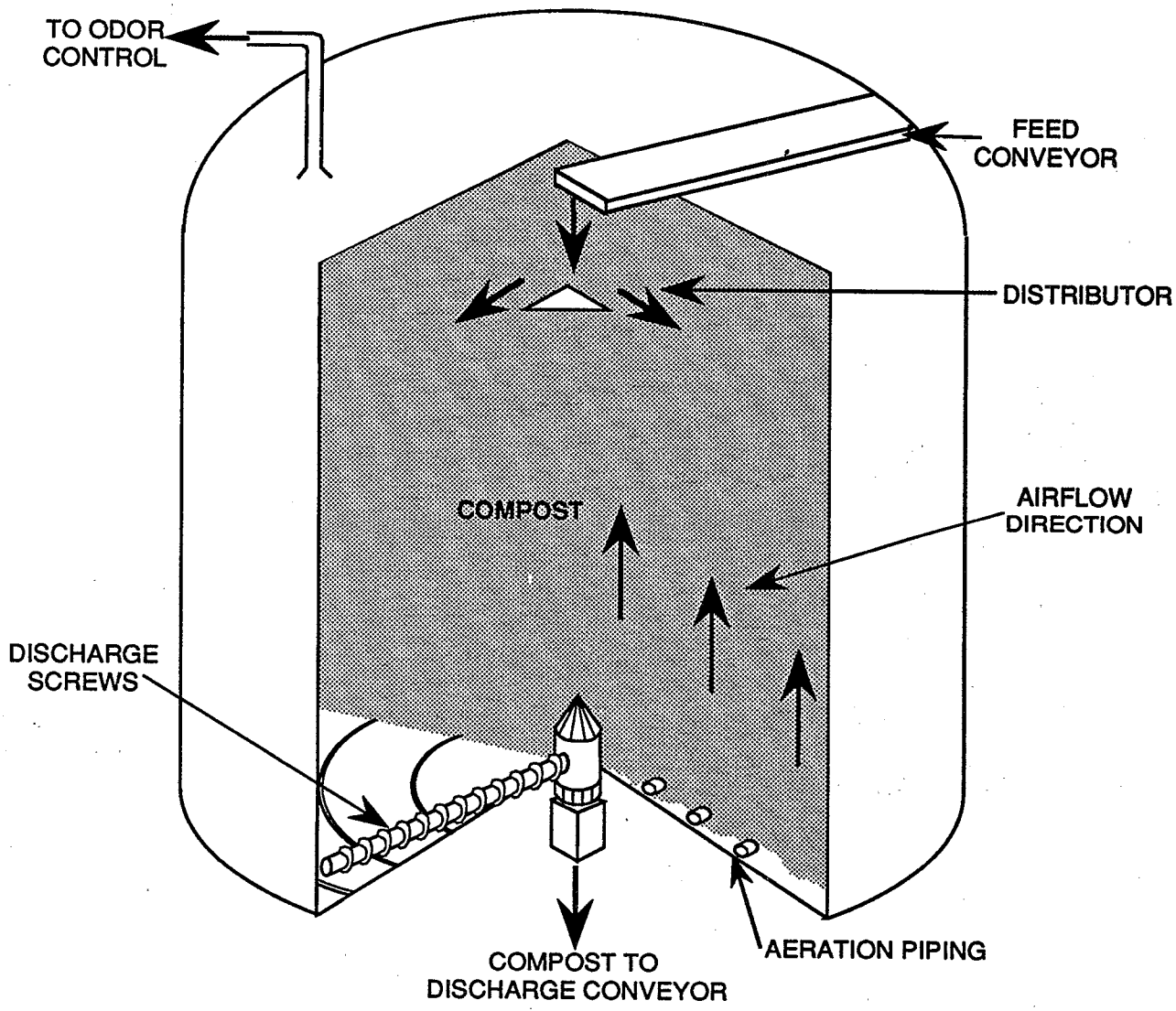
One centrifugal exhaust blower per reactor (six total), rated at 1.1 kg m^3/s (2,330 cfm) at 26,000 Pa (3.76 psi) 4,500 W (60 hp) removes the air from the headspace of the reactors (process air). The ability of the exhaust systems to remove the air blown into the reactors is satisfactory under normal circumstances. If all the blowers, including the auxiliary units, are operating at maximum capacity, however, a slight pressure builds up inside the first-step reactors. Each adjustable reactor is fitted with an adjustable pressure/vacuum relief valve that opens automatically if the pressure exceeds 62,000 Pa (9 psi) (factory setting).

11.3.4.4 Outfeed Device

The outfeed device for all reactors is a center pivot screw that pivots around the center of the reactor much like the hand of a clock. A cam operated brake assembly at the end of the screw grips an I-beam rail, which runs around the circumference of the reactor (see Figure 11.7). The clamping assembly rotates the screw in a circular path around the bottom of the reactor. To remove the compost from the reactor, the clamp must be secured. Once it is secured, a variable speed hydraulic piston powered by a hydraulic motor located in the center pivot pushes the outfeed screw into the compost. The screw then rotates on its axis, feeding the compost through a discharge gate located in the center of the reactor, where it drops onto a reversible conveyor belt. From there, the material from the first-step reactors goes up the vertical drag chain to the accumulator where it is either used as recycle and directed to a first-step reactor via a mixer, or directed to the second-step reactor. Material from the second-step reactor is conveyed to a drag chain that takes the compost outside the building to a waiting dump truck.

The reactor outfeed device has experienced four problems, the first being excessive wear on the screw. Although not hard-surfaced, the screws were expected to last 7 years. Nevertheless, after 14 months of operation, during an annual inspection, screw wear was noted as "extreme." Four of the six screws had to be replaced and all of the screws were subsequently hard-surfaced. Facility personnel believe the continued presence of ash (from the Mt. St. Helens eruption) in the sludge contributes to the excessive wear. This is supported by the observation that wear on the end of the screws from the midpoint to the center of the reactor is greater than wear on the outer end.

Figure 11.6 First Reactor from Portland Train



The second problem with the reactor outfeed device involved the clamp assembly. This mechanism would not hold the I-beam rail securely enough to enable the piston to rotate the screw into the carpet. The clamp was modified into a mechanically operated cam that grips the rail more firmly. This modification did not sufficiently improve the reliability of the unit, however, so at the time of the site visit, an engineering firm was preparing design improvements. Access to this brake mechanism is very restricted — a 0.91-m by 1.2-m (3-ft by 4-ft) space around the outside edge of the reactors. A third, though less serious, problem is that the filters in the hydraulic power units must be replaced more often than anticipated because of the dirty work environment.

The fourth problem is that the outfeed screw must move regularly, even though it was designed to operate only when outfeeding the compost. If it does not move regularly, the screw becomes trapped in the composting mass. If the compost is too dry, it forms a hard, tunnel-like structure that is difficult to penetrate. If too wet, the mass will collapse around the screw (so-called "oozing" compost), making the screw hard to turn. Oozing compost can also move beneath the annular ring of the reactor (see Figure 11.7), blocking the path of the drive mechanism. To avoid this, a plow has been welded onto the braking mechanism to clear material from between the rail and the annular ring.

11.3.4.5 Leachate/Condensate

In each reactor, four leachate drains discharge the leachate to the WWTP. These drains are closed by valves to prevent short-circuiting of air and must be manually opened each day. The city is contemplating replacing these valves with automatic valves. Typical leachate volumes are 0 to 7.6 L/day (0 to 2 gal per day) per first-step reactor. There is usually no leachate from the second-step reactors.

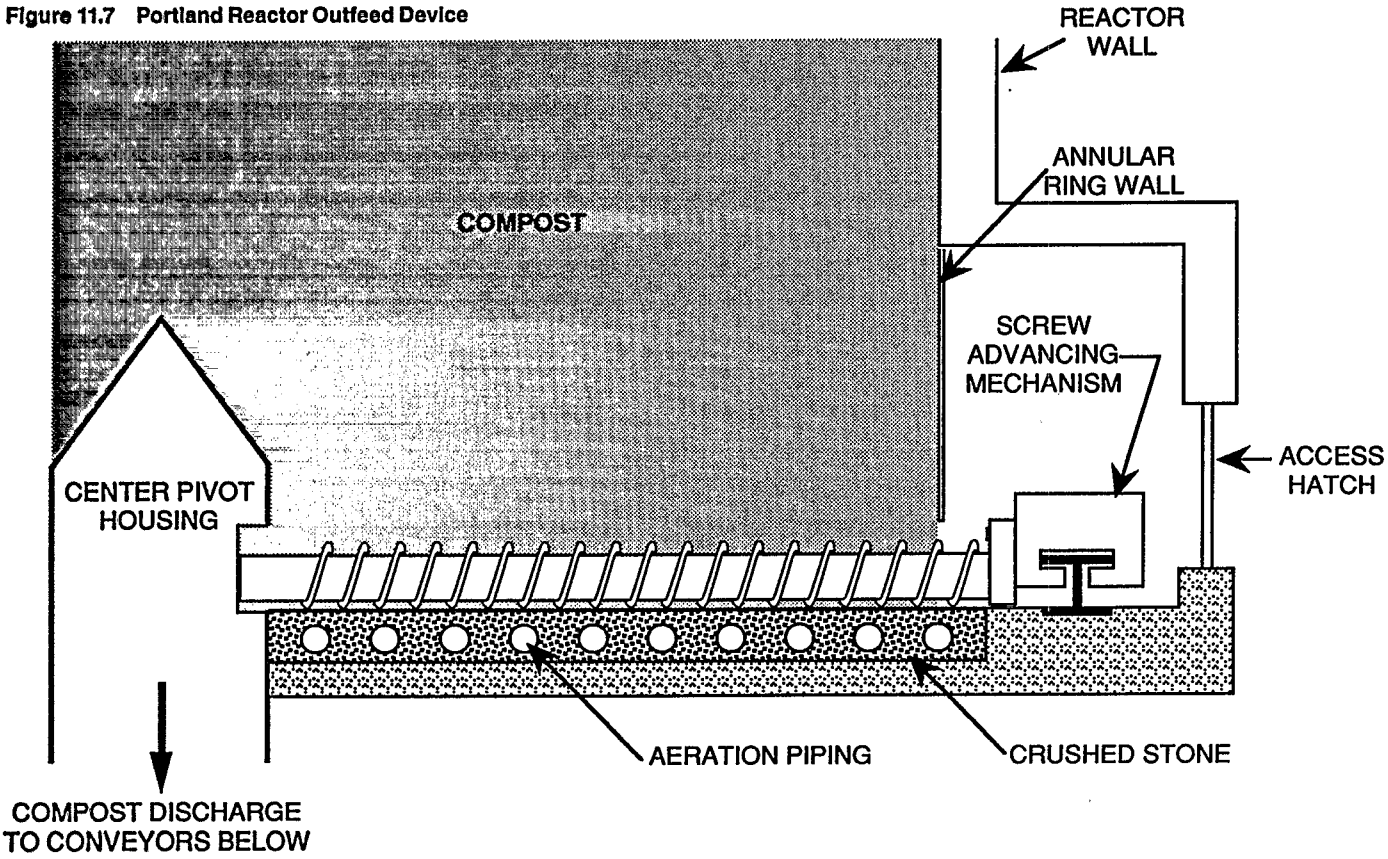
11.3.5 Exterior Curing/Storage

North American Soils (NAS) assumes responsibility for handling the material after it leaves the reactors.

The compost is cured/stored short-term on an open asphalt pad, then moved to unpaved ground for long-term storage. The runoff from the curing/storage areas drains into the ground. A new, larger pad is being planned that will capture the runoff and return it to the treatment plant. Once the new pad is constructed, all of the compost will be cured/stored on it. At the time of the site visit, more than half of the compost was cured/stored directly on the ground.

The curing/storage piles are not controlled and there are no State regulations on minimum curing/storage times. NAS sells the oldest material first. Generally they do not

Figure 11.7 Portland Reactor Outfeed Device



screen the compost, but they do mill it if the particle size is too large for the customer's intended use.

11.3.6 Nonprocess Air Handling

The mixing room, which is actually just an enclosure around the mixer, is ventilated by a small wall fan. The dewatering building is reportedly odor-free.

The process building air is vented directly to the atmosphere by a number of small ventilating fans in the roof and walls. (The overall exchange rate is not known.) To increase airflow, operators commonly leave the doors of the building open, even in winter.

The operators' control room/office is located in the process building. Originally, this room did not have an air conditioner, but the operators installed one. The ventilation in this room is provided by fans that pull air out of the office and exhaust it to the atmosphere. As a consequence, the ammonia is pulled into the control room from the rest of the building. The operators plan to modify the ventilation system so that the fresh air is brought in from the outside.

11.3.7 Odor Control

11.3.7.1 Characterization

The Columbia River forms the north boundary of the plant site and North Columbia Boulevard forms the south boundary. On the other side of the boulevard, there are homes on sloping land approximately 305 m (1,000 ft) from the plant and 150 m (500 ft) from the compost curing/storage yard. The part of the yard nearest these neighbors is reserved for the oldest and least odorous compost. There are no neighbors on the river side of the plant. Other industries, including a rendering plant and a box factory, are located to the east and west of the site.

As of March 1, 1989, there had been only one citizen odor complaint, which was made when fresh compost was cured/stored near North Columbia Boulevard. The fact that the sludge is anaerobically digested may be an important factor behind the lack of odors associated with this plant.

Ammonia has been problematic in the process building, where ammonia concentrations up to 38 ppm have been measured. Although the level is below the EPA 8-hour exposure limit of 25 ppm, the operators find the odor objectionable. The source of the ammonia appears to be freshly removed material as it is discharged from the first-step reactors by the outfeed devices. There have been no complaints of ammonia odors offsite.

11.3.7.2 Treatment

Process air is bubbled into the collection channel for the primary clarifiers at the WWTP and then released at ground level. The channel is covered except for open grates at a slide gate installation. Near the grates, the compost odor could be detected during the site visit, but it was not offensive. The treatment system is not monitored.

11.3.8 Support Facilities

The operators' control room is in the process building, which is located on the first floor of the reactor complex. The supervisor's office is in the WWTP building as are restrooms, showers, lockers, lunch room, and laboratory. The maintenance facilities are also shared with the WWTP.

11.4 Monitoring and Performance

11.4.1 Reactor Control Strategy

The composting system is operated to meet EPA time and temperature criteria for pathogen reduction.

The operators use temperature probes (metal pipes containing thermistors suspended in oil) to measure the temperature manually in each reactor at nine vertical points. They also measure the offgas temperature. The temperatures are recorded on strip charts and noted in daily logs. The temperature data are not used for process control or reported to the State.

In the first-step reactors, the temperatures are typically higher in the middle and bottom of the compost mass than on the top. In the second reactors, the temperatures are generally highest in the top and lowest in the bottom. The aeration system for the reactors was designed for oxygen feedback control based on the oxygen necessary to maintain aerobic conditions to produce a stable finished product. The amount of oxygen supplied by the oxygen control system was not enough to dry the compost to the desired level, given the moisture content of the mix. Consequently, the oxygen control system was abandoned. Now the compost in the first-step reactors is aerated continuously at 90 to 95 percent blower capacity to produce a drier product.

Operators have not found good correlation between the total solids measured with a heat lamp and those measured in the lab with a drying oven. Consequently, they do not use the heat lamp for "real-time" mix control. Instead, the quality of the mix during loading is determined "by eye." A sample of the mix from every batch is also collected and analyzed with a drying oven for solids content.

11.4.2 Mass Balance and Reactor Detention Time

A materials flow diagram, constructed from available plant records, is shown in Figure 11.8. There was not enough data available to construct a mass balance. The system was designed for a 30-day plug-flow detention time that encompasses the time in both first- and second-step reactors. The estimated plug-flow detention time of the system was about 19 days at the time of the site visit; the split between time in the first- and second-step reactors was not known.

11.4.3 Product Quality

The compost from the Portland facility is meeting the EPA pathogen requirements. When the compost emerges from a first-step reactor, its solids content is 38 to 40 percent. Material discharged from the second-step reactor has a solids content of 40 to 42 percent (with a maximum of 45 percent) and a bulk weight of about 590 kg/m³ (37 lb/cf).

The compost can be used in accordance with the following State regulations for sludge:

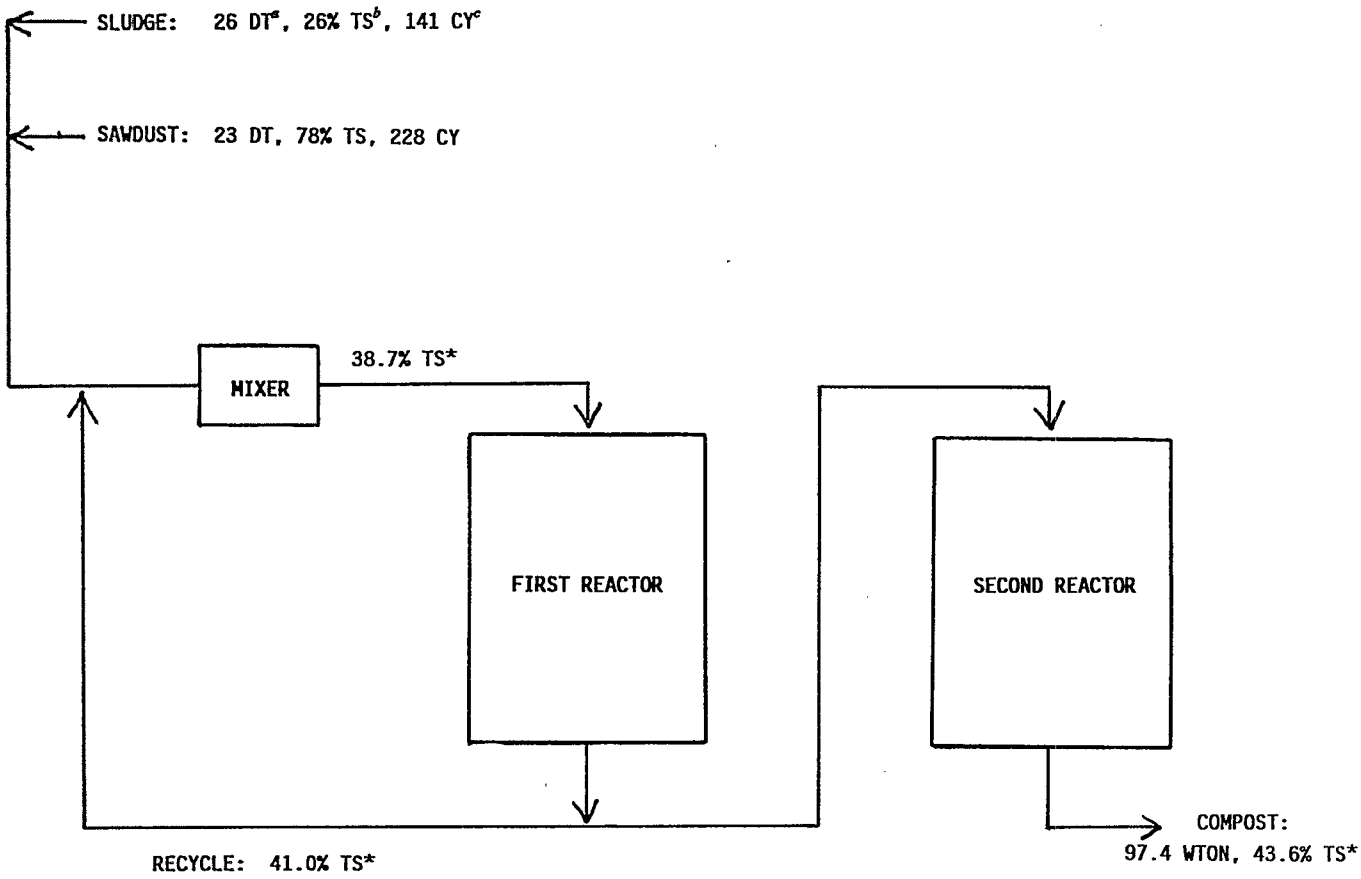
- No sludge may be applied to fruits or vegetables that are to be eaten raw.
- Sludge applications shall not exceed the nitrogen requirements of the crop. Metals loadings shall be limited to those shown in Table 11.1.
- Crops grown for direct human consumption shall not be planted for 18 months following sludge application. (This restriction is waived if the edible parts of the crop are not in contact with the soil or if the crop is processed before consumption so that pathogen contamination is not a problem.) Grazing animals are not allowed on land treated with sludge for 30 to 180 days following application.
- There are no restrictions on growing food chain crops if the crop is not grown for direct human consumption, if the part of the crop eaten by animals is not in direct contact with the sludge, and if the concentrations of metals in the sludge are less than those shown in Table 11.1.

Table 11.1 Maximum Heavy Metal Loading Recommended for Sludge Applications to Privately Owned Farmland

	Maximum Metal Addition (kg/ha[a]) with a Soil Cation Exchange Capacity (meq/100 g)		
Metal	Less than 5	5-15	Greater than 15
Pb	500	1,000	2,000
Zn	250	500	1,000
Cu	125	250	500
Ni	50	100	200
Cd[b]	5	10	20

[a]ha = hectare. Kg/ha is roughly equivalent to lb/acre.
[b]The maximum application of Cadmium (Cd) for soils with pH values of 6.5 or less is 4.5 lb/acre of the cation exchange capacity.

Figure 11.8 Portland, Oregon, Materials Flow Average Daily Quantities, December 1987 to May 1988



* BASED ON DATA FROM APRIL 1988 TO JUNE 1988.
NOTE: PLANT STAFF REPORT THAT THE TYPICAL MIX RATIO FOR THIS PERIOD WAS 1/16/0.6 BY VOLUME.

[a] DTON (WTON) X 0.9072 = DT(WT)
[b] TS = TOTAL SOLIDS
[c] CY X .765 = M³

The compost may be used without restriction on indoor and outdoor ornamental plants, shrubs, trees, and grass. Typical metals concentrations for Portland's sludge and compost are reported in Table 11.2.

Table 11.2 Product Quality[a]

Constituent (unit)	Oregon State Standard for General Application to Agricultural Land	Belt Press Cake (average of 3 composite samples)	Finished Compost (average of 3 grab samples)
Zinc (mg/kg)	2,000	2,073	1,151
Lead (mg/kg)	1,000	582	319
Copper (mg/kg)	800	843	427
Nickel (mg/kg)	100	175	102
Cadmium (mg/kg)	25	38	22
Chromium (mg/kg)	—	409	244
Total Nitrogen (%)	—	3.83	1.85
Total Phosporus (%)	—	1.95	1.45
Potassium (%)	—	0.20	0.17

[a]Sampling conducted on September 17-28, 1987; December 15-28, April 5-18, 1988.

11.5 Operations

11.5.1 Staffing

The plant is staffed by two operators per shift for two shifts per day, 7 days per week. The lead compost operator on each shift has 2 to 3 years of experience and an associate's (2-year) degree in wastewater technology. Most assistant operators also have an associate's degree, but do not have experience in wastewater treatment. The city reportedly pays well and has no trouble getting qualified operators.

Initially, the equipment suppliers gave the operators several hours of classroom training followed by hands-on training. Continuing training, which covers both process and equipment operation, is organized in house and delivered by the supervisor. The current supervisor is a Grade IV (highest level) certified treatment plant operator with 11 years experience. He has associate's degrees in wastewater treatment technology and waterworks technology.

The compost facility supervisor is a full-time position. The operating staff rotates through the composting plant. Because relatively little process control is being exercised, short tours by the operators do not create problems, despite the fact that the mixture quality is dependent on the operator's judgment. The maintenance budget anticipates running one shift 5 days per week with three persons. Maintenance personnel are supplied by the central WWTP maintenance pool. The plant supervisors feel that the present size of the maintenance staff is adequate.

The rotating maintenance workers from the pool of workers at the WWTP have no comprehensive training in composting system maintenance. In addition, the maintenance department's responses to problems at the compost plant have been lax, due to the unavailability of parts and the department's assumption that there were redundancies in the systems. The compost plant, however, has little redundancy, and there have been times when the plant has been shut down, waiting for maintenance personnel. This problem has recently been recognized by the WWTP management, who are revising the maintenance procedures and developing a preventive maintenance program to forestall plant shutdowns. In addition, the plant is trying to streamline parts procurement procedures.

11.5.2 Marketing and Distribution

Although the compost meets State standards, the product is relatively wet and the market has been slow to develop. The primary customers have been golf courses, landscapers, nurseries, and public works departments, who use the compost on highway median strips. The nursery industry is a growing market, but has been slow to develop. Currently, nurseries are conducting long-term compost testing before accepting the compost as a substitute for peat in their potting mixes.

Until June 1988, NAS bought compost for $11/t ($10/ton). This price has been renegotiated to $39/dt ($35/dton) of sludge processed under a joint marketing agreement between the city and NAS. Under the new agreement, which specifies profit sharing rather than revenue sharing, the city will pay for the advertising. Previously, NAS was committed to buying everything produced by the system, and product quality was not an important issue to the city. Now it is in the city's as well as NAS's interest to maximize product marketability. Spring 1988 was the first time NAS sold more than the plant produced during a given period.

11.5.3 Operating Costs

Operation and maintenance costs for 1988 were estimated by Taulman at the time of the 1982 proposal. The estimated 1988 costs compared to actual 1988 budget amounts are shown in Table 11.3. The table does not include costs for replacement parts and materials and the supervisor's salary. The costs were higher than expected in the following categories: operations (due to higher labor requirements), sawdust, and maintenance labor.

The price for sawdust varies according to its quality (bulk weight and moisture content), ranging from $3.4 to $4.9/m^3 ($19 to $28 per 200 cf), with an average price of $3.7/m^3 ($21/200 cf). Recent competition among sawdust suppliers has driven the price down dramatically from 1985 levels, which exceeded $39/m^3 ($30/cy). Even though these prices dropped, total amendment costs were still higher than expected because more sawdust was used than anticipated.

Table 11.3 Operation and Maintenance Costs (Major Items)

	Annual Cost	
	1982 Projection of 1988 Costs	1988 Budget ($)
Electricity	110,000[a]	179,000
Sawdust	197,000	335,000
Labor and Miscellaneous Materials	234,000	331,000[a] 260,000[b]
	541,000	1,105,000
Basis of Estimate (dt/day of sludge)[c]	46	30

[a]Operations.
[b]Maintenance.
[c]d/ton × .9072 = dt.

11.6 Update

In March 1989, the survey team received the following information by phone from the facility.

Operations have changed substantially since the site visit. The lagoon system that previously stored waste activated sludge (WAS) before composting has been bypassed. In addition, the dewatering system now receives digested primary and WAS (50/50 mixture) directly from their respective anaerobic digesters. Also, the tmperatures are higher in the first-step reactors now (typically over 70°C for 6 days), presumably because the volatile solids content of the sludge is higher.

The city is running the reactors at a lower throughput rate (10 dt/day [11 dton/day] sludge) than design (15 dt/day [16.5 dton/day]). The purpose of this change was to promote drying and improve product quality (fewer ammonia odors, cooler, more friable). Based on the volumetric mix ratio of 1/1.6/0.6, the current plug-flow detection time is estimated to be 14 days in the first-step reactors.

The combination of higher temperatures and longer detention times (aeration has not changed) has increased the drying capability of the system. The mix is 37 percent total solids, as before, but the discharge solids from the first-step reactors are about 45 percent total solids (compared to 38 to 40 percent previously). The second-step reactor discharge is 50 to 55 percent total solids (compared to 40 to 42 percent previously). These solids contents represent a substantial improvement over performance at the time of the site visit. To further promote drying and improve product quality, NAS is installing an aeration system and a cover for the curing/storage area. NAS is also installing a bagging operation.

Numerous minor mechanical problems continue to plague the plant and reduce its capacity. Most of these problems are related to parts and equipment wearing out faster than expected. For example, the city now expects outfeed screws to last 18 months, drag chain flights and chains to last 1 year, and drag chain housings to last 3 years.

A number of measures, in addition to those discussed in Section 11.5.1, are being taken to reduce down time. A new computerized maintenance management system is being implemented to help the maintenance staff track equipment performance, anticipate problems, and plan preventive maintenance activities. A new spare parts storage building is being built (which serves the entire WWTP complex), and the compost supervisor is steadily acquiring the needed stockpile of spare parts.

When called in June 1989, the Portland facility had nothing to add to the information they gave in March 1989.

Chapter 12
Sarasota, Florida

12.1 Introduction

The Sarasota, Florida, in-vessel composting facility is owned by the city and managed by the Water Utilities Department. The system uses two rectangular vertical reactors supplied by Purac Engineering, Inc., in series. The design capacity of the facility is 5.67 dt/day (6.25 dton/day) based on a 7 day per week operation.

The facility is located at the existing wastewater treatment plant (WWTP), which is situated in the midst of a commercial neighborhood. Businesses are built up to the fenceline all around the facility, with no buffer zone and no room for the compost facility to expand. The composting facility site area is 3,500 m^2 (0.86 acres).

The site visit took place on June 29 and 30, 1988. Except as indicated, the equipment, processes, data, and issues described in this case study are representative of that period only. The plant supervisor feels that the only period in which the operations were stable enough to be considered "normal" were in May and June of 1988. Thus, much of the data presented below are based on short-term averages.

12.2 History of the Plant

12.2.1 Procurement and Construction

A 1982 sludge management study, conducted for the City of Sarasota by Smith and Gillespie Engineers, Inc., recommended composting as a more energy-efficient method of managing sludge than hauling liquid sludge or pelletizing. Of the composting processes, Sarasota chose in-vessel composting because the city wanted to locate the plant at the existing WWTP and in-vessel facilities require a relatively small area. A turn-key project was not considered because the city wanted to be involved throughout the process and be totally familiar with the plant.

The city hired Smith and Gillespie Engineers to develop the prequalification design criteria, plans, and specifications. The design specifications were based on a Taulman-Weiss (Taulman) system, and included an "or equal" clause. To qualify, the contractors had to have proven experience working with vertical plug-flow reactors, composting sewage sludge, and handling compost using an outfeed screw device. In addition, the system had to contain three outfeed devices in a two-stage system designed for flexibility, meeting space limitations, and even distribution of compost over the reactor surface. Estimates for motor loads with kilowatts per hour consumption had to be included in the specifications.

In the conceptual plan, odor control was not an issue. During the design phase, however, an ozone system was added as a contingency measure. The ozone system would control anaerobic odors occurring due to blower failures or other unusual events.

The city issued an RFP for wastewater treatment plant improvements, of which composting was 50 percent of the estimated cost. Gulf Constructors, Inc. was awarded the project; Purac was the compost system subcontractor. Several design changes occurred during the submittal/construction process that affected the project costs. These changes were a result of different interpretations of the plans and specifications by the engineer and the system supplier. The issue is still being disputed.

12.2.2 Capital Costs

An EPA Innovative Alternative (I/A) Grant provided 75 percent of the funds for the project; the city funded the remainder. The costs contained in the grant application were estimated at $5.066 million, including the costs of dewatering facilities.

Actual construction costs were $4.1 million, including the dewatering system, which could not be separated from the total capital costs. The costs related to change orders totaled $86,000.

An odor control retrofit project, budgeted at $200,000, is planned to replace the ozone system.

12.2.3 Operating History and Current Status

The facility began operating in September 1987. Although it has been running continuously since then, the first year was primarily "trial" operations. During this period, the sludge flow rate, product quality, and operations were inconsistent due to various startup problems. Also during this period, the contractor performed warranty work, the computerized control system was installed and debugged, and a variety of amendment sawdusts were tried.

At the time of the site visit, the facility was processing all available sludge, but it was not running at full capacity (5.7 dt/day [6.25 dton/day]). Based on annual sludge production at the WWTP, the city estimates that the plant will process 3.5 dt/day (3.9 dton/day) in summer (April to September) and 4.3 dt/day (4.7 dton/day) in winter (October to March).

After startup, the Florida Department of Environmental Regulation (DER) classified the plant as a "solid waste volume reduction facility." The plant therefore must obtain a solid waste operating permit to process and market its compost. The facility has submitted a permit application.

12.3 Description of the Plant

12.3.1 Systems Overview

The Sarasota facility consists of a dewatering building, a sawdust receiving station, a sawdust storage silo, two reactor buildings, and a compost curing/storage building. The reactor buildings also contain the mixing, blower, and control/administrative rooms. Figure 12.1 provides an overview of the facility.

The conveyance and mixing systems for the two reactors are parallel in design. Both reactors can operate as the first or second in the series, and materials can be fed from either side of the materials train. Only one system operates at any one time, however.

In the process flow of the Sarasota facility, conveyors carry dewatered sludge from the dewatering building and sawdust from the sawdust storage silo to one of the two mixers in the mixing room. The sludge, amendment, and recycle are combined in either mixer to create the raw compost mixture. The mix is then conveyed to the top of either reactor. An outfeed reclaiming screw, located at the bottom of each reactor, loads the processed material onto a conveyor which carries the material from either reactor to the mixers. The material is then carried to and deposited in the top of the curing/storage area. Figure 12.2 illustrates the process flow.

Figure 12.1 Sarasota, Florida, Sludge Composting Facility

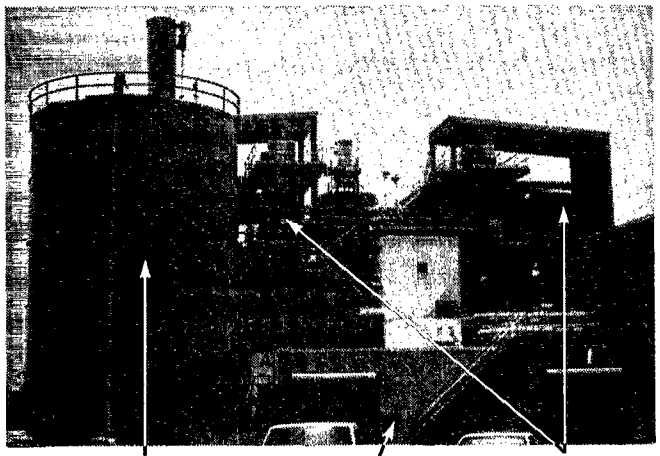
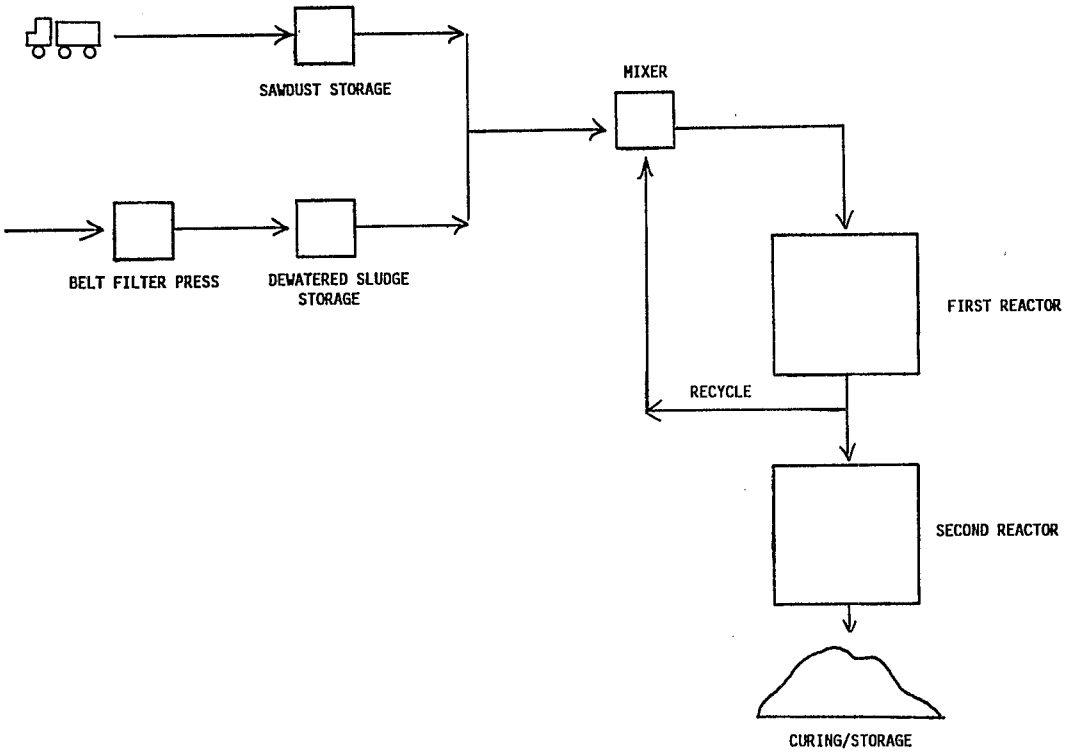


Figure 12.2 Sarasota, Florida, Composting Process Train



The aeration/temperature control system contains supply and exhaust air blowers, a heat exchanger, pneumatically controlled air valves, flow meters, pressure meters, and temperature meters. By design, the reactor inlet air is drawn from the dewatering building. In practice, the supply air blowers also draw air from the blower room. Air is supplied to the compost material through a series of distribution pipes located in the bottom of the reactor beds and regulated by a series of pneumatic valves. The air is drawn out of the reactors by a series of exhaust air blowers and an exhaust air piping system located within the upper level of the compost material.

The process air drawn from the reactors can be ducted through a heat exchanger to preheat supply air. It is then channeled into an ozone contactor, where it is treated to remove odors and released into the atmosphere. Nonprocess air is ventilated throughout the facility with a number of exhaust fans.

The facility does not have an automatic fire protection system.

12.3.2 Feed and Mix Characteristics

12.3.2.1 Sludge

The facility receives waste-activated sludge (WAS) that has been thickened in dissolved air flotation (DAF) units to 3.0 to 3.5 percent solids. The sludge is stored in unaerated liquid holding tanks at least 1 day every weekend. This sludge turns septic in about 24 hours.

The liquid sludge is dewatered by belt filter presses 6 days/week to 15 to 16 percent solids. At the time of the site visit, the volatile solids were about 76 percent and the bulk weight was 918 kg/m^3 (57.3 lb/cf). However, although measured during the startup phase, bulk weight is not measured on a regular basis unless the solids content deviates significantly.

12.3.2.2 Amendment

The sawdust is supplied by several kiln-dried lumber operations. The only specifications for the sawdust are that it must be "as per the sample provided" at the beginning of the contract. The sawdust is from softwood, probably pine, and has the following characteristics: both the total solids and volatile solids contents are 90 percent; the pH is about 4.5; the bulk weight is 290 kg/m^3 (18 lb/cf); and the nominal particle size is 0.006 m (0.25 in.). The city has recently changed to a sawdust with an increased particle size that is typical of a small chip.

When cypress sawdust was tried during startup, reactor temperatures were lower and they peaked deeper in the bed. According to the plant supervisor, this was probably because cypress wood is more resistant to decay. This unusual temperature profile was not considered desirable by the operator.

12.3.2.3 Recycle

The compost from the second reactor is most often used for recycle. At the time of the site visit, the dry solids content in the recycle from the first reactor was 50 to 55 percent, although it can range up to 70 percent. The compost from the second reactor is generally 10 to 15 percent drier than the compost from the first reactor.

12.3.2.4 Mix

The 35 percent solids design mix ratio initially caused mixer plugging problems; thus, during startup, the sawdust to recycle ratio was estimated, tested, and modified until clogging in the mixer was reduced. The present operational goal is to create 40 percent solids in the initial mix. The average mix achieved from May through June 1988 was 40.4 percent, with a range of 33.8 to 46.4 percent.

The design volumetric mix ratio of sludge to sawdust to recycle is 1/1/2, and 1/0.72/1.76 by dry weight. Actual volumetric mix ratio at the time of the site visit was 1/0.56/2.44 and 1/1.13/5.18 by dry weight.

The facility is using more sawdust and recycle than anticipated (dry weight), primarily because the present mix is drier than the design mix, and the sludge cake is lower in solids content. The problem has been somewhat alleviated by using sawdust and recycle that are drier than anticipated in the design. Also, sludge production is less than expected.

12.3.3 Materials Handling

Figure 12.3 is a schematic of the materials handling system. From the belt filter presses, the sludge drops directly into an uncovered live-bottom sludge storage bin containing open core (shaftless) discharge screws. Based on the availability of the sludge, the reactors are loaded only 5 days/week. Because dewatering takes place 6 days/week, dewatered sludge is stored in the bins at least 1 day/week, but usually for not more than 2 days/week.

Sawdust is delivered by bottom-feed trucks to a modified hopper. A metal shroud built around the receiving bin doors controls blowing dust during delivery. Two shaftless screws then transfer the material from the hopper to a pneumatic feed that conveys the sawdust to the top of a 26 ft diameter by 34 ft tall storage silo. The pneumatic system shuts down if the air pressure in the sawdust storage system becomes greater than 20,700 Pa (3 psi).

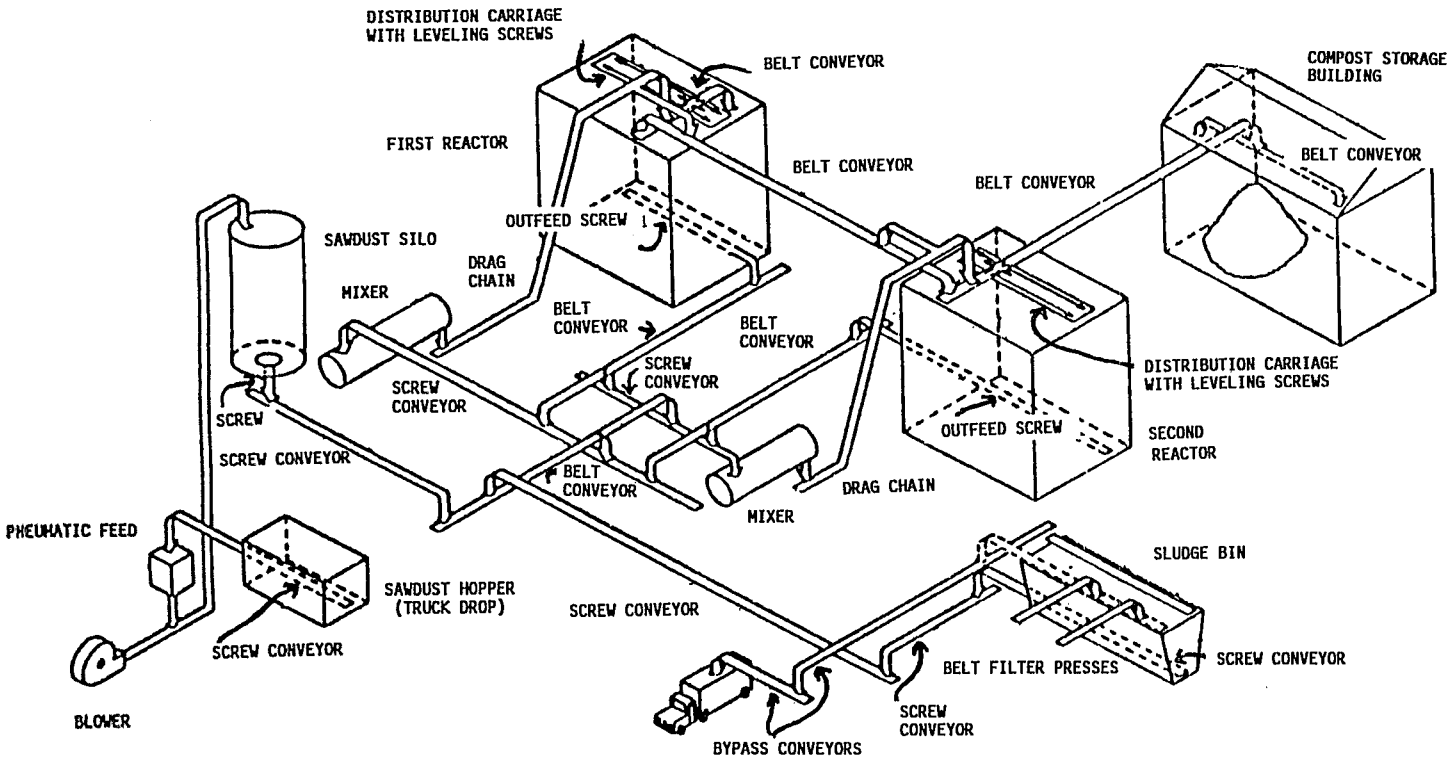
An auger circulates around the bottom of the sawdust storage silo to move the sawdust onto a variable-speed screw conveyor and then onto a belt conveyor for transport to the mixing room.

The hollow-core sludge and sawdust discharge screws, both shaped like springs with support at only one end,

have worked very well. One or two horizontal bars installed perpendicular to and just above the screws hold down their free ends, which have a tendency to rise out of the material.

The recycle material is not stored but brought directly from the reactor to the mixer feed system.

Figure 12.3 Sarasota, Florida, Materials Handling System



Two variable-speed screws feed the sludge from the storage bin to a cross conveyor and then to a transport screw, where it is deposited on the belt conveyor with the sawdust. The sludge feed rate is varied to control the solids content of the mix. The speed is usually controlled automatically, but the operators have a manual control option. Under normal operating conditions, only the sludge feed rate is varied, while the sawdust and recycle feed rates remain constant.

A series of bypass conveyors can remove the sludge from the belt presses and convey the material for discharge into sludge containment vehicles in a staging area adjacent to the mixing room. The bypass system is designed for use if the facility cannot accept the sludge.

Each reactor has a flat belt collecting conveyer that transports the recycle to the mixer feed screw conveyor; only one collecting conveyor at a time is used within the mixing room. Two motor-driven rotary plow-type mixers combine and mix the three components.

The system has a central control computer with interlocking plug and zero speed indicators that sense when a belt or screw has stopped. When one piece of equipment shuts down, all areas upstream of the shutdown automatically stop. Apparently, this feature works well.

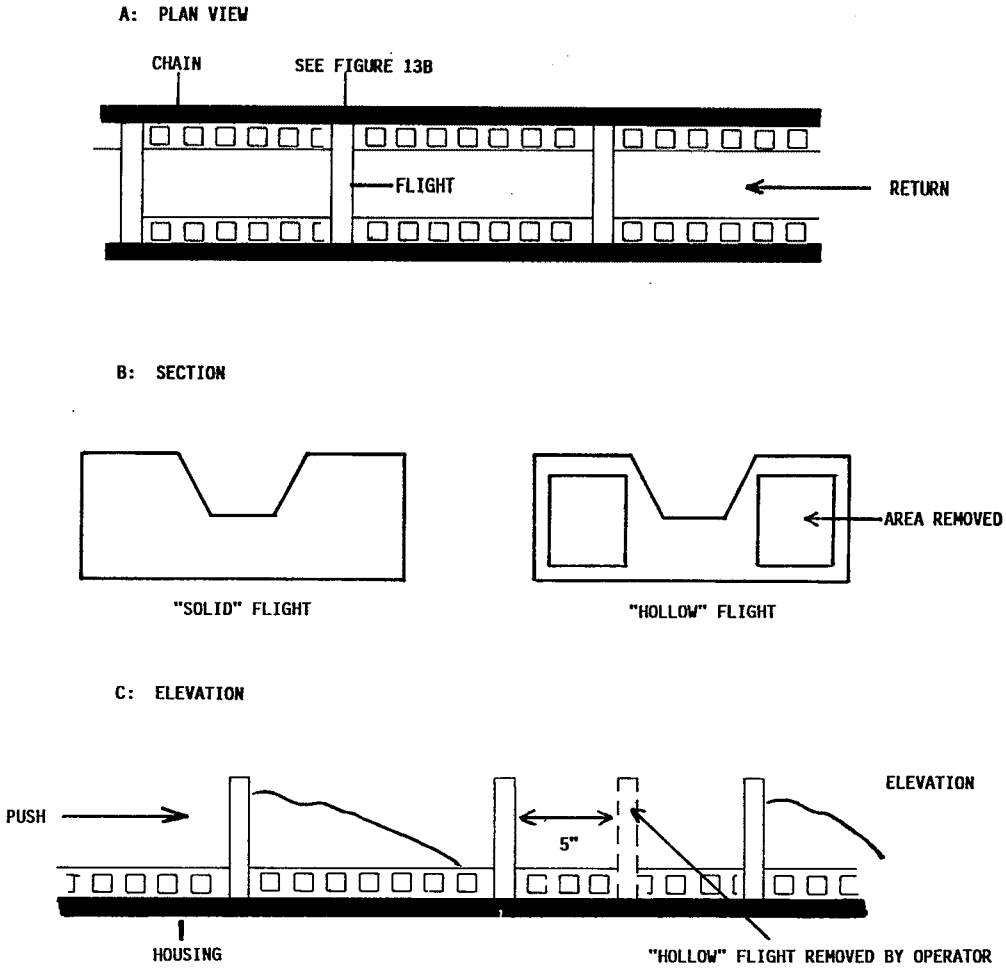
The amperage of the mixer motors and surrogate measurement of mix wetness (see Section 12.4.1) are used to manually monitor the solids content of the mix during the loading operation. The aim is to maintain 24 to 25 amps. In addition, operators sample the contents of the mixer discharge every 20 minutes using a heat lamp test.

12.3.4 Reactors

12.3.4.1 Reactor Feed System

Each reactor has an identical feed system in which the mix is transported from the mixer to the top of the reactor by a vertical S-type drag chain conveyor. Alternate flights of the conveyor have been hollowed out because, in the past, compressed mixed material has jammed and stopped the conveyor. Both the carry and return chains are contained in the same housing, and apparently, there is enough room between the top of the flight and the housing for materials to escape rather than jam. Operating the chain at a higher speed has reduced operating time by one third. Figure 12.4 is a diagram of the drag chain conveyor, showing the modifications.

Figure 12.4 Drag Chain Modifications



The mix drops from the drag chain to either a reactor distribution belt conveyor or to a reversible cross belt conveyor that can shuttle the mix to the other reactor. A reactor distribution carriage located on top of the reactor places the mix in the reactor, where it is leveled with dual leveling screws. Figure 12.5 shows the top of the reactor after loading. Uneven settling of the compost overnight is a normal occurrence.

The metal equipment in the reactor area has been painted with vinyl chloride enamel for corrosion protection.

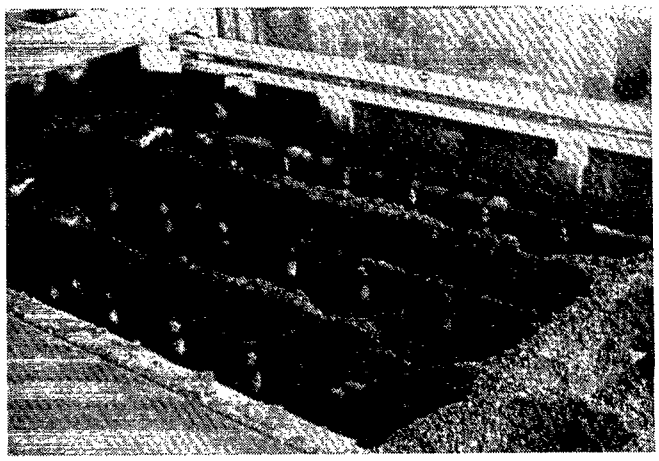
12.3.4.2 Configuration

The first and second reactors are each 7.6 m wide by 15 m long (25 ft wide by 50 ft long), with a full volume of 990 m^3 (35,000 cf). The average depth of the compost in both reactors is 8.2 m (27 ft).

12.3.4.3 Reactor Aeration System

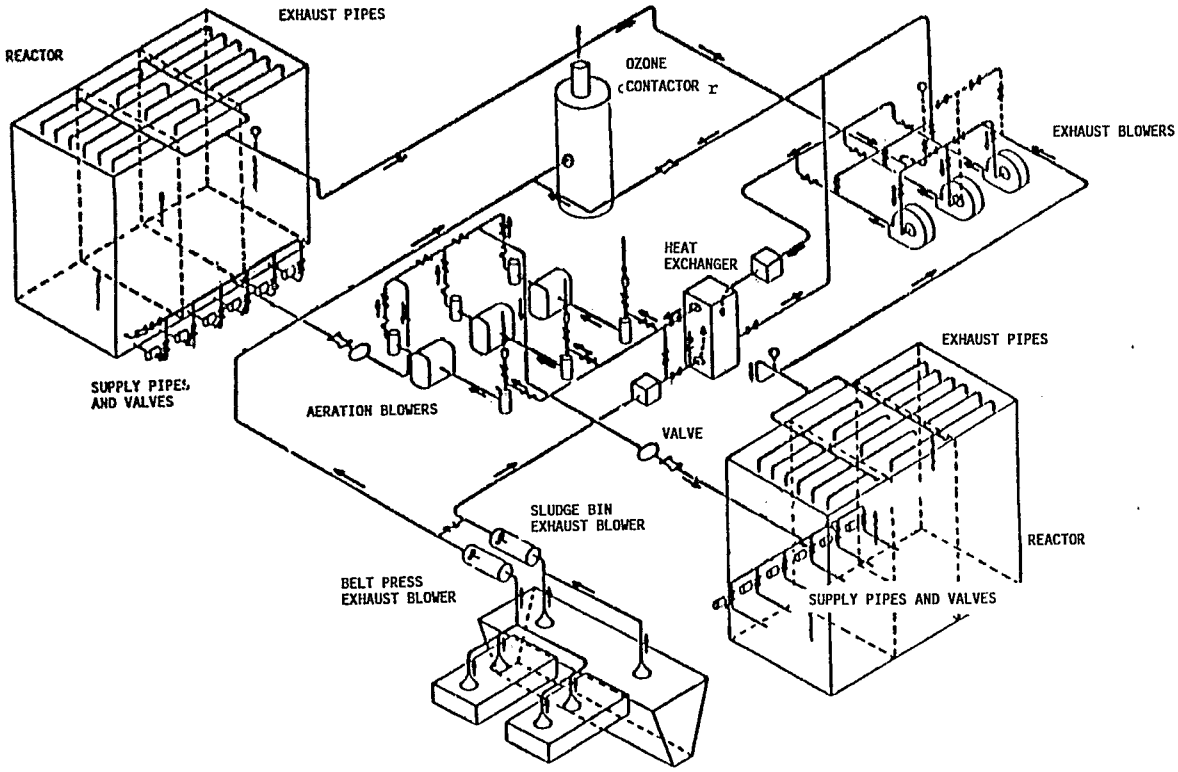
As designed, inlet air is drawn from the dewatering building to a heat exchanger and three variable-speed positive displacement aeration blowers. Two of the blowers supply air to the first reactor; one supplies air to the second reactor. At the time of the site visit, the dewatering system did not provide air intake for the composting operation because the operators felt that the heat and humidity of this air would shorten the life of the blowers. Inlet air is now obtained from the outside atmosphere, except for a few days in winter when the outside air is too cold.

Figure 12.5 Top of the Reactor After Loading. The uneven settling of the compost overnight is a normal occurrence.



The aeration blowers force air through a series of pipes (located beneath the outfeed device) into the bottom of the two reactors. The pipes are galvanized steel, perforated, and covered with approximately 0.3 m (12 in.) of crushed stone, 0.01 m (0.5 in.) or less in size, to protect the pipes from the compost and to disperse the air through the reactor. Each reactor has three side-by-side aeration zones based on the configuration of the piping system (see Figure 12.6).

Figure 12.6 Supply and Exhaust Distribution System



A series of valves located on the supply pipes is used to correct differential temperatures (hot and cool spots) in the reactors (see Section 12.4.1). Each aeration zone has two valves (i.e., six valves per reactor).

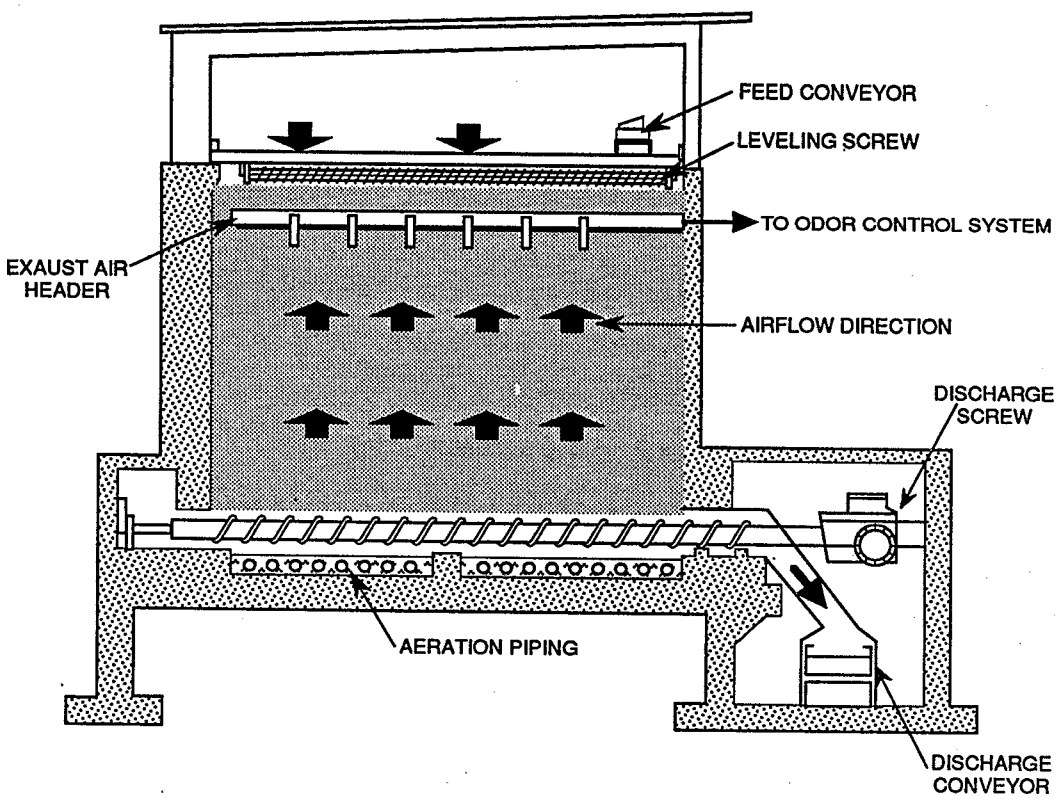
The exhaust piping system consists of a series of vertical pipes extending 1.8 to 2.1 m (6 to 7 ft) down into the compost mass, and connecting to a series of pipes leading to the exhaust blowers. Three fixed-speed centrifugal exhaust blowers draw air up through the compost from the bottom (50 to 65 percent) and down through the top 1.8 to 2.1 m (6 to 7 ft) of the compost from the top of the reactors (35 to 50 percent). The blowers, which service both reactors, contain fiberglass rotors to aid in corrosion control. The system has no blower back-up.

By design, air from the exhaust blowers then moves to either the heat exchanger (to heat inlet air) or to the ozone contactor of the odor control system. The heat exchanger condenses and collects the moisture in the airstream, and the condensate drains to a sanitary sewer lift station. Air from the heat exchanger and sludge feed bins also is fed directly into the ozone contactor. At the time of the site visit, inlet air bypassed the heat exchanger due to odor leaks. Also, the exchanger was not effective because of short residence times.

12.3.4.4 Outfeed Device

At the bottom of each reactor is a horizontally mounted discharge screw, enclosed in a pressurized tunnel (see Figure 12.7). An outfeed reclaiming screw conveyor moves the compost from the bottom of the reactor to a collecting belt. The collecting belt, in turn, carries the compost to the mixing room for further processing. The material from the first reactor is then either conveyed from the mixer to the second reactor or used as recycle. From the second reactor, the material is transferred to the distribution conveying system, located at the top of the reactors, for transport to the curing/storage area.

Figure 12.7 Purac Composting System, Sarasota

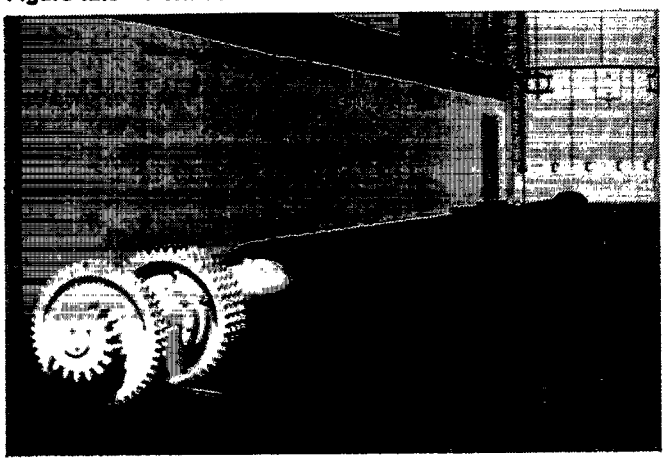


The outfeed device is removed from the composting bed after each use. The operators feel that if the device is left in the bed too long, it will not restart because the composted material will "set" around the screw and cause excessive friction. According to the design specifications, however, the drive has enough torque to start while embedded in the material, even if it has not been in operation for a few days. To date of the site visit, the screw had not gotten stuck in the compost pile. A spare screw was supplied during construction, in case of failure.

One problem with the screw did occur when the motor amperage sensor burned out. When the operators received no amperage feedback, the screw was accidentally overworked and the bearing was damaged.

The outfeed screws were originally hard-surfaced only on the edge of the flight by hard steel welding, according to system specifications. Despite this hardening, the first reactor screw suffered heavy wear on the flight face (see Figure 12.8) (15 percent wear after 6 months) and was replaced by a screw with additional Triten steel hard-surface on the flight face. The wear on Triten steel is one-tenth that on hard-surfaced flights. The spare screw and the second reactor screw, which is not often used, were both hard-surfaced with Triten steel in the field.

Figure 12.8 Worn Outfeed Screw



12.3.5 Exterior Curing/Storage

The distribution conveyor at the top of the second reactor conveys the material to the top of the curing/storage building. This conveyor connects to a reversible belt conveyor with a blade that can be manually moved across the top of the building to create several compost piles. By settling on the rails and piling up under the belt, the compost, which is quite dusty, has caused the reversible conveyor to misalign.

The curing/storage building is a three-sided, roofed steel and precast concrete structure about 6.1 m (20 ft) high and 293 m² (0.06 acres) in area. Because of the dimensions of the curing/storage area, high piles, about 4.6 m (15 ft), need to be formed. The front wall of the curing/storage building is formed by tarpaulins that can be raised or lowered with motorized rollers, but which are usually kept down to control wind-blown dust. At the design processing rate, this space is reportedly adequate for 2 weeks of curing/storage in the summer and 1 week in the winter. The operators plan to increase the height of the walls to increase the curing/storage capacity. There is no open curing/storage at the Sarasota facility, which also increases the potential for anaerobic conditions and odor production.

There is no space on site for emergency or long-term curing/storage. This lack of space may force the city to continue its current practice of hauling the compost for land-spreading disposal, even if a sufficiently large but seasonal market develops for the compost. A front-end loader is used to load the finished product onto trucks for removal.

12.3.6 Nonprocess Air Handling

Exhaust vents are situated above the belt filter presses and the sludge storage bins. Ventilation air is piped to the odor control system.

An exhaust fan in the mixing room roof, capable of 15 air changes per hour, discharges air to the atmosphere. The exhaust fan is not always used because it is a direct source of odors. The doors in the mixing room are kept open, however, because ventilation is inadequate, as evidenced by the prevailing wet and odorous conditions.

Air from the outfeed screw tunnel is vented only when the operators enter the tunnel. A mixing fan was installed in the tunnel to eliminate condensation that occurred on equipment and walls. Three exhaust fans are used to vent the curing/storage building.

12.3.7 Odor

12.3.7.1 Odor Sources and Characterization

Formal site studies have not been conducted to characterize and measure any odors except for ammonia, which is present in the outfeed screw tunnels at approximately 250 ppm. Uncontrolled sources of odors include the exhaust fan and open doors in the mixing room, the reactor headspace, the curing/storage building, and the sludge storage tanks, which are particularly odorous when sludge is stored for 3 to 4 days (a situation that has only happened once since startup).

Competing odor sources include hydrogen sulfide and other sulfate odors from the adjacent WWTP (due to sulfur in the ground water) and unaerated stored sludge from the WWTP. Odors are worse in summer when the

humidity is high and winds are light. In winter, however, when the weather is generally dry and windy, condensate from the odor control exhaust stack offers "visible proof" of odors.

The plant and the DER have received many odor complaints from local commercial establishments, including one local weekly newspaper. The complaints started immediately after the facility began operating. Staff members have detected odors 1.6 to 3.2 km (1 to 2 miles) away, but all complaints have originated in the local neighborhood from individuals situated downwind of the plant. There are fewer complaints in winter.

The plant has kept a log of odor complaints since it began operations. Individuals with complaints are called back if they so request. The plant also maintains contact with certain individuals and solicits their opinions with respect to the odor control system.

Local complaints have prompted DER to issue a consent order addressing odor control. The order, which was being prepared at the time of the site visit, will address compliance activities and establish a schedule for eliminating the nuisance conditions at the plant. The DER also has the authority to limit operations or shut down the plant.

12.3.7.2 Odor Control System

The system consists of ozone oxidation in a 88-m^3 (3,100-cf) contact chamber containing simple baffles that deflect air in a spiral pattern to increase the residence time in the chamber. The design detention time is 19.9 seconds, based on 4.42 m^3/s (9,364 cfm). The maximum airflow rate detention time is 14.7 seconds, based on a flow rate of 6.0 m^3/s (12,700 cfm): 2.4 m^3/s (5,000 cfm) from the dewatering room; 0.9 m^3/s (2,000 cfm) from the sludge storage bin; and 2.7 m^3/s (5,700 cfm) from the reactor exhaust system.

A stack on top of the ozone tank with an elevation of 24 m (80 ft) above ground serves as the dispersion system. Convenient access to the top of the stack and a way to sample the stack gases were not built into the system. Except to keep the ozone generator working, operators do not monitor the odor control system.

12.3.7.3 Odor Pilot Treatment

Because the ozone system was not effective in controlling odors, a two-stage scrubber (first stage, acid; second stage, sodium hypochlorite with caustic soda pH control) was tested on site. According to an informal odor panel consisting of plant and city staff members, ammonia and most other obnoxious odors were removed during the pilot. The two-stage scrubber was scheduled for installation in the spring of 1989. With the odor control retrofit, the existing ozone contact chamber will be used as a cooling tower for air from the dewatering room, sludge storage bin, and reactor exhaust before it enters the two-stage system.

The facility also has plans to aerate the sludge storage tanks. Past experience at the plant has shown that aerobic digestion is less odorous than anaerobic sludge storage.

12.3.8 Support Facilities

The control room/administrative area is a combination office, operating center, lunch room, and conference room, which has proved to be inadequate for office work because the area is noisy and lacks privacy. An office area separate from the operations area has been requested. The staff can also use the WWTP lunchroom and showers. A bench near the mixer serves as the laboratory area for the heat-lamp solids test. Other laboratory tests, including the drying oven solids tests, are conducted in the WWTP laboratory.

12.4 Monitoring and Performance

12.4.1 Reactor Control Strategy

12.4.1.1 Temperature Monitoring and Control

There are nine analog-to-digital thermometers in each reactor, three per adjacent aeration zone, at depths of 1.5, 3.7, and 6.1 m (5, 12, and 20 ft). The locations vary from zone to zone. The probes are 1-in. diameter stainless steel pipe sealed on the bottom, with each probe containing a resistive thermal device (RTD) suspended in a pool of glycerine. A temperature probe also monitors the exhaust temperature in the uppermost area of the bed.

The aim is to keep the temperature of the top probes in the first reactor between 64° and 68°C (147 and 154°F) and to meet EPA's 3-day, 55°C (131°F) time-temperature criterion. The temperatures are recorded by computer every 30 minutes, stored on computer disk, and displayed in the control room. Only three digital readouts, one from each zone, are displayed. Daily averages are printed out as needed to meet reporting requirements.

There are several problems related to the temperature monitoring system in the first reactor. First, although adequate temperatures are most often maintained at the bottom two probes of the first reactor without any operator intervention, the temperature at the upper probes is more difficult to regulate. In addition, the three temperature probes per reactor section do not provide enough information on temperatures in the reactor. Also, the automatic temperature feedback program cannot differentiate between low temperatures due to cooling and low temperatures due to "bad" anaerobic conditions. This is important because low temperatures due to cooling require less air to correct than those due to poor anaerobic conditions. Since the operator feels that low temperatures would cause the computer to decrease the airflow allowing anaerobic conditions to develop, this program is not used.

The temperature in the second reactor is not closely monitored or controlled because the EPA time-

temperature criterion is met in the first reactor, and the second reactor is emptied only enough to provide room to load material from the first reactor. If the second reactor is kept full, the exhaust vents are not exposed, and odorous air cannot be released into the atmosphere.

Temperature profiles for the first and second reactors are depicted in Figure 12.9. The temperatures are the mean daily averages for May through June 1988, for the three aeration sections in each reactor.

12.4.1.2 Aeration Quantities and Rates

To control temperatures, aeration is regulated by manually setting the speed of the blowers that input air to the reactors. Generally, the valves on the air supply pipes are operated in one aeration zone at a time. The valves open automatically for 2 to 11 minutes, according to a schedule set by the operator. Airflows are measured, recorded, and compared to temperature readings to determine the optimal operating conditions of the reactors.

During startup, before the proper air pressure could be created within the reactors, the outfeed screw tunnel had to be pressurized. At one time, the first reactor operated at 1.65 m^3/s (3,500 cfm), but this rate caused temperatures to be too low (mid-50s°C [mid 130s°F]). Since that time, the first reactor has operated mainly at 1.32 m^3/s (2,800 cfm). Since startup, the second reactor has operated at 0.38 m^3/s (800 cfm).

12.4.1.3 Oxygen Monitoring

Oxygen-measuring equipment was supplied but has never worked properly because the probes were not designed for use in a high humidity environment. For the equipment to work properly, the air upstream of the probes must be dried before reaching the probes.

12.4.1.4 Other Tests and Equipment

During every load, the operators measure the solids content in the reactor with a heat lamp. This measurement is checked daily against the results of the drying oven tests conducted in the WWTP. Other parameters are routinely measured as follows: bulk density, twice per month; heavy metals, quarterly; volatile solids, twice per month; and pH, twice per month.

12.4.1.5 Data Management

Information from the daily logs kept by operators is fed into a computerized spreadsheet once per month. A summary spreadsheet generated by the facility is shown in Table 12.1.

12.4.2 Mass Balance and Reactor Detention Time

A materials flow diagram, constructed from operator records for May through June 1988, is shown in Figure 12.10. A mass balance is not shown because the calculations to close the balance yielded negative volatile solids destruction in the reactors. The operators have not been able to determine the reason for this.

The design detention time in the first reactor is 16 days. From May through June of 1988, plug-flow detention time was calculated to be 12.5 days.

The design detention time in the second reactor is 20 days. This is 4 days longer than the detention time of the first reactor because of the loss of mix volume created by the composting process. That is, for every 91 t (100 ton) of mix that enter the first reactor, only 73 t (80 ton) are removed from the second reactor. As a result, a greater percentage of the first reactor compost batch can be loaded into the equal-sized second reactor, and the plug flow detention time is longer. From May through June 1988, the detention time in the second reactor was calculated to be about 61 days.

12.4.3 Product Quality

Overall, the composting process regularly meets the EPA time-temperature criterion and consistently produces a compost of adequate dryness. From May through June 1988, compost production was 0.88 m^3/wt (28.5 cf/wton) of sludge cake processed or 0.39 wt product/wt (0.43 wton product/wton) of sludge cake processed.

During November 1987, three samples were tested for Salmonella and phytotoxicity. None of the samples tested positive for Salmonella. Two of the samples passed the germination test for phytotoxicity, but in the third sample, the germination rate was only 28 percent of the control sample. This failure was attributed to the presence of ammonia in the compost due to a short detention time (7 days) at the time the sample was taken.

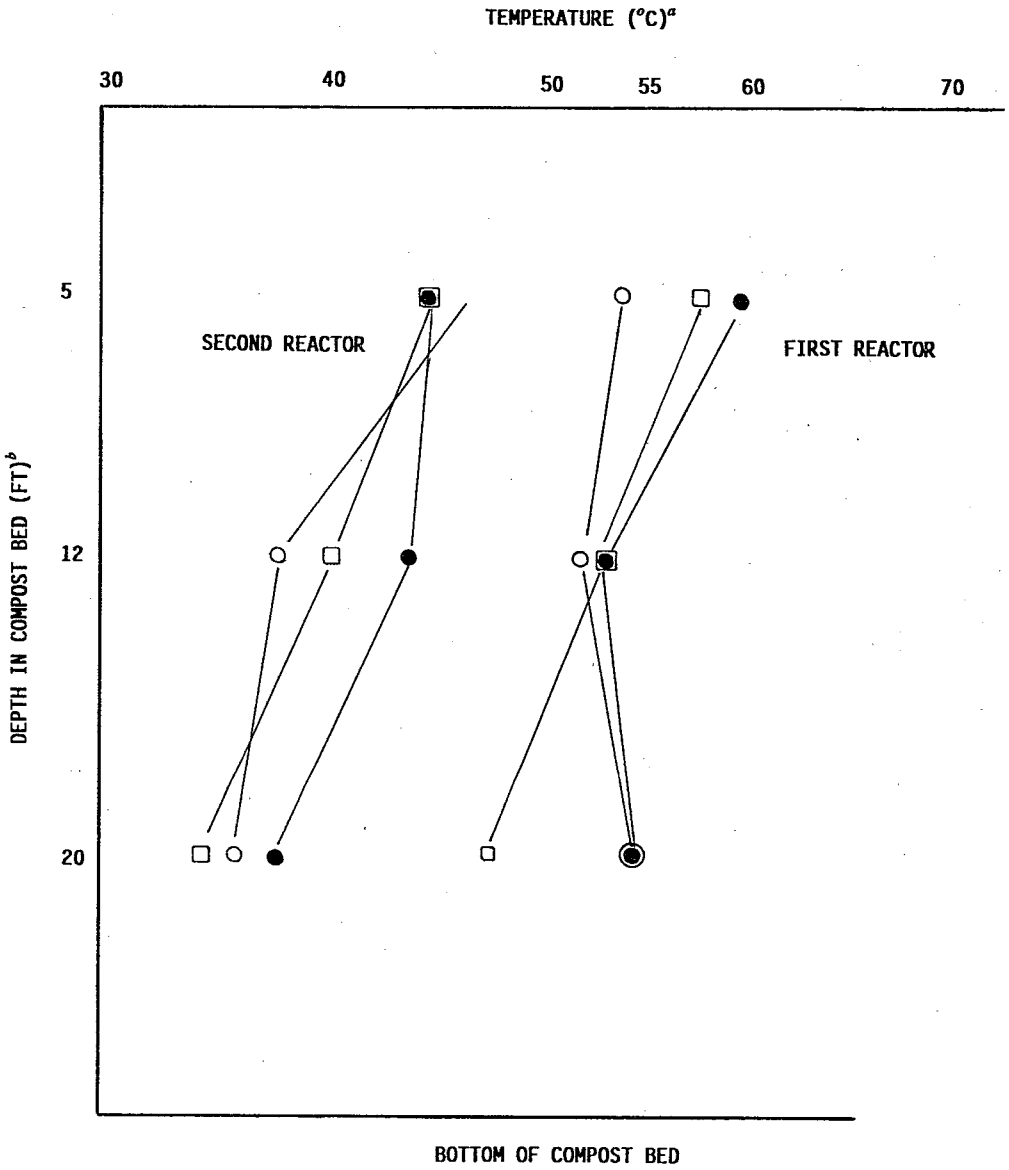
The composting product meets the State of Florida criteria for Class I sludge. The constituents, their criteria, and the amount of each component contained in the Sarasota compost are shown in Table 12.2. The compost can be applied legally on sod farms, pasturelands, forests, highway shoulders, plant nurseries, land under reclamation, playgrounds, parks, golf courses, lawns, other unrestricted public access areas, and agricultural soils including those growing food crops (except root crops, leafy vegetables, tobacco, and vegetables to be eaten raw). Up to 198,000 kg/m^2 (500 lb/acre) total nitrogen of the compost can be applied annually.

12.5 Operations

12.5.1 Staffing

The facility employs four full-time, permanent staff: one supervisor and three operators. The supervisor has two associate degrees, one in electricity and one in electronics, and is experienced with instrumentation and conveyor systems, but has no wastewater treatment experience. One of the operators at the Sarasota facility has a Class A (highest) WWTP license. The other two operators have no prior wastewater treatment experience.

Figure 12.9 Temperature Profiles Averages, May to June 1988



LEGEND

- ● WEST SECTION
- ○ CENTER SECTION
- □ EAST SECTION

[a] (°C X 1.8) + 32 = °F
[b] FT X .3048 = M

Table 12.1 City of Sarasota Compost Plant Production Calculations Spread Sheet

Date: 6/1/88

Mix Calculations

Target Solids	37.9
Sludge lb/cf	57.5[a]
Sludge Dry Solids	14.7
Recycle lb/cf	29.7
Recycle Dry Solids	50.4
Recycle Volume	941[b]
Sawdust lb/cf	18
Sawdust Dry Solids	90
Sawdust Volume	205
Actual Run Time	4.3

	Volume	*Density*	*Wet lbs*[c]	*% D.S.*	*Dry lbs*
Sawdust	205	18	3,690	90	3,321
Recycle	941	29.7	27,948	50.4	14,086
Sludge	406	57.5	23,345	14.7	3,432
Cal. Mix Solids	37.9				

Loading Summary

	Recycle	*Sawdust*	*Sludge*	*Input*
Volume Loaded cf	4,046	882	1,746	6,674
Density lb/cf	29.7	18	57.5	35.4
Wet Tons	60.4	7.9	50.2	118.2
% Dry Solids	50.4	90	14.7	37.9
Dry Tons	30.3	7.1	7.4	44.8
Actual Run Time	4.3			

Transferring Calculations

Bio to Cure		**Cure to Storage**	
Recycle Volume	941	Recycle Volume	941.0
Recycle Density	29.7	Recycle Density	29.7
Recycle Dry Solids	50.4	Recycle Dry Solids	67.7
Actual Run Time	1.4	Actual Run Time	1.0

Transferring Summary

Bio to Cure		**Cure to Storage**	
Comp Transferred cf	1,317	Comp transferred cf	941
Comp lbs/cf	29.7	Comp lbs/cf	29.7
Comp Wet Tons	19.6	Comp Wet Tons	14.0
Comp Dry Solids	50.4	Comp Dry Solids	67.7
Comp Dry Tons	9.9	Comp Dry Tons	9.5
Actual Run Time	1.4	Actual Run Time	1

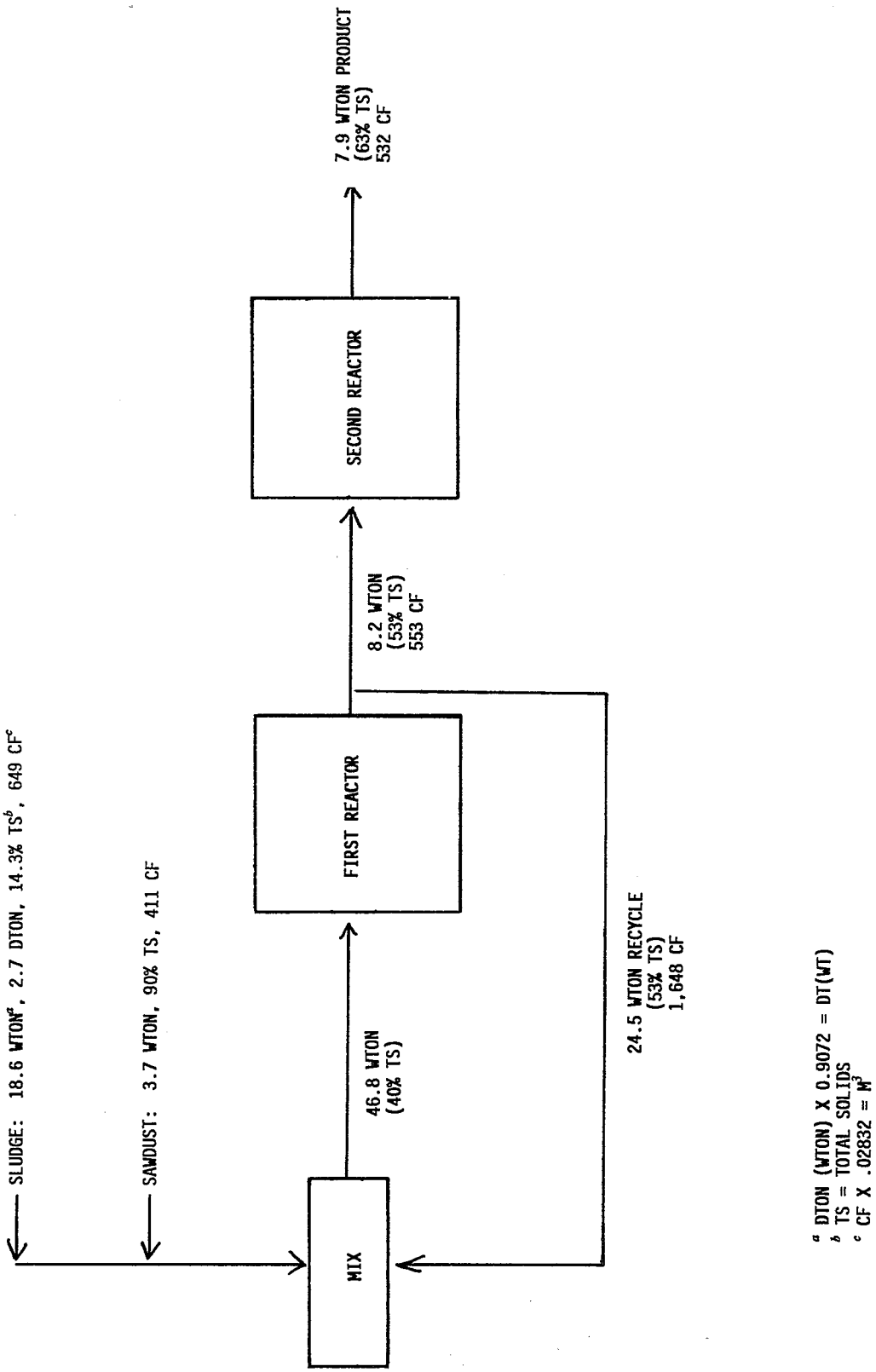
[a]lb/cf × 16.02 = kg/m³.
[b]ft³ × 0.02832 = m³.
[c]lbs × 0.4536 = kg.

Table 12.2 Compost Constituents (mg/kg)

Component	Sarasota Compost[a]	Florida Criteria for Grade I	I	III
Total Nitrogen, N	2.2%[b]	—[c]	—	—
Total Phosphorus, P	0.88%[b]	—	—	—
Potassium	0.15%[b]	—	—	—
Cadmium	1.7%[d]	≤30	30–100	>100
Copper	210[d]	≤900	900–3,000	>3,000
Lead	20[d]	≤1,000	1,000–1,500	>1,500
Nickel	6.0[d]	≤100	100–500	>500
Zinc	281[d]	≤1,800	1,800–10,000	>10,000
Chromium	73[d]	—	—	—

[a]Lab report dated 3/28/88 of sample composited from grab samples taken 2/23, 2/25, 3/1, and 3/3/88.
[b]Percent dry weight.
[c]— No criteria is established for these components.
[d]mg/kg dry weight.

Figure 12.10 Sarasota, Florida, Materials Flow Average Daily Quantities, May to June 1988



[a] DTON (WTON) X 0.9072 = DT(WT)
[b] TS = TOTAL SOLIDS
[c] CF X .02832 = M^3

During plant startup, there were high demands on the operating personnel that resulted in high staff stress and turnover. These demands were caused by Sarasota's attempts to start up, train, debug, and process all at the same time without a complete control system.

Smith and Gillespie subcontracted with Envirotech Operating Services, who subcontracted with Purac, to provide startup activities and training. Purac conducted a 40-hr course on composting principles and equipment operation, which was then repeated because of the high turnover of the initial plant staff. Manuals and software, which are used to support continued operations and maintenance proficiency, were also produced. A continuing training program has not been established, however.

The WWTP crews provide maintenance and repair services at rates equivalent to 50 hours per week of preventive maintenance, 40 hours per week of electrical repair, and 40 hours per week of mechanical repair. The city's mechanical and electrical personnel must be reoriented somewhat every time they do a job on site. In addition, the maintenance and repair service needs of the compost plant compete with those of the WWTP for limited personnel.

12.5.2 Marketing and Distribution

A marketing study, conducted prior to the procurement process as part of the city's 1982 sludge management study, concluded that there was a market for pellets but not for compost. Later, the city came to believe that a compost market could be developed if sufficient high-quality product was available for use in a wide range of legal applications. The city also reasoned that a market could be created easily because Florida has such sandy soils. This outlet has not yet been exploited, however, due to the inconsistency of the product during startup.

At the time of the site visit, a local rancher was taking the compost at no charge. In addition, the compost was being hauled away for land-spreading. Prior to the site visit, an RFP was issued for compost-hauling services; one bid offered $3.3/m³ ($2.50/cy), but at the time of the visit a contract had not been issued.

12.5.3 Operating Costs

A budget was prepared for fiscal year 1987-1988 (October through September) prior to startup (see Table 12.3). The cost to process sludge per dry ton at the Sarasota facility is $419/dt ($380/dton).

The amount of electricity used by the compost plant is integrated in the WWTP bill. On the basis of motor horsepower, power usage at the compost plant is estimated at 15 percent of the total electricity bill.

Sawdust is bought from a trucker of wood waste, with whom a 1-year, fixed-price $15.0/m³ ($11.50/cy) contract is in place. The sawdust is more expensive than expected.

Sludge hauling costs have been $9.80/m³ ($7.50/cy). These costs are higher than anticipated, partly because the facility expected to sell the compost and therefore avoid compost disposal costs.

12.6 Update

Sarasota received a permit to process and market compost in September 1988. The actual amounts of materials processed and operating costs are shown in Tables 12.4 and 12.5.

Table 12.3 Dewatering and Composting Operations and Maintenance Costs ($1,000)

	Estimated[a] 87/88	% of Estimated	Budget 88/89	% of Budget
Labor (2 positions)				
Operations	59.8	11.9	89.6	15.0
Maintenance[b]	99.5	19.8	102.7	17.2
Power	56.0	11.2	56.0	9.4
Materials (mainly sawdust)	100.7	20.1	210.0	35.1
Mechanical and Electrical Supplies and Services	23.3	4.6	21.9	3.7
Chemical Supplies (incl. polymer)	44.8	8.9	67.4	11.3
Building and General Supplies	7.6	1.5	9.4	1.6
Engineering and Architectural	9.5	1.9	0	0
Other	0	0	20.8	3.5
Compost Disposal	100.9	20.1	20.0	3.3
TOTAL	502.1		597.8	

[a]Earlier O&M cost estimates not available; this estimate prepared before startup.
[b]Includes maintenance and repair provided by WWTP personnel.

Table 12.4 Materials Processed (October 1, 1987 through September 30, 1988)

Material	Amount Processed[a]	Percent Average	Solids Range	Mix Ratio
Sludge	1,319[a]	14.8	13–17	1
Amendment	8,232[b]	85.4	60–90	0.75
Recycle	20,411[b]	59.6	50–68	2.5
Compost Product	10,076[b]0	56.0	50–62	

[a]Total dry tons (dton × 0.9078 = dt).
[b]Cubic feet ($ft^3 \times 0.02832 = m^3$).
[c]None of the product was sold.

A two-stage, packed tower wet scrubber to treat 2,830 L/sec (6,000 cfm) of reactor exhaust became operational in March 1989. Sulfuric acid is used in the first stage and hypochlorite in the second. The wet scrubber is preceded by the old ozone contact chamber, which has been converted to a wet scrubber to remove ammonia. The chamber is fitted with 22 nozzles, which spray 11 L/sec (250,000 gal/day) of chlorinated effluent from the WWTP.

In December 1988, a 0.9 m by 1.8 m (3 ft by 6 ft) airtight door and frame assembly, leading to the outside from the reactor's pressurized tunnel, was "blown out" because the frame anchor failed. At the time of the blowout, the operators were in the process of "turning over" the reactor, which had gone anaerobic due to a mix that was too wet (28 percent solids). When about one-third of the reactor was empty, the operators closed the doors and turned on all the air supply blowers. It is assumed the pressure rose about 34 kPa (5 psi).

Table 12.5 Operating Costs (October 1, 1987 through September 30, 1988)

Item	Amount	% of Total
Labor (operations)	$ 59,875	17
Labor (maintenance)	99,459	29
Power and Fuel	47,592	14
Amendment	100,746	29
Maintenance materials	30,655	9
Other	9,782	3
TOTAL	$348,109	
Revenues	0	
Product disposal costs	100,927	

[a]Includes 35% fringes.
[b]Cost of city water and chemicals.
[c]Breakdown of these costs not given.

To prevent future over-pressurization, the city has established operator protocols that alert operators to potential problem situations and help them avoid a recurrence. Also, the plant is currently using a volumetric mix ratio of 1/1/1 (sludge to amendment to recycle) to guarantee a drier mix. They recommend that future installations include a pressure alarm or sacrificial blowoff diaphragm.

Chapter 13
Schenectady, New York

13.1 Introduction

The city of Schenectady owns an in-vessel composting facility that was supplied by American Bio Tech (ABT). The facility uses five rectangular vertical reactors, with a 15 dt/day design capacity and a 9 to 17 dt/day (10 to 19 dton/day) range.

The composting plant is located at the existing wastewater treatment plant (WWTP) on a 4,450-m^2 (1.1-acre) site at the edge of a broad river valley. A high ridge and a mixed residential/commercial neighborhood border the facility on the south side of the plant, and generally open and flat terrain and a county airport lie across the river on the north side. The nearest neighbor is 150 m (500 ft) away.

The site visit took place on November 16 and 17, 1988. All information presented in this study is representative of the period of July 1987 through January 1988, the only time that the plant processed material through the entire system prior to the site visit (see Section 13.2.3).

13.2 History of the Plant

13.2.1 Procurement and Construction

In response to sludge disposal problems, the City of Schenectady hired O'Brien and Gere Engineers to investigate disposal alternatives and prepare a sludge management facilities plan. Completed in November 1983, the plan reviewed many alternatives that were similar in cost. In-vessel composting was the favored alternative based on the results of a sensitivity analysis of manpower and energy costs, and in-vessel's ability to meet major criteria as follows:

- Adequately contain odors
- Provide aeration at a relatively low cost
- Provide proper air distribution and water removal
- Handle upset conditions
- Operate with flexibility and ease of routine maintenance

Because site restrictions required installation of a vertical-style reactor, city officials investigated various vertical-reactor systems and visited existing plants in the United States and in Europe. Finally, they prequalified three systems: two, Taulman and Purac, on the basis of experience; and one, ABT, on the basis of a successful pilot test conducted at the Schenectady facility during the summer of 1984.

With extensive input from the three system suppliers, O'Brien and Gere developed plans and specifications for a conceptual system, after which a two-step bidding process took place. The first bid was for the design of the equipment, including the reactors, infeed and outfeed devices, mixer, conveyance system, sludge and amendment storage facilities, and aeration system. The second bid was for the construction and installation of the equipment. In May 1985, ABT was awarded the contract, based on its low equipment bid of $975,000.

The construction and installation contract was bid and executed according to New York State regulations, with the city providing all funding for the project. As part of the contract, ABT had to provide 2-year extended guarantees for the outfeed devices and the in-vessel piping; all other equipment was guaranteed for 1 year.

The city and consulting engineer worked together very closely during the procurement process and the city felt well represented throughout the process. The engineer and ABT also provided construction administration and inspection services to the city. At the end of the procurement process, the plant operator felt prepared to handle any technical and administrative problems that might arise.

13.2.2 Capital Costs

The December 1985 construction cost estimate was $4.368 million, not including $550,000 in improvements that were made to the WWTP. Actual 1987 construction costs, however, were $6.2 million, including engineering, contract administration, construction inspection services, and change order costs. In addition, costs for the postconstruction modifications (see below) were estimated to be $470,000.

13.2.3 Operating History and Current Status

The facility started operating on July 8, 1987, and conducted an acceptance test 3 months later. During the test,

the plant operated using recycle in the mix, and the compost produced was examined for 30 consecutive days. To pass, the product had to meet the specifications set forth for the compost by the State (see Section 13.4.3). The compost passed the test in terms of both low moisture content and metals concentrations. During the acceptance test, sludge loading varied from 12 to 23 dt/day (13 to 25 dton/day).

Shortly after passing the acceptance test, the facility experienced a number of setbacks. In November 1987, one of the outfeed devices failed. Although the plant continued to operate, it did so at a reduced throughput (see Section 4.3.4.4). In January 1988, three fires occurred in the reactor system, one in each of the two first-step reactors on January 12 and 19, and one in a second-step reactor, also on January 19. All operations were halted and the first- and second-step reactors were emptied. Since that date the sludge from the WWTP has been incinerated.

Due to an unrelated incident, the plant has also been undergoing modifications since the spring of 1988 to repair structural problems in the "conditioning" reactor, which resulted from mechanical difficulties in the outfeed device.

In addition to damage caused by the fires and the mechanical difficulties, odor problems and odor treatment modifications have extended the plant shutdown period.

At the time of the site visit, the plant was not operating, except for the "conditioning" reactor which was being run to test reactor structural changes, to test operations using mix without recycle, and to evaluate odor production and treatment. Other parts of the system were functional, but the operator was waiting until the odor control modifications were completed before resuming operations. Other planned modifications include installing infrared heaters in various parts of the main process building to provide added heat and upgrading the interior ventilation capacity.

13.3 Description of the Plant

13.3.1 Systems Overview

The Schenectady facility contains one main process building with an administrative wing, an amendment silo, an odor scrubber, and a transformer; it also has covered and uncovered curing/storage yards. The main building is an unheated three-story steel framework covered with uninsulated fiberglass, with the bottom of the reactors, the outfeed devices, and conveyors situated on the first floor. The aeration blowers are located in hallways around the midlevel of the reactors, and the top level of the building provides access to the top of the reactors and the loading mechanism. The dewatering building is adjacent to the main building.

Figure 13.1 is a generalized schematic of the materials handling train. Amendment and sludge are placed on the same belt conveyor and carried to the accumulator and mixer. If recycle is used in the mix, it is carried to the accumulator and mixer by an outfeed conveyor belt from the reactors.

The mix is carried to the top of the reactor system. There are five reactors in the system: one "conditioning" reactor, two first-step reactors, and two second-step reactors. The two first-step and the two second-step reactors are adjacent to each other (see Figure 13.1). The "conditioning" reactor is located between the first- and second-step reactors. An outfeed device (screw auger) located at the bottom of the reactors moves the compost onto a series of belt conveyors, which carry the compost to an outdoor curing/storage area.

The reactors are aerated through a series of air lances that hang from the top of the reactors. Air is alternately blown into and drawn out of the composting mass by several supply and exhaust blowers. The process air is then directed into a single stage scrubber.

13.3.2 Feed and Mix Characteristics

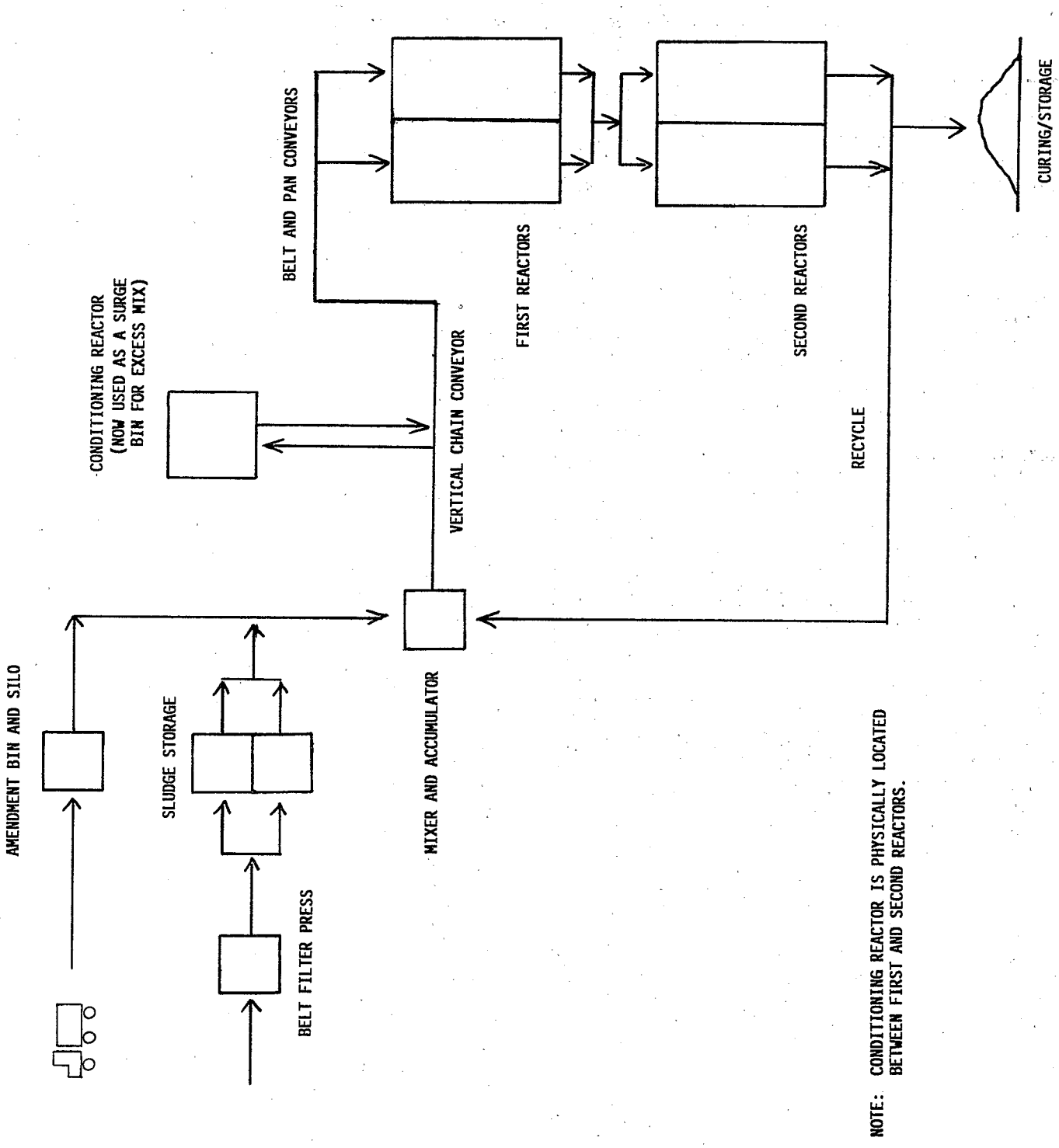
A mixture of 60 percent waste-activated sludge (WAS) and 40 percent primary sludge is dewatered by two belt filter presses. Typically, 50 kg of polymer solution per dry ton of of sludge (100 lb/dton) are used in the dewatering process. The plant is designed to handle 25 percent solids in the sludge; for 3 years prior to startup, total solids in the sludge averaged 25 percent with a range of 20 to 28 percent. During the acceptance test, sludge solids averaged 23 percent and volatile suspended solids were approximately 73 percent.

The amendment specifications call for roughcut green pine sawdust with an average particle size of 0.003 m (0.125 in.), containing no more than 50 percent moisture and an average total solids of 55 percent. Despite the specifications, after the acceptance test, the plant received sawdust that contained a greater amount of fine powder hardwood material. The resulting compost mix was very pasty and hardened when dried. This problem was alleviated when the hardwood sawdust was no longer used.

The bulk weight of the recycle is approximately 504 kg/m^3 (850 lb/cy). At the time of the site visit, recycle was not used in the tests performed in the conditioning reactor because the recycle acted as a binding agent and reduced the friability and porosity of the mix.

The mix without recycle contains 35 to 39 percent total solids and has a good consistency when pine sawdust is used as amendment. Contract specifications call for 35 percent dry solids in the mix.

Figure 13.1 Schenectady, New York, Composting Process Train and Materials Handling System



13.3.3 Materials Handling

Figure 13.2 is a schematic of the materials handling system, minus the conditioning reactor. The system can operate in either the automatic or manual mode. In the automatic mode, all devices in the system are interlocked through a central computer, and local controls are available. The interlocks are not designed to work when the system is running in the manual mode. One problem with the automatic system is the lack of an audible signal to indicate when the equipment is about to start.

Belt-washing devices exist throughout the conveyance systems to periodically clean the belts, but they are seldom used because they are not needed. Spillage from the belts has not been a major problem.

The belt conveyors also are equipped with scrapers to push materials off the belts. Because the scrapers are surrounded by other pieces of machinery, access to them is limited, so they are difficult to adjust. The operators plan to retrofit the belts with a different type of scraper, thereby making them more accessible.

The sludge is delivered to two storage bins from the adjacent dewatering building via a covered, exterior flat belt conveyor. Each bin is 4.9 by 2.0 by 4.3 m (16 by 6 by 14 ft) with a material storage depth of 3.7 m (12 ft).

Each sludge storage bin is equipped with a live-bottom discharge screw conveyor with six 0.25-m (10-in.) diameter screws. The bins have removable covers and three 0.15 m (6-in.) drains that are vented to the odor control system (see Section 13.3.7). The mixer feed system can remove material from the storage bins faster than it can load them; the system is equipped with an alarm that indicates when the sludge bins are full.

Slide gates were installed on the sludge bins to prevent sludge from oozing out of the bins where the screws from the screw conveyor penetrate the bin wall. The slide gates remain closed when the screws are not operating.

The sawdust receiving bin is located near the sawdust silo. The bin is sunk into the ground so that trucks can dump material directly into it. The bin is covered by a stationary grate and a movable solid door. Fugitive dust is not a problem. A single 0.46-m (18-in.) screw conveyor moves the sawdust out of the bin onto a belt conveyor.

The sawdust is fed from the belt conveyor to the amendment silo via a vertical bucket elevator with a capacity of 22,700 kg/hr (50,000 lb/hr). The silo is 8.0 m (26 ft) in diameter and 12 m (40 ft) high with a 370 m^3 (13,000 cf) minimum capacity. In the base of the silo, a ground-level work space with 1.9 m (76 in.) of head room contains the outfeed device, screw conveyor, motors, and other mechanical equipment.

The amendment silo has a level sensor to indicate how much material is in the silo, but no motion detector or alarm. Thus, the operator cannot detect when the sawdust feed stops, unless he or she observes the feed belt directly. The operators plan to install a motion detector.

The amendment silo outfeed device is a 0.3-m (12-in.) diameter screw conveyor. A rotary disk screen with two rotating drums and intermeshing teeth is located at the end of the screw conveyor. The disk removes large 0.02- to 0.07-m (1-to 3-in.) diameter chunks of wood, stones, and other trash before the sawdust is deposited onto the amendment infeed conveyor. This infeed conveyor, which takes the sawdust into the main process building, is a flat belt conveyor with a capacity of 0.009 m^3/s (1,150 cf/hr).

There is no surge storage for the recycle material, so recycle is fed to the mixer directly from the bottom of the reactor. The reactor has a variable speed outfeed device that can be adjusted by the computer to provide the appropriate rate of recycle.

The first step in the mixer infeed system is deposition of sawdust from the amendment infeed conveyor onto the mixer infeed conveyor, which has a 0.016 m^3/s (2,000 cf/hr) capacity. Next, sludge from the storage bins is deposited onto the same mixer infeed conveyor as the amendment. The sawdust/sludge combination is added to the recycle in the accumulator, which has a dual reversible screw (0.3 m [12-in.] diameter, 32 rpm) with a capacity of 0.02 m^3/s (2,500 cf/hr). From the accumulator, materials can go to the mixer and then to the reactors, or they can bypass the mixer and go directly to the top of the second-step reactor. The mix ratio, based on volume, is regulated by adjusting the speeds of the discharge screws of the storage silo and bins.

The mixer is a plow-blade type with a maximum working volume of 1.2 m^3 (42 cf). Running at a constant speed of 1,775 rpm, it can process 71 m^3 (2,500 cf) of material per hour. The mix remains in the mixer for approximately 1 minute, then it is removed by a 0.4-m (16-in.) diameter screw conveyor.

On several occasions, the mixer at the Schenectady plant became overloaded and jammed. The mixer discharge port has been enlarged, but it is not known if this will solve the problem because the mixer has not been tested to capacity since the adjustment.

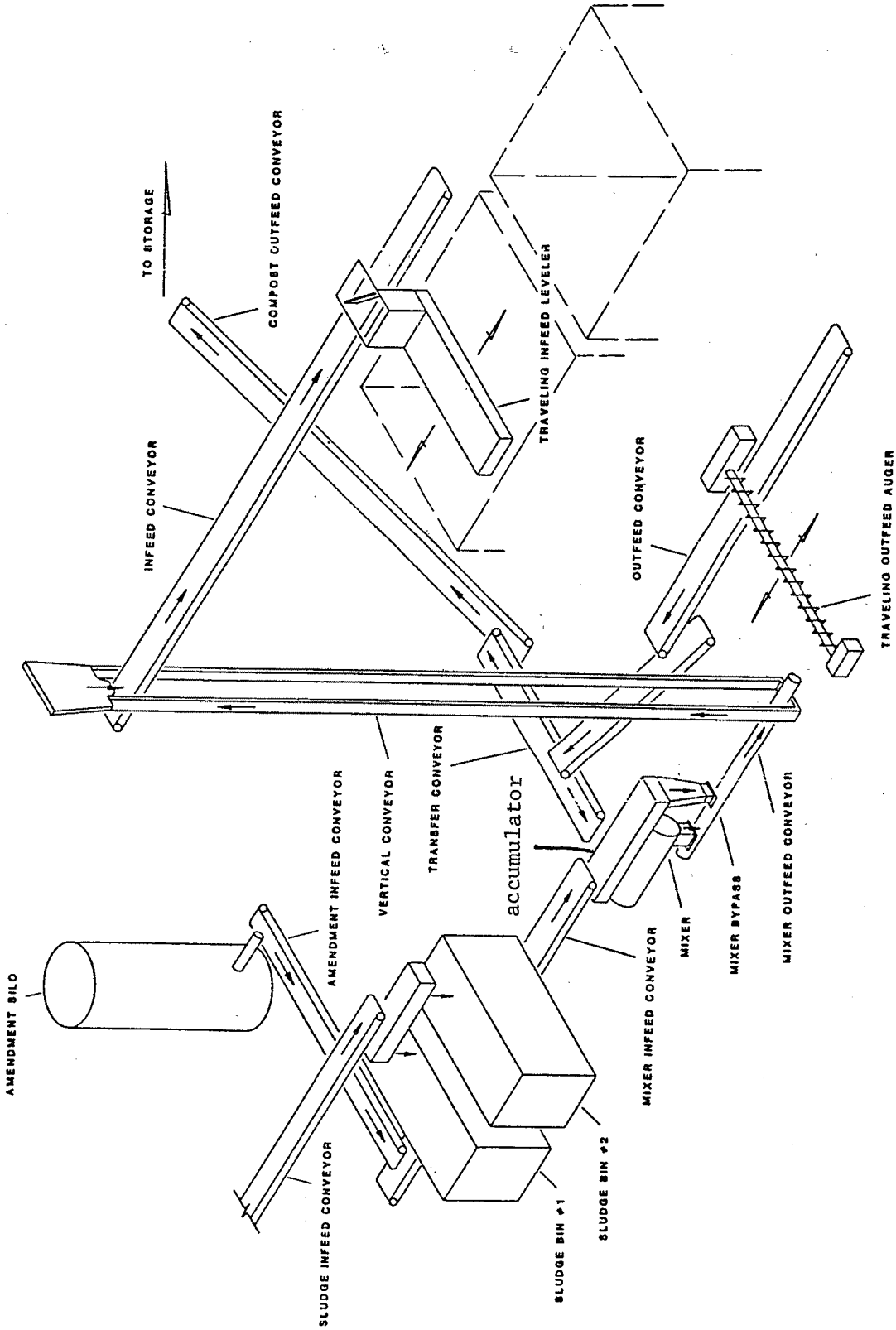
Fog forms in the mixing room because it is not heated and there is a large amount of moisture in the air.

13.3.4 Reactors

13.3.4.1 Reactor Feed Systems

The mixer outfeed screw deposits material on the reactor elevator, which is a vertical drag chain conveyor with 0.2- by 0.33-m (8- by 13-in.) double-leg flights. Thus far, the drag chain has worked well; flights have not been modified, and the chain has not jammed.

Figure 13.2 Schenectady, New York, Materials Handling Schematic



The reactor infeed transfer conveyor is a flat belt conveyor with a 0.02 m^3/s (2,500 cf/hour) capacity. A rail-mounted traveling bridge with a belt conveyor plow removes material from the reactor infeed belt conveyor and deposits it onto a pan conveyor, which then distributes it across the width of the reactor.

The materials-handling system is designed so that when recycle is moved to the mixer from one of the reactors, the operator cannot simultaneously transfer material from the first-step reactor to the second-step reactor, or discharge material from the system (see Figure 13.2).

13.3.4.2 Configuration

The "conditioning" reactor is 283 m^3 (10,000 cf) in volume. The other reactors are each 496 m^3 (17,500 cf) in volume with an average depth of 7.5 m (26 ft) when completely filled (see Figure 13.3). The conditioning reactor is 283 m^3 (10,000 cf) in volume.

In the original operating plan, the mix was to be processed in the conditioning reactor to adjust its characteristics prior to longer-term composting. However, the reactor was not actually operated in this manner because conditioning of the mix was unnecessary to produce an acceptable compost product. At the time of the site visit, the conditioning reactor was used as a test reactor, and there are plans to use it as a surge bin for overnight storage of excess mix.

All reactor walls are made of corrugated fiberglass and hang above a concrete base slab. The walls of the reactors are supported on an exterior steel frame. A 0.9-m (3-ft) space between the bottom of the reactor walls and the concrete floor forms an outfeed device gallery that allows the outfeed device to pass completely through the reactor space. Steel beams form a reactor "floor" above the outfeed device. This design allows easy access to all parts of the vessel.

Fog is created in the headspace when the reactors are loaded and in the outfeed device gallery when the reactors are unloaded. Due to inadequate ventilation, the headspace is damp, causing the wheels of the traveling bridge to slip on the rails. To improve traction, a gritty material is applied to the rails, but this has caused the rubber drive tires supporting the traveling bridge to wear out more quickly than expected.

The conditioning reactor has had several structural problems. The first occurred at a bottom corner of the reactor when a weld connecting a beam to a perpendicular cross beam broke, causing it to fall onto the outfeed screw. The corner of the reactor was rebuilt and a reinforcing plate was added. As a precaution, all of the corners in all of the reactors were rebuilt in the same manner.

The second structural problem was caused by compost that was pushed or "plowed" ahead of the outfeed device as it traversed the reactor (see Section 13.3.4). One of the bottom beams of the conditioning reactor bent outward. The plowed compost also caused the auger of the outfeed device to rise up off the bottom of the reactor. Because of the close tolerances between the top of the auger and the bottom of the cross beam, the auger's teeth cut notches into the lower edge of the beam before the operators could stop it. The beam has since been replaced and slightly raised, and the same modifications were made to the equivalent beams in the other reactors.

The outfeed device is now run at a traverse speed slower than the one recommended by the manufacturer to minimize plowing of the compost (see Section 13.3.4.4).

There have been three fires in the reactors since the start of operation. Because there were no smoke detectors or fire alarms and the temperatures measured in the reactors were not unusual, the fires were not discovered until the operators noticed smoke in the building.

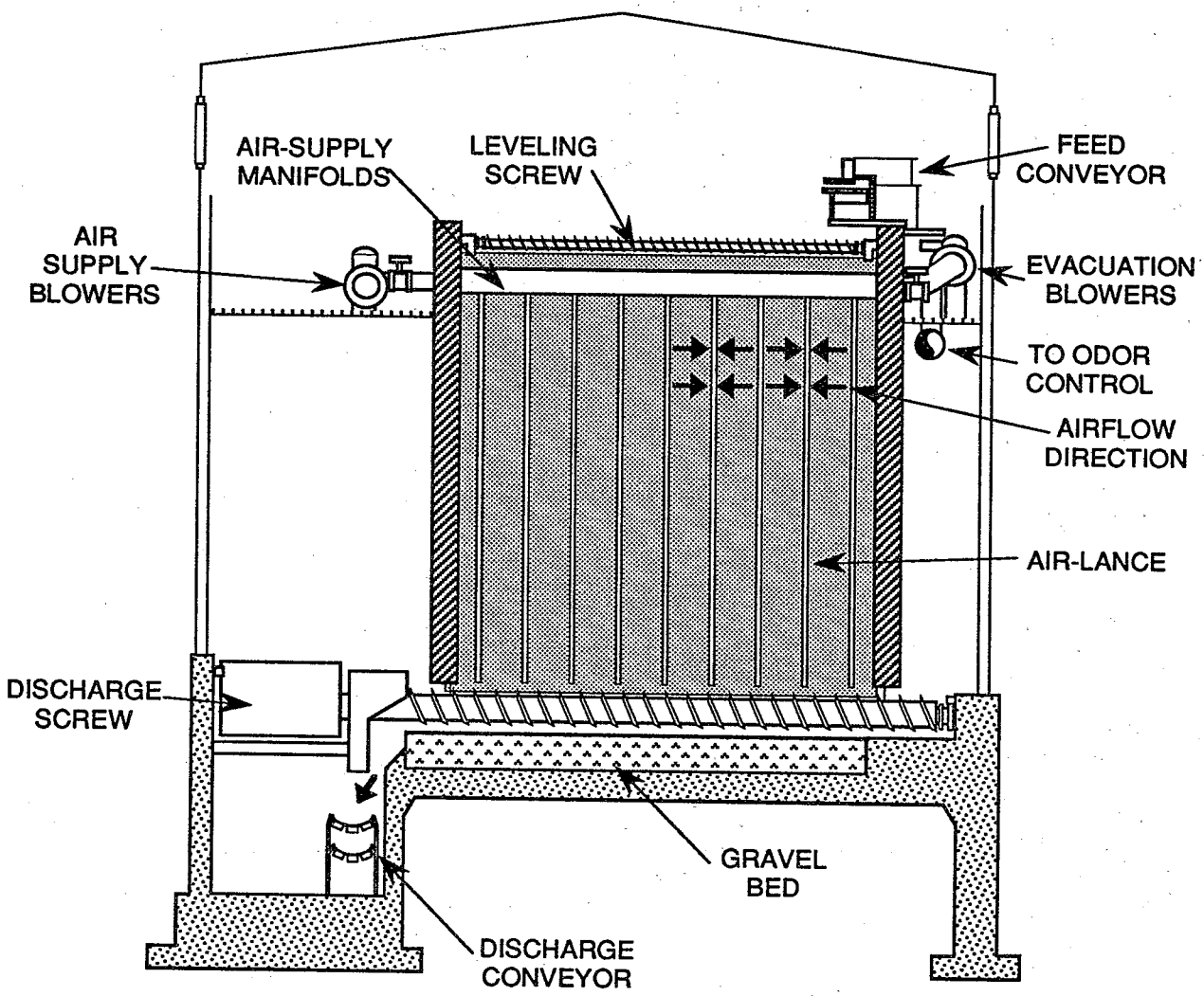
To extinguish the first fire, firefighters poured water into the reactor. This created compost mud, which took operators 14 hours to unload from the reactor. During the second and third fires, firefighters set up fans and misting hoses to clear the smoke and contain the fire within the reactor.

Damage from all fires was relatively minor: the fiberglass reactor body was scorched and some of the air lances melted. The cause of the fires and melted air lances is not known. One scenario is that CPVC inserts in the lances caught fire due to air from the fans, thereby setting up a localized "blow-torch" effect hot enough to melt steel. The compost probably ignited prior to the aeration pipes, because the ignition temperature of the excessively dried compost 93°C (200°F) is well below the melting temperature of CPVC 260°C (500°F).

Plant operators believe the cause of all three fires may relate to a contingency operating policy put into place to reduce the operating throughput rate, increase the compost detention time, and ease the burden for compost curing/storage space, which had decreased. Since the city did not have a New York State permit to sell compost at that time and the facility was running out of space to store compost, the city operated the plant at a reduced capacity. The reduced throughput rate raised the total reactor detention time from 60 to 90 days. As a result of the longer detention time, the contents of the second-step reactor dried to 85 to 90 percent total solids, and spontaneous combustion occurred. Operating procedures were changed so that under lower throughput conditions, the reactors are not completely filled. This procedure prevents overly long detention times.

There is no built-in, automatic fire detection or suppression system. The operator purchased portable fire extinguishers after facility construction was completed. Two fire hydrants are provided outside, one near the process building and one near the curing/storage yard. No modifications for fire prevention or extinction are planned.

Figure 13.3 American Bio Tech Reactor at Schenectady Plant



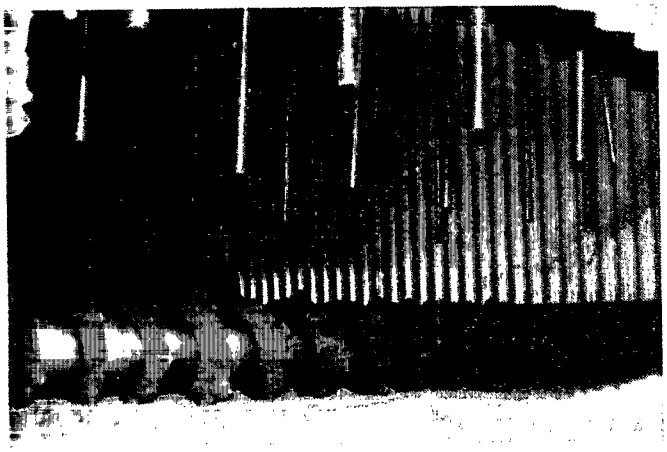
13.3.4.3 Reactor Aeration System

The aeration systems in all the reactors are identical. The first- and second-step reactor systems use three large low-pressure centrifugal industrial blowers as air supply blowers (0.47 to 1.5 m^3/s [1,000 to 3,200 cfm] at 0.3 m [12-in.] water column [W.C.]): one for the first-step reactors, one for the second-step reactors, and one as a standby unit. A smaller blower (0.47 m^3/s [1,000 cfm] at 0.3 m [12-in.] W.C.) aerates the conditioning reactor.

In addition to these blowers, three large low-pressure centrifugal industrial blowers exhaust air from the first- and second-step reactors: one for the first-step reactors, one for the second-step reactors, and again one for standby. Each large exhaust blower draws 1.9 m^3/s (4,000 cfm) at 0.5 m (20-in.) W.C. with a discharge pressure of 0.35 m (14-in.) W.C. The conditioning reactor is exhausted by one smaller blower that draws 0.6 m^3/s (1,250 cfm) at 0.5 m (20-in.) W.C. Control dampers are attached to all of the supply and exhaust blowers, and flow rates are adjusted by means of a butterfly valve on the suction side of the blowers.

Air supply pipes in the reactors are composed of vertical air lances made from stainless steel well-screen cylinders. The pipe inserts are CPVC pipe. The air lances hang from a manifold located at the top of the reactors (see Figure 13.4). There are six header channels in the first- and second-step reactors with eight air lances per header section. In the conditioning reactor, there are three headers with eight air lances per header.

Figure 13.4 Outfeed Screw and Air Lances in Empty Reactor



The header channels operate in alternating supply and exhaust aeration modes (i.e., one head is supply; the next head is exhaust, etc.). The operating mode of the headers is reversed every 20 minutes.

The airflow to individual headers cannot be adjusted in the field. Airflows can be adjusted and equalized by inserting air profile tubes in the air lances. The air distribution system was designed to create uniform distribution of flows and pressures throughout the lances. However, the system is not designed to measure airflows through the individual headers or lances. At the time of the site visit, the airflows had not been adjusted.

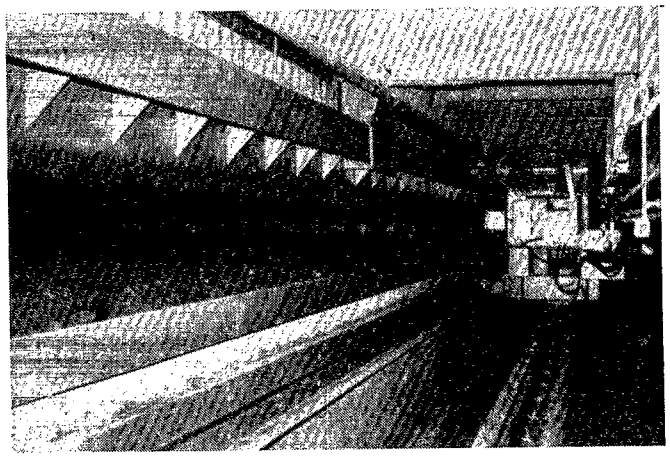
The practice of operating reactors at less than capacity at low sludge throughput rates leaves some of the air distribution holes in the lances exposed. Because the plant has no method to measure airflows through the distribution system, it is not known if short-circuiting occurs.

The headers are connected to the exhaust blowers via steel ducting. From the blowers, the air is channeled to an air-to-air heat exchanger, which cools the exhaust air and heats the incoming process air. The heat exchanger is sized to heat incoming air from 1° to 85°F (34° to 185°F). The actual observed temperature increase is from 0° to 50°C (0° to 122°F).

13.3.4.4 Outfeed Device

On the floor of the processing building are two traveling outfeed devices consisting of a screw auger, drive carriage, carriage rack and rail, cable festoon system, and controls. The augers run on two metal channel tracks and are pushed through the compost by gears located at the support carriages (see Figure 13.5). Each auger has a variable-rotation speed of up to 15 rpm. Two thousand bolts and bushings are installed across the open sides of the channels, spaced to accommodate the gears' teeth. Both outfeed devices can operate under all five reactors, but only one device can be operated at a time. The other device is for standby use.

Figure 13.5 Drive End of Outfeed Screw at the Bottom of the Reactor



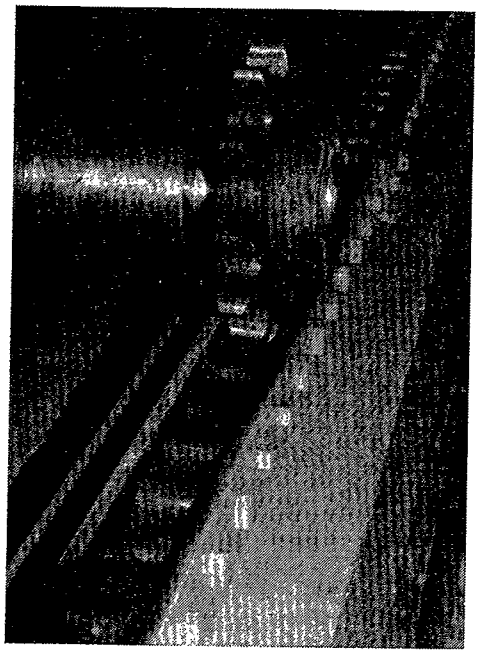
When operated for recycle, the outfeed device typically discharges the material at a rate of 0.004 to 0.006 m^3/s (480 to 760 cf/hr), based on 609 to 673 kg/m^3 (38 to 42 lb/cf) of product. The reactor outfeed conveyor has a capacity of 0.02 m^3/s (2,500 cf/hr).

Although wear on the outfeed device has been nominal during its short operating period, the device has had two major problems. First, the pins connecting the screw to

the reduction gears that drive the nonmotorized support carriage failed. Consequently, although the screw kept turning, the nonmotorized support stopped advancing through the compost and "fell behind" the motorized end of the screw. Eventually, a 0.76 (2.5-ft) skew developed in the screw and the screw stopped. Within several days, the screw had been straightened enough to remove it from the reactor. This did not require the reactor to be emptied.

The second outfeed problem occurred when the channel bolts on the outfeed device broke because the grade of steel used was not strong enough (see Figure 13.6). The bolts were being replaced during the site visit.

Figure 13.6 Outfeed Drive Tracks Where the Channel Bolts Were Breaking



13.3.4.5 Leachate/Condensate

Condensate from the air is collected in the heat exchanger and drained to the WWTP. The condensate from the reactor and process building is sent to the WWTP aeration tanks.

At the bottom of each reactor is a shallow basin filled with gravel, where leachate from the compost originally was collected, drained away, and pumped to the WWTP headworks. The original sump pump was undersized, however, and limited the amount of leachate that could be drained from the compost to the sump. This problem restricted the use of belt washing devices and the amount of water that could be drained from the odor scrubber. To overcome this limitation, at the time of the site visit, only wastewater drainage from the odor control scrubber (see Section 13.3.7) drained into the sump.

13.3.5 Exterior Curing/Storage

The curing/storage area is a 15 m by 29 m (50 ft by 96 ft) paved area covered by a pole structure with three open sides. Material is stored without aeration in approximately 2.7-m (9-ft) high piles. Because this area is surrounded by lawns on three sides, only one side of the structure can be approached with a vehicle. This limits the operator's ability to maneuver the material and to choose the age of the material to be moved off site, because the last product deposited in the structure must be the first product removed. There are plans to correct this situation.

The curing/storage area is reportedly designed to hold 3 months' of material. Material is also being stored in an adjacent unpaved area.

All runoff from the paved curing/storage area is collected and returned to the WWTP.

13.3.6 Nonprocess Air Handling

The sawdust silo is equipped with a separate air supply system to promote sawdust drying. The air is delivered with the same kind of lance system used in the reactors. The supply blower delivers 0.71 m^3/s (1,500 cfm) at 0.3 m (12-in.) W.C. and the exhaust blower draws 0.88 m^3/s (1,875 cfm) at 0.3 m (12-in.) W.C. This system dries the sawdust to 45 to 60 percent solids, increasing the solids content of the sawdust by approximately 5 percent.

Two roof exhaust fans are provided in the mixing room; each removes air at a rate of 0.272 m^3/s (576 cfm). To prevent the discharge of excess odors to the outside atmosphere, the use of these fans was discontinued. Finally, one fan in the reactor headspace removes a total of 2.8 m^3/s (6,000 cfm) of air to the odor control scrubber. Although this flow rate is equivalent to 1.8 air changes per hour, the fans are not large enough to satisfactorily reduce the fogging and odors generated in the headspace area. The proposed modifications to the odor treatment system (see Section 13.3.7) recommend that this flow rate be doubled to 5.7 m^3/s (12,000 cfm).

13.3.7 Odor

13.3.7.1 Sources and Characterization

The existing WWTP incinerator began operation about 1980. It was not well maintained and sludge was often pumped to an onsite lagoon when the incinerator was not operating, resulting in complaints from neighbors. When the incinerator operated on a regular basis, the plant only received odor complaints five to six times over a 5-year period.

After the composting plant started operating, there were 17 odor "incidents" and many more complaints until composting was stopped in January 1988. When the conditioning reactor was started in the summer of 1988, the plant received only one complaint until November of that year.

North and northeast winds carry plant odors directly to the neighbors, and odor complaints have generally been limited to the immediate neighborhood. Although experience is limited, odors appear to be worse in summer when neighbors complain of a "compost" smell (rather than ammonia).

The plant manager investigates and responds to most odor complaints. According to his findings, there is some question as to what the neighbors are actually smelling, although occasionally, the odors have been clearly linked with the composting plant. Regardless, the city council made a policy decision to satisfactorily address the odor concerns of the neighbors.

13.3.7.2 Odor Treatment System

The odor treatment system is a single-stage vertical wet scrubber 1.5 by 3.0 m, 7.1 m^3 (5 by 10 ft, 250 cf) designed primarily to remove ammonia from the process air. The scrubber was sized for a flow rate of 6.6 to 11 m^3/s (14,000 to 23,000 cfm), with a calculated scrubber detention time of 0.65 to 1.1 seconds.

Sulfuric acid is used to keep the scrubbing solution pH between 5 and 6. This solution is recirculated, and "DeAmine" (a proprietary odor control chemical) is injected into the airstream before it reaches the scrubber. The plant's ability to replenish scrubber water (i.e., replace the scrubber water with fresh water and chemicals) is limited by the undersized sump pump (see Section 13.3.4.5).

Air exits the top of the scrubber, which is located approximately 1.5 m (5 ft) from the side of the reactor building and approximately 4.5 m (15 ft) below the top of the building. This arrangement limits the dispersion of the discharge air. Based on the ineffectiveness of the original odor control system, a new odor control system for process air was being designed at the time of the site visit, but exact specifications had not been decided. The new system will be two-staged and sized to handle 11.0 m^3/s (24,000 cfm) of process air, mixing room air, and air from the reactor headspace. The existing scrubber will be used to cool the process air before it is fed into whatever new control devices are installed.

There is currently no odor control for the mixing room air, although the system just described will include provisions to control the odors from this area. The operations room in the process building has a separate air conditioning system. Odors (and noise) in this area are reportedly "acceptable."

Potassium permanganate is added to the sludge before dewatering to decrease odors.

13.3.7.3 Control Studies and Modifications

Due to complaints received since the start of composting operations, the city hired TRC Environmental Consultants to conduct an odor control study. In the study, the air flowing both to and from the existing odor scrubber was analyzed using dynamic olfactometry and gas chromatography/mass spectrometry (GC-MS). The tests indicated that the scrubber was ineffective at removing odors when using either water or sodium hypochlorite solutions.

A number of organic compounds were identified in the airstream. In this stage of the testing, a person familiar with the odors produced at the plant sniffed the various compounds alongside the mass spectrometer samples collected from the plant, as they were eluted from the gas chromatographic column. In this way, the most unpleasant and most intense odor could be correlated with a particular compound. Dimethyl disulfide was identified as the "worst" compound.

To reduce these odors, TRC recommended increasing the oxidation capabilities of the existing scrubber by ceasing recirculation of the scrubber liquid and by either increasing the hypochlorite dose or switching to a stronger oxidant such as potassium permanganate.

Ammonia is the only compound measured regularly (several times per week) at the plant and, typically, the scrubber is found to remove 50 percent of the ammonia from the airstream. The week before the site visit, with only the conditioning reactor in operation, the ammonia concentration was 12 ppm in the air flowing in the scrubber and 6 ppm in the air discharged from the system. "Normal" concentrations in the process air are 20 to 30 ppm. Slight increases in concentrations were observed just after reversal of the aeration valves. Some ammonia was also present in the blower room on the middle level of the reactor building.

The plant experienced greater odor problems when using very dry and powdery recycle in the mix (and either hardwood or pine sawdust). It is not known whether this was a coincidence. When the plant starts up again, the operator intends to compost the sludge both with and without recycle to observe the effects on odor production.

13.3.8 Support Facilities

The administrative wing of the main process building supplements the WWTP facility. This area contains the supervisor's office, a spare office, a reception area, restrooms, and a conference room. Showers and lockers are also located in the process building as well as in other locations in the WWTP. The composting facility uses the WWTP laboratory.

13.4 Monitoring and Performance

13.4.1 Reactor Control Strategy

The existing control system does not include automatic control of blowers. Instead, based on reactor temperature, the operator manually controls the aeration system rate, which is normally kept at full capacity because of the high reactor temperatures.

13.4.1.1 Temperature Monitoring and Control

The operator would like to keep temperatures in the 55° to 70°C (131o to 158°F) range. The upper limit of 70°C (158o F) was chosen for two reasons: first, more odors appear to be produced in reactors that are operated at temperatures above 70°C (158o F) than those operated below 70°C (158o F); and second, the operator is concerned about the possibility of spontaneous combustion of the compost.

The facility must meet the Federal EPA regulatory requirements for maintaining a compost temperature of at least 55°C (131°F) for 3 days, but it had difficulty getting its reactor temperatures down into the desirable range set by the facility. At the time of the site visit, the bottom of the conditioning reactor was 65° to 75°C (149° to 167°F). Temperatures in the first-step reactors were generally greater than 70°C (158°F) and appeared to be relatively uniform throughout the reactor (i.e., there was no defined profile of hot or cool zones). Second-step reactors exhibited the same temperature range.

Temperature is monitored by three temperature probes mounted on the centerline of each reactor. Each probe has thermocouples to measure temperatures at three different depths. The facility's original temperature probes had calibration problems and new probes were being installed during the site visit.

13.4.1.2 Other Tests and Equipment

To monitor plant performance, heavy metals in the sludge are measured on a monthly basis; heavy metals in the compost must be measured more frequently before the compost can be sold. Currently, the facility measures heavy metals each week in the compost from composite samples (see Table 13.1).

Table 13.1 Sludge and Compost Constituents (Average Values and Ranges)

Constituent	Sludge[a]	Mix[b]	Compost to Storage[c]	Finished Product[d]	NY State Standard for Case 1
Cadmium, Cd	8.4	2.3	3.4	4.9	10
(mg/kg)	(7.2-9.6)	(2.3-<4)	(2.7-4.0)	(3.5-6.2)	
Chromium, Cr	553	15	44	36	1,000
(mg/kg)	(450-650)	(12-18)	(37-50)	(23-42)	
Copper, Cu	733	87	155	141	1,000
(mg/kg)	(740-870)	(57-117)	(130-180)	(57-180)	
Mercury, Hg	0.47	0.12	0.12	0.42	10
(mg/kg)	(0.3-0.78)	(0.1-0.14)	(0.12)	(<0.03-0.6)	
Nickel, Ni	35	6	8	9.4	200
(mg/kg)	(28-46)	(5.7-6.3)	(7.5-8.5)	(4.8-13)	
Lead, Pb	111	20	50	42.1	250
(mg/kg)	(95-140)	(18-22)	(41-58)	(29-50)	
Zinc, Zn	2,173	100	155	141	2,500
(mg/kg)	(600-5,000)	(100)	(136-173)	(84-180)	
Polychlorinated biphenyls, PCB	—[e]	—	0.25	0.5	—
(mg/kg)	—	—	(0.2-0.3)	(<0.1-1.6)[f]	
Percent solids	19.7	—	—	68.0	—
	(18.22)	—	—	(66-72)	—
pH	—	—	—	7.2[g]	—
	—	—	—	(7.0-7.45)	
Fecal coliform/g	—	—	—	5.2×10^5	—
	—	—	—	$(0.24\text{-}930) \times 10^5$	

[a]Five samples, 8/88-10/88.
[b]Two samples, 9/87-10/87.
[c]Two samples, 12/87.
[d]Seven samples, 9/87-11/87.
[e]— = No standard.
[f]Four samples, 9/87-11/87.
[g]Five samples, 9/87-11/87.

To determine the percent solids in the compost mix, measurements are taken with a heat lamp several times per shift (or loading period). One sample per load is sent to the laboratory for solids determination using the standard oven-drying technique.

Mix solids are tested again twice per loading period using an analytical microwave technique, which gives results in 15 minutes. In the operator's experience, the results from the microwave technique correlate well with the conventional oven-drying technique. During operations, the mix is controlled "by eye," and is then verified by the microwave test.

13.4.1.3 Data Management

To verify that the facility is meeting time-temperature and detention-time criteria, the facility must submit a monthly summary of operating data to the State.

The software of the computer data acquisition system at the Schenectady facility was upgraded so that it could record a greater number of measurements, in addition to simply controlling operations. The aeration and temperature data are now recorded on a computer every 4 hours. Once per month, these data are printed in a spreadsheet format.

13.4.2 Mass Balance and Reactor Detention Time

Due to a lack of data, a mass balance or materials flow diagram is not included in this case study.

Contract specifications call for a plug-flow detention time of 28 days under average conditions using recycle in the mix. The operator calculated that the actual plug-flow detention time ranges from 18 to 21 days, based on the average input and output volumes when operating at 17 dt/day (19 dton/day).

13.4.3 Product Quality

Compost is regulated under the New York State sludge land application regulations. In New York, compost is classified as a Class I product and can be land-applied except where food crops are grown. Under New York State regulations, the user must be notified of the product's origin and characteristics via package labeling.

The design specifications call for a product that is essentially pathogen-free, based on normal reactor operations at a minimum temperature of 55°C (131°F) maintained for a minimum of 3 days. The product must also have the following characteristics:

- Friable texture
- No objectionable odor of sludge or ammonia
- Complete inactivation of weed seed
- pH between 5.5 and 8.0
- Product moisture of no more than 55 percent

Typical constituent concentrations are shown in Table 13.1. The product does reheat when it is piled in the curing/storage yard. Even after a year, the center of a pile produces steam and is slightly odorous when disturbed. The operator aims for a solids moisture content of 55 to 65 percent. In his opinion, the potential materials handling problems (stickiness, etc.) and the greater product weights of compost that contain less than 50 percent solids decrease the attractiveness of the material to users. Conversely, the operator's experience has been that product with a solids content greater than 65 percent is very dusty and has the potential to cause fires.

13.5 Operations

13.5.1 Staffing

The facility operates 5 days per week, with the hours determined by the length of time needed to load the reactors. Reactor loading time is based on two factors:

- The time needed to dewater the day's sludge. (The capacity to dewater one day's production of sludge in 8 hours is not usually a limiting factor.)
- The time needed to produce recycle or to clear space in the reactor. (The outfeed device traverse speed is limited to minimize plowing of the compost in front of the auger.)

The plant staff consists of one shift supervisor and two operators, one on permanent assignment and one who rotates in from the WWTP staff to perform housekeeping. One front-end loader operator is provided by the WWTP on an as-needed basis, usually 1 day per week,, and maintenance crews are also provided by the WWTP staff as needed. The WWTP plant supervisor oversees the compost plant as well.

The WWTP supervisor has a B.S. degree in environmental microbiology; 7 years of laboratory experience; 10 years of WWTP experience; and a Grade Ia (highest) operator certification. All operators are certified Grade IIa. No one on the staff has had prior composting experience.

No formal training on composting principles or process operations has been provided. On-the-job training in equipment operation was provided by ABT, who was on site for training purposes during July through September 1987. The foreman of the WWTP was also trained as a backup composting plant shift supervisor. A preventive maintenance program is in place.

13.5.2 Marketing and Distribution

The city does not want to market the product by itself, but a long-term marketing plan is not in effect. Although local demand for the product and its marketability have not yet been determined, to date of the site visit, all compost produced had been sold to local individuals for $4/m³ ($3/cy). The city was evaluating four different marketing proposals from different commercial bidders, as follows:

- Guarantee to take all compost produced for $0.65/m³ ($0.50/cy)
- No guarantee but will pay $1.3/m³ ($1/cy) for all compost sold
- No guarantee but will pay $4.0/m³ ($3/cy) for all compost sold
- No guarantee but will split revenues with the city for all compost sold

Final users are expected to be nurseries and landscapers.

13.5.3 Operating Costs

Due to the lack of operating experience, it was not possible to estimate operations and maintenance costs. As discussed, the odor control system upgrades, reactor structural modifications, and the outfeed device modifications all increased the costs of operating the facility; in addition, the incinerator had to keep operating.

13.6 Update

As of June 1989, the plant was still not operating pending completion of construction of the new odor treatment system. The three-stage, packed tower wet scrubber is expected to go on-line by the end of September 1989.

Pilot testing for the odor treatment system was performed in January using the conditioning reactor. Some odor sampling and testing, including "sniff" panels was also done.

APPENDIX A

Glossary

Aerobic — A condition in which free molecular oxygen is available.

Amendment — An organic material added to the feed mix to increase air voids for proper aeration and increase the quantity of degradable organics in the mixture.

Anerobic — A condition in which no free molecular oxygen is available.

Back Pressure — The pressure required to force air from the discharge side of a blower through an aeration distribution system and a compost pile.

Belt Filter Press — A mechanical dewatering device that uses a combination of gravity and pressure filtration to remove water from sludge.

Biofilter — A compost or soil bed through which gases are passed used for odor control purposes.

Blower Agent — A material of sufficient size to provide structural support and maintain airspace when added to wet sludge.

Chokepoint — A point in a system at which the flow of materials is constricted or reduced.

Clarifiers — A tank through which wastewater is passed to remove settleable solids.

Compost — A stabilized product consisting largely of decayed organic matter that can be applied to land without adverse environmental effects.

Composting — The biological decomposition and stabilization of organic substrates under conditions that allow development of thermophilic temperatures as a result of biologically produced heat. The final product is sufficiently stable for storage and application to land without adverse environmental effects.

Curing — Phases of the composting process in which degradation of refractory organics takes place. Curing is differentiated from the early stages of the composting process by a slower overall rate of biological activity.

Dewatered Sludge — A sludge that has had some of its water content removed by physical and chemical means. A mixture of primary and waste-activated municipal sludge that has been thickened and dewatered may have a solids content ranging from 15 to 40 percent depending upon the thickening, conditioning, and dewatering technologies employed.

Dewatering — A physical/chemical process that removes part of the water in sludge.

Diffuser — A porous pipe used to introduce air into a compost pile or reactor.

Energy Balance — The accounting of all exchanges and transfers of energy within a defined system in accordance with the principle that energy is neither created or destroyed.

Extractoveyor — A device used to remove compost from Paygro reactors for the purposes of mixing or conveying to another part of the compost system.

Fan — A device used to move air or gas at low pressures. At a compost facility, fans are generally used for building ventilation.

Feed — The input to the compost process.

First Reactor — The first reactor in series in a compost system. The first reactor may be the only reactor in the compost system or it may be followed by other reactors.

Gravity Thickener — A tank used to thicken sludge by gravity settling.

Headloss — The loss of hydraulic pressure as a fluid or gas moves through a conduit or porous medium.

Live-Bottom Bin — A storage bin with one or more screw conveyors located at the bottom for the purposes of extracting material from the bottom of the bin.

Mass Balance — The accounting of all exchanges and transfers of mass within a defined system in accordance with the principle that mass is neither created or destroyed.

Mix — The combination of sludge, amendment, and recycle that is fed to the composting process.

Negative Aeration — An aeration system which draws air from the atmosphere through compost by creating a vacuum at the base of the compost pile.

Nonprocess Air — Air collected from within a solids handling system that has not been used for the aeration of compost.

Pathogens — Disease causing organisms.

Phytotoxicity — A toxic or poisonous quality injurious to plants.

Plenum — An enclosed space in which the pressure of the air within the closed space is greater than atmospheric pressure. Plenums are used to convey air or gas streams throughout a treatment facility.

Plow-Blade Mixer — A device for mixing solid materials. Mixing is accomplished by several plowshare-like mixing tools fastened to the ends of short arms, which are perpendicularly attached to a rotating shaft. The device is enclosed in a metal housing. Although dual shaft units

are also manufactured, all of the units observed at the compost facilities surveyed were single-shaft devices.

Plug-Flow Detention Time — The time required for materials that enter a plug-flow reactor (including any recycle stream) to pass through the reactor.

Plug-Flow Reactor — A reactor in which all materials that enter the reactor at the same time flow through with the same velocity and leave at the same time.

Porosity — The ratio of void volume to total volume.

Positive Aeration — An aeration system which forces positive pressure air through compost to the atmosphere.

Primary Sludge — Sludge from a primary clarifier. This sludge generally consists of settleable solids and tank skimmings. Primary sludge produced by a municipal wastewater facility typically contains degradable organics and some inerts.

Process Air — Air that has passed through composting material (i.e., from the active component of the compost process; not biofilters). Process air may be collected in a headspace above the pile of compost, collected by a diffuser system below the pile of compost, or collected by an exhaust system within the pile of compost.

Pugmill Mixer — A device for mixing solid materials. Mixing is accomplished by dual rotary shafts with perpendicular paddles or blades, which intermesh when the shafts are turning. The shafts are enclosed in a metal housing.

Recycle — Compost product that is returned to the beginning of the compost process and incorporated into the feed mix.

Scrubber — An apparatus for removing impurities from gases, usually by means of a chemical solution.

Second Reactor — The second reactor in a compost system. A compost system may or may not have a second reactor.

Septic — Anaerobic.

Sludge — The solid and semisolid residuals and concentrated pollutants removed by wastewater treatment processes.

Solids Retention Time — The average time that a typical solids particle remains within a reactor (including recycle). Because some portion of the reactor product is generally recycled back to the reactor feed, the solids retention time is generally longer than the plug-flow retention time.

APPENDIX B

Conversion Factors

Unit	Multiply by	To get
°C	1.8 (°C + 32)	°F
kg	2.205	lb
kg/m^3	6.243×10^{-2}	lb/cf
kg/m^2	5.448×10^{-4}	lb/acre
kg/s	132.2	lb/min
km	0.6214	mile
kJ/kg	0.430	Btu/lb
kJ/kg	126.0	kWh/lb
kg/m^3	1.686	lb/cy
L	0.2642	gal
m	3.281	ft
m	39.37	in.
m	1.094	yd
m^3	35.31	cf
m^3	1.308	cy
m^2	10.76	ft^2
m^2	2.471×10^{-4}	acre
m^3/s	2,119	cfm
$m^3/m^3 \times s$	5.999×10^4	cfm/1,000 cf
m^3/s	1.271×10^5	cfh
m^3/s	22.83	mgd
m^3/t	32.15	cf/ton
Pa	1.45×10^{-4}	psi
t	1.102	ton (short)

APPENDIX C

Examples of Technical Information Required of System Suppliers and System Selection Criteria

In this appendix are lists of information requirements and selection criteria used in four different in-vessel projects. These lists provide examples of the kinds of issues others have considered important in choosing an in-vessel system. Each public agency must to develop its own list to reflect the purposes and constraints of its project.

City A (1988)

The procurement process at City A includes three phases. In Phase 1, the City's consulting Engineer will formally solicit information from equipment suppliers and prepare system layouts and life-cycle costs from the suppliers' submittals. From this information, and using the criteria listed below, the individual suppliers will be categorized as Preferred (one vendor only), Acceptable, or Unacceptable. In Phase 2, the Engineer will prepare plans and specifications based on the preferred technology. The Engineer will also prepare cost estimates for the redesign of the facility to accommodate each of the acceptable technologies. In Phase 3, construction bids will be solicited. The final selection will be based on the lowest bid. Bids from acceptable technologies (other than the preferred one) must include the Engineer's redesign costs.

Technology Selection Criteria

(Weighting factors shown in parentheses are those used by City A and are not EPA recommendations.)

A. Cost (Group Weighting Factor 30)

1. Initial Construction Cost

   Note: After completion of the evaluation process, but before selection of the preferred system, the City will request a guaranteed price on all equipment provided by the Supplier.

   The Engineer will determine the overall capital costs of the facility based on information submitted by the supplier and with costs developed by the Engineer. The Supplier should provide the following information:

   - Costs for each item of equipment that will be supplied and/or installed.
   - Information for all other equipment required so that Engineer may develop these costs.
   - Information (including construction materials) on all buildings and other facilities required so that the Engineer may develop these costs.
   - Reference all costs to July, 1990, the estimated bid date.

2. Annual Operation and Maintenance Cost

   The Engineer will determine the annual operation and maintenance costs based on an average sludge production of 9 dt/day (10 dton/day) using the following information provided by the Supplier:

   - Indicate the number of operators for operation and maintenance of the facility.
   - Provide annual costs for spare parts.
   - Provide an estimate of the proposed amendment usage based on the average month mass balance.
   - Provide the average daily energy requirement in kilowatt-hours per day. List motor sizes and operation time requirements for each piece of equipment provided. Include conveyors, blowers, fans, mixers and reactor equipment. Include heating and lighting requirements.
   - Determine the peak power demand in kilowatts. Identify equipment operation assumptions.

3. Present Worth

   - The Engineer will use a 20-year life cycle, and a discount rate of 8.75%.

B. Operations and Maintenance Considerations (20)

1. Number of Operators Required for Operation and Maintenance (2)

   This criterion will address the likelihood that the City will be able to hire and train qualified operators for the facility. (The cost aspect of the number of operators is considered under O&M cost criterion.)

2. Frequency and Description of Major Maintenance Tasks (2)

   Provide a description.

3. Special Skills or Training Required for Operation and Maintenance (2)

   Identify contract maintenance requirements or training required for the City's operation and maintenance staff.

4. Adequacy of Area for Equipment Access and Removal (3)

   Provide dimensions and descriptions.

5. Method of Adjustment to Loading, Mix Characteristics, Solids Content or Temperature (1)

   Include information on how the feed to the mixer is adjusted (weight or volume basis), and use of variable speed drives.

6. Simplicity of Instrumentation and Control System (2)

   Describe reliability of systems and level of skill required for operation.

7. Simplicity of Equipment Systems (4)

   Describe reliability of systems and level of skill required for operation.

8. Operator Environment (4)

   Describe the operator environment for normal operation and routine maintenance. Submit assurances that safety, environmental and health conditions have been addressed, and that these conditions meet State and Federal standards.

C. Process and Performance Considerations (25)

1. Ability to Meet or Exceed Project Performance Requirements (7)

   Project performance requirements are shown in separate design criteria and a mass balance. The supplier must provide backup design calculations that show how each of the requirements are to be met or exceeded.

2. Redundancy Provided for Critical System Components and Standby Equipment (2)

   Identify the capacity and the number of backup equipment units used for short-term or long-term requirements.

3. Quality of Materials of Construction (2)

   Describe the materials used for construction and the rationale for their use. Include the materials and type of construction for the composting buildings, even if they are not provided by your company.

4. Proposed Hours of Mixing and Materials Transfer (1)

   Provide an operating schedule in bar chart (time line) form.

5. Flexibility of Operation/Plan for Process Upset (2)

   Identify possible upset conditions and remedial actions.

6. Aeration System Design Approach — Normal and Upset Conditions (2)

   Provide design approach to meet peak, average and upset conditions.

7. Characteristics of Process Air (4)

   Include a description of the air collection points and the chemical characteristics, volume, pressure, humidity and temperature of the process air. Describe a recommended method for odor control. (Engineer will design the odor control system.)

8. Characteristics of Nonprocess/Ventilation Air (1)

   Include a description of the air collection points and the chemical characteristics, volume, pressure, humidity, particulate content, and temperature of the nonprocess/ventilation air.

9. Building and Site Layout/Total Area Requirements (2)

   Show the arrangement of all facilities and equipment required, including those facilities not provided by your company. Consolidation of operation and visual screening of operation from neighbors are important considerations.

10. Access Arrangements (1)

    Show pedestrian and vehicle access on a site plan.

11. Utility Relocation Requirements (1)

    Provide a utility relocation plan.

D. System Experience and Reliability (25)

1. Provide capacity, configuration, and required modifications and costs for each example project.

2. Service Record of Major Equipment/Mechanical Reliability (5)

   For major proprietary equipment items, list facilities with identical or similar equipment, number

of years of service, performance, and major equipment modifications/improvements.

3. Operating Records of Representative Projects/ Performance Test Results (6)

   Include data where available.

4. Company Qualifications/Staff Qualifications (3)

   Provide company organization and total staff, and an indication of who will likely work on this project.

5. Service Capability of Company (5)

   Provide equipment and performance warranty. Indicate length, coverage and conditions, and extended service capability.

6. Financial Capability (4)

   The City intends to require a labor and materials bond and a performance bond for the construction contract. Suppliers are requested to furnish certification that such bonds have been issued on other projects and can be issued for this project.

City B (1988)

Evaluation Criteria (Not in order of importance)

1. Construction Costs — From take-off of proposal submittals using standard cost estimating documents.

2. Life Cycle O&M Costs — Based on information submitted in proposals on labor, power, sawdust, and maintenance costs.

3. Reliability of Equipment and Process

   a. Required Downtime
   b. Track Record of Proposed in/out Feed Devices
   c. Conveyance Systems
   d. Process Reliability
   e. Equipment Complexity

4. Marketing Program

5. Flexibility of Equipment and Process

   a. Complexity of Equipment
   b. Control of Process

6. Efficiency of Site Layout.

   a. Aesthetics
   b. Land Requirement
   c. Logistics of Layout

7. Ease of Operations and Maintenance

   a. Ease of Access
   b. Control of System
   c. Ease of Upset Recovery

8. Qualifications, Experience, and Responsibility of Bidder

   a. Qualifications
   b. Experience
   c. Responsibility of Bidder

9. Ability to Meet Needs of the Project

   a. 45% Solids in Compost Product
   b. Odor Control Provisions
   c. Schedule

City C (1987)

City C solicited proposals for private sludge composting services. Prospective bidders were requested to submit financial as well as technical proposals. Documents required with the proposal:

1. Signed bid proposal filled out as required and enumerated in the Proposal Section of the Project Manual.

2. Cash, Certified Check, or Bid Bond in the amount of 5 Percent of the Bid Price as bid security.

3. Corporate Certificate duly authorized including Source of Authority.

4. Written Affirmative Action Program as specified in the Project Manual.

5. Bid Letter from approved Surety Company agreeing to furnish a Performance Bond and a Labor & Materials Bond in the event of an award.

6. Contractor's Certification.

7. Subcontractor's Certification (if any).

8. Certificate of Insurance.

9. Any Power of Attorney or other Certification, if requested.

10. Minority Business Utilization Certification.

11. Description of the Proposed Disposal and/or Reuse Facilities, if applicable, to be provided by the bidder.

Selection Criteria

A. Completeness of Proposal

1. Has all required information been supplied?
2. Bid letter supplied?
3. Any affirmative action plan or program submitted?

B. Experience

1. Performance and Accountability

   a. Experience level of the firm in completing and operating projects of a similar nature and scope to that detailed in this Request for Proposal.

   b. References from past or current contracts.

   c. Established business office and staff.

   d. Previous Municipal Contracts.

   e. Defaults within past 5 years.

2. Operations

   Two years minimum experience in sewage sludge composting.

3. Personnel

   a. Experience qualifications of the personnel to be assigned to the project.

   b. General performance.

   c. Training and/or experience.

   d. Experience on similar projects.

4. Experience Rating

   a. Prior systems, materials and equipment in relations to the City's requirements.

   b. Size of prior similar contracts.

   c. Size of other types of work contracts in relation to this project.

C. Financial Strength

1. Financial stability of the proposing firm and the adequacy in the aggregate of all insurance, indemnities, and other protections and security offered the City to protect the City from liability and expenses, other than the Contract price, that may arise or be incurred in connection with the contract or the construction, if any, and the continued operation of the project.

2. Solvency of business as evidenced by financial statements.

3. Ability to finance new equipment through bank, equipment manufacturer or vendor, and/or letter of credit.

4. Has firm been engaged in performing similar services under the same name and organization for a minimum of 1 year? (For joint ventures, each firm shall meet same requirement.)

D. Business Proposal

1. Ability of the proposing firm to provide the service for the entire proposed contract period.

2. The adequacy of the project development plan, scheduling and ability to complete the tasks within the project time frame.

3. Has the proposer indicated his acceptance of the City's sludge within a reasonable period of time?

4. The tipping fee or purchase price per wet ton.

City D (1985)

City D solicited proposals for private sludge composting services. The City was particularly interested in avoiding any technology which had not operated successfully on a commercial scale. Accordingly, the information requirements for each respondent to the Request for Qualifications were to be based on an existing sludge composting plant designed, constructed, owned or operated by the respondent or using the respondent's licensed technology. This is the so-called "Reference Plant". Reference plants could be either domestic or foreign. The primary stipulation was that the Reference Plant must have been operative commercially for at least 1 year.

Besides the technological information requirements detailed below, the City requested information on marketing plans, the organization of the project, and the financial resources of each respondent. The relative weights used in making the final choice were:

Technical Information	2
Compost Marketing Information	2
Organizational Information	3
Financial Information	3

Technical Information Requirements

1. Reference Sludge Composting Plant — Minimum Criteria

   The Reference Plant must meet the following criteria:

   a. The Reference Plant must be equipped with control devices which operate effectively in order to alleviate potential environmental problems. These must include means for removal or containment of particulate mat-

ter, elimination of pathogens, and suppression or containment of odoriferous compounds. In addition, any liquid effluents must be safely disposed.

b. The Reference Plant must provide for the on-site storage, mixing and processing of materials (sludge, bulking agents and recycle compost) in such a manner that the requirements of paragraph 1.a are met.

c. The Reference Plant must include integral appurtenances for composting and subsequent curing at the same time.

d. The processing line(s) must be equipped with automated process controls which allow for the optimization of the plant's operating parameters. Typically, these include oxygen, carbon dioxide and temperature monitors.

e. The Reference Plant must perform in a utility-like capacity, providing dependable sludge disposal services to an affiliated wastewater treatment plant and delivering quality compost for export and sale on a continuous basis.

f. The Reference Plant must have been in continuous operation for at least one (1) year under the direction of a licensed, professional wastewater treatment plant operator, or an individual with similar documented qualifications.

2. Reference Plant — Description

Provide a short written description of the Reference Plant which includes:

a. Name and location of plant.

b. Owner of plant.

c. Operator of plant.

d. A block diagram showing the principal parties responsible for the Reference Plant and the contractual relationships between the principal parties.

e. Technical description:

— Give the name of Reference Plant's designer.

— Give the name of Reference Plant's builder.

— Give the name of the regulatory agency which approved permits.

— Briefly describe the facilities used for materials storage (i.e. sludge, bulking agent and recycle compost), giving storage capacity in tons and the design bulk weights (in storage) in lb/cu. ft.

— Briefly describe the mixing equipment in terms of its purpose, type, and throughput capacities in maximum continuous rating (MCR), wet short tons per hour (WSTPH). The MCR capacities must be stated separately for each component and the total mix.

— State number of independent sludge processing and containment vessels and/or buildings used together with their MCR capacities of sludge throughput in WSTPH for a given solids concentration (in % of TS). Each independent processing line is meant to comprise all equipment necessary to process sludge after mixing into a finished compost product, including any curing and screening steps.

— State the number and type of major materials-handling equipment associated with each line, including front-end loaders, bulldozers, conveyors, mixers, screens, extractors, and the like, giving their unit capacities in WSTPH or cu. yd. per hour, as appropriate.

— State the type of air pollution control device(s) associated with each line and provide actual test information which quantifies the controlled emission rate. Reference the test methods used.

— State the disposal method and/or treatment method associated with each line for the treatment of leachates and/or run-off and provide actual test information which quantifies the following effluent parameters: BOD (mg/L), COD (mg/L) and SS (mg/L).

— Describe briefly the extraction, transport, and storage system used for each processing line with special emphasis on the measures taken to avoid materials blockage.

— Describe briefly the type of energy recovery system used, if available, in terms of the millions of Btu per hour recovered at MCR and identify the type of heat transfer fluid involved, together with its design pressure (psig) and temperature at the reactor outlet on the gas side and at the heat exchanger outlet on the liquid or vapor side.

f. Drawings/Figures

— Site layout plan showing main buildings,

traffic pattern(s) and access from major highway.

- Area map which relates the composting facility to the wastewater treatment plant which supplies the sludge.
- Main processing area/building layout plan showing handling and storage systems for sludge and bulking agents, mixing equipment, metering equipment, independent processing lines, air and water pollution control equipment, and finished compost removal screening and storage systems.
- Main process area/building cross-section showing each elevation with installed equipment.
- A cross-section of one sludge processing line including the composting and curing steps together with the finished compost discharging mechanism.
- One complete mass balance. This mass balance must be subdivided into its gaseous, liquid and solid components. Supporting calculations should be attached.
- One complete energy balance. This energy balance must be subdivided into its electrical, thermal and chemical components. Supporting calculations should be attached.

g. Operating Schedule and Staffing Plan

- Briefly describe the normal operating schedule of the Reference Plant (hours per day, days per week, and days per year). State the normal operating mode (in terms of number of processing lines operating at the same time, scheduled maintenance periods, number of shifts, etc.).
- Submit a staffing plan showing the number of operating and administrative personnel employed during each shift and their functions.

h. Sludge Supplier (for the Reference Plant)

- Give name of sludge supplier(s) and how the sludge is delivered.
- Describe the type of sludge delivered (raw or digested, primary, secondary, tertiary and/or mixed). Give solids concentration, volatile solids concentration, and heavy metals content (cadmium, copper, lead, mercury, nickel and zinc). Other pertinent parameters such as iron, nitrogen, phosphorus, potassium and the pH factor should be included as well.

i. Compost User(s)

- Describe compost user(s) and how the compost is used.
- Describe the type of compost sold (semi-finished or finished compost, soil conditioner, blended with additives, fortified with chemicals, etc.). State the mesh size which the average particle will pass, together with average moisture content and representative bulk weights in lb./cu. ft.
- One laboratory report either from the regulatory agency, or from the compost user, or from an independent testing laboratory which characterizes the physical, chemical microbiological and organoleptic properties of the compost typically produced by the composting plant and which certifies the acceptability of the compost for its intended use(s).
- Describe the form and major terms and/or conditions of the compost sales contract between the compost plant and compost user(s).

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