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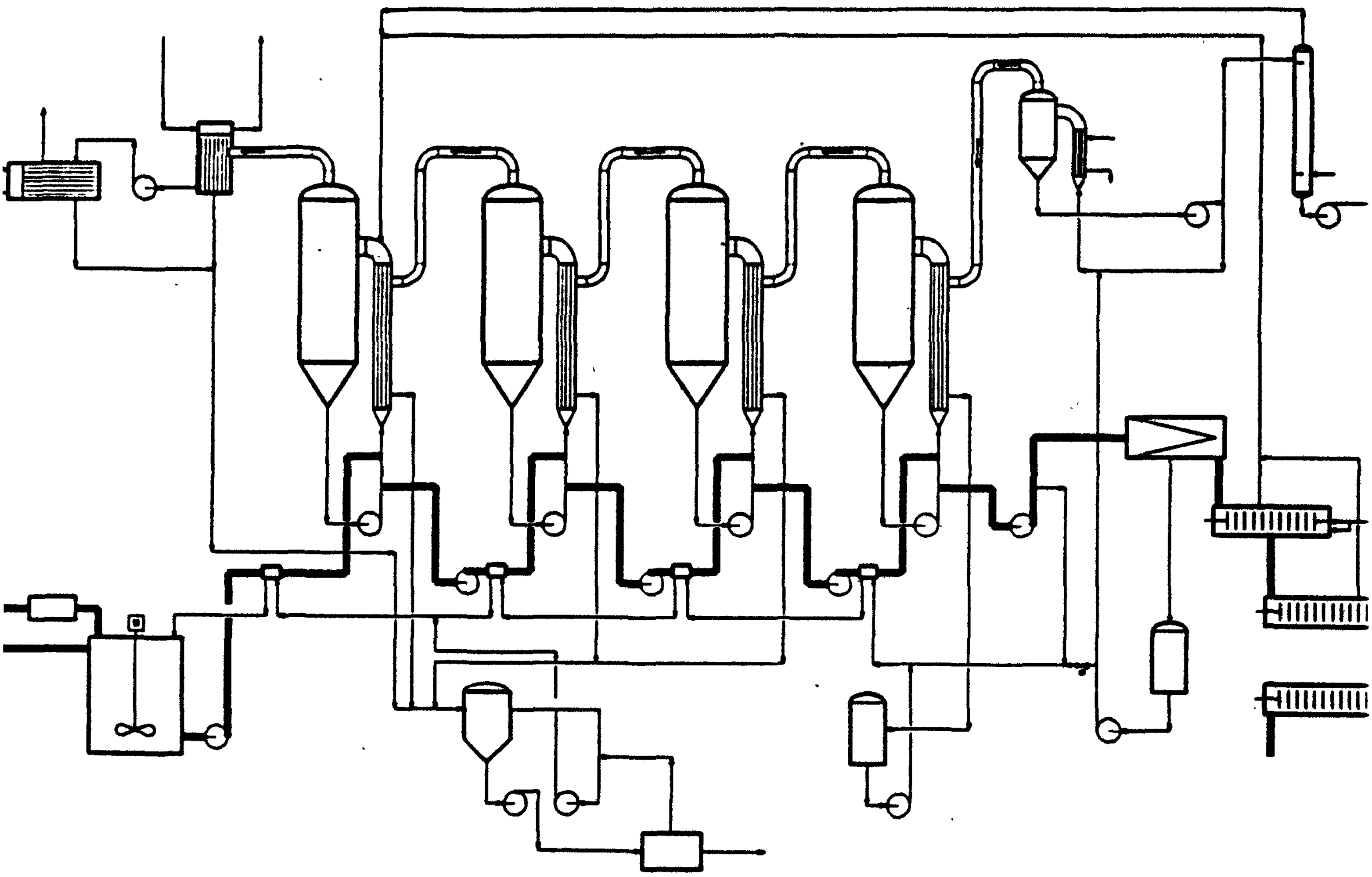
The Carver-Greenfield Process For Sludge Drying



STARTUP AND OPERATION OF
CHEMICAL PROCESS TECHNOLOGIES IN THE MUNICIPAL SECTOR:
THE CARVER-GREENFIELD PROCESS FOR SLUDGE DRYING

by

A Review Team of Engineers from the
Chemical Process and Petroleum Refinery
Industries

Manuel Gonzalez
Frank Y.W. Liao
Kathryn A. Pluenneke
Gilbert Rowe
Martin J. Siecke

for

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John M. Walker, Project Manager
Office of Municipal Pollution Control
Washington, D.C. 20460

Harry E. Bostian, Work Assignment Manager
Risk Reduction Engineering Laboratory
Cincinnati, Ohio 45268

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Environmental considerations have led to the introduction of more sophisticated methods of treatment and disposal of municipal wastes than have been practiced in the past. In many respects, these new techniques are similar to those used in the chemical processing and petroleum refining industries, which have over many years developed and implemented complex processes for their own purposes. For the purpose of simplifying the text, "chemical process industries" will be used in this report to refer to those industries involved in chemical manufacturing and petroleum refining.

The Carver-Greenfield Process is an example of a more complex technology that has been adapted to the drying of municipal sewage sludge. There are currently four Carver-Greenfield municipal projects in the United States, three under construction and the fourth involved in a long and difficult startup.

It has become increasingly apparent, especially after the United States Environmental Protection Agency (EPA) sponsored a workshop in 1987 on the Carver-Greenfield municipal projects, that a number of startup problems could be due to difficulties with the approach and experience of the startup personnel as well as with the design of the system. To further explore this area, EPA decided to organize an industrial review team of engineers with startup and operations experience in the chemical process industries. The designer of the Carver-Greenfield municipal sewage sludge plants, Foster Wheeler USA Corporation, was instrumental in making initial contact with a number of the larger chemical processing and petroleum refining companies in the United States, and in assisting EPA to screen potential candidates for the review team.

A five-person industrial review team was assembled in June, 1988. After studying background information on the Carver-Greenfield Process and the four municipal sewage sludge drying projects in the United States, the Industrial Review Team gathered further information on these projects through a series of meetings with representatives of three of the project owners: the Mercer County (New Jersey) Improvement Authority, the City of Los Angeles, and the Los Angeles County Sanitation Districts.

Based on their professional experience with chemical processing installations and the information gathered in the course of this project, the Industrial Review Team developed certain conclusions and recommendations regarding the startup, operation, and maintenance of Carver-Greenfield municipal sewage sludge drying plants. Recommendations were also developed for the general case of implementing chemical process technologies in a municipal application.

The Mercer County Improvement Authority plant, which was in construction at the time of the review, was chosen for specific case study, and suggestions were developed for starting up, operating, and maintaining that facility. Because the City of Los Angeles Carver-Greenfield facility was the only plant of its type that was completed and in startup at the time of this review, it was of particular value in developing the material presented in this report. A brief update has been included regarding progress that has occurred at that facility and the facilities under construction since the first draft of this report was presented in September, 1988.

The Carver-Greenfield technology is substantially different from traditional municipal wastewater and sewage sludge management systems, with process characteristics, equipment, and unit operations found more frequently in chemical processing systems. This process involves flammable liquid and vapor, operation under reduced pressure, and feedforward/feedback complexity. Because of its similarity to chemical plant and petroleum refinery operations, it is to be expected that those practices that have proven to be essential in industrial facilities will prove to be of value in municipal sewage sludge drying Carver-Greenfield plants.

For the startup of a facility similar to a Carver-Greenfield municipal sewage sludge drying plant, chemical and petroleum companies have found that a team of engineers with many years of specialized experience starting up and operating the type of equipment and unit operations present in the new facility are needed on a twenty-four-hour-per-day basis, seven days per week. After the plant achieves normal operation, fewer engineers are required. Daily coverage five days per week and on-call weekends is normally adequate.

In addition to startup and/or operations engineers, there are certain specialized technical skills and talents that have proven to be essential to the successful startup, operation, and maintenance of complex chemical processing facilities. These include health and safety, corrosion/materials, piping stress, thermal expansion, instrumentation, rotating machinery, and electrical/

utilities expertise. There are also certain practices, such as the development and maintenance of detailed documents on how to operate and maintain the plant that are vital not only to a successful startup effort but for continued operations.

Because the potential for serious disaster with chemical processing systems is much greater than with typical publicly-owned treatment works units, great emphasis must be placed on health and safety. Industrial experience has proven that risk can be reduced and controlled at acceptable levels by planning, practicing, and continually reviewing health and safety procedures. A health and safety specialist experienced with chemical processing systems should be involved with the project prior to initial startup to assure that all health and safety planning, documentation, and training programs are in place. A member of the plant's permanent engineering staff should be designated safety officer responsible for carrying out and continually updating the program.

Preparations for initial startup should begin many months before the end of construction, to allow time for development of a startup plan, hiring and training personnel, developing operations documents, arranging for maintenance services, monitoring the final phases of construction, developing an inventory of spare equipment and parts, locating specialty mechanical service shops for particular jobs, and pre-commissioning. Startup preparations should include planning for and locating temporary startup expertise, in the form of full- or part-time personnel with specialized background in starting up and operating chemical processing facilities. These personnel are available by contract from a number of companies. One option for municipalities is to contract directly for comprehensive services with a single company that specializes in startup of similar facilities.

The initial startup of a chemical processing facility frequently requires some modification to the system. However, it must be remembered that the primary objective is to get the plant to operate continuously as designed, and not to change, optimize, or debottleneck until after continuous operation is achieved. Experience has proven that changes other than those where design or equipment problems actually prevent continuous operation should be postponed. There are a number of reasons for this approach, including the fact that problems at low operating rates may not be significant at high rates, and that continuous operation is essential to maintaining personnel morale and gaining operations experience.

For plants that involve process and/or equipment innovations compared to existing facilities, chemical/petroleum industry experience suggests that process modifications amounting to as much as ten percent of the capital cost of the plant might be expected. In addition to modifications, other startup expenses might run as high as another ten percent of the capital cost of the plant. Adequate funds for both startup and modification expenditures should be included in the project budget. Also, immediate access to funds should be arranged before initial startup is attempted, because many startup expenditures must be made on an emergency basis.

In any facility where a technology is being implemented for the first time in a particular application, it is likely that the facility will not achieve one hundred percent of design capacity as originally installed. The plant owner should have contingency arrangements for treating and disposing of the feedstock while modifications are made on the new facility.

Through discussions with the Carver-Greenfield municipal plant owners, it became apparent that there are a number of factors inherent in municipal organizations that complicate the implementation of such complex technologies. There has been little opportunity in the past for the municipal facility owner to develop startup, operations, and maintenance expertise for unfamiliar complex systems. Restrictions on hiring, wage scale, and promotion and benefit practices may make it difficult to hire and keep the more highly trained and properly experienced personnel that are needed. This situation leads to dependence on outside sources for expertise. These outside sources may not be able to provide enough highly trained personnel, because the need for such personnel in municipal facilities is a fairly recent development. There are also a number of institutional obstacles to implementing more complex technologies in municipal applications, including authorization, procurement, and purchasing practices that are not adapted to the demands of operating such facilities.

The startup, operation, and maintenance of Carver-Greenfield municipal sewage sludge drying plants require different skills and procedures than are required for traditional municipal treatment systems. By way of general assessment, the Review Team found that, as of July, 1988, the approaches for startup being used or planned by the Carver-Greenfield municipal facilities visited during this review were not adequate to successfully perform the task.

Acquiring new skills, modifying procedures, and dealing with the restrictions imposed by municipal practices present a significant challenge to the owner of a chemical processing type facility in a municipal application. Flexibility and innovative thinking will be required to successfully accomplish this transition.

The emphasis of this report is on startup, operation, and maintenance of facilities. This report is not intended to be a review of the Carver-Greenfield technology, its appropriateness for the municipal sewage sludge drying application, or the design of any of the Carver-Greenfield facilities mentioned.

SECTION 1

INTRODUCTION

The Carver-Greenfield Process is a patented drying technology (briefly described in Appendix A) that has been applied to a variety of feedstocks and has been adapted for the drying of municipal sewage sludge. There are currently four major Carver-Greenfield municipal sewage sludge drying facilities in various stages of completion in the United States, three under construction and the fourth involved in a long and difficult startup.

The Carver-Greenfield technology is substantially different from traditional municipal wastewater and sewage sludge treatment systems, with process characteristics, equipment, and unit operations found in chemical processing systems. The Process involves flammable liquid and vapor, operating a vacuum system, and feedforward/feedback complexity. For the purpose of simplifying this text, the phrase "chemical processing" will be used to indicate both chemical manufacturing and petroleum refining.

It became increasingly apparent, especially after a workshop was sponsored by the United States Environmental Protection Agency (EPA) in 1987 on the Carver-Greenfield municipal projects, that a number of the startup problems could be due to difficulties with the approach and experience of the startup personnel as much as with the design of the system. To further explore this area, EPA decided to organize a review team with startup and operations expertise in chemical and refinery processes. The designer of the Carver-Greenfield municipal plants, Foster Wheeler USA, was instrumental in making initial contact with a number of the larger chemical and petroleum companies in the United States, and in assisting EPA to screen potential candidates for the review team.

This report presents the findings and recommendations of that industrial review team, who, on behalf of EPA, applied their professional expertise from the chemical process industries to the problems of starting up, operating, and maintaining a Carver-Greenfield municipal sewage sludge drying facility.

The chemical engineers who served on the Industrial Review Team are (see also Appendix B):

> Mr. Manuel Gonzalez of Mobil Research and Development Corporation (twenty-four years total technical experience),

Mr. Frank Y. W. Liao of Mobil Research and Development Corporation (twenty years total technical experience),

Ms. Kathryn A. Pluenneke of Technical Services; previously with Dow Chemical Company (eleven years total technical experience),

Mr. Gilbert Rowe of Environmental Consultants; previously with Exxon Corporation (thirty-seven years total technical experience),

Mr. Martin J. Siecke, P.E., of National Starch and Chemical Corporation (twenty-five years total technical experience).

EPA Project Management:

Dr. Harry E. Bostian, P.E., Chemical Engineer, Risk Reduction Engineering Laboratory, EPA, Cincinnati, Ohio; previously with Exxon Corporation and Universities of New Hampshire and Mississippi (thirty years total technical experience),

Dr. John M. Walker, Physical Scientist, Office of Municipal Pollution Control, EPA, Washington, D.C.; previously with U.S. Department of Agriculture (twenty-eight years total technical experience).

The members of the Review Team wish to stress that the limited time available for this review precluded detailed evaluation of startup problems and of operational solutions. The Team's efforts were directed at determining the status of current startup, operations, and maintenance activities, so that they could provide information based upon their professional experience by which the startup, operations, and maintenance personnel, systems, and approaches could be modified to better meet the needs of a Carver-Greenfield municipal sewage sludge treatment facility.

By way of general assessment, the Review Team found that, as of July, 1988, the approaches for startup being used or planned by the Carver-Greenfield municipal facilities visited during this review were not adequate to successfully perform the task. While conditions varied from location to location, it was obvious to the Team that there was in general a lack of familiarity with the requirements for successful startup and operation of chemical processing systems. Problems observed (see also Appendix C) included lack of properly trained and experienced personnel for startup of the relatively complex installations, inadequate use of monitoring and sampling for documentation and control of component performance, and, as of July, 1988, not having run all parts of the system per the design (e.g., acid addition and sewage oil separation components). Lack of experience with starting up chemical/refinery type systems had apparently contributed to the problems with bringing a major Carver-Greenfield municipal sewage sludge drying system into full operation.

As a basis for improvement, the Review Team has met with the several municipalities for frank and open discussions of problems and possible solutions and has prepared this short informational document. The Team gained a great deal of insight regarding the problems surrounding the implementation of the process in the municipal environment and hopes that the plant owners and operators, the system developer, and the system designer have also gained from this exchange of information. The frankness and cooperation of all those individuals who met with the Team is greatly appreciated (see Appendix D).

1.1. Objectives and Scope of Project

This project was undertaken to develop suggestions, based on professional experience with chemical processing systems, for the startup, operation, and maintenance of Carver-Greenfield municipal sewage sludge drying facilities. This report outlines the staffing, personnel training, operations documents, and other support that the chemical process industries would typically provide for the successful startup and operation of such a facility. As a specific case, suggestions are presented for the Mercer County (New Jersey) Improvement Authority facility, which is currently under construction. On a larger scale, general considerations are presented for future municipal projects involving technologies of a similar complexity to the Carver-Greenfield Process.

A brief update of the status of the four Carver-Greenfield municipal facilities, particularly the City of Los Angeles facility, is included in Appendix E. Many of the activities which have occurred since this review was undertaken in July, 1988, are consistent with recommendations made by the Review Team.

The emphasis of this report is on startup, operation, and maintenance of facilities. This report is not intended to be a review of the Carver-Greenfield technology, its appropriateness for the municipal sewage sludge drying application, or the design of any of the Carver-Greenfield facilities mentioned.

1.2. Approach to Task

At the beginning of the project, documentation concerning the Carver-Greenfield Process (see References) and the Piping and Instrument Diagrams and Operating Manual of The Mercer County Improvement Authority (MCIA) Project were distributed to and studied by each member of the Industrial Review Team. Additional information was gathered through a series of meetings held in New Jersey and California and from design and operating documents examined at the three California locations.

The first project meeting was held in the MCIA building in Trenton, New Jersey, on July 8, 1988. The morning meeting was attended by the Review Team and EPA Project Management. At noon, this group was joined by representatives of:

MCIA and its supporting municipalities (Trenton, Hamilton, and Ewing-Lawrence);

Clinton Bogert Associates (the prime contractor on the MCIA Project);

Foster Wheeler USA (subcontractor to Clinton Bogert and licensee of the Carver-Greenfield Process for the MCIA Project);

Dehydro-Tech Corporation (licensor of the Carver-Greenfield Process).

Included in the afternoon session was an inspection tour of the MCIA project construction site.

Two days, July 11 and 12, were spent at the City of Los Angeles Hyperion Energy Recovery System facility in order to collect as much information as possible about the single existing Carver-Greenfield facility in a municipal sewage sludge drying application that is fully constructed and currently in startup. Meetings were held with representatives of:

The City of Los Angeles Hyperion Construction Division Bureau of Engineering;

The City of Los Angeles Department of Public Works Bureau of Engineering;

Dehydro-Tech Corporation (providing startup assistance);

James M. Montgomery Consulting Engineers, Inc. (providing startup and operations management);

The Ralph M. Parsons Company (providing startup and operations management).

The visit included a tour of the City of Los Angeles' Carver-Greenfield plant.

The third day of meetings in California, July 13, was held at the Los Angeles County Sanitation Districts' (LACSD) Carver-Greenfield plant site. LACSD project management provided background information about their Carver-Greenfield installation and conducted a tour of the construction site.

The final meetings in California took place on July 14, 1988, at FW Martinez, Inc., a cogeneration facility built, owned, and operated by Foster Wheeler that provides the adjacent Tosco petroleum refinery in Martinez, California with steam and electricity. Plant management provided information about the startup and operation of their Carver-Greenfield unit, which uses steam from the cogeneration facility to dry an alum/clay sludge from a municipal water treatment plant operated by the Contra Costa Water District. This information was used as a basis of comparison, and to confirm impressions about Carver-Greenfield systems gained at other locations. FW Martinez was the last site visited in California.

After the California trip, the recommendations of the Industrial Review Team were assembled and used as the basis for drafting this report. A meeting was then held at the Nassau Inn in Princeton, New Jersey, on September 15 and 16, 1988, for the purpose of discussing the startup, operation, and maintenance of Carver-Greenfield municipal sewage sludge drying facilities. Those invited to attend included the developers and designers of the process, the owners and operators of the four municipal facilities, the architect/ engineering firms on the four projects, consultants, representatives of EPA and state environmental agencies, vendors of equipment used in the process, and the Industrial Review Team. Additional material included in the final report was gathered from this meeting and from the documentation listed under References.

SECTION 2

SUPPORTING A MUNICIPAL SEWAGE SLUDGE DRYING CARVER-GREENFIELD FACILITY

The Carver-Greenfield Process has qualified as an "Innovative and Alternative" approach to municipal sewage sludge disposal, according to government funding definitions, which qualifies installations for increased federal funding. Four major projects utilizing the process for drying municipal sewage sludge were funded under this incentive. The process was chosen because it was an effective, established technology in other applications, and because its calculated energy consumption for the application was favorable when compared to other drying technologies. The dried sludge product from this process can be land-applied as fertilizer, if the raw sewage sludge quality is good, or burned as a fuel, to recover energy.

Because of the differences in equipment design, unit operations, process configuration, operating conditions, and level of control required, the Carver-Greenfield Process requires a different approach to initial startup and normal operation and maintenance and to the financing of those activities than is required by traditional municipal wastewater treatment/sludge management systems. In fact, the Carver-Greenfield Process more nearly resembles chemical processing or petroleum refining installations than traditional municipal systems in many ways. For this reason, many of the approaches and procedures that are common in the chemical process industries may be better suited to a Carver-Greenfield sewage sludge drying facility than traditional municipal sector approaches and procedures.

2.1. Initial Startup

As is the case with any fairly complex system, the requirements for initial startup of a Carver-Greenfield facility are significantly different from the requirements for normal operation and maintenance of that facility. Furthermore, the initial startup, operation, and maintenance requirements of the Carver-Greenfield system, which involves a volatile, flammable hydrocarbon and a potentially explosive dried product, are very different from the startup, operation, and maintenance requirements of a typical wastewater treatment facility.

The startup and line-out of any new plant, municipal or industrial, is much more difficult than the operation of an established plant. Every piece of equipment in a new installation is a potential source of trouble if it is not properly installed, operated, and maintained. In addition, there may be shortcomings in the basic process or design if the plant involves unproven technology or equipment or a new application. Anticipating problems, avoiding problems, recognizing trouble symptoms, and applying corrective action are all vital startup functions. To carry out such functions requires a quite different, larger organization with more specialized skills than will be needed in the permanent organization.

During initial startup of chemical processing facilities, there should be twenty-four-hour-a-day engineering supervision in the plant. For this reason, the startup organization requires many more engineers than the normal operations staff. These engineers are needed to supply "trouble-shooting" skills that no other background can provide, specifically, to perform heat and material balances and evaluate equipment performance versus design, which may include determining heat exchange coefficients, pump head/capacity curves, and quality of liquid-liquid and liquid-solid phase separations. Such procedures are necessary to evaluate and prioritize the need for plant shutdowns or changes.

In a Carver-Greenfield municipal sewage sludge drying facility, startup engineers should have a minimum of three to five years startup and operations experience with systems similar to the Carver-Greenfield Process; engineering supervisors should have ten-plus years startup and operations experience with similar processes.

There are a number of technical disciplines that are typically available for a chemical processing plant or petroleum refinery startup on a system similar to a Carver-Greenfield installation, including:

Mechanical engineering for corrosion/materials, piping stress, thermal expansion, and other problems;

Instrument systems engineering;

Rotating machinery engineering;

Electrical/utilities engineering;

Safety engineering;

Startup operations advisers - foremen or operators who are experienced in the process or in similar processes. These personnel will assist in training and serve as additional operating staff during the startup.

Temporary startup expertise, in the form of full- or part-time personnel, is available by contract from a number of companies. The most straightforward arrangement for a facility owner is to contract with a single company that specializes in startup of similar facilities.

In the initial startup of a chemical plant or refinery, the first objective is to get the plant to operate continuously as designed, and not to change, optimize, or debottleneck until after continuous operation is achieved. Experience has proven that changes other than those where design or equipment problems actually prevent continuous operation should be postponed. There are a number of reasons for postponing changes if at all possible, including the fact that a problem that is significant at a low feed rate may not be significant at a high feed rate, and that the plant needs to be running continuously as soon as possible to maintain personnel morale and gain operations experience.

Experience in the chemical process industries has been that new plants, especially those involving innovative design features or new applications, such as is the case with the Carver-Greenfield municipal sewage sludge drying application, may take a relatively long time to start up and may operate at less than one hundred percent of design capacity as originally installed. Some modifications should be expected in order to achieve continuous operation even at a nominal level that is less than design capacity. Further modifications to bring the plant up to design capacity may require substantial capital outlays, as much as ten percent or more of the total capital cost of the project. In addition to the cost of modifications, typical startup expenses, including staff training, vendors' assistance, additional engineers, and emergency equipment parts and service, may run as high as another ten percent of the total capital cost of the project. Since many of the startup expenditures are on an emergency basis, immediate access to a contingency fund is essential.

During startup, the job procedures and other operations documents are used and modified continually. These documents must be upgraded not only to achieve smooth operation, but for personnel safety. Other than crises, initial startup is the most dangerous time in a plant's twenty to thirty year life. Subsequent startups are also dangerous.

2.2. Data Collection and Retention

Complete documentation of the system's actual performance, to be compared to design specifications, is vital to a successful startup. In order to develop this documentation, it is important that engineers who have an intimate knowledge of the operating characteristics of the system's components work closely with instrument specialists during the final phases of construction and startup, to assure that the facility has adequate sampling and instrument installations to monitor and control its operation.

Comprehensive, systematic recording of operating data is critical during startup, because, if the plant shuts down, data analysis is the only method of tracking a developing problem and isolating possible causes. Any correction to plant design or operating parameters should be based on firm data, if unwarranted and inappropriate changes are to be avoided.

Even in an established operating plant with a computerized instrumentation system, operators should fill out data sheets that contain temperatures, pressures, levels, and flows throughout the plant at least once per shift. During startup, data should be recorded several times per shift. As well as providing a written record, this activity causes the operators to learn the plant layout and the normal operating characteristics of the equipment.

Data from laboratory analyses of samples are also essential to the startup and operations effort. Sample analysis is the means by which activity inside the system can be tracked and corrective action can be taken. At least once per day, a complete set of samples should be collected from every important point in the process along with a complete set of written data. This gives the operations engineers a point in time when all variables they are trying to control are characterized. More frequent sampling should be performed as needed during startup and whenever an operations problem is to be evaluated.

2.3. Pre-Startup Activities

Planning for startup should begin very early and should be a factor in making the final selection of any system that is relatively complex compared to typical wastewater treatment/sludge management operations. This early beginning is important for the municipal owner and/or operating authority, because it allows time to understand and make allowances for the needs of this different type of facility. Early startup planning considerations include hiring and training staff, procuring startup and maintenance expertise, making arrangements for the treatment and disposal of the feedstock while the system is not up to design capacity, and procuring and making arrangements for readily accessible startup funds.

Plant management should spend the year before startup on organizational activities to remove foreseeable obstacles as long in advance as possible. Because hiring and training is time-consuming, an important goal of these endeavors is to phase people and talents into the support organization for the facility. Pre-startup activities should include:

> Development of a detailed startup plan;
>
> Hiring and training plant operations and maintenance staff;
>
> Development of operations documents;
>
> Development of emergency response plans and documents;
>
> Development of contract maintenance availability;
>
> Checking instrumentation and adding instrumentation and sample points so that performance of each piece of equipment can be tracked;
>
> Development of warehouse parts and equipment inventory based on manufacturers' recommendations and evaluation of breakdown probability;
>
> Locating specialty mechanical service shops for such services as rotor balancing, motor rewinding, hard surfacing, etc.;
>
> Pre-commissioning (testing plant construction at operating conditions with water, air, or steam).

A major milestone in the pre-startup phase of the project is mechanical completion, the date when the construction contractor has satisfactorily finished construction, with all components properly installed, the system successfully pressure tested, all motors turning in the proper direction, all instruments properly calibrated, and all control valves opening and closing as specified. After mechanical completion, operations personnel can begin pre-commissioning.

Pre-commissioning usually takes the form of using water, air, and steam to simulate normal plant operating conditions. This allows equipment to be checked using non-hazardous materials that can be dumped or vented without problems. Regardless of the quality of the design work, this exercise uncovers omissions and problems that need correcting. If the design involves unfamiliar equipment and concepts, these are given priority for check-out, to allow time for possible modifications. Sometimes the problems identified in pre-commissioning could pose a major problem to startup.

2.4. Plant Staffing for Normal Operation and Maintenance

Although the number of personnel varies with the design, size, and layout of each particular facility, there are certain talents and skills that are necessary for the successful operation of any Carver-Greenfield municipal sewage sludge drying plant. Because the light oil process and the municipal sewage sludge application are relatively recent, the opportunity for sharing staff with other similar plants is limited. Therefore, it is critical that all plant requirements be anticipated so that qualified personnel will be available when needed. The staffing effort should start long in advance of startup, to allow adequate time for recruiting personnel with specialized skills and for training personnel.

It generally takes two to five years in process operations for an engineer to become proficient in field applications of what he was exposed to in a college or university. A substantial part of this proficiency comes from working with other engineers with substantial field experience. In the case of a Carver-Greenfield facility where there are only a handful of experienced engineers available in the U.S. today, it would be advisable to acquire process operations experience from the chemical and refining industries. This would create an experience base for in-house technical personnel development.

In the experience of the chemical process industries, it is necessary to have engineers working days and on call nights and weekends to analyze problems as they develop and to devise and implement solutions in a timely fashion. The nature of the equipment and process steps require engineering training in the unit operations present in a particular plant, to perform the necessary calculations and devise and implement procedures to evaluate the performance of each piece of equipment.

The Carver-Greenfield municipal sewage drying control system is complex enough that an inexperienced operator will have difficulty working with it until he gains experience. In addition, the hazards of processing hot flammables bring significant risks of fire, explosion, and personal injury. For these reasons, it is advisable to have control room and outside operators with chemical plant or refinery experience in order to reduce risks to an acceptable level and assure successful operation.

Shift and operations supervisors should have experience at a control room operator or higher level in similar unit operations and operations involving flammable hydrocarbons. Related experience that would be of value includes:

> Evaporation or distillation operations;
>
> Particular equipment, such as oil/water separators, coalescers, devolatilizers, or centrifuges;
>
> Solids handling;
>
> Sludge or slurry processes.

If the engineer, operator, or foreman applicant has no experience with unit operations or equipment similar to that in the Carver-Greenfield Process, almost any chemical plant or refinery operations experience is still of value. At least this would assure some familiarity with nonambient operating conditions, process control systems, heat exchange, and health and safety procedures in the presence of hazardous substances. In the absence of chemical plant or refinery experience, background in the operation of mechanical equipment or systems, such as large engines or boilers, would be beneficial.

In the case of maintenance personnel, experience with similar equipment is a great asset. For maintenance planning and warehousing of spare parts, lack of experience with a process of similar complexity and equipment is very difficult to overcome.

Laboratory personnel should have experience with analyses of similar complexity, preferably having used some of the same procedures and types of equipment.

2.5. Personnel Training

It will take approximately six months to train a totally inexperienced operator to work in a Carver-Greenfield municipal sewage sludge drying facility and three months to train someone with process or equipment operations background. Engineers and operations and maintenance supervisors should have a minimum of three months to learn the process and plant.

The operations documents are the most essential source of training for any plant. Engineers and operations and maintenance supervision can prepare, use, correct, and expand these documents in a self-education procedure. Sessions for operators should be supervised, and sections of the documents that repeatedly cause difficulties should be rewritten or expanded.

In addition to the operations documents, video-taped or live classroom sessions on the basics of physics and chemistry, heat transfer, evaporation, fluid flow, etc. give a broader picture of why and how things occur in the process.

A very important training aid is a scale model of the facility, especially when construction is not complete enough to see physically how the pieces described in the operations documents fit together in the field.

Hands-on training at a pilot- or full-scale facility is always a tremendous asset. A substitute for this is computer modeling to simulate hands-on operating experience.

In-plant trainig at other Carver-Greenfield municipal sewage sludge drying plants that are already in startup or operation would be of significant value to plant management and engineers. Depending on startup status, such visits could also be useful to operations and mechanical personnel.

Vendors of equipment and instrumentation are usually good sources for training of instrument, maintenance, and operations supervisors.

An essential segment of employee training for all plant personnel is health and safety. The Carver-Greenfield Process involves flammable liquids and potentially explosive vapors. Minimum health and safety training includes emergency procedures and information on proper handling techniques for chemicals present in the plant. Safety meetings for reviewing material and presenting new material should be held on a monthly basis after the plant is operational.

2.6. Operations Documents

In the experience of the chemical process industries, it has proven to be essential in both initial startup and normal operation to have certain documents in place, and to keep these documents updated:

Health and safety writeups - These documents include important health and safety considerations for the chemicals and operating conditions present in the plant. Material Safety Data Sheets and other manufacturers' bulletins giving information on special handling requirements and protective equipment are included, as well as the locations, testing, and maintenance schedules for fire extinguishers, pressure relief devices, eyewash and shower stations, and sprinkler systems. Emergency procedures are covered, plant evacuation routes listed. Health and safety writeups must comply with state and federal regulations.

Operating manual - This document gives a generalized description of what the process is and how it works. It describes how the plant is to be started up, shut down, and operated during normal periods, as well as how to handle emergencies such as power or steam failure. The operating manual should include manuals from equipment suppliers which describe equipment operation. A first version of the operating manual is normally prepared by the plant designer. A more complete version should be prepared by the technical staff prior to startup.

Operating or job procedures - A collection of detailed instructions which describe, step-by-step, how to do each particular job that has been described in general in the operating manual. For example, the operating manual may say, "Pump water from Tank 1, using Pump 1, to Tank 2, until a 50 percent level has been established." The job procedure for this operation will give step-by-step instructions of how to accomplish the task, including very detailed descriptions, such as the position of every valve in the system, what pressure the pump pressure gauge will read, and how long the transfer will take under normal conditions. It will also contain instructions for handling minor problems, using appropriate protective equipment, and responding to emergencies. Job procedures also usually contain special instructions to be followed if the system has been out of service for maintenance. Operating procedures are very specific and concise, rarely more than two or three pages in length, because they deal with simple component procedures, not complex combined component procedures. It is very desirable that these procedures be prepared by the new operators as part of their training program.

Maintenance procedures - These procedures are as specific and detailed as operating procedures. They give step-by-step descriptions of how to ready a piece of equipment for maintenance and how to perform the maintenance, listing the tools that are required, and often listing what spare parts should be kept on hand and where they can be found. There is usually a special section on instrumentation maintenance and calibration. These detailed procedures should be prepared by maintenance personnel, with input from the technical and operations staff, during their training program.

Laboratory procedures - These are step-by-step written procedures for performing all analyses necessary for the control of the system. For a Carver-Greenfield system, these analyses might include moisture in feedstock and product, oil in product, oil in condensate, oil in wastewater, condensate pH, and heavy and light oil distillation. Laboratory procedures also include safety and health information and procedures. Plant analytical personnel review and, where necessary, revise these procedures which are initially prepared by the designer or licensor.

The operations documents are important tools for training new personnel. Use of these documents by the plant manager, engineers, foremen, technicians, operators, and maintenance staff during pre-startup and startup is both a training exercise and an excellent method of identifying inaccuracies and omissions in the documents. The documents should be used and revised continually, especially during startup, so that they accurately reflect the most current expertise for operating and maintaining the plant.

2.7. Health and Safety Documentation and Procedures

Introducing more complex technologies, such as the Carver-Greenfield Process, into the municipal environment will also, in most cases, introduce unfamiliar risks due to the unfamiliar substances, equipment, and procedures in the new facility. Although health and safety documentation and procedures are mentioned elsewhere in this report, they are of such critical importance that they merit special discussion.

Over many years, the chemical process industries have experienced accidents involving hazardous and toxic substances. In response to this experience, these industries have developed methods of minimizing the risk of accidents that are foreseeable due to the nature of the substances, equipment, and operations present in a plant. These methods of minimizing risk are strictly followed, not only to avoid injury to employees, but to avoid financial injury to the corporation due to lawsuits, down-time, and costly repairs to facilities.

It is strongly recommended by the Review Team that the prospective owners and/or operators of chemical processing type facilities borrow from the experiences of these industries rather than go through a dangerous learning curve that involves repetition of past chemical plant and refinery accidents.

In a typical industrial facility, there is a health and safety officer or department that is responsible for seeing that certain guidelines are followed. It is recommended that in any more complex municipal facility, one of the plant supervisors be appointed health and safety officer, and that certain activities be included in the job description:

> Train or oversee training of new personnel - Before new personnel can work in the facility for the first time, they must receive intensive indoctrination regarding potential risks and how to avoid them. Initial training should include "right-to-know" information about the health aspects of exposure to materials present in the plant, discussion of the explosion and fire hazards specific to each part of the plant, training in safety procedures (such as proper tagging of equipment to avoid accidental operation during maintenance), and emergency procedures;
>
> Conduct or supervise continuing employee training program - All plant personnel should attend monthly training sessions (plus emergency sessions as needed), at which new health and safety developments are discussed and initial training material is reviewed, reinforced, and expanded;
>
> Investigate and report on work-related illnesses and injuries, including required OSHA and NIOSH reporting;
>
> Maintain and update emergency response plans;

Review issued work permits, to assure compliance with procedures;

Review designs and inspect completed work for safety before placing in service.

It is advisable to involve as many plant personnel as possible, especially front-line supervision and union representatives, in implementing the health and safety program. This helps assure compliance and communication to all groups of personnel.

It is necessary to have a designated supervisor on call for emergencies, twenty-four hours per day, seven days per week. The "on-call" schedule should be posted at telephones.

An essential part of a good health and safety program is developing and drilling personnel in emergency response procedures. In an emergency, personnel must be able to act without hesitation, relying on their response procedure training, in order to avoid injury. The Emergency Response Plan should give specific answers to questions such as:

Who is in charge?

Who is the spokesperson?

Who calls the fire department or other emergency services?

Who contacts the regulatory agencies?

Who informs the treatment works supplying sludge to the plant, and how should they respond in their own locations?

Who will ask for and who will provide plant security in case of a major incident?

Who will interface with community leaders and the media, and how and where will he meet with their representatives?

Defining specific roles and responsibilities is essential to the success of any health and safety plan. Each employee should know exactly what he must do, and he must also know what other employees in the plant will be doing during an emergency. The plant emergency organization should be posted in clear view in several locations in the plant and reviewed in monthly safety meetings. Telephone numbers that may be needed during an emergency, including fire department, ambulance, and environmental regulatory agencies, should be posted by telephones.

A great deal of time and effort is required to maintain good health and safety practices in the typical chemical processing facility. A similar level of effort should be anticipated and planned for by the prospective owners and/or operators of municipal facilities involving such technologies.

2.8. Technology Acquisition and Retention

Each plant is unique, with idiosyncrasies due to individual pieces of equipment, plant design, and layout. For this reason, initial startup of a new facility is a learning experience for all personnel, even those with many years of startup and operations background. Consequently, it is important to collect as much information as possible from the licensor, designer, and equipment vendors. During startup, personnel devise methods of getting particular jobs done, and learn to detect and act upon early signs of developing trouble. In order to assure continued successful operation of the plant, this accumulated knowledge needs to be retained in the facility in the form of operations documents and experienced personnel.

A very important element in any startup plan is a procedure for transfer of accumulated operations expertise from temporary startup personnel. One method of achieving this transfer is for permanent plant personnel to accompany temporary startup personnel and observe their activities. When the permanent personnel take over a function, the startup personnel can accompany and supervise. Acquired expertise is also stored and transferred by continually updating operations documents and bringing any changes to the attention of plant personnel.

There is a critical need to retain permanent staff members after training, especially because the Carver-Greenfield municipal sewage sludge drying application is relatively new. In the case of any new type of facility, there is no existing pool of experienced manpower from which to draw information or new employees, so it is particularly important to retain experienced staff.

SECTION 3

RECOMMENDATIONS TO THE MERCER COUNTY IMPROVEMENT AUTHORITY

The Mercer County (New Jersey) Improvement Authority (MCIA) Carver-Greenfield sewage sludge drying facility was selected as a specific example of a chemical process technology being implemented in a municipal application. The Industrial Review Team developed a number of recommendations for MCIA based on their experience of how the startup and operation of similar facilities are handled in a chemical plant or petroleum refinery environment. It is expected that applying some of the practices from these industries will be of value in implementing relatively complex processes in municipal applications.

Work on the MCIA facility has been halted since September, 1987, with construction approximately eighty percent complete, because of construction contractor problems. When construction is resumed, it will take approximately ten months to complete. The Plant Manager should take advantage of this unexpected delay to prepare for a challenging startup. There are certain actions that can be taken now to help minimize foreseeable problems and assure the success of the initial startup and operation efforts:

> Hiring an Assistant Plant Manager as soon as possible is strongly recommended. His duties would include serving as designated safety officer, filling in for the Plant Manager when he is not available, assisting in employee training, assisting in the development of operations documents, updating the operations documents, and interviewing potential employees and comparing his impressions with the results of the Plant Manager's interview. During and after startup, the Assistant Plant Manager would perform engineering support functions, such as performance evaluations of equipment, and share on-call supervisory duty. The Assistant Plant Manager should be a chemical engineer with at least five years of chemical/refinery startup and operations experience, specifically in facilities with unit operations similar to those in the Carver-Greenfield Process.
>
> The Plant Manager and Assistant Plant Manager should undertake a self-training program that would include studying the piping and instrument diagrams and other process information. The plant

operations and health and safety documents should be developed and reviewed through this self-training, so that they will be in good condition for the training of other personnel. Extended, preferably hands-on, visits to the City of Los Angeles plant, the Dehydro-Tech pilot plant, and the Burlington Industries or other Carver-Greenfield light oil plants are very strongly recommended.

As an extension of self-training, the Plant Manager and Assistant Manager should investigate resources to be used for training of other personnel, such as programmed instruction courses and vendor courses. Contract arrangements for training assistance should be made as necessary.

The Plant Manager and Assistant Plant Manager should carefully review the talents and skills required for startup, and decide how to satisfy any additional temporary personnel needs. It would probably not be feasible for MCIA to hire in employees with the specialized skills necessary because of hiring restrictions and the fact that many of the positions would be temporary (less than twelve months). One strongly recommended alternative is to contract out the startup.

Some modifications to the MCIA plant will probably be required during startup, for a number of reasons: the process application is a relatively new one, feedstock characteristics are unique to each location in the municipal sewage sludge application, and there are design features of the MCIA plant that are unique to that facility, such as the the pelletizing/granulation operation. Chemical plant/refinery experience with relatively innovative plants like the MCIA facility suggests that up to ten percent of the total capital cost of the plant may be required for modifications during startup. In addition to the cost of modifications, other startup expenses may run as high as another ten percent of the total capital cost of the project. Funds to cover both modification and other startup expenses must be accessible on an emergency basis, or startup activities will be delayed.

The Plant Manager and Assistant Plant Manager should develop a comprehensive plan of pre-startup activities, to be implemented as soon as construction is resumed.

3.1. Permanent Staff

The Plant Manager and Assistant Plant Manager are the nucleus of the permanent operations staff for the MCIA Carver-Greenfield facility. One of their most important functions is to interview and hire other permanent staff members after construction resumes. The suggested schedule for bringing these personnel into the organization is shown in Figure 1 on page 3-4. The recommended normal operations organization is shown in Figure 2 on page 3-5. The suggested organization would include:

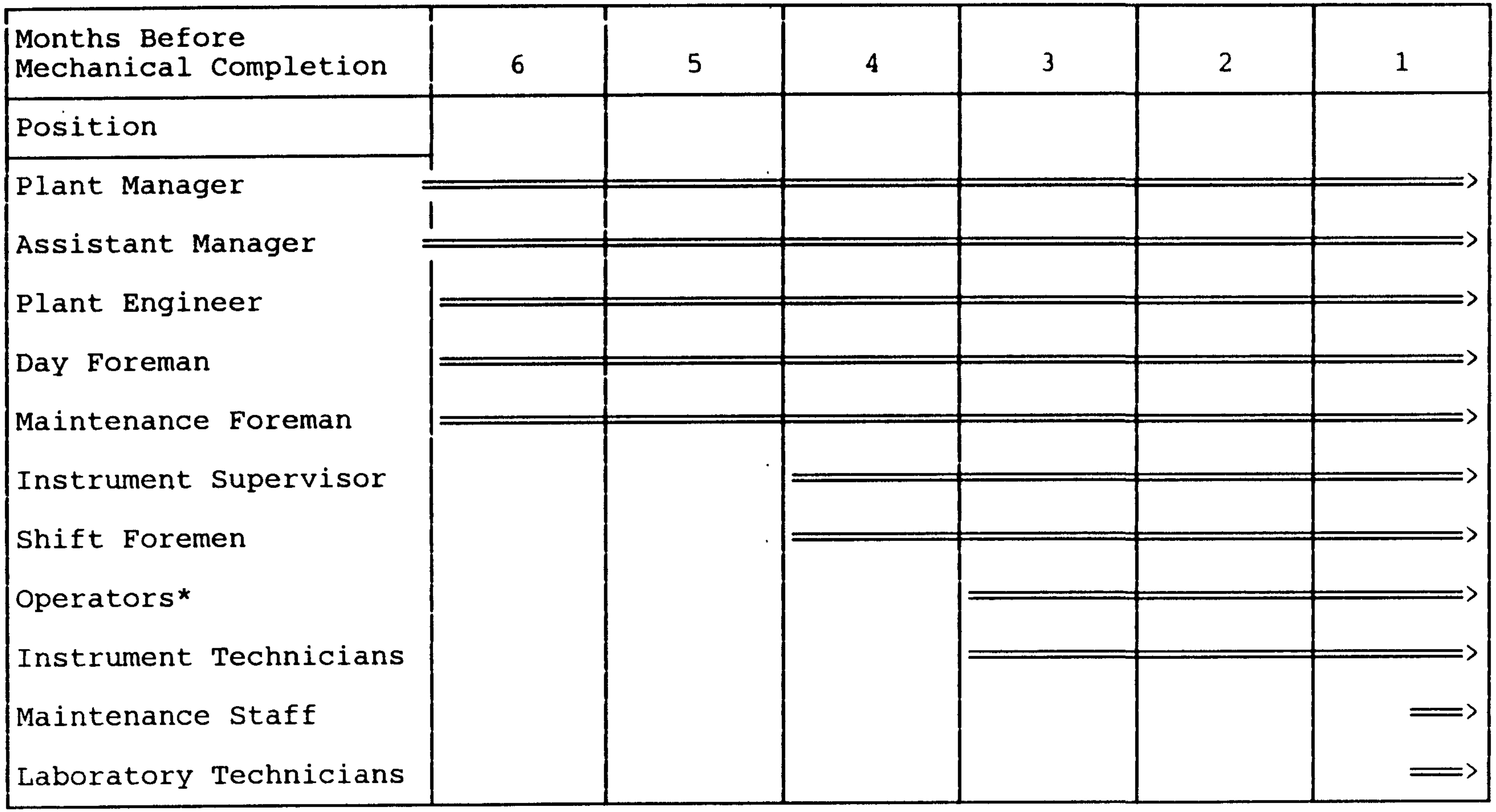
Plant Engineer - Should join the plant staff six months before the end of construction and should follow the same self-training program as the Plant Manager and Assistant Plant Manager. Responsibilities should include process and project engineering functions such as monitoring equipment performance, designing plant modifications, and supervising implementation of modifications. Should also share on-call duty. B.S.Ch.E. plus three to five years chemical/ refinery process and operations experience should be required.

Day Foreman - Should join the operations staff six months before the end of construction and become familiar with plant layout, equipment, and design. Should study operations documents and assist in developing operating procedures, attend all training sessions, and assist in hiring shift foremen and operators. Chemical processing plant or petroleum refinery experience at control room operator or shift foreman level is recommended.

Maintenance Foreman - Should join the operations staff six months before the end of construction. Should study plant layout, equipment, and operations documents, as well as attend training sessions and develop maintenance procedures with input from vendor experts. Should study installations, recommend modifications for maintenance accessibility, and develop a list of warehouse spare parts to be kept on hand. Should work with plant management to develop contract resources for special maintenance services and develop plans for scheduled and unscheduled shutdown mechanical work. Experience with similar process equipment is very important.

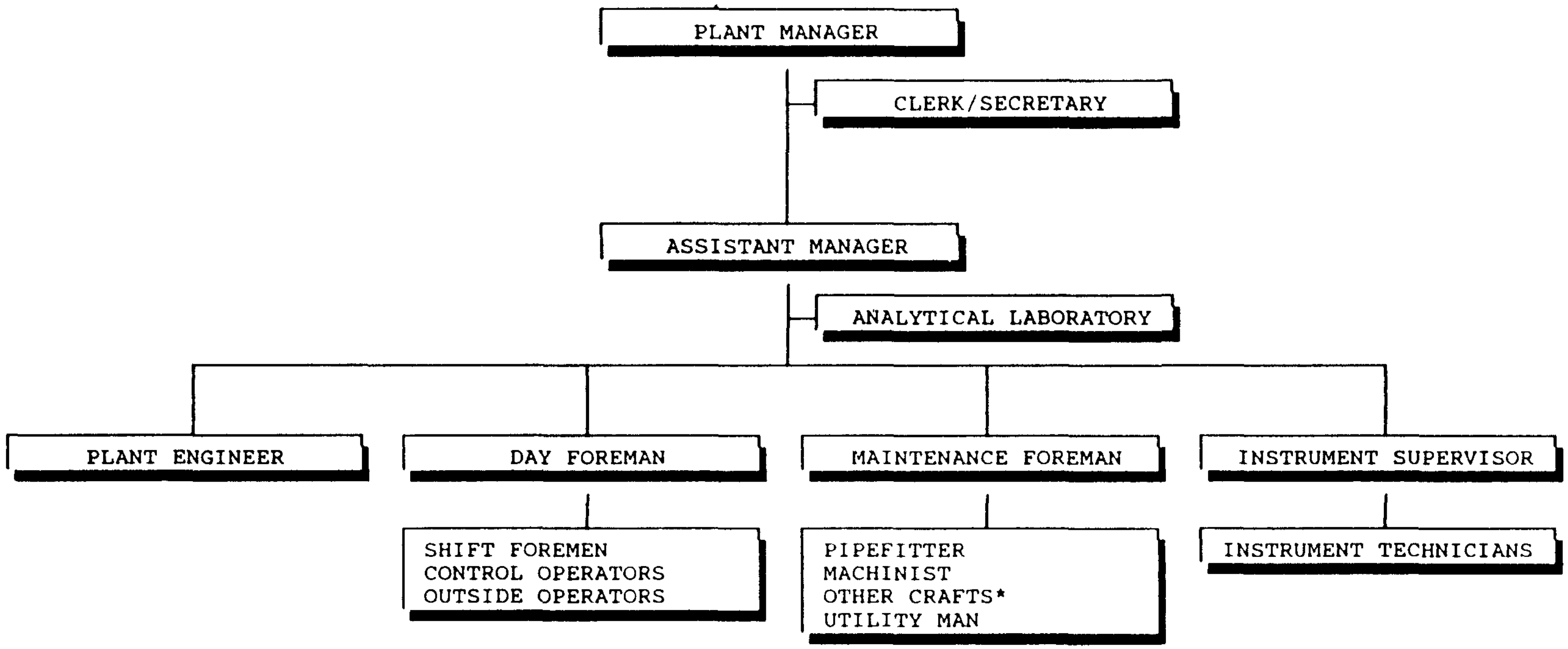
Instrument Supervisor - Should join the operations staff four months before the end of construction,

Figure 1. MCIA PLANT STAFFING SCHEDULE -
PERMANENT PERSONNEL ONLY



* Inexperienced operators will require longer to train

Figure 2. MCIA
NORMAL OPERATIONS ORGANIZATION



* MAY BE CONTRACTED

go through the training program, and assist in hiring instrument technicians. Should follow the final phase of construction, check as-installed instrumentation, recommend modifications, and develop a list of parts to keep on hand. Experience with similar instrumentation and the same type of instrument control method is very important.

Shift Foremen - Should join the operations staff four months before the end of construction, go through the training program, study the plant layout, and help develop job procedures. Should also help with training operators. Chemical plant or refinery foreman or control room operator background is recommended.

Operators - Should join the operations staff at least three months before the end of construction. Their pre-startup training should include process technology, plant layout, equipment, instrumentation, and operating and safety procedures. Control room operators should have chemical processing plant or petroleum refinery experience or have demonstrated capability in related operations, such as boiler or engine room. Inexperienced operators require six months training.

Instrument Technicians - Should join the operations staff three months before the end of construction, go through the training program, and study vendor information on plant instrumentation. Vocational or practical experience is recommended.

Maintenance Staff - Should join the operations staff a few weeks before the end of construction. Their training should be supervised by the maintenance foreman with the assistance of vendor experts on specific equipment and job procedures. Millwright/mechanic, pipefitter, and utility man will be needed full-time; other crafts may be contracted for as needed.

Laboratory Technicians - Should join the operations staff two to three weeks before startup, to become familiar with procedures and sample schedules and handling. Should have previous experience with similar analyses, and may receive specific training with the licensor. Permanent staff laboratory technicians should perform daily operations control testing, such as percent oil in product and condensate. Supplemental testing for heavy metals, pathogens, certain toxic organic compounds, etc., may be performed by an outside laboratory under contract.

3.2. Additional Startup Assistance

Because initial startup of a new facility is substantially more demanding than continuing operation of an existing facility, additional manpower and expertise is necessary (Figure 3, page 3-8). Experienced engineering supervision is required twenty-four hours per day. Special assistance with equipment may be provided by vendors and contract maintenance services, who should be put on notice prior to the startup. In addition to the permanent plant staff, the startup staff should include:

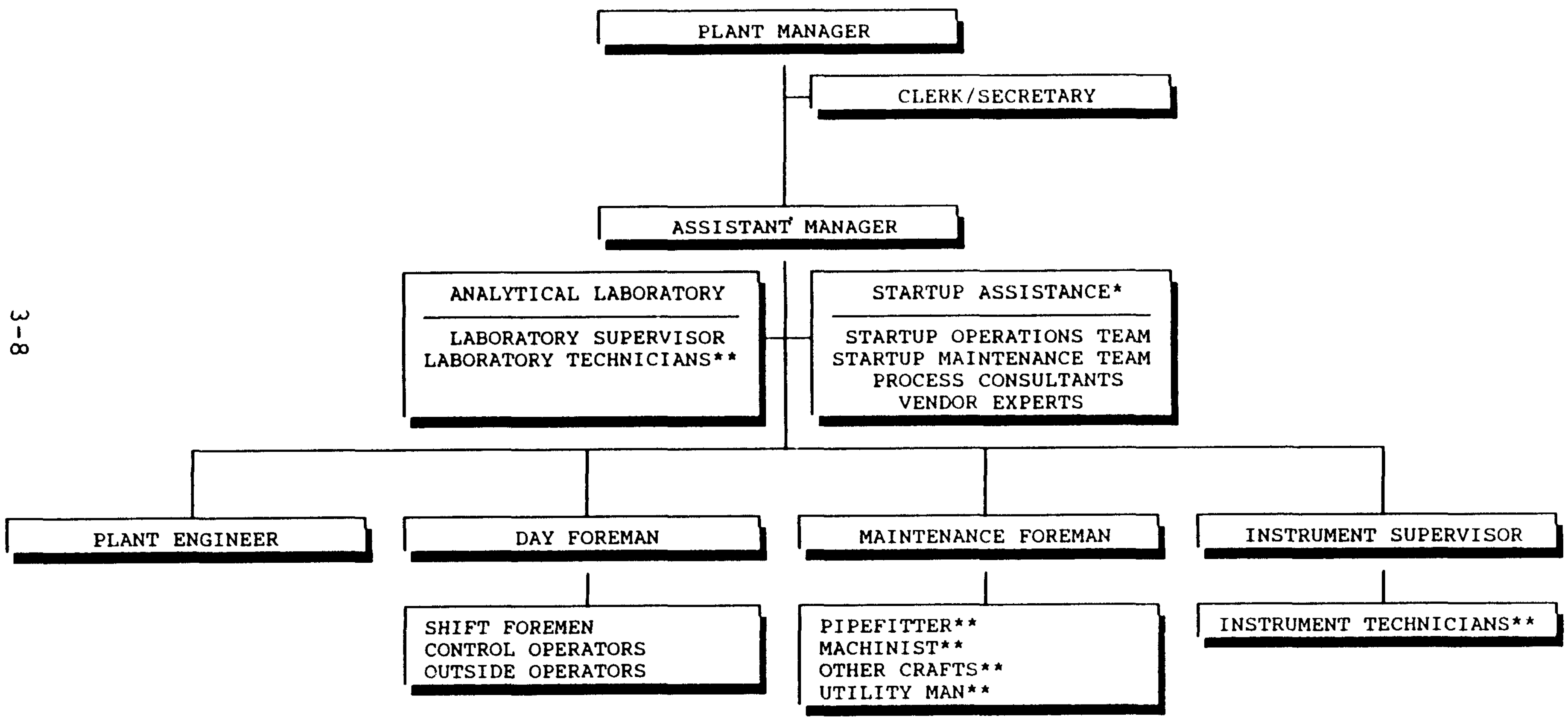
Startup Team - Should include both chemical and mechanical engineers selected and assigned to the plant at least two months before the end of construction. The head of the team should be assigned six months before the end of construction to work with the permanent plant personnel on pre-commissioning and commissioning schedules. The startup team will provide twenty-four-hour-per day technical leadership until the permanent plant staff develops sufficient expertise and confidence to assume operation of the plant. Extensive experience in startup and operation of chemical/refinery type facilities as well as understanding of process control and instrumentation systems is required.

Startup Maintenance Team - A group of maintenance specialists, including a maintenance planner, a rotating equipment specialist, and an instrumentation expert, plus instrument men and craftsmen to supplement the permanent plant staff and provide twenty-four-hour-per-day coverage. The maintenance specialists should assist in the development of the startup plan and schedule. This activity should take about three to four weeks, within the three months before the end of construction.

Process Consultants - Expert services to be provided by the process licensor.

Vendor Experts - Should be called in as needed when their equipment is started up or tested.

Figure 3. MCIA
INITIAL STARTUP ORGANIZATION



* Specialized Personnel Temporary for Initial Startup.

** Extra Coverage on Position Needed for Initial Startup.

3.3. Training Program

A training program should be developed by the Plant Manager and Assistant Manager, with input from the Day Foreman, Maintenance Foreman, the process licensor, and the plant designer. The Plant Manager, Assistant Manager, Maintenance Foreman, and Day Foreman should go through the course and discuss and implement modifications where necessary.

The training program should be tailored to the needs of the operating staff of this specific plant. In order to accomplish this, plant supervision should first identify what these specific needs are and then participate in the selection of training materials and their preparation, modifiying available materials to fit their plant. The operators should be trained to acquire an integrated view of the process in addition to the specifics of their positions.

Suggested operator training would include:

Health and safety training, including general background as well as specific procedures;

Fundamental concepts, such as heat, temperature, materials, steam, hydrocarbons, pressure, vacuum;

Carver-Greenfield Process specifics, sewage sludge technology, process chemistry;

Unit operations basics, such as fluid flow, heat transfer, evaporation, distillation, drying, solids handling;

Specific equipment descriptions, functions, and operating characteristics, such as pumps, heat exchangers, boilers, centrifuges, pelletizers, filters, conveyors, hydroextractors;

Process instrumentation descriptions and functions;

Operating procedures;

Startup procedures.

Experienced operators should have a minimum of three months training prior to startup. Inexperienced operators should have up to six months training.

Training sources include:

Dehydro-Tech Corporation;

Foster Wheeler Management Operations Ltd. (USA);

Contract training companies;

Programmed instruction supervised by in-house engineering and operations personnel, such as those developed by Technical Publishing Company for maintenance and safety skills, and E.I. DuPont training courses on topics like instruments, boilers, chemical processing operations, and other equipment needs;

Lectures by operations engineers from the City of Los Angeles plant and Carver-Greenfield pilot plants.

3.4. Startup Planning Considerations

The startup team may be composed of members of various organizations or firms but should have a consistent nucleus of permanent plant personnel and startup personnel assigned for the duration of startup. During this period, personnel should report to and follow directions from the startup operations manager. If startup arrangements include a startup operations manager who is not the permanent plant manager, the permanent plant manager needs to remain in control of his plant, and work in close conjunction with the startup operations manager.

The Carver-Greenfield Process is still in the early stages of development for the drying of municipal sewage sludge. For this reason, some process modifications may be required during startup to achieve continuous operation. Further modifications or debottlenecking, which may be required to achieve design capacity, should be postponed until continuous operation at a reduced rate is achieved.

Before any proposed modifications are undertaken, it is critical that the operations, technical, and maintenance teams agree on the scope of the modifications and the benefits to be derived from them. In order to achieve this, a plan to identify and prioritize these modifications should be developed. This plan should include the following steps:

Problem identification and documentation;

Priority and personnel assignment;

Trouble-shooting;

Process and engineering study;

Evaluation of alternatives;

Design;

Cost estimating;

Review and approval;

Implementation/construction;

Evaluation and documentation.

Process and engineering review of equipment operating conditions during the various stages of the startup is necessary to assess performance of the equipment, and mechanical and process capabilities. A first estimate is made, in effect, by the design engineering firm in designing the equipment. This first estimate should be reevaluated in detail by the startup team before startup, to anticipate the need for circulation lines and other temporary arrangements needed while the plant is brought up to design capacity. The procedure is repeated again after the plant is operating.

Operations management and process engineering personnel from the owner's staff should be assigned as part of a project team to follow up the project throughout all the stages of development. This continuity will help prepare and achieve a smoother startup. Another good practice is retaining project and construction personnel to continue working in the plant at the end of construction.

3.5. Assuring Continued Operations

Because it would be financially prohibitive for MCIA to develop in-house all the skills and talents necessary for startup of the Carver-Greenfield facility, many of the engineering and supervisory people during the startup will be temporary contractors. It is important that the Plant Manager and Assistant Manager see that a plan is developed and carried out for the transfer of technology from these "temporaries" to the permanent staff.

3.6. Mode of Plant Operation

Based on their previous experience with systems containing solids, the members of the Industrial Review Team would prefer to choose continuous, seven-day-per-week, operation to reduce the potential for difficulties caused by plugging of piping and equipment during shutdown and restart.

Another problem caused by intermittent operation is that repeated temperature and pressure cycles from intermittent operation will result in shorter equipment life.

It is recognized that the MCIA plant will not initially receive enough sewage sludge to operate continuously. Also, plans are being discussed to allow for flushing of equipment with clean carrier oil when the plant is shut down and for circulating hot carrier oil to pre-warm equipment before startup. However, according to information from the City of Los Angeles, it may take longer than a weekend to turn the MCIA plant around, and, even if the turn-around can be made over a weekend, the high weekend pay rates for personnel to shutdown, repair, and startup may make this approach very costly.

An important consideration in planning the mode of operation is health and safety. The highest hazard and risk periods in any plant operation occur during startup and shutdown. For this reason, continuous operation is generally safer than intermittent operation.

SECTION 4

IMPLEMENTATION OF CHEMICAL PROCESS TECHNOLOGIES FOR MANAGEMENT OF MUNICIPAL WASTES

Implementation of the Carver-Greenfield Process in municipal sewage sludge drying is one case of a broader movement toward seeking new, more sophisticated solutions to the management of wastewater, sewage sludges, and other solid waste disposal problems. Although the future roles of federal and state agencies are uncertain, it is inevitable that the requirements for the management of sewage sludge and municipal solid waste will become more stringent.

Pioneering new applications, even of proven technologies, for managing these wastes will continue to bring problems. Some of the initial implementation problems of chemical process technologies can be made less troublesome for both the system designer and municipal owner and operator by an increased awareness of the exacting requirements for starting up, operating, and maintaining these new systems, and the additional restrictions imposed by the procurement, funding, and staffing policies that most municipal institutions must follow. This increased awareness is necessary to plan for and adequately provide for successful management of chemical processing systems in municipal applications.

4.1. Factors That Influence Facilities in Municipal Applications

One of the factors that makes a municipal application of a chemical process technology very different from an industrial application is that municipal facilities are non-profit, public service operations. In contrast, chemical industry operations are profit motivated, and management decisions are based primarily on economic considerations. If the potential profit warrants the expenditure, private industry focuses tremendous manpower and capital on a startup or operations problem.

In a municipal facility, guidelines for management decisions are not so clear-cut. Elected officials who influence plant operations are very much aware of public reaction to both apparent and real increased waste treatment and disposal costs, and the cost has to be balanced with complicated public health and environmental considerations. Under these circumstances, the municipal facility manager may well be criticized for what would be "normal" expenditures in a similar facility belonging to a chemical or refining company. The owner of a new type of municipal facility should always consider whether increased current expenditures, especially during startup, will be offset by longer term savings.

Another factor that makes the implementation of chemical process technologies difficult in municipal applications is a general lack of common experience among the personnel in the chemical process industries and municipal sectors. These differences start with educational background and on-the-job training and continue through professional experience. For example, the majority of technical personnel in chemical processing operations are chemical engineers by training, while the majority of technical personnel in municipal operations are civil and sanitary engineers. Each of these engineering disciplines and each of these sectors (chemical processing and municipal) has its own vocabulary, organizational characteristics, priorities, and standard operating procedures. After a few years of on-the-job experience, engineers in each sector begin to assume that the approaches they use are typical and familiar to all engineers, even though practices and experience in different sectors are often quite different.

The differences between the chemical process industries and the municipal sector extend to the companies and consultants that serve them. Suppliers of technologies, services, and equipment to the chemical/refinery industries have developed capabilities to respond to the needs and demands of their clientele, which may be quite different than the needs and demands of a municipal client. Suppliers and clients are both inclined to make certain assumptions based on their previous experience, assumptions that may be unwarranted when they deal for the first time with a person from a different type of background. This situation can make effective communication very difficult in cases where full communication is critical. For example, the past experience of a system designer that had traditionally served a chemical/refinery clientele would lead that designer to assume that the client would have substantial in-house resources for startup and operation of a new system involving complex technology. A municipal sector client dealing for the first time with a chemical/refinery system designer would probably assume that his own operations personnel possessed adequate startup and operations expertise for a chemical processing type of system, because they had been successful starting up and operating municipal systems in the past. In this case, the municipal client would probably not ask for startup assistance, and the chemical/refinery system designer would probably not offer it. A likely end result of this situation would be that additional startup and operations resources would be needed but not provided for when initial startup was attempted.

In addition to personnel and communications problems, there are a number of institutional problems that create obstacles to the successful implementation of these more complex technologies in the municipal sector:

- Municipalities and other public sector entities generally lack the resources and time to conduct detailed research and development work to ensure the feasibility of a new technology. This can cause difficulties during the startup and operation of the new facility;

- Public bidding requirements and time limits on contracts for even minor goods and services create timing, continuity, efficiency, and quality control problems on municipal projects;

- Municipal project management may have limited control in selecting highly qualified construction companies because of bidding requirements;

- Specifications on municipal projects may allow for "or equivalent" purchasing. This leads to quality control problems if the evaluator is not sufficiently skilled to evaluate equivalency;

- Traditional municipal sector authorization and purchasing systems may be slow and cumbersome compared to those supporting the industrial chemical and refinery facilities. Startup, especially of complex systems, often demands short-notice or emergency expenditures and procurement;

- The additional attention to architecturally pleasing building design that may accompany municipal projects may be at the expense of process design considerations, e.g., equipment layout and sizing may be inhibited. Walls and floors also inhibit visibility in a plant. This limitation is more critical in more complex systems, and extra staff may be required to cover areas that are blocked from view. Building design can also cause accessibility problems that increase the time required and cost for maintenance;

- Municipal facility owners may have limited in-house engineering resources to perform evaluations and design work. Many have traditionally depended on outside consultants who do not have the responsibility for operating and maintaining the facility once it is built. Also, the traditional experience of municipal technical staff and their consultants does not typically include management of chemical processing systems;

Hiring and keeping the personnel necessary to operate and maintain a complex facility may be quite difficult because of hiring restrictions, wage scale, and promotion and benefit practices that have long been established and in place in a municipal environment;

Funding from various sources, such as the federal government, brings other constraints that may impede the implementation of municipal projects. For example, for many years regulations governing the use of federal funds allocated under EPA's Clean Water Act prohibited "turn-key" plants; that is, the designer was not permitted to also construct the facility;

Procurement is often done by the construction contractor who is asked to reconfirm the system design based on the specific equipment purchased. Few general contractors have the capability to make the process and mechanical calculations necessary to accomplish this task where the design involves complex technologies.

4.2. Making the Transition

Introducing chemical processing type facilities into municipal applications represents a major transition for municipal owners and operators. As discussed in subsection 4.1, the first step is to recognize that chemical processing type facilities are different from traditional municipal treatment and disposal systems and that they require very different handling if they are to be successfully implemented. The second step in making the transition to more complex systems is to devise ways to meet these different needs and to minimize limitations imposed by governmental requirements.

Several key points should be remembered and provided for:

Technical personnel who start up complex systems must possess highly specialized skills and training;

It is essential for a successful startup to follow a very comprehensive specialized routine of careful performance evaluation of all components of the system as the startup proceeds;

Instrument specialists are essential in a startup, especially to install and maintain monitoring systems for performance evaluation;

Temporary startup personnel should work very closely with the permanent plant personnel, so that the acquired operations expertise will be retained in the plant and insure continued successful operation;

Since the municipal sector is non-profit and service oriented, the technology used should be cost competitive for the degree of treatment and environmental protection afforded;

The municipal owners must work under many governmental limitations not often found in industrial applications.

4.3. Obtaining Necessary Skills/Training

In order to be able to identify and hire the best qualified contractors and/or permanent personnel, the municipal facility owner should know the process, its specific unit operations and equipment, and the level of operations and maintenance support required. He should also be aware that industrial backgrounds are so specialized that many personnel with years of chemical processing experience may be of limited assistance in starting up or operating a particular plant.

Specialized and direct assistance is also essential when a traditional municipal consultant or architect/engineering firm is involved in the project. It would be advisable for the owner to be able to communicate directly with specific technology consulting and engineering experts in addition to his traditional consultants. Second only to the technology experts, the owner should become the most knowledgeable person on the project, because he is the one who must ultimately deal with the problems that arise. It is essential for the owner and his staff to have the following information available and learned for the new system:

Basic theory of the technology and unit operations;

Plant design, including the function of each piece of equipment;

Startup, shutdown, operations, and maintenance procedures;

Hazard, risk, health, and safety considerations and procedures;

Specifics of plant layout, including how layout affects personnel movement and access for maintenance and cleaning;

How the new system differs from traditional municipal operations and what additional support it will require.

Key plant personnel would benefit greatly from an extended visit, possibly several months, to at least one plant using the technology. This time would be well spent in observing and discussing operations and maintenance with experienced plant personnel.

Startup and operations personnel for chemical processing systems have a totally different type of background to call upon than traditional municipal operations personnel. Since the startup of these complex systems is so specialized, it will generally be more efficient for the municipal owner to carefully contract for this qualified assistance. For the municipal facility owner who wishes to develop the capabilities of his own operating staff (the normal case), qualified contract startup personnel should participate in the startup and first few months of continuous operation, and help train the owner's staff to assume their responsibilities.

It is also important to take special steps to retain newly acquired and trained personnel. The work in the new facility is likely to be very demanding, and a system of appropriate compensation should be provided. If the needed talents cannot be developed and retained within the system, an important alternative is to contract out these essential services.

Training of maintenance personnel can be done through vendor and other programs. Most vendors are willing to hold training sessions on the maintenance of their equipment at no cost or at some nominal charge to the customer. This same type of program is usually available for plant instrumentation. Vendors of the main control system generally have simulators set up specifically to demonstrate their system and train those who have purchased it.

Engineer, operator, and maintenance staff training can also be contracted out to a firm qualified to train in the operation of the particular process. Generic training courses are of assistance in gaining generalized background, but personnel should be exposed to the specifics of the facility they will be expected to operate. Training and experience with a complex technology can also be gained from use of models and pilot plant operation.

If a facility will be using a new technology or an established technology in a new application, pilot plant operations should be carefully planned and conducted. In order to serve as a representative design model, a pilot plant should have the same feedstock and additives present and simulate all the operations that are to be performed in the full-scale operation. To the greatest extent possible, the pilot plant should have the same type of equipment as the full-scale facility. Differences between the pilot- and full-scale plant should be minimized, because even minor changes in scale-up are potential sources of problems. Particular attention should be paid to duplicating the effects of system recycle streams on overall plant operation and material balances. Also, engineering evaluation is needed to determine whether the pilot scale is sufficient to allow confident scale-up of critical equipment.

4.4. Cost and Operational Expectations

In the chemical process industry, typical startup expenses of an established technology and application run five to ten percent of the total capital cost of a project. If a new technology or application is involved, startup is likely to run ten to as much as twenty percent of the total capital cost of a project. This cost of startup includes personnel, consumables, modifications, and other startup expenses. The owner needs to arrange for funds to be immediately accessible, because many startup expenditures are on an emergency basis. Delays lead to a total absence of progress while capital and personnel costs continue. One way of allowing for immediately accessible funds would be to include startup expenses as part of project capital allocations.

The owner of a plant that involves design innovations or a new application should expect that the new facility may not reach one hundred percent of design capacity as originally installed. In the chemical process industries, modifications to achieve design capacity are usually postponed until after continuous operation is achieved at the highest capacity possible as originally installed. Postponing modifications that do not actually prevent continuous operation is advisable for several reasons: problems observed at low operating rates may change or disappear at higher operating rates, and, in the worst case, a modification that solves a problem at low operating rates may actually cause problems at higher operating rates.

Because the design and installation of modifications is time-consuming, especially if long-delivery items are involved, the owner should have an interim procedure for treating and disposing of the sewage sludge or other feedstock that was scheduled for treatment in the new facility. Alternative treatment and disposal plans are also helpful in dealing with normal startup problems, such as unscheduled down-time and off-specification product. Some operational problems should be expected for a year after mechanical completion even with facilities involving familiar technologies and applications. In the case of a new application or design innovation, this problem period may be considerably longer than one year.

SECTION 5

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2. Hyde, H.C., "Technology Assessment of Carver-Greenfield Municipal Sludge Drying Process," PB 85-138634, EPA-600/2-84-200, U.S. Department of Commerce, National Technical Information Service, 12/84.

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APPENDICES

APPENDIX A

THE CARVER-GREENFIELD PROCESS

The Carver-Greenfield Process is a patented drying process invented by Mr. Charles Greenfield. "Carver" in the process name refers to the fact that Mr. Greenfield did some of his early process development work in a laboratory supplied by Fred S. Carver, Inc. The Carver-Greenfield Process patents are the property of Dehydro-Tech Corporation of East Hanover, New Jersey.

The first commercial application for the Carver-Greenfield Process was the processing of slaughterhouse waste, to recover tallow and dry protein-bone meal. Since the process was first implemented in 1961, there have been a total of seventy-four full-scale plants put into operation worldwide, and three more major plants are scheduled for startup by 1990. These plants have been designed to dry a wide variety of feedstocks, including sludges from industrial and municipal wastewater treatment facilities.

The Carver-Greenfield Process was chosen for the purposes of this review as an example of a more complex technology that has been adapted to a municipal sector application, the drying of municipal sewage sludge. There are currently four federal/state jointly funded Carver-Greenfield projects in the United States, one is involved in a long and difficult startup and three more are under construction.

A.1. Heavy and Light Oil Carver-Greenfield Processes

The characteristics of the Carver-Greenfield Process that give it an advantage over other technologies in many difficult drying applications are energy-efficiency and the introduction of a "carrier" or "fluidizing" oil into the feedstock. The most essential function of the carrier oil is that it keeps the material fluid, so that it can be pumped through the process equipment even after virtually all of the water has been removed. This carrier oil also enhances mixing and heat transfer, and, in some applications, acts as a solvent for indigenous oils that are recovered as a by-product.

In the original slaughterhouse waste application, the carrier oil is tallow, which is relatively nonvolatile or "heavy." A major process innovation, which was developed in the mid-1970's, is the use of a volatile or "light" carrier oil. A light carrier oil is easier to separate from the dried solids than a heavy oil, but it does require more stringent safety procedures than a heavy oil, to avoid fires and explosions. A total of seven Carver-Greenfield light oil plants have been built, in addition to the four municipal sewage sludge facilities that are in startup or under construction in California and New Jersey.

A.2. Carver-Greenfield Multiple-Effect Evaporation

Three of the four U.S. municipal sewage plants, The City of Los Angeles (California) Hyperion facility, The Los Angeles County (California) Sanitation Districts facility, and The Mercer County (New Jersey) Improvement Authority facility share the same basic process configuration: four-stage multiple-effect evaporation.

Multiple-effect evaporation was already a well-established, proven technology when Mr. Charles Greenfield adapted it for use in his original process application. Multiple-effect evaporation is very energy-efficient compared to other drying technologies, because it recovers heat from the water vapor that is driven off during the drying process.

A process flow diagram for a municipal sewage sludge four-stage multiple-effect Carver-Greenfield system is shown in Figure 4 on page A-3. In this process configuration, the feedstock or material to be dried (indicated by the heavy line, moving from left to right) passes through a grinder and into a "fluidizing" tank where it is mixed with carrier oil and dried solids recycled from the process. Some of the dried solids must be "added back" to the feedstock to increase the solids concentration in the mixture and avoid an undesirable phenomenon called "gummy phase." Acid to control the formation of "soaps" is also mixed with the feedstock in the fluidizing tank.

From the fluidizing tank, the process stream passes into the first stage vaporizer, where it is heated under vacuum to evaporate a portion of the water. The process stream then passes through the second, third, and fourth stage vaporizers in sequence. Virtually 100% of the water has been evaporated out of the process stream by the time it leaves the fourth stage vaporizer. Most of the process stream from the fourth stage vaporizer is pumped to the centrifuge, but a portion is added back to the fluidizing tank to raise the solids concentration.

In the centrifuge, most of the carrier oil and the indigenous sewage oil are separated from the dried solids in the process stream. The process stream then passes into the first of two "hydroextractors" or devolatilizers, where heat is used to drive off the remaining oils as oil vapor from

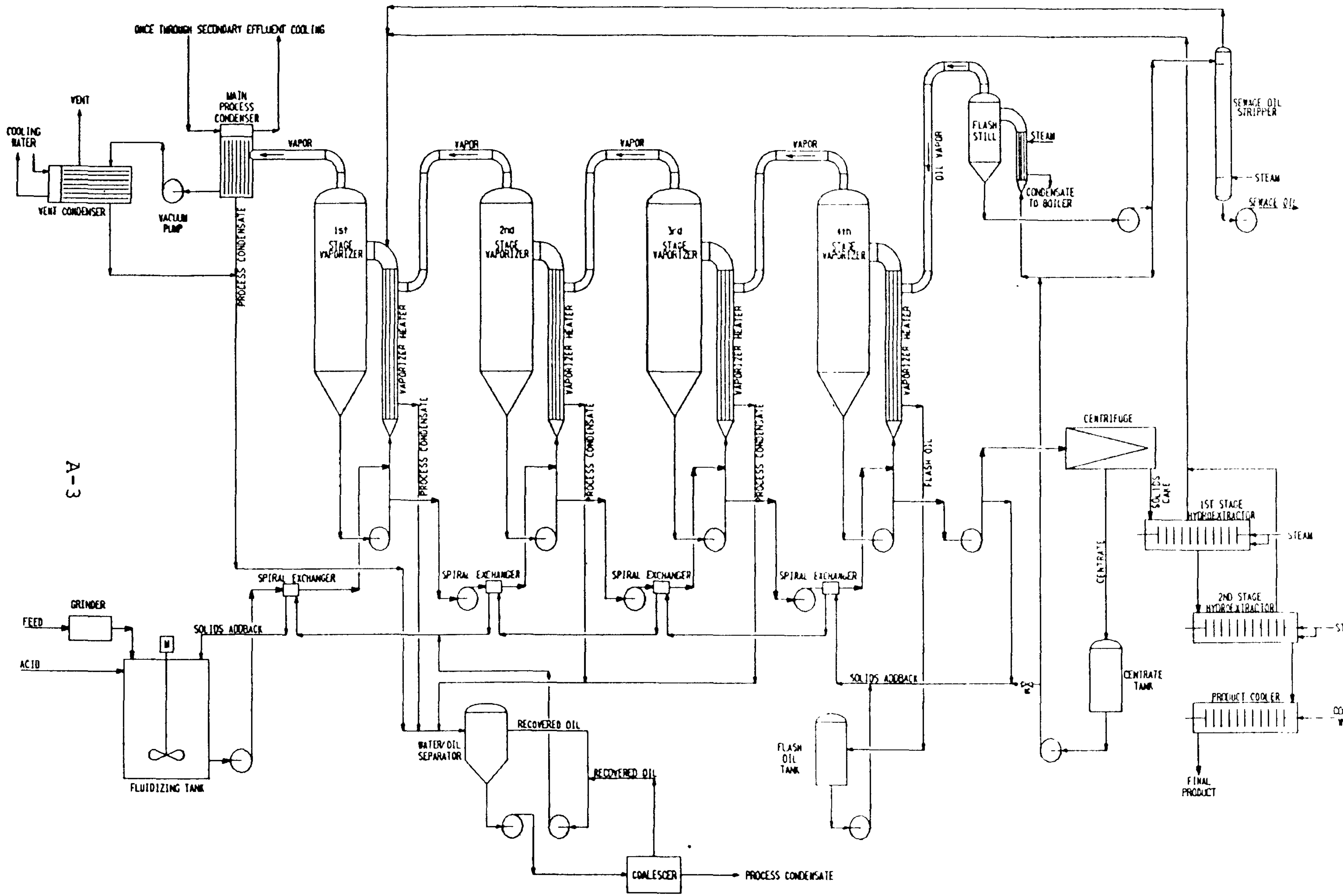

Figure 4. FOUR-STAGE CARVER-GREENFIELD MUNICIPAL SEWAGE SLUDGE DRYING SYSTEM

the dried solids. The hot, dried solids then pass through a cooler before being sent to storage. This dried sewage sludge may be used as a fuel or as a fertilizer, if heavy metals or other contaminants are not a problem.

In the upper right corner of Figure 4 are a "sewage oil stripper" and a "flash still," where the carrier oil is separated from the sewage oil. The carrier oil is recycled into the system. The sewage oil can be burned as a fuel.

The energy-efficiency of this multiple-effect system is due to the fact that an external heat source, steam, is used to heat only the fourth stage vaporizer (by means of the flash still). The third stage vaporizer is heated by the water vapor that is driven off in the fourth stage; the second stage, by the water vapor from the third stage; the first stage, by the water vapor from the second stage.

A.3. Carver-Greenfield Mechanical Vapor Recompression

The fourth U.S. municipal sewage sludge plant, located in Ocean County, New Jersey, will have a new feature, mechanical vapor recompression (MVR). MVR is a proven technology that has recently been adapted for use in the Carver-Greenfield Process. Carver-Greenfield MVR has been demonstrated in a commercial facility in Holland since 1983 and in pilot facilities in Italy and Holland.

Referring to Figure 5, page A-5, which shows the Ocean County facility, the water vapor evaporated out of the process stream in the vapor recompression evaporator, along with the vapor from the first of two non-MVR drying stages, passes through a powerful compressor and then back to the heat exchangers that supply heat to the vapor recompression evaporator. The process stream then passes from the vapor recompression evaporator through two multiple-effect drying stages that do not utilize MVR. The centrifuge, hydroextractor, and sewage oil systems serve the same functions described in subsection A.2.

One advantage of using MVR in a Carver-Greenfield system is that it simplifies the process. In the four-effect system described in subsection A.2, it is necessary to add back some of the dried solids in order to avoid problems with "gummy phase." With MVR, the solids concentration in the process stream entering the vapor recompression evaporator is below the solids concentration where gummy phase occurs, and the solids concentration out of the MVR stage is higher than the level where gummy phase occurs. This undesirable phenomenon is therefore contained and effectively bypassed in the MVR drying stage.

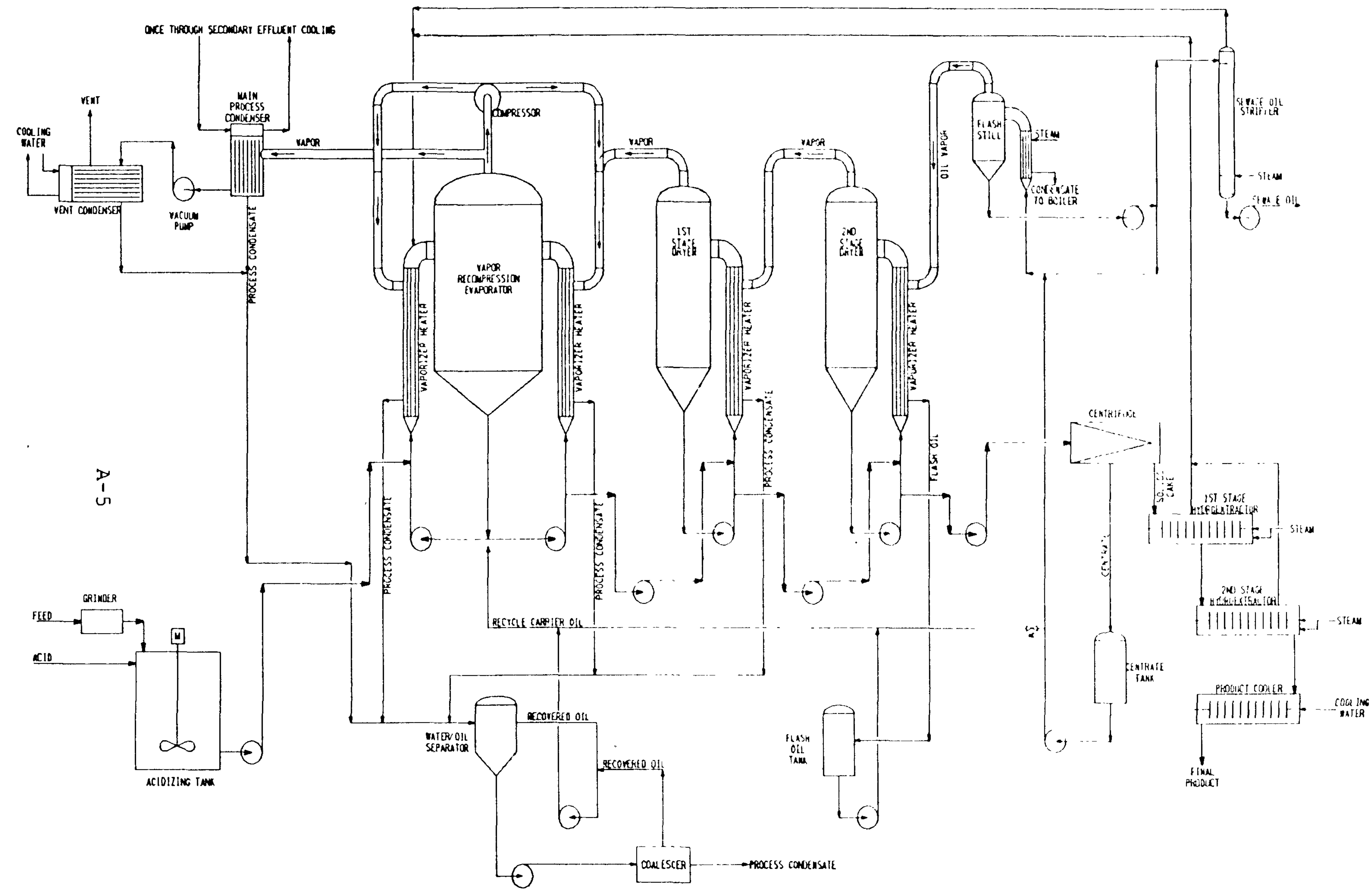

Figure 5. CARVER-GREENFIELD MECHANICAL VAPOR RECOMPRESSION SEWAGE SLUDGE DRYING SYSTEM

A second advantage of MVR is increased energy-efficiency. The Carver-Greenfield MVR system at Ocean County is expected to use approximately the same amount of energy as the four-effect Carver-Greenfield municipal sewage sludge drying systems to produce one ton of dried product, even though the feedstock at Ocean County will contain 6% - 8% solids compared to 18% - 22% solids at the other facilities.

APPENDIX B

QUALIFICATIONS OF INDUSTRIAL REVIEW TEAM MEMBERS AND EPA PROJECT MANAGEMENT

Manuel Gonzalez
Associate Engineer
Mobil Research and Development Corporation
Pennington, New Jersey 08534
(609)737-5261

Bachelor of Science in Chemical Engineering from the University of Puerto Rico (1964). Twenty-four years industrial experience with Caribe Nitrogen Corporation, Commonwealth Oil Refining Company, Davy McKee Corporation, and Mobil Research and Development Corporation. Special expertise in design, process development, startup, trouble-shooting, and other support functions for refinery and petrochemical manufacturing facilities. Background also includes petrochemical plant operations and management, plus technical support for a multiple-effect evaporation system. Currently provides technical services and operations assistance to Mobil facilities worldwide.

Frank Y. W. Liao
Senior Associate Engineer
Mobil Research and Development Corporation
Pennington, New Jersey 08534
(609)737-4955

Bachelor of Science in Chemical Engineering from Chung Yuan College (1965) and Master of Science in Chemical Engineering from the University of Mississippi (1968). Twenty years industrial experience with the Mobil Corporation, ANG Coal Gasification Company, and ITT Rayonier, Inc., including nine years experince in refinery and petrochemical plant operations support. Special expertise in multiple-effect evaporative and fluidized-bed incineration systems. Designed, started up, provided trouble-shooting services, and developed training manual and job procedures for a six-effect evaporation system. Current responsibilities include environmental engineering support for capital projects and solving pollution control problems for Mobil facilities worldwide. Member of the American Institute of Chemical Engineers and the Water Pollution Control Federation.

Kathryn A. Pluenneke
Proprietor
Technical Services
590 Mountain Avenue
Gillette, New Jersey 07933
(201)647-7424

Bachelor of Science in Chemical Engineering from the University of Houston (1978). Four years experience with the Dow Chemical Company, plus seven years as an independent consultant. Dow experience in chemical and petrochemical plant operations and support services. Previously a licensed water and wastewater treatment operator in the state of Texas. Currently proprietor of business that provides support services to companies involved in technical consulting, engineering, and engineered products. Services offered include research of technical subjects and technical markets, and technical writing. Member of the American Institute of Chemical Engineers.

Gilbert Rowe
Environmental Consultants
110 Hillcrest Avenue
Morristown, New Jersey 07960
(201)267-2920

Bachelor of Science in Chemical Engineering from City College of New York. Thirty-five years industrial experience with Exxon, plus two years as an independent consultant. Exxon experience covered all phases of refinery and petrochemical plant design, startup assistance, and technical and operations management; as well as developement of wastewater and solid waste treatment technology and design of treatment plants. Responsibilities included personnel and organizational development, in addition to startup, and after startup technical and operations supervision. Currently provides consulting services in hazardous waste and wastewater management; problem assessment and mitigation; and planning, study, and evaluation of other environmental problems. Author of "Evaluation of Treatment Technologies for Listed Petroleum Refinery Wastes," a major report for the American Petroleum Institute, May, 1988.

Martin J. Siecke, P.E.
Safety Manager
Safety and Environmental Affairs
National Starch and Chemical Corporation
10 Finderne Avenue
Bridgewater, New Jersey 08807
(201)685-5119

Licensed Professional Engineer with Bachelor of Science in Chemical Engineering from Newark College of Engineering (1963). Twenty-five years experience with the National Starch and Chemical Corporation, including seventeen years in all phases of chemical and petrochemical plant startup, operations, and maintenance. Responsibilities involved staffing, training, and organizational development. Previously a licensed industrial wastewater operator in the state of Illinois and Chairman of the Supervisory Committee for the Plainfield Joint Meeting Sewerage Authority. Currently responsible for National Starch's health and safety concerns, including personnel training for risk and crisis management. Member of the American Society of Safety Engineers, National Fire Protection Association, and National Society of Professional Engineers.

John M. Walker, Ph.D.
Physical Scientist
U.S. Environmental Protection Agency, WH-595
Office of Municipal Pollution Control
Washington, D.C. 20460
(202)382-7283

Bachelor of Science from Rutgers University (1957); Masters (1959) and Doctors (1961) degrees from Purdue University. North Atlantic Treaty Organization Postdoctoral Fellow in Rothamsted Experiment Station in England. Twelve years with the U.S. Department of Agriculture in environmental and agricultural research, including development of techniques for composting and land application of sewage sludge. Twelve years with EPA. Current responsibilities include evaluation and improvement of design and operation of technologies for sludge management and development of guidelines for safe use and disposal of sludge. Fellow of American Association for the Advancement of Science; member of Water Pollution Control Federation and many other professional organizations. Author of more than 150 publications.

Harry E. Bostian, Ph.D., P.E.
Chemical Engineer
Water and Hazardous Waste Treatment Research Division
Risk Reduction Engineering Laboratory
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268
(513)569-7619, FTS-684-7619

Bachelor of Science in Chemical Engineering from Bucknell University (1954), Masters in Chemical Engineering from Rensselaer Polytechnic Institute (1956), and Doctor of Philosophy in Chemical Engineering (1959) from Iowa State University. Thirty years technical experience with EPA, Universities of New Hampshire and Mississippi, and Exxon Corporation. Experience in distillation, solvent extraction, fluidization, computer applications, operations research, municipal and industrial pollution control including sludge management, energy-environmental considerations. Teaching of almost entire undergraduate and graduate chemical engineering currricula. Advisor for masters and doctoral candidates. Over 70 papers, reports, and theses, including presentations at meetings and publications in journals that are of international stature. Contributed to "Technology Assessment of Carver-Greenfield Municipal Sludge Drying Process" (Reference 2, p 5-1) as Technical Manager for EPA during final editing and review. Member of American Institute of Chemical Engineers, Water Pollution Control Federation, American Association for Advancement of Science, Sigma Xi, Tau Beta Pi, and other honoraries.

APPENDIX C

OTHER OBSERVATIONS BY INDUSTRIAL REVIEW TEAM MEMBERS

<u>Note</u> <u>to</u> <u>reader</u>: The observations in this appendix are based solely on information available to the Industrial Review Team in July, 1988. Some of the changes and developments that have occurred since July, 1988, at the Los Angeles City (LAC) and other facilities are discussed in Appendix E, "Status of the Carver-Greenfield Municipal Sewage Sludge Drying Facilities: A Brief Update."

As of July 12, 1988, the LAC plant had not yet operated continuously for a period of time sufficient to determine whether design modifications may be required.

Compared to the full-scale Carver-Greenfield municipal sewage sludge drying facilities, the Los Angeles - Orange County Metropolitan Area (LA/OMA) pilot plant work involved a different carrier oil, different feedstock, a single-stage system, and no sewage oil/carrier oil separation.

The abrasive characteristics of the LAC sludge were unexpected, and it is uncertain whether erosion problems are now under control.

LAC had not yet attempted acid addition as per design to control formation of soaps.

The unsolved problem of carryover of solids into the oil/water separation system inhibits plant function at LAC. Much of the solids carryover appears to be from the hydroextractor overhead.

LAC had not yet operated the sewage oil/carrier oil separation system as of July 12, 1988. The separation has not been attempted in the absence of the facilities to burn the product sewage oil.

There were still unresolved startup and shutdown problems at LAC as of July 12, 1988, including:

Line plugging and exchanger fouling at low flow rates;

Formation of clinkers during hydroextractor warm-up.

The fire and explosion hazards associated with the process were not fully appreciated until after the fact at LAC.

Health and safety procedures and training were inadequate by chemical or refining industry standards.

If the Mercer County Improvement Authority (MCIA) milling operation is not effective, the fouling problems with the spiral heat exchangers due to human hair that LAC has experienced may be more frequent at MCIA, where the undigested sludge feedstock is more inclined to have intact fibers than digested sludge.

A startup team with the types of skills and experience that a chemical processor or petroleum refiner would concentrate on an initial startup was lacking at the LAC plant as of July 12, 1988.

The Industrial Review Team recommends that startup and operations personnel at LAC have chemical plant or refinery experience because of the similarity of the plant to industrial facilities.

At LAC, the carrier oil concentration in the product is still higher than the design level of 1 to 2 percent. High carrier oil concentration occurs during cold startups. Similar carrier oil levels at MCIA could cause problems for using the dried product as a soil conditioner.

On-line analyzers at LAC were not functioning as designed when the Review Team visited the plant. The control of oil/sludge ratio was based on a daily material balance, which is not adequate to maintain product quality control. However, there is optimism regarding new on-line analyzers.

Regular shutdown and startup at LAC takes about three days, to allow time for cool-down, draining, and clean-out. The tentative MCIA plan to operate five days and shut down weekends may not be feasible in view of this turn-around time.

Equipment layout in the LAC plant makes maintenance difficult. For example, the tube-bundle in the condenser unit cannot be pulled out because there is not enough head space.

The LAC plant suffers from high personnel turn-over due to wage scale and job classification problems.

The Los Angeles County Sanitation Districts (LACSD) plant has incorporated modifications to their system in order to avoid some of the LAC problems.

The LACSD plant has a central control room with three sets of CRT stations to monitor and control the process. There is also a supervisor CRT station to back up the operator's control unit.

LACSD plans to use an engineering contractor to provide technical assistance during initial startup.

Training materials prepared at LAC could probably be made available and would be of value to others.

LAC has had far too little continuous operating time to experience expected system problems resulting from buildup of impurities in the system, such as sewage oils and fines.

Tungsten carbide has been the most successful hard-facing material used at the LAC facility.

The inertia of the LAC municipal purchasing system has required building the spare parts inventory to four times the manufacturer's recommended level.

Based on their most recent experience, LAC expects a train of spiral heat exchangers to plug every six to eight weeks.

Based on pilot plant experience, LACSD anticipates some problems with odor.

APPENDIX D

ACKNOWLEDGEMENTS

The Review Team and EPA wish to express their gratitude for the excellent cooperation and assistance of those parties involved with the Carver-Greenfield Process who provided information, plant visits, and meeting facilities. Special thanks to:

The City of Los Angeles Department of Public Works Bureau of Engineering;

The City of Los Angeles Hyperion Construction Division Bureau of Engineering;

Clinton Bogert Associates;

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Foster Wheeler Martinez, Inc.;

Foster Wheeler USA Corporation;

James M. Montgomery Consulting Engineers, Inc.;

The Los Angeles County Sanitation Districts;

The Mercer County Improvement Authority and its supporting municipalities, Trenton, Hamilton, and Ewing-Lawrence;

Mobil Research and Development Corporation;

The Ralph M. Parsons Company.

APPENDIX E

STATUS OF THE CARVER-GREENFIELD MUNICIPAL SEWAGE SLUDGE DRYING FACILITIES: A BRIEF UPDATE

The purpose of this appendix is to provide the reader with information on developments that have occurred in the four Carver-Greenfield municipal projects (the City of Los Angeles, Los Angeles County, Mercer County Improvement Authority, and Ocean County) since this review was undertaken in July of 1988. The owners of these facilities were of great assistance in providing information to the Industrial Review Team and were further involved with this review project as recipients of the Drafts of this report issued for comments on September 9, 1988, and on May 18, 1989. Their representatives also participated in the meeting held in Princeton, New Jersey, on September 15 and 16, 1988, for the purpose of the Industrial Review Team's discussing their findings and making recommendations to each municipality and to the system designer and developer.

E.1. The City of Los Angeles Facility

When this review project was undertaken, the City of Los Angeles Hyperion Energy Recovery System (HERS) Carver-Greenfield municipal sewage sludge drying facility was the only one of the four EPA-funded Carver-Greenfield municipal facilities that was fully constructed and in startup. For this reason, the HERS Carver-Greenfield plant was extremely important to this project and was the basis for many of the comments and recommendations made by the Industrial Review Team.

A number of changes have occurred at the HERS facility and in the Carver-Greenfield operation since the Industrial Review Team visited in July, 1988. At an August, 1988, meeting at Los Angeles City Hall, the President of the City's Board of Public Works requested that all of the engineering companies involved in the project redouble their efforts to achieve consistent and continuous operation of the Carver-Greenfield and sludge combustion systems. At this meeting, it was also announced that the system designer, Foster Wheeler, would supply four petrochemical/ petroleum refinery startup/operations experts to serve as twenty-four-hour-per-day shift advisers. In addition, the overall management responsibility for HERS operations was shifted from the City's construction to the City's operations department. This change recognized the need to proceed forward into the operations phase, following the substantial construction phase effort that had successfully improved the quality and reliability of equipment supplied under various construction contracts.

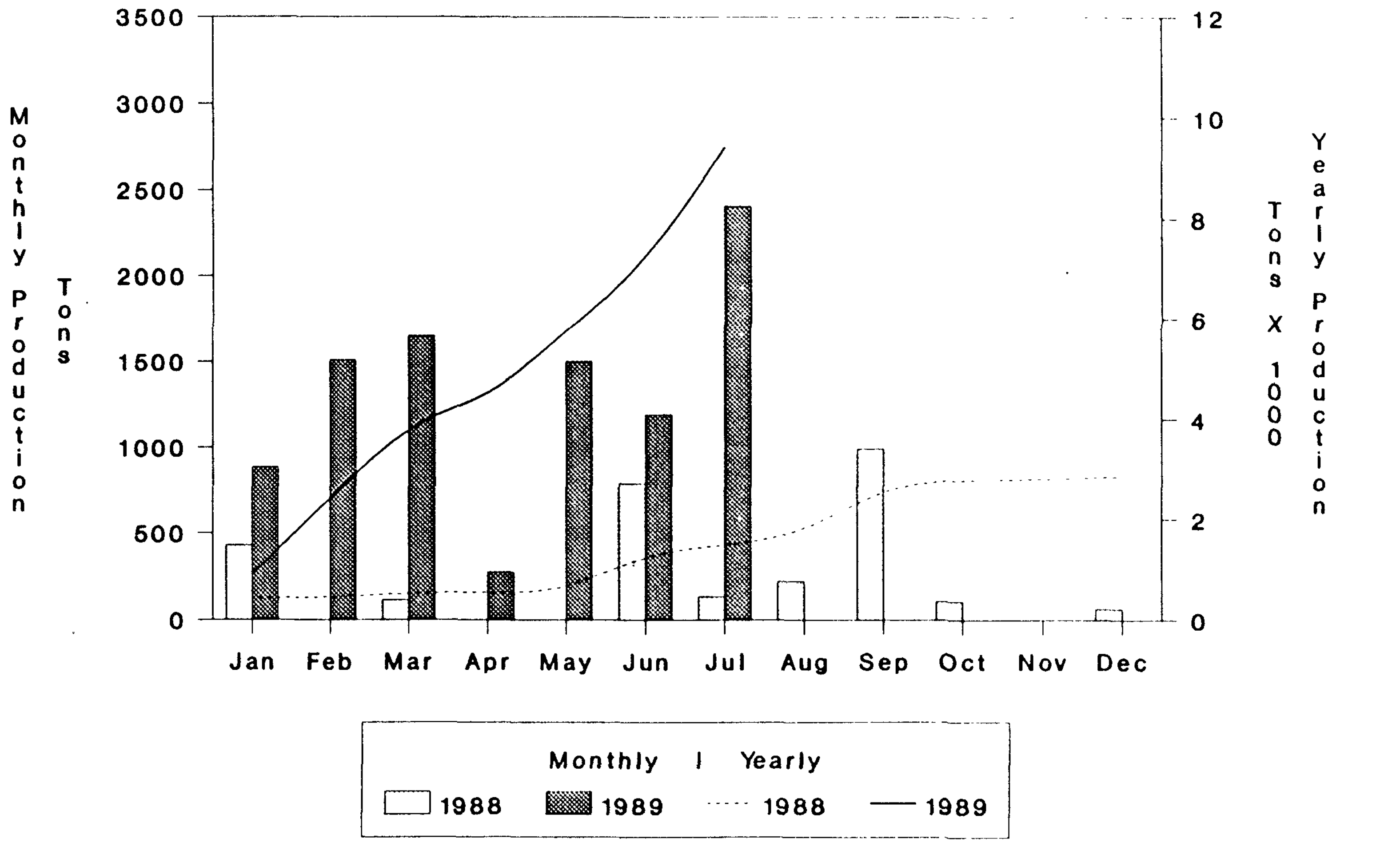
A great deal of progress has been associated with these changes since July, 1988. Even though an unfortunate maintenance accident, which occurred in early October, slowed progress by keeping the combustion and sludge drying systems shut down until the end of the year, the plant underwent comprehensive cleaning, vacuum testing, and equipment and instrumentation review as a preliminary step to continued full-scale startup activities. All operations and maintenance manuals (including safety procedures) were updated. Also, during the last quarter of 1988, in-plant studies revealed that some of the slurry pumps had been installed with undersized motors. Corrections were made where possible to achieve near design velocities in the spiral heat exchangers.

Following this shutdown period, the improvements in the operation of the sludge drying system were dramatic. This improvement was achieved by attempting to operate two of the three trains at all times, per the original design concept. During the first 69 days of 1989, more sludge was dried than during the entire year of 1988 (see Figure 6, page E-3). Continuous operation was achieved with dry sludge being produced 83 days out of the 90 days in the first quarter of 1989. Between February 3 and March 31, dry sludge was produced on 57 consecutive days, a facility record. Most of this dry sludge powder was burned to generate steam and electricity.

According to plan, the operating level of the Carver-Greenfield system was increased incrementally during the first quarter of 1989 to somewhat below 50% of design capacity, as the operators gained familiarity with the system and as the comprehensive performance testing of each of the various components continued. All parts of the plant were operated, including the flash still to remove sewage oil and acid addition to inhibit the formation of soaps. With continuous operation, many parts of the plant that did not operate well in an "up and down" mode began to operate as designed. Such previously troublesome operating areas as the spiral heat exchangers, the centrifuges, and the evaporator non-condensable over-pressuring began to operate acceptably.

On March 23, 1989, the six-month scheduled participation of the four-member Foster Wheeeler startup team came to an end. Referring again to Figure 6, during April, the plant was shut down most of the month, and little dry sludge was produced. In May, the plant performed close to its February

Figure 6. City of Los Angeles Production Statistics 1988 and 1989 (To Date)



Production Through
July 31, 1989

level. However, in June, production dropped off, and twenty-four-hour-per-day engineering supervision was reinstituted at the end of the month. Under this supervision, there was a dramatic improvement in July, when a record 2,407 tons of dry sludge was produced.

It is important to note that, to date, no specific design problems have been identified that would limit dry sludge production to 50% of design capacity. It is hoped that progress will continue in increasing the output of the system incrementally toward design capacity.

Many of the observations and/or recommendations made by the Industrial Review Team for EPA have been addressed in Los Angeles. Persons highly skilled in startup of complex technologies that involve equipment and unit operations similar to Carver-Greenfield were present and working as advisers on every shift. Startup procedures that had been developed through many years of experience in the chemical manufacturing and petroleum refining industries were followed. This may have occurred coincidentally as the Los Angeles startup progressed, and, to some degree, it may also be a positive result of the Industrial Team's review. For whatever reason, the operational improvements have been dramatic.

These operational improvements strongly emphasize the necessity for specialized petrochemical engineering startup expertise and techniques in a municipal sewage sludge drying Carver-Greenfield system. It is hoped that these specialized skills will continue to be available during startup at Los Angeles and the other municipal facilities using the Carver-Greenfield technology until the functional capabilities of the system can be fully tested. This is very important in determining the suitability of the current design, the need for any possible further modification of design and operating procedures, and the ultimate cost-effectiveness of this technology for drying municipal sewage sludge.

E.2. Facilities Under Construction

At the expanded Los Angeles County Sanitation Districts (LACSD) sludge management facility, construction of the Carver-Greenfield system is 98% complete, and the incineration system where the dried sludge product will be burned is 50% complete. Key technical and maintenance personnel have been present during the latter stages of construction. Contractual arrangements have been made by LACSD for startup assistance by technical personnel with specialized knowledge of the Carver-Greenfield system.

Construction of the Ocean County, New Jersey, Carver-Greenfield facility is due to be completed in May, 1990. Ocean County has budgeted substantial funds for engineering review and startup of the facility, including funds to pay for contract engineering supervision from a specilized startup and operations firm that has experience with Carver-Greenfield sludge drying systems. After construction is completed, there will be a nine-month period for commissioning, trial runs, and acceptance testing. During this period, permanent plant personnel will be trained under the direction of the contracted startup engineers, so that they will be able to take over operation of the plant. The construction contractor will not be released from responsibility until after the nine-month system check-out is successfully completed.

Construction of the Mercer County Improvement Authority (MCIA) Carver-Greenfield facility was halted in September, 1987, because of construction contractor default. As of August, 1989, bidding for the completion of the facility was underway. However, since the first bid responses were rejected as high, it is difficult to estimate a date a which construction may resume. There is approximately ten months of construction work remaining to complete the facility. While construction work has been halted, MCIA has authorized considerable engineering assessment and design modifications for the facility. MCIA is currently exploring the possibility of contracting for specialized startup engineering assistance.