PB85-197044

Investigations of Existing Pressure Sewer Systems

Rezek, Henry, Meisenheimer and Gende, Inc.
Libertyville, IL

Prepared for

Environmental Protection Agency, Cincinnati, OH

Apr 85

PB85-197044

EPA/600/2-85/051
April 1985

INVESTIGATIONS OF EXISTING PRESSURE SEWER SYSTEMS

by

Joseph W. Rezek
Ivan A. Cooper
Rezek, Henry, Meisenheimer and Gende, Inc.
Libertyville, Illinois 60048

Contract Number 68-03-2603

Project Officer
James F. Kreissl
Wastewater Research Division
Water Engineering Research Laboratory
Cincinnati, Ohio 45268

WATER ENGINEERING RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U. S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA/600/2-85/051	2.	3. RECIPIENT'S ACCESSION NO. PB85 197044/AS
4. TITLE AND SUBTITLE Investigations of Existing Pressure Sewer Systems		5. REPORT DATE April 1985
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Joseph W. Rezek and Ivan A. Cooper		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Rezek, Henry, Meisenheimer, and Gende, Inc. Libertyville, Illinois 60048		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. Contract No. 68-03-2600
12. SPONSORING AGENCY NAME AND ADDRESS Water Engineering Research Laboratory - Cin., OH Office of Research & Development U.S. Environmental Protection Agency Cincinnati, Ohio 45268		13. TYPE OF REPORT AND PERIOD COVERED Final 9/77 to 6/78
		14. SPONSORING AGENCY CODE EPA/600/14

15. SUPPLEMENTARY NOTES

Project Officer: James F. Kreissl (513)684-7614

16. ABSTRACT

Two areas previously undocumented in pressure sewer evaluations are operation and maintenance history and septic tank effluent treatability. Nine sites were visited to highlight these considerations, especially their relationship to overall system cost-effectiveness.

Pressure sewer systems require numerous specialized components, each of which demand varying degrees of operation and maintenance. This report considers operations and maintenance for the following: on-lot, mainline, and treatment facilities.

On-lot maintenance tasks differ for the two major types of systems - grinder pump (GP) and septic tank effluent pumping (STEP). Both preventive maintenance and breakdown maintenance duties were investigated. Operation and maintenance (O&M) task frequencies for the nine investigated systems and differences between O&M tasks and frequencies for continuous occupancy homes versus vacation homes are presented.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS (This Report) UNCLASSIFIED	21. NO. OF PAGES 134
	20. SECURITY CLASS (This page) UNCLASSIFIED	22. PRICE

EPA Form 2220-1 (9-73)

DISCLAIMER

The information in this document has been funded wholly or in part by the United States Environmental Protection Agency under Contract No. 68-03-2600 to Joseph W. Rezek and Ivan A. Cooper. It has been subject to the Agency's peer and administrative review, and it has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water systems. Under a mandate of national environmental laws, the agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. The Clean Water Act, the Safe Drinking Water Act, and the Toxics Substances Control Act are three of the major congressional laws that provide the framework for restoring and maintaining the integrity of our Nation's water, for preserving and enhancing the water we drink, and for protecting the environment from toxic substances. These laws direct the EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Water Engineering Research Laboratory is that component of EPA'S Research and Development program concerned with preventing, treating, and managing municipal and industrial wastewater discharges; establishing practices to control and remove contaminants from drinking water and to prevent its deterioration during storage and distribution; and assessing the nature and controllability of releases of toxic substances to the air, water, and land from manufacturing processes and subsequent product uses. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

It is the expressed purpose of this report to describe and analyze actual case histories of typical installations of pressure sewer systems in the United States. The majority of this information was collected prior to and during 1977. As additional data have become available, these histories have been updated.

Francis T. Mayo, Director
Water Engineering Research Laboratory

ABSTRACT

Two areas previously undocumented in pressure sewer evaluations are operation and maintenance history and septic tank effluent treatability. Nine sites were visited under a U. S. EPA contract to highlight these considerations, especially their relationship to overall system cost-effectiveness.

Pressure sewer systems require numerous specialized components, each of which demand varying degrees of operation and maintenance. This report considers operations and maintenance for the following: on-lot, mainline, and treatment facilities.

On-lot maintenance tasks differ for the two major types of systems - grinder pump (GP) and septic tank effluent pumping (STEP). Both preventive maintenance and breakdown maintenance duties were investigated. Operation and maintenance (O & M) task frequencies for the nine investigated systems and differences between O & M tasks and frequencies for continuous occupancy homes versus vacation homes are presented.

Mainline O & M tasks include periodic cleaning, repairing of leaks, and maintaining system control and air release valves. Some systems require periodic flushing of mains, particularly GP systems with low velocities. Systems with existing loads significantly less than design flows tend to have excessive grease build-ups in mains, thus reducing capacity. Operating experience with grease build-ups are reported. O & M tasks for periodic manual operation of air release valves depend on the designer's choice of manual or automatic air release valves. Other information gathered is presented similar to that for on-lot O & M.

Other areas included, but not previously reported in detail, are O & M tasks for treatment systems receiving predominantly pressure sewage, startup problems for either GP or STEP systems, and how startup procedures relate to initial system and treatment O & M. Odor control needs and examples of odor abatement techniques are included, as well as considerations for corrosion prevention.

Treatability of pressure collected sewage from both GP and STEP systems is no more exotic than treatment of conventional gravity collected sewage. Secondary treatment standards can be met with conventional aerobic treatment of either type of pressure collected sewage. Treatment plant considerations include deletion of comminutors in total pressure systems, and an increase in STEP plant treatment efficiency due to substantially reduced pollutant loadings.

A discussion of management practices, procedures, recurrent problems, and public relations policies is included. This is especially important when two or more users share a common on-lot pumping facility.

This report was submitted in fulfillment of Contract Number 68-03-2600 by Rezek, Henry, Meisenheimer and Gende, Inc. under the sponsorship of the U. S. Environmental Protection Agency. This report covers the period from September 1, 1977 to June, 1978.

CONTENTS

FIGURES

FIGURES (continued)

TABLES

TABLES (continued)

ABBREVIATIONS

MGD	---	million gallons per day
GP	---	grinder pump
STEP	---	septic tank effluent pump
O & M	---	operation and maintenance
BOD_5	---	biochemical oxygen demand, 5 days
SS	---	suspended solids
FRP	---	fiberglass reinforced pipe
NEMA	---	National Electrical Manufacturer's Association
PVC	---	polyvinyl chloride
MUD	---	municipal utility district
NPT	---	National Pipe Thread
GPM	---	gallons per minute
MTBSC	---	mean time between service calls
H-O-A	---	hand-off-automatic
EPA	---	Environmental Protection Agency
STP	---	sewage treatment plant
S & L	---	Smith & Loveless
DWV	---	drain waste vent
CATV	---	community antenna television
C factor	---	Hazen-Williams coefficient
NFPA	---	National Fire Protection Association
NEC	---	National Electric Code
ABS	---	acrylonitrile-butadiene-styrene
kw	---	kilowatt
hp	---	horsepower
kPa	---	kilopascal
psi	---	pounds per square inch
lf	---	linear foot
ft	---	feet, foot
in	---	inch
RPM	---	revolutions per minute
ISF	---	intermittent sand filter
RSF	---	recirculating sand filter

ACKNOWLEDGMENTS

Joseph W. Rezek served as Project Director for this study with Ivan A. Cooper acting as Project Manager. William C. Bowne of the Douglas County, OR Engineer's office served as the Project Consultant, and C. Joseph Touhill of Touhill, Shuckrow and Associates, Pittsburg, PA, functioned as Manuscript Preparation Consultant. Professional assistance was provided by R. J. Devery and S. M. Lacy. The excellent technical assistance provided by F. J. Bradke, N. G. Brown, G. E. Wilson and R. W. Magnuson is especially appreciated. The secretarial and technical typing efforts of Cynthia Mickley Harris are gratefully appreciated.

Special thanks to to various members of the staff of the EPA's Water Engineering Research Laboratory in Cincinnati, OH, particularly James F. Kreissl, Project Officer, who provided helpful guidance throughout the program.

We gratefully wish to thank all the system operators, consultants, and state and local officials who participated in this study, sharing their time and effort to bring this survey document to the user community.

SECTION 1

INTRODUCTION

In view of the need to provide smaller communities with low cost solutions for collection and treatment of wastewater, there is a need to provide more definitive information on methodologies for evaluating the potential of pressure sewage collection systems. Likewise, regulatory agencies and consulting engineers need to define bases for evaluating and designing cost-effective alternatives. There are many advantages for a community to install a pressure sewage collection system. Among these are the lower costs associated with a less expensive piping infrastructure. Pressure sewer piping material is less expensive than a conventional gravity sewer system, and excavation, dewatering and shoring costs are generally substantially less. Areas with considerable rock close to the surface also will experience significantly lower costs. Developer advantages also exist, since the homesite pumping unit need only be added when a homeowner decides to build on a purchased lot. Although there is potential for infiltration and inflow between the house connection and the pumping unit, most of the pressure sewer system consists of sealed piping which greatly diminishes this possibility.

Certain disadvantages also may be experienced with a pressure sewer system compared to a gravity collection system. The chief disadvantage is that the pressure sewer is more highly mechanized. Therefore, more maintenance is involved for the individual home pumping unit and its associated on-lot facilities, as well as piping system components such as inline control valves, air release valves, flushing mechanisms and control of odor.

There also are treatment considerations in pressure sewer collection systems that may be different from conventional gravity systems. In a STEP system there is a potential for greatly reduced organic loading to the treatment facility at the equivalent flow of a gravity collection system. This lower organic loading may translate into a higher treatment plant flow capacity with same unit sizing. Grinder pump collection systems, however, usually have a higher unit organic loading than the gravity system, because all of the wastes from a homesite will be conveyed to the treatment facility at a reduced flow volume compared to the gravity system which often would have the transported wastes diluted with infiltration and inflow. If the treatment facility receives solely pressure collected sewage, whether it be from a GP or a STEP system, a comminutor is unnecessary. The areas of operation and maintenance (O & M) history and treatability of wastewater, have been relatively unexplored in other published works on pressure collection systems.

This report intends to fill the gap in information transfer and offers positive examples of effective and economical collection facilities in low density areas, areas with construction problems, and second home development situations.

SECTION 2

CONCLUSIONS

The following are major conclusions reached based upon detailed analysis of field investigations.

ON-LOT FACILITIES

Both GP and STEP pump units showed acceptable maintenance results. STEP pumping units showed a particularly high reliability. This was only for the Hydr-O-Matic sump pump type of units. Other effluent pumps, such as Peabody Barnes, do not have a long enough service history to yield accurate results. GP reliability also has been acceptable with the highest reliability shown by the Hydr-O-Matic Hydrogrind units followed in descending order by Environment/One, and Peabody Barnes. Units such as Toran, F. E. Meyers, and others either do not have sufficient units in service or their products are too new to evaluate. Solids handling type pumps, such as the Peabody Barnes 5.1 cm (2 in) sewage ejector pumps, used in several marina type installations, have an acceptable reliability.

Pumps should not use pressure switches as the primary on - off control device. Mercury floats are better suited for this type of installation.

Alarm systems should be provided to alert the homeowner that a malfunction has occurred.

PIPING SYSTEMS

All inline shutoff control valves and air release valves should be inspected and manually operated at least twice per year.

Systems that have mainline piping sized for a significant number of future users have problems. The problems are more severe with GP systems since they carry significant volumes of grease. Slow velocities create conditions suitable for grease and detergent deposition.

In STEP systems, increased residence time and slower velocities increase the chances of gas and odor formation.

CORROSION

Corrosion is a problem in STEP systems. Connection bands and valves for on-lot facilities should be stainless steel and bronze. Plastic piping is superior to galvanized. Grey iron and admiralty brass are not recommended. Brass will lose zinc, leaving the copper susceptible to corrosion.

ODORS

Odors can be a problem in both the GP and STEP pumping systems. Odors in STEP systems have shown up mainly at intermediate lift stations and not in the on-site facilities or at the STP. There have been examples of GP systems that have had intermittent odor problems. One means of controlling odor is by the addition of hydrogen peroxide.

TREATMENT

GP sewage has a higher organic loading than conventional gravity collected sewage because there is no infiltration or inflow to dilute GP sewage. STEP system sewage is considerably lower in BOD_5 and SS than gravity sewage because substantial portions of the organic solids and BOD_5 are removed in the septic tank. Both BP and STEP sewage are amenable to conventional aerobic treatment.

OPERATION AND MAINTENANCE

Systems having yearly or semi-annual inspection of pumps and piping system components are less likely to need emergency breakdown maintenance.

Pump weight is a factor in servicing. Effluent pumps typically are light enough for an individual to lift with one hand. Grinder pumps, such as the Hydr-O-Matic, Toran, and Meyers, are light enough for one individual to lift. Others, such as the Peabody Barnes and Environment/One, usually require two individuals. However, several systems have used one individual to service these heavier units.

Significant operator time is involved with construction coordination, particularly in continually developing communities. Plans should be made to take these factors and costs into consideration when preparing O & M budgets.

COSTS

Existing STEP systems have an on-lot construction cost of between \$1,000 to \$2,000 per unit. GP units have a slightly higher installed cost, from about \$1,300 to \$2,500 per unit.

SYSTEM MANAGEMENT

Systems with formal maintenance organizations had fewer customer complaints and less system problems. Moreover, customers showed more interest and were kept better informed about system operation than systems that lacked these types of organizations. Where homeowners lacked formal assistance, many expressed an interest in securing help from a formal, centralized entity.

SECTION 3

RECOMMENDATIONS

The following recommendations are made to alleviate problems in systems under design or planned. Implementation of these recommendations plus the results of future investigations should provide more highly reliable, easier to operate, and less expensive systems.

On-lot facilities should have a well thought out alarm system to advise the homeowner when problems exist in his on-lot pressure sewer components. Investigations should be made on use of plastic and other non-corrosive components, particularly in STEP systems, to improve longevity and cost-effectiveness of valves and other piping components. Plastics also should be investigated for use in pumping units to lighten the weight for ease of removal for service.

New excavation techniques and smaller diameter piping should be investigated to reduce excavation and construction costs in pressure sewer systems. Automatic release valves of sufficient number should be used because manual air release valves result in extraordinarily high O & M costs. Future systems should use pipe locaters to help maintenance personnel during fault finding procedures, or to aid other utility constructors when they are installing electrical, telephone, or water lines. Also, systems should use color-coded pipe to prevent cross-connections.

Although pressure collected sewage is easily treatable, research should be directed toward treatment optimization. For systems that discharge less than 10% pressure collected sewage into a gravity-fed plant, no difference from conventional treatment should be noticed.

Pressure sewer systems should be used only if the design engineer determines there is clear and significant cost-effectiveness over a conventional gravity sewer system. A slight capital cost advantage should not be justification for the use of a pressure sewer in areas where conventional systems can be installed for a slightly higher initial capital cost, since a conventional system may result in significantly less operation and maintenance throughout its lifetime.

All systems using pressure collected sewage should investigate alternative management techniques to determine which is most suitable for their particular situation. Existing regulations, codes, and standards should be revised to reflect the use of pressure sewer systems where economical and cost-effective.

SECTION 4

CASE HISTORIES

BACKGROUND

According to the 1970 U. S. Census, 71.18% of U. S. housing units are sewered, 24.52% are served by septic tank systems, and 4.30% use other methods (1). Numerous smaller communities and rural areas fall in the unsewered category (2). EPA notes that providing centralized collection and treatment systems is often very expensive for smaller communities, sometimes exceeding $10,000 per home (3). Walton, NY's centralized collection and treatment system, for example, cost 43% of the town's assessed valuation (4). Collection systems may be a substantial portion of these high costs. The EPA suggests generally over 80% (3), while Bowne reports 91% in the Glide-Idelyde, OR area (5). Construction of a gravity sewer system may also be a distruptive element in community life (Figure 1).

As a result of high construction costs associated with conventional collection systems, lower cost alternatives have been investigated. Gordon Maskew Fair proposed a "sewer within a sewer" concept for separating combined sewerage facilities in larger municipalities (6). These systems were found to be impractical, but the pressure sewer concept was determined to have considerable merit in a study by the American Society of Civil Engineers (6). One of the earliest systems, now abandoned, was designed by Clift in Kentucky in the 1960's (7). The EPA has sponsored full scale experimental research of pressure sewer systems in Albany, NY; Phoenixville, PA (Figure 2); Grandview Lake, IN; and Bend, OR (8, 9, 10, 11). The study reported on here has identified over 60 existing pressure sewer systems with approximately an equal number under construction or in some phase of design, as shown in the Appendix.

GENERAL

Case histories of several existing pressure sewer systems are included in this section. As a condition of this contract, project team members traveled to nine pressure sewer systems to investigate in detail several aspects, including design para-

Figure 1. Gravity sewer construction may not be cost-effective in certain areas.

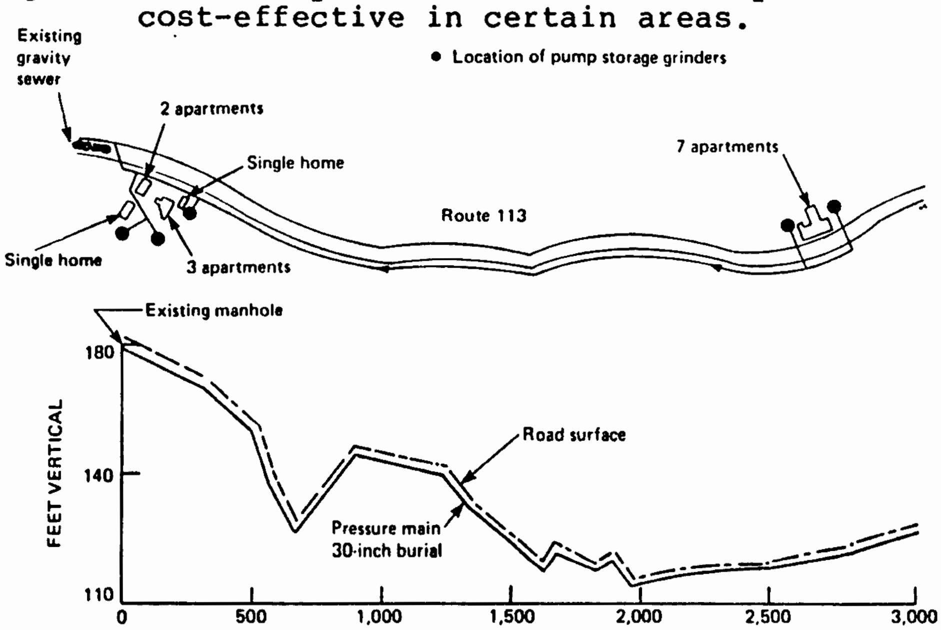

Figure 2. Phoenixville, PA pressure sewer system.

meters, construction. treatment, operation and maintenance, costs, and management considerations. Other pressure sewer systems which were near the selected systems were visited on side trips to gain additional background information.

Along with interviewing the system operator, discussions were held with contractors, state regulatory officials, pump company repair personnel, and representatives of the major manufacturers of pressure sewer system pumps. Much of the substantiating information was obtained from Environment/One, Inc. (Paul Farrell); Peabody Barnes Pump Company (Robert Langford), and Hydromatic Pump Company (Robert Holdeman).

A generalized history of each system is presented in this section. More specific data relating to system components can be found in the technical sections.

CASE HISTORIES

Apple Valley, OH

This development is located a few miles east of Mount Vernon, OH, and is sometimes referred to as the "Little Jelloway" system. The system is operated by the Knox County Sewer and Water Department (Malcolm Bone, Supt.). In general, operator and resident comments regarding the system have been favorable.

The Apple Valley facility is primarily a gravity sewer system with various areas on the lakefront property served by small localized pressure sewer systems emptying into the gravity sewer (Figure 3). There are 425 homes, a school, laundromat, campground area, two beach houses and restaurants on the Apple Valley system, a development owned by American Central Corporation. Presently, 50 homes are served in pressurized lakefront loops, with 225 homes ultimately to be served by pressure sewers out of the 670 total planned connections. Therefore, this system has characteristics of both pressure and gravity collection systems. Operators have been pleased with the reliability and performance of the Hydromatic 1.1 kw (1.5 hp) simplex grinder pumps, located in canisters outdoors. Typically, two homes are connected to one grinder pump installation. The first home on-line supplies the electric power and receives a small monthly credit for the electric power it provides.

The system was financed by borrowing money on the open market. Per lot cost is obtained by dividing the capital costs by the total number of lots. When a homeowner buys property he must pay his share within thirty days. If the homeowners elects not pay this amount within the thirty day period, the Knox County Sewer and Water District then charges the individual for twenty years a set amount on his tax bill. Each lot owner is charged $14.00 per year, billed semi-annually, whether his lot is connected to the sewer system or not. There is a usage charge of $12.00 per quarter when connected.

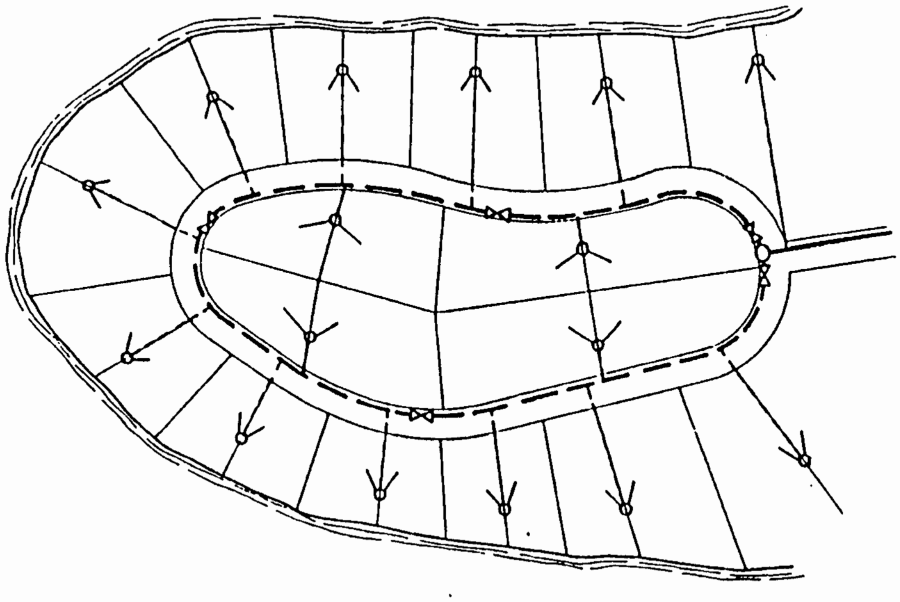

Figure 3. Typical lakefront pressure sewer loop at Apple Valley, OH.

Grandview Lake, IN

The Grandview Lake pressure sewer system, east of Columbus, IN, was designed during 1968 to 1970 by Seico, Inc. of Columbus, IN (Figure 4). The system was intensively monitored and reported as a demonstration project, funded through a joint EPA-FHA grant-loan agreement. The system, as reported to EPA, has changed considerably, (3) and now 150 connections are served by 125 Environment/One and 25 Hydr-O-Matic SP150 grinder pumps (Figure 5). About 20 of these units pump septic tank effluent. These units show signs of corrosion. Other units that pump directly from the house use the septic tank as an overflow device. Check valves are cast iron for Hydr-O-Matic and PVC for Environment/One pumps. Cast iron valves, for ease of removal, are recommended to be located horizontally, and PVC vertically to prevent solids deposition from interfering with flap seating. Brass gate valves are used for shutoff. Environment/One uses a 2.5 cm (1 in) service line, while Hydr-O-Matic uses 3.2 cm (1.25 in).

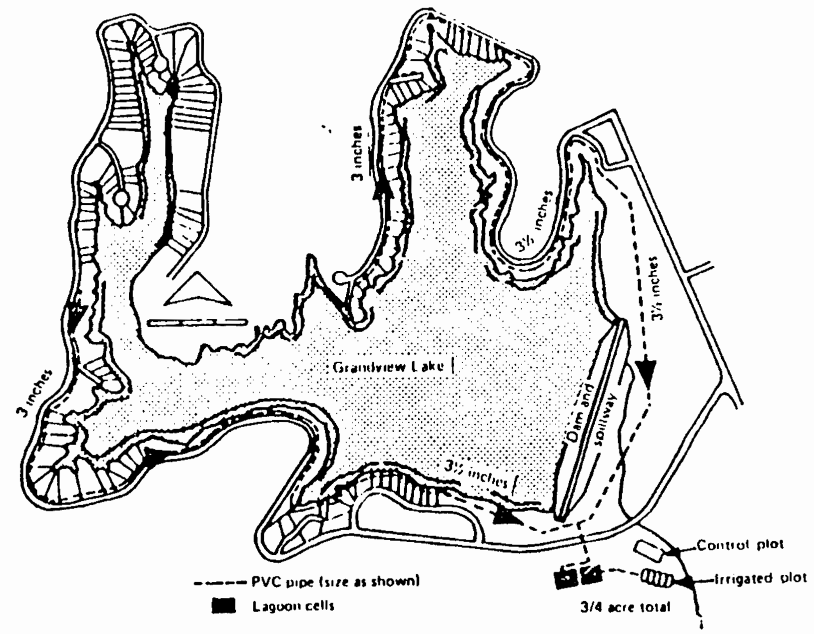

Figure 4. Grandview Lake, IN pressure sewer system prior to expansion.

Figure 5. Typical Hydr-O-Matic slide rail pressure sewer pump installation at Grandview Lake, IN.

The treatment system receives only pressure sewage from Grandview Lake. It consists of two lagoons, 39.6 m x 36.6 m (130 ft x 120 ft) each flowing into a common clarifier and chlorinator unit, then to a metering chamber with a V-notch weir. Some dilution water is added from the lake to the effluent, but dry weather sewage flow is estimated to be 38 - 57 m^3/day (10,000-15,000 GPD). Design capacity for the Hinde aeration lagoons is 228 m^3/day (60,000 GPD).

Effluent limits are 30 mg/l BOD_5 and 30 mg/l SS. Effluent sampling showed the lagoon was able to meet these limits. BOD_5 and SS removals are within effluent limits, and ammonia nitrogen effluent concentrations, during the period that data are available, show excellent results. Effluent temperatures ranged from a high of 24.9° C down to a low of 11.3° C.

The system has no central operation and maintenance force; all service calls are performed by local pump representatives. Preventive maintenance is not performed on the pumping units or the piping system. Maintenance on the pump units is performed by an Environment/One representative in Indianapolis (previously Ralph Conn in Clarksville, IN), and Hydr-O-Matic pumps are maintained by Dick Sherwood in Greenwood, IN.

The Lake Association charges $65.00 per year to each lot owner, plus $7.00 per month as a user fee for occupied lots. New connections must install a pump unit themselves, at a cost of $1,800 to $2,000 complete, plus pay a $125 tap-on fee.

Horseshoe Bay, TX

The Horseshoe Bay pressure sewer system near Marble Falls, TX, was designed by Coulson and Associates, Houston, TX. The system is in an expensive development on Lake Lyndon Baines Johnson, an impoundment of the Lower Colorado River. The system was installed in late 1971.

The Lower Colorado River Water Authority has specific requirements for septic tank installations bordering the Lower Colorado River. Between 0 to 61 m (0 to 200 ft) from the river, septic tank installation requirements are extremely severe, essentially prohibiting their use. The requirements are somewhat less restrictive, but still severe for the next 610 m (2,000 ft). Beyond 671 m (2,200 ft), conventional requirements apply.

The Phase 1 pressure system includes 607 ha (1,500 ac) with a potential of 4,500 dwelling units. A 1,093 ha (2,700 ac) ranch nearby has been acquired for future development. Design criteria assume a population for Phase 1 of 6,000, and a flow rate of 0.38 m^3 (100 gal) per capita per day. About 410 connections on the pressure sewer system have been installed. Approximately 19,800 lineal meters (65,000 lf) of 10.2, 15.2, 20.3, 25.4, and 30.5 cm (4, 6, 8, 10 and 12 in) pressure sewer main have been installed with about 3,050 m (10,000 ft) presently under construction in a mobile home area. Pressure sewer pipe is rated at 1,110 kPa (160 psi) with a working system pressure of 243 kPa (35 psi). The pipe is buried at a depth of 76 cm (30 in) with cleanouts at the ends of pipes. Special flushing devices are located throughout the system, and are operated by an electronic timer. There are about 125 Environment/One grinder sewer pumps and about 60 Hydr-O-Matic Hydrogrind pumps installed.

Horseshoe Bay clubhouse and 60 original condominium units were served by four experimental General Electric grinder pump units until 1974. They caused continual maintenance problems for the system operator. In 1974, the four General Electric units were removed and three 1.1 KW (1.5 hp) Hydr-O-Matic Hydrogrind pumps were installed. In 3 1/2 years of operation, there have been no problems. Recently, these pumps were refurbished on a scheduled basis. Dual cutters in the clubhouse Hydrogrind units are still sharp enough to be workable; however, impellers have shown severe pitting and corrosion due to impact of aluminum foil from baking potatoes as well as other wastes from the kitchen area.

Although many areas of the pressure sewer system at Horseshoe Bay are uphill from the treatment facility, the pressure system was used throughout the entire development, except for the septic tank area, which is well back from the lake. Two reasons the pressure sewer system was used in an area that potentially could be served by gravity were: 1) rock was close to the surface which required dynamiting trenches for installations of both sewer and water lines within the same trench (at a maximum possible separation) and 2) the landscape planner wanted to save as many existing trees in the area as possible. In a conventional gravity sewer system, installed in straight lines between manholes, many trees would have to be removed. With the pressure sewer system, however, tree removal was reduced to a minimum.

Three 30.5 cm (12 in) and one 25.4 cm (10 in) pressure sewer lines deliver sewage to the treatment plant. The treatment plant is a 379 m^3/day (100,000 GPD) Neptune Microfloc package facility. Discharge standards are 5 mg/l BOD_5, 5 mg/l SS, and 1 mg/l phosphorous. Treated effluent is discharged to a holding pond and then pumped to a golf course holding pond. At the golf course holding pond the effluent is diluted by lake water on the order of ten to one. The water is used to irrigate the golf course.

There is a 1,893 m^3/day (500,000 GPD) Neptune Microfloc unit completed and ready for use. This plant will begin operation as plant flows exceed the design capacity of the original 379 m^3/day (100,000 GPD) plant.

Port Charlotte, FL

The General Development Company, a subsidiary of GDV, Inc., has developed over 95,000 ha (235,000 ac) on the Atlantic and Gulf coasts, and the south central lake country of Florida. Nearly 60,000 people live in seven General Development Company properties. Table 1 shows areas and populations for these properties.

TABLE 1. GENERAL DEVELOPMENT PROPERTIES, FL

Location	Area (hectares)	(acres)	Population
Port Charlotte and North Port	40,000	100,000	35,580
Port St. Lucie	19,600	48,500	10,295
Port Malabar	17,500	43,200	7,685
Port Labelle	12,700	31,500	115
Port St. John	2,200	5,500	1,725
Sebastian Highlands	2,000	5,000	685
Vero Shores and Vero Beach Highlands	650	1,600	835

Utility construction and service to these communities are provided by a subsidiary division, General Development Utilities, Inc. General Development Utilities is a regulated utility company with over 1,480 km (925 mi) of utility lines, 15 operating facilities and 5 gas plants, representing an investment of nearly $40,000,000. Active in research and development, General Development Utilities has been instrumental in the evolution of a pressure sewer system designed to relieve wastewater disposal problems and rising costs of conventional systems. The new system, called "Suburbanaer", has received conditional approval from the State of Florida and a demonstration project has been constructed at Port Charlotte. Testing continues at Port Charlotte and Port St. Lucie.

In conjunction with Suburbanaer, the utility subsidiary has an extended aeration facility for treating septic tank effluent and has been conducting tests on a demonstration "Bullrush" area of reed-like water plants for possible use as a virtually energy-free treatment process (Figure 6).

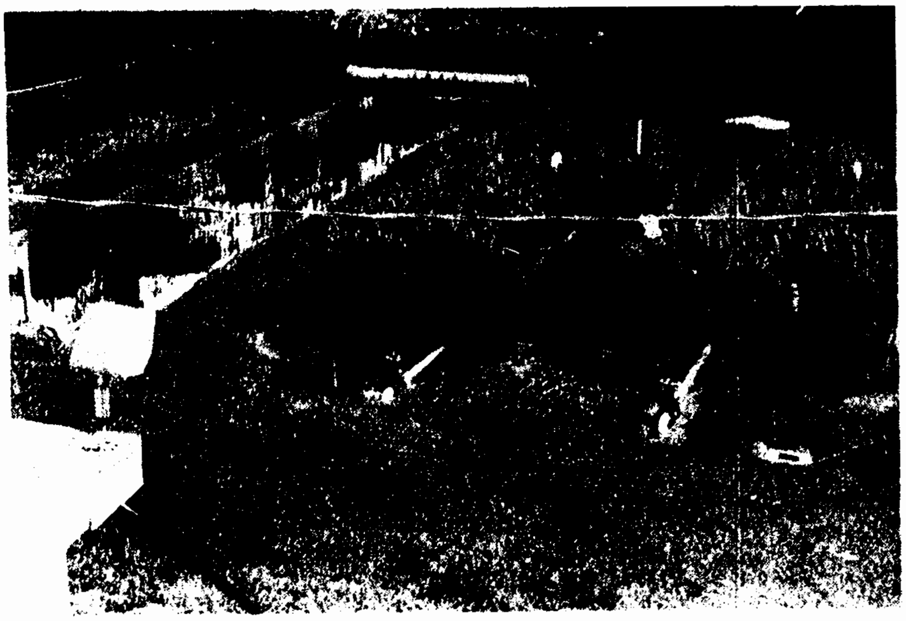

Figure 6. "Moses" treatment plant using scirpus (bullrush) phragmite (reeds), Port Charlotte, FI.

General Development Utilities' President, Harold Schmidt, was interviewed in connection with this project. He described the system in general, a state monitoring program for the next 230 interceptor tank/pumping units to be installed, and system performance and operation. However, he declined to be specific on design details, operation requirements, maintenance history, economics, or treatability.

There are two areas in Port Charlotte with pressure sewers, Section 54 (the older original area with its own treatment plant, also called Gulf Cove Area shown in Figure 7) and Section 18. Other areas are planned, and are being designed using a computer program.

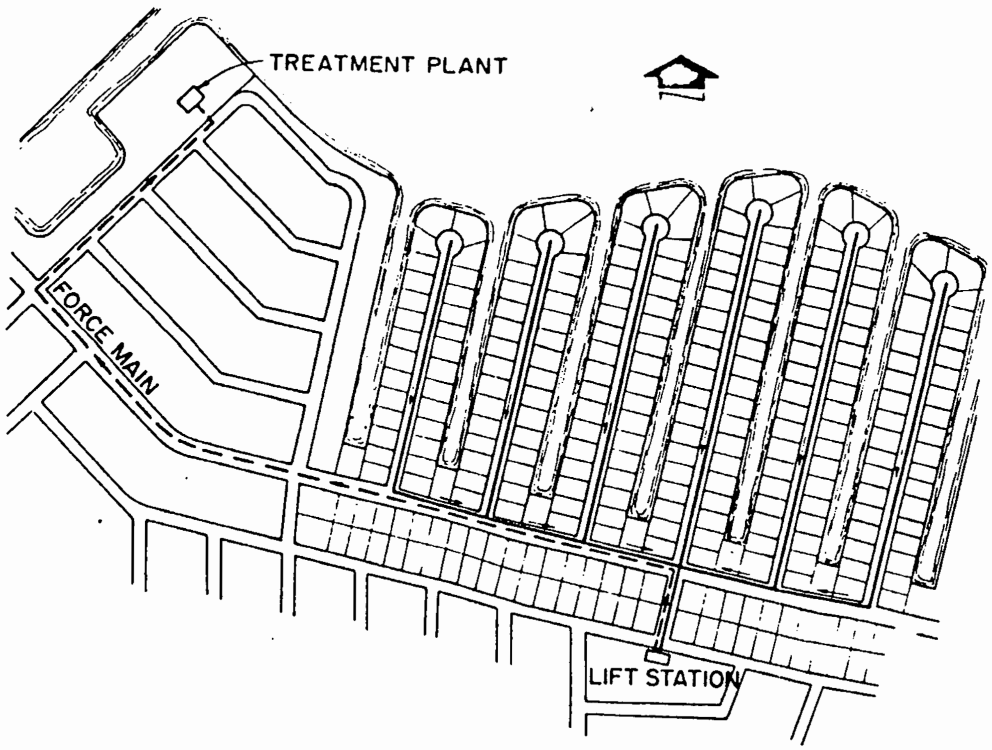

Figure 7. Gulf Cove pressure sewer area,
Port Charlotte, FL.

Homes in Port Charlotte originally had no warning system. All newly installed units have alarm systems and all old units have or will have battery-operated remote control warning systems retrofitted.

Original pumping equipment at Port Charlotte was Hydr-O-matic SP-33 sump pumps, but rapid failures were experienced. Presently, oil filled OSP-33 Hydr-O-Matic pumps are used. A new type of mercury float with a delayed off switch will be tested for potential replacement of the troublesome pressure switch, and a new type of high level alarm transmitter (in prototype) also will be evaluated.

The Gulf Cove area has six streets, all with 7.6 cm (3 in) push-tite Johns-Manville pipe, flowing to a pump station where chlorine or ozone could be injected, but is not, according to the operator. Odors were not noticeable anywhere at the site, including the conventional treatment facilities and the Bullrush "Moses" plant.

Port St. Lucie, FL

Port St. Lucie also is part of the General Development Company properties, and likewise is serviced by General Development Utilities, Inc. Much of the information on this system was obtained from Paul Kloser, General Development Utilities engineer. He works on both the Port St. Lucie and Port Charlotte pressure sewer systems, spending three days per week at Port St. Lucie. Mr. Kloser is assisted by a maintenance man at each location and part of their time is spent on installation supervision.

The Port St. Lucie Suburbanaer system became operational August 1, 1973, and presently serves 191 homes, each having an interceptor tank/pumping unit. Table 2 lists the year and number of units installed each year.

TABLE 2. PORT ST. LUCIE SUBURBANAER SYSTEM

Year		Number Units Installed
1973		12
1974		60
1975		38
1976		29
1977		46
1978*		6
	Total	191

* Through February, 1978.

Klaus System, Portland, OR

Portland, OR is located at the confluence of the Willamette and Columbia Rivers. Numerous residents reside in houseboats and originally disposed of their wastes directly into these rivers. In 1967, the Oregon Department of Environmental Quality required all houseboats to eliminate raw sewage discharges. Several homeowner organizations had pressure collection systems designed and installed in the approximately 25 moorages in the Portland area (Table 3). Various modes of treatment exist: pumping to gravity sewers, septic tanks and drainfields; small package sewage treatment plants, floating package plants, and floating or land-based septic tanks (Figure 8). Table 3 also shows many of the moorage sizes and types of treatment used.

Each houseboat uses a Peabody Barnes solids handling pump, capable of passing 5.1 cm (2 in) solids. Pumps are housed in galvanized steel basins, with newer units in fiberglass basins (Figure 9). A 3.8 cm (1.5 in) flexible hose carries the pumped waste to a mainline pressure sewer. The 0.2 m^3 (50 gal) basins are suspended from the houseboats. Pumps operate over a 25.4 cm (10 in) differential pressure, pumping 0.04 to 0.06 m^3 (10 to 15 gal) per operation. Power is supplied either with a conventional plug in an outdoor receptacle or through an NEMA 3 cabinet. Pump discharges have swing check valves constructed of both bronze and brass mounted horizontally and vertically.

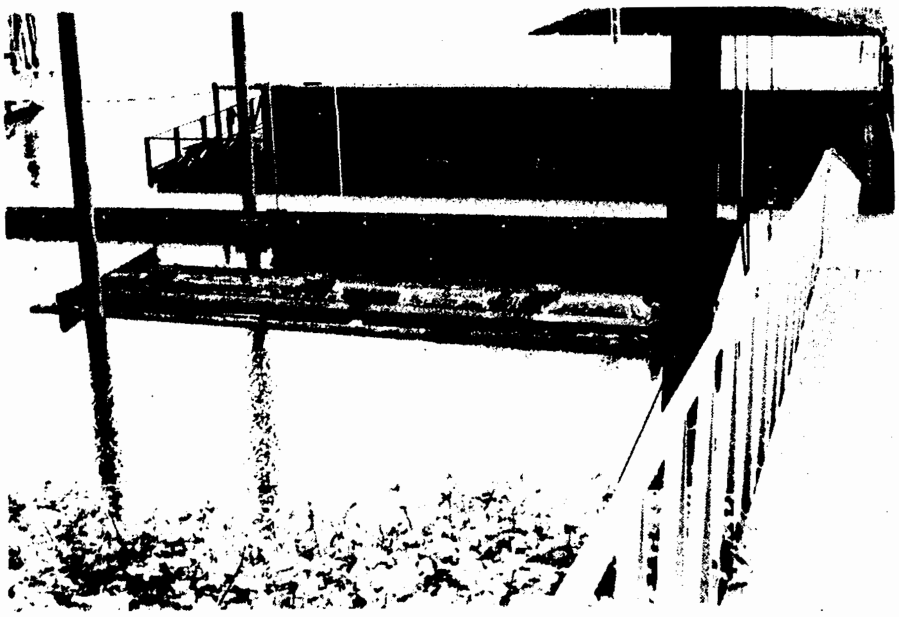

Figure 8. Floating septic tanks.

TABLE 3. HOUSEBOAT PRESSURE SEWER SYSTEMS NEAR PORTLAND, OR

Number of Houseboats	River	Location	Treatment
250 - 300	Columbia	Hayden Island	To secondary STP
80	Columbia	East of airport - 3 close together	Pump to sewer
	Columbia	3 moorages at 185th - 190th	Floating septic tank
	Columbia	4 moorages just east of airport	
100	Columbia	13 moorages just west of I 5	
32	Columbia	South side of Tomahawk Island	
40 - 50	Columbia	North side of Tomahawk Island	To sewer
10	Willamette	I 205	To sewer
60	Willamette	2 moorages east side just south of downtown	To sewer
50 - 60	Willamette	East side of downtown	Septic tank on land
20 - 25	Willamette	West side of downtown	To sewer
125	Willamette	U. S. 30 and Sauvies Island	1 to sewage lagoon 4 to septic tank
50 - 60	Willamette	Sauvies Island	Floating S & L STP
20	Willamette	West of Sauvies Island	To floating STP
35	Willamette	West of Sauvies Island	To lagoon
25 - 30	Willamette	West of Sauvies Island	Septic tank on land
28	Willamette	West of Sauvies Island	Small S & L STP

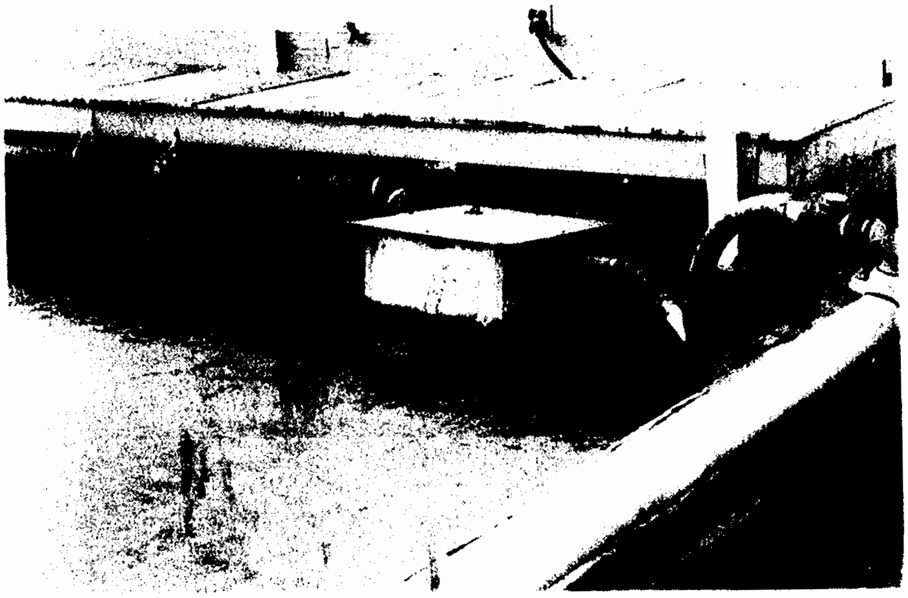

Figure 9. Houseboat pumping unit.

Pump operation is controlled by pressure switches, but due to problems, mercury floats are now being installed. Pump malfunction is noticed by the homeowner when a toilet backs up or acts sluggishly.

Pipe material is ABS solvent welded with some PVC solvent welded Schedule 40. Pipe rated at 694 kPa (100 psi) PVC was considered too thin. Pipe jointing is by solvent welding with rubber expansion and flex joints between some sections to account for movement (Figure 10). The suspended pipe under walkways is ABS or PVC, with cast iron or ductile iron where underground construction was necessary. Depth of burial was 0.9 to 1.2 m (3 to 4 feet).

Figure 10. Flexible pipeline connector in Klaus system, Portland, OR.

Coolin and Kalispell, ID

Information gathered on these two systems, both located on Priest Lake, is based upon interviews and discussions with Messrs. Chris Warren, head of maintenance; Ken Durtschi, system designer, Couer D'Alene, ID; and Bert Kilbeck, head of the repair department of Dickerson Pump and Irrigation Company, Spokane, WA.

When the systems were originally installed, Coolin had 345 customer equivalents, and 11 more have been added, making a total of 356. Kalispell had 218 original customer equivalents, and has since added 14 new hookups for a total of 232 (Figure 11).

Treatment data is non-existent, due to the complete lack of testing. Because no effluent is discharged from this system, testing is not required. The three cell lagoon system has a net evaporation loss, but spray irrigation facilities are provided to spray effluent on nearby forestland if an accumulation of sewage above maximum lagoon liquid level were to take place.

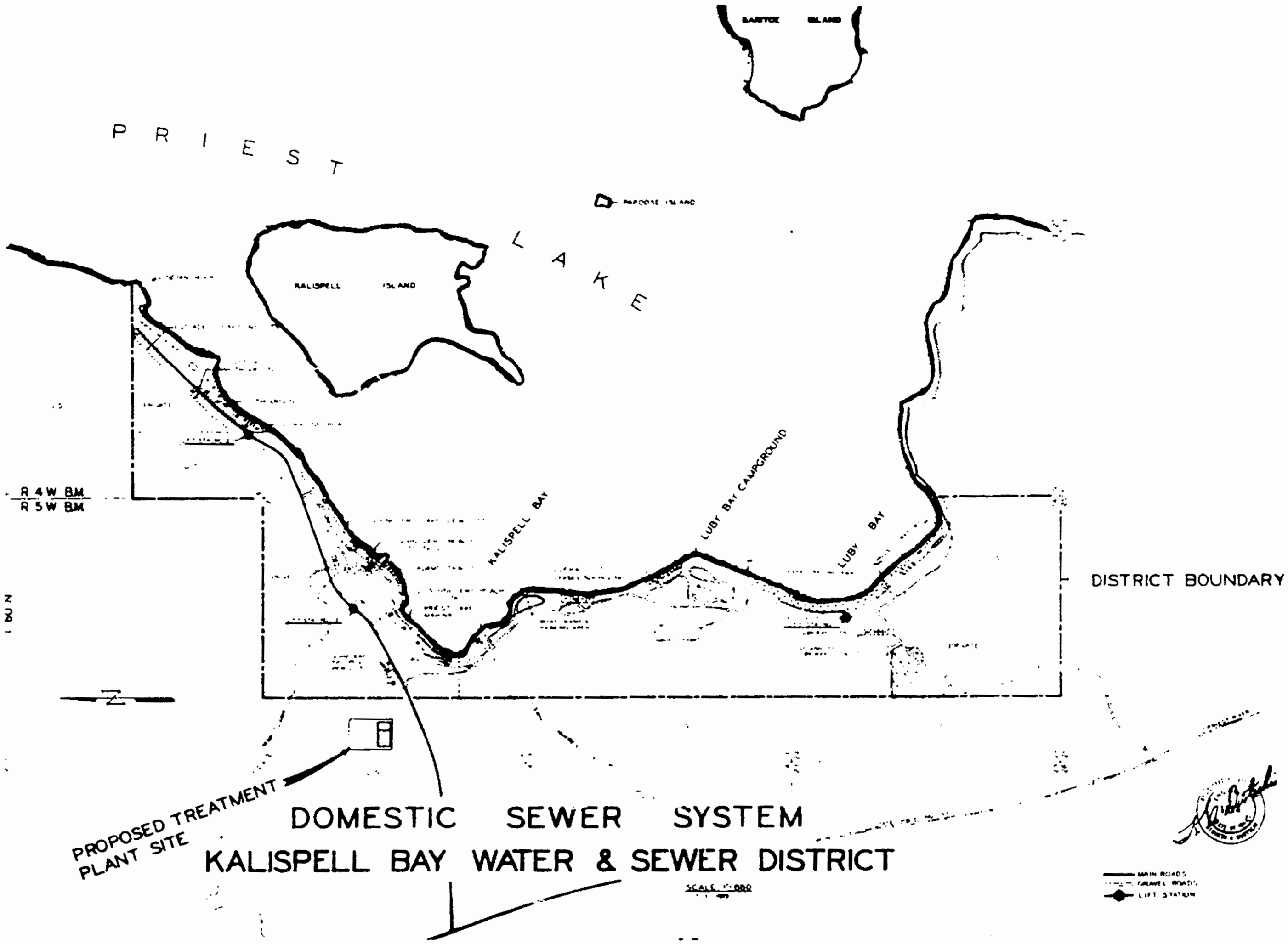

Figure 11. Domestic sewer system, Kalispell Bay Water & Sewer District.

Weatherby Lake, MO

The city of Weatherby Lake, 19 km (12 mi) northwest of Kansas City, MO, had on-site disposal systems which were polluting Weatherby Lake so severely that Larkin and Associates were hired in 1971 to devise a community collection system. A pressure sewer system was chosen as the most cost-effective solution, and presently 362 Environment/One pumps serve the community (Figures 12 and 13).

The design engineer, Glen Gray of Larkin and Associates, reported (11): "The final project design consisted of 309 grinder pump units; 10,700 lm (35,000 lf) of main pressure sewer located in the street rights-of-way and varying in size from 5.7 cm to 15.2 cm (2 1/4 to 6 in); 11,300 lm (37,000 lf) of 3.2 cm 1 1/4 in) pressure service lines from pumps to street mains; 42 air release valves; 24 flushing and cleanout connections and 1,600 lm (5,300 lf) of 20.3 cm (8 in) gravity sewer for connection to existing Kansas City interceptor sewers. Electrical load centers in raintight enclosures are located on an outside wall of each house for easy access by maintenance personnel. Located with the load centers is a receiver tank high water level alarm horn to alert not only the homeowner but neighbors in case of pump failure. Recorders are to be installed at four selected points to monitor the system pressure over a long period of time. Hopefully, this will furnish data for refinement of future designs and provide an indication of probable maintenance requirements."

The low pressure sewer system is constructed of SDR-26 (1,112 kPa or 160 psi rated) PVC pressure pipe. Solvent welded joints were specified because of favorable experience in achieving pressure-tight continuous lengths of pipe with built-in thrust takeup. However, the contractor requested, and was permitted to use, compression type gasketed joints, and added thrust blocks where necessary to resist the possibility of axial movement. Since the normal system pressure will be 243 kPa (35 psi) or less, a static pressure test 416 kPa (60 psi) for two house was specified. In those portions of the system which were laid through rock, a rock saw was used, and sand bedding and backfill was placed around the pipe. Otherwise clean earth backfill was used and no unusual precautions were required.

Treatment data is unavailable since the Weatherby Lake system pumps to the Kansas City municipal system. The treatment plant treating this waste receives approximately 99% gravity collected sewage and 1% pressure sewage.

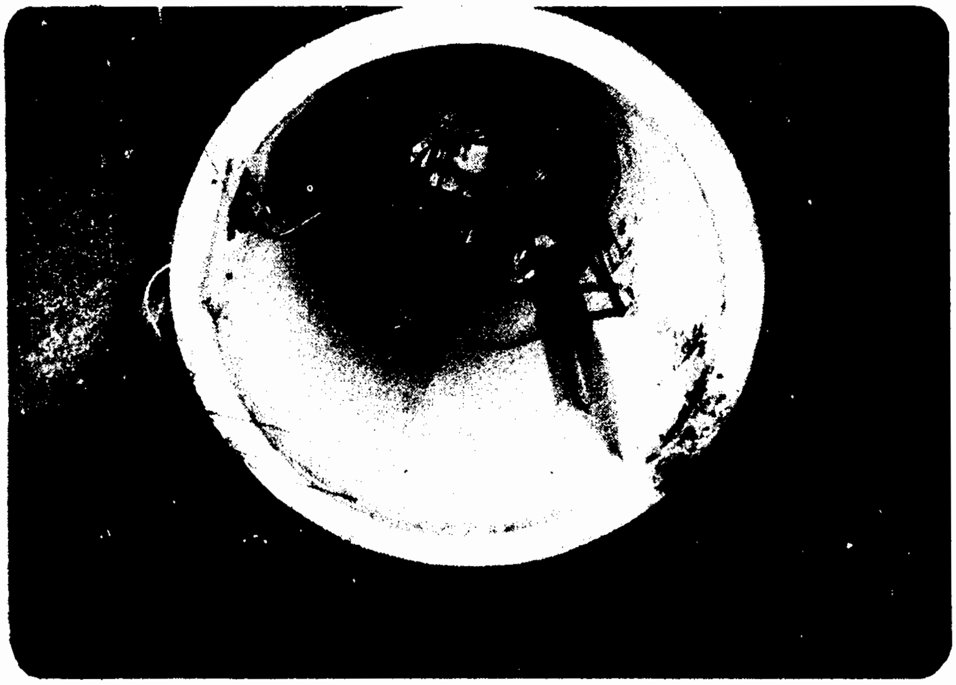

Figure 12. Weatherby Lake, MO pressure sewer system pump chamber.

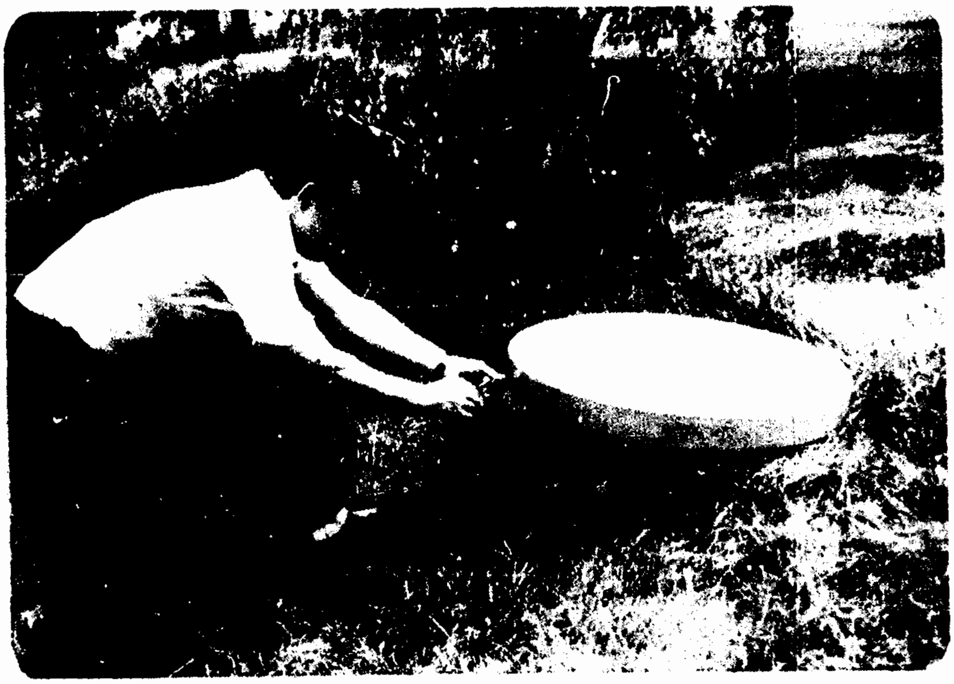

Figure 13. Access to Environment/One pump chamber.

Clifton Park, NY

The Country Knolls South development, north of Albany, NY, in the town of Clifton Park, is owned and operated by Robert Van Patten. Country Knolls now has 355 homes with a projected ultimate development of 510 homes. Environment/One grinder pumps are used (Figure 14). On the grounds that this is a privately owned system, Mr. Van Patten declined to give installation and O & M for the majority of the system. He also preferred not to disclose treatment costs and performance data.

The system was started in 1972 and is located only a few miles from the Environment/One manufacturing plant in Schenectady. As a result, the system has been studied extensively by the manufacturer.

The treatment facility originally was an Environment/One plant. However, this plant was taken out of service recently and the system is now served by a county interceptor sewer.

Figure 14. Inside home installation, Country Knolls Subdivision, Clifton Park, NY.

Kappas Marina, Sausalito, CA

Kappas Marina is located at Gates 6 and 6 1/2 in Sausalito, CA. There are 117 users on the two systems. Residents on Gate 6 use a combination of a total of 82 grinder pumps manufactured by Environment/One, Hydr-O-Matic, Peabody Barnes, and Toran, while Gate 6 1/2 residents use Peabody Barnes solids handling pumps, capable of passing a 5.1 cm (2 in) sphere.

All houseboat - mounted pumps discharge to 3.8 cm (1.5 in) B. F. Goodrich radial flex piping which connects into an Andrews bronze quick disconnect through a 90° elbow. Flow then passes through a bronze T pattern flap check valve, cast iron plug valve, and into the main through a DeSanno #87 bronze connection combined with a 7.6 cm x 7.6 cm x 5.1 cm (3 in x 3 in x 2 in) PVC tee with a threaded end (Figure 15). The two systems have 430 m (1,410 ft) of 7.6 cm (3 in) PVC collection main flowing to a lift station, and 520 m (1,700 ft) of 15.2 cm (6 in) force main. Gate 6 pumps are all grinder pumps, including 52 Environment/One, 23 Peabody Barnes, 5 Hydr-O-Matic and 2 Toran.

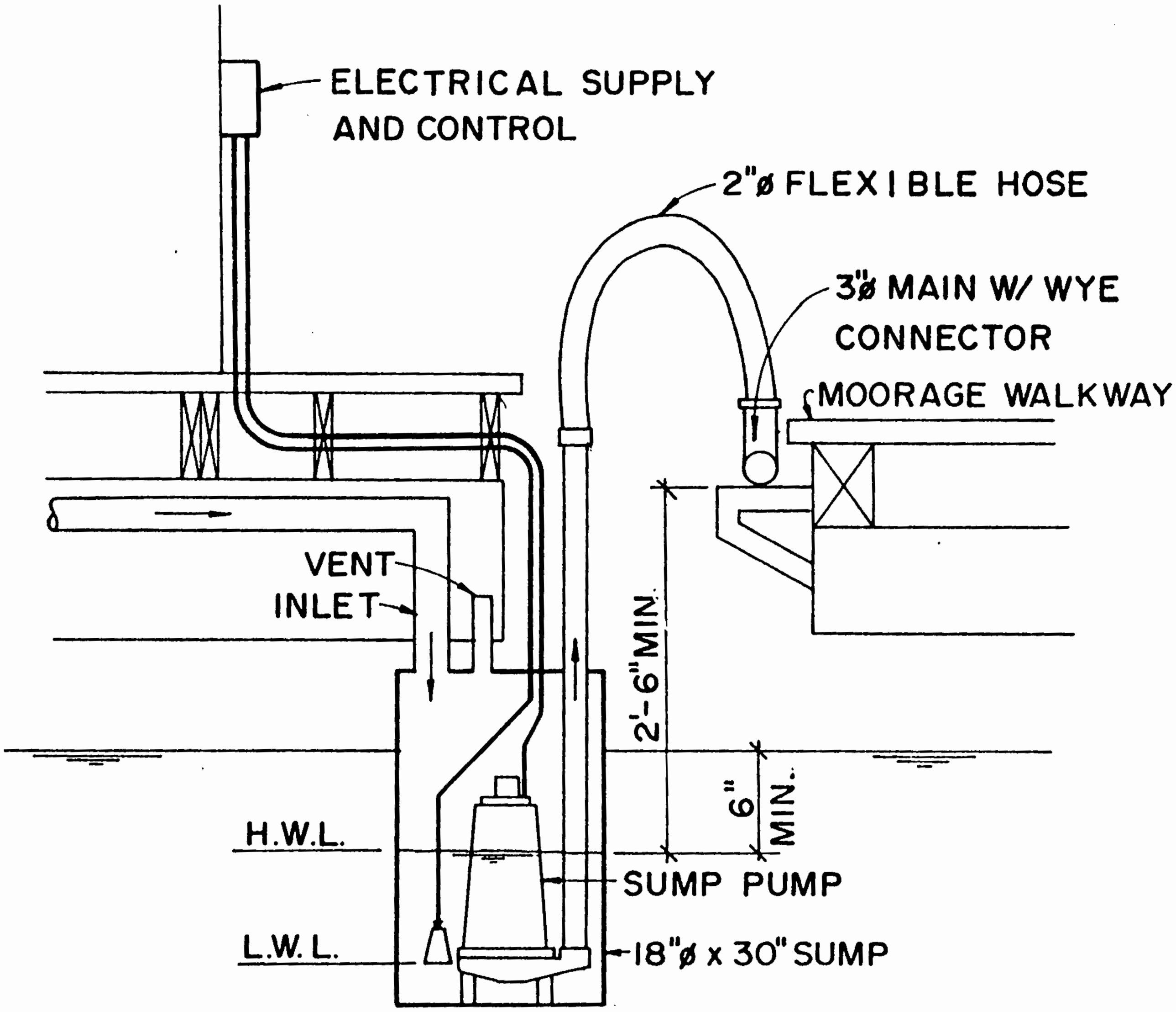

Figure 15. Details of Sausalito, CA's pressure sewer pump installation.

Lake Mohawk, OH

The Lake Mohawk development is located in Malvern, OH, approximately 32 km (20 mi) southeast of Canton. The development, started in 1963, surrounds a 206 ha (508 ac) lake with approximately 1,660 lots. Currently, the pressure sewer system is served by 225 Environment/One grinder pumps. Environment/One has a multi-year O & M contract for both the pressure sewer system and the treatment facilites for this private, second home development lake area. John Robertson, the system operator, is under contract with Environment/One. He also owns the central water system.

Originally, on-lot waste disposal was planned and installed on some lots using individual septic tank systems, but failures due to unsuitable soil caused the concept to be abandoned. The homeowners association then looked at various alternatives. The gravity sewer estimate proved too costly, so, in 1974, engineers investigated a pressure sewer system alternative which was accepted. The contract was let with an individual lot assessment of $640 which included all collection mains and the treatment plant If an existing septic tank system fails, then an outside pump installation is necessary. The original owner of the O & M contract, the Ohio Environmental Service Corporation (now defunct), sold their contract to the Environment/One Corp.

Robertson's responsibilities include installation of the pumps in new houses or replacement of an existing failed septic tank system with outside Environment/One units. He handled 80 service calls during 1977 on approximately 210 units. The engineer for the system, Friedal and Harris, North Canton, OH, designed the pressure sewer system into 3 zones, having six lift stations, three on each side of the lake.

Two treatment plants operate side by side. One is an Environment/One batch type physical-chemical-biological treatment plant and the other is an extended aeration facility. The extended aeration plant is located outdoors and the Environment/One plant is covered. Total plant design capacity is 758 m^3/day (200,000 GPD). Each of the two plants account for half of the design flow capacity. Effluent from both of these plants flow into a Hydroclear tertiary filter unit.

Seabrook, TX

The Seabrook, TX, pressure sewer system uses Hydr-O-Matic Hydrogrind grinder pumps to deliver pressure collected sewage from two streets and a boat docking area to gravity mains which flow to a STP. Presently, there are three duplex units and 22 simplex units installed (Figure 16).

Seabrook is located on Galveston Bay, about 32 km (20 mi) southeast of Houston, TX. Because of rapid population growth, municipal wells withdrew water from the shore area of Seabrook at a rate faster than fresh water could be replenished. Hence, the ground structure subsided, lowering the local ground elevation. Large areas of Seabrook, including platted streets and lots, are now under water. As a section or area of the gravity sewer system became unusable due to its invert sinking below the subsequent downhill invert, the section is replaced by pressure sewer mains and pumps.

Ultimately, when all gravity sewers become unusable, the pressure sewer system will deliver the total sewage flow under pressure to the treatment plant. Ground is subsiding so fast that a small lift station at the corner of 11th Street and Toddville Road that was three feet above ground ten years ago is now three feet below grade.

Figure 16. Hydr-O-Matic pump equipment mounted below residence.

Point Venture, TX

The Point Venture pressure sewer system is located approximately 32 km (20 mi) from Horseshoe Bay, across the Lower Colorado River, 64 km (40 mi) northeast of Austin, TX. It is a recreational development with 125 townhouses and 17 single family homes. An additional 37 single family homes are expected to be built. The system operator is Wilson McDougal. The system uses 37 Environment/One pumps, both simplex and duplex, to pressurize sewage for transport in small diameter PVC mains to a wastewater treatment facility. Townhouse units are served by duplex Environment/One pump units; however, there was only one workable pump in most duplex units. The other unit was out for repairs.

The pressure collected sewage flows to a contact stabilization package treatment facility and then to a holding pond, which takes the treated sewage plus 5 times as much lake water to achieve a diluted mixture. It then flows to a polishing pond. From the polishing pond the water is pumped intermittently to the golf course for spray irrigation.

SECTION 5

DESIGN OF ON-LOT FACILITIES

SYSTEM COMPONENTS

General

On-lot pumping components are the heart of the pressure sewer system. These components must be thoroughly investigated and designed to function as a coherent system for all components to function effectively. STEP components normally include the interceptor tank for removing as much grease and solids as possible; the pumping chamber, which houses the effluent pump; the effluent pump itself; discharge piping including check and discharge shutoff valves; control systems for turning the pumps on and off; high level alarms; overflow device; and service lines (Figure 17). GP components include a holding basin with sufficient volume to accumulate enough liquid for a 1 to 2 minute GP cycle operation; grinder pump, with a combination grinding and macerating unit attached to the bottom of the pump; discharge piping including check and discharge shutoff valves; control circuits and components for operating the units; an alarm system to alert the homeowner that a high level is exceeded in the storage tank; and on-lot piping between the pump tank unit and the main in the street (Figure 18). Both the STEP and GP units must have power supplied to the units either through a control cabinet mounted nearby or through a conduit directly into the chamber unit which also contains the controls. Service connections on both types of systems are the same.

Piping components and treatment systems applicable to pressure collected sewage are covered in other sections. Engineering design of the types of units selected will be covered briefly because they are well detailed in other publications. The following sections deal primarily with descriptions of existing types of units. It should be noted that most manufacturers offer the above components as package units. However, some cost savings may be realized by the engineer putting together his own package components rather than relying on the manufacturer's selections.

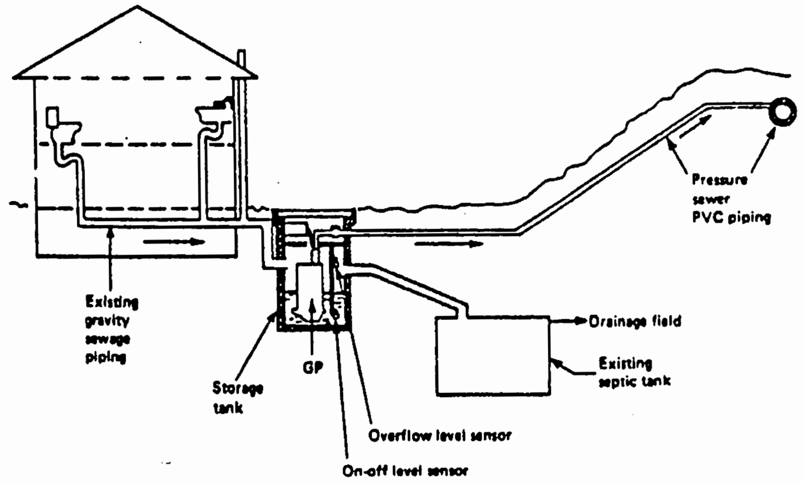

Figure 17. Typical grinder pump on-lot facilities.

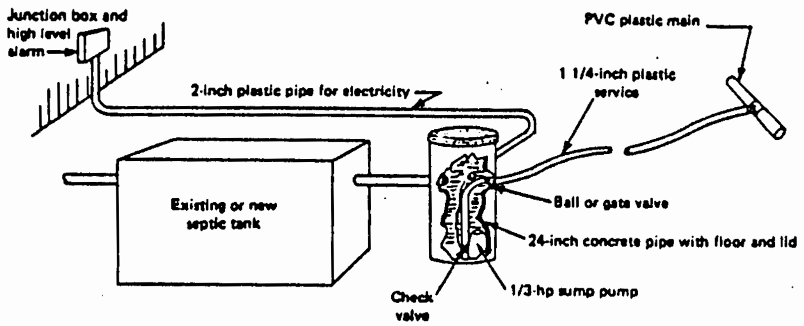

Figure 18. Typical STEP system on-lot facilities.

STEP ON-LOT FACILITY

Interceptor Tank

The function of the interceptor tank is to remove as much grease and solids as possible and may provide storage volume in case of a power outage. Interceptor tanks are either constructed out of concrete, steel (usually coated with protective bitumastic covering), fiberglass or polyethylene. In some systems, existing septic tanks which are found to function well and in good structural condition are used for this purpose. In most situations, the existing septic tank is unsuitable and a new tank is required. If a concrete tank is used, it usually is rectangular and has a separate pumping chamber. Its advantage is that it may be obtained locally and usually is the lowest in cost. Steel septic tanks are used in the Priest Lake, ID, systems at Coolin and Kalispell Bay. The tank size varies from 300 to 700 gallons, they are cylindrically shaped and installed vertically.

The majority of newer septic tanks used in these systems are fiberglass. Fiberglass is the material of choice in the Florida General Development Utilities systems, and at Glide-Idleyld, OR (Figure 19). The fiberglass units usually are cylindrically shaped, installed horizontally and contain between 3.4 m^3 and 4.17 m^3 (900 and 1,100 gal). The pump chamber is integral with these units. The major advantages are water-tightness and corrosion resistant. They are constructed with a continuous layer of resin over the fiberglass media. Construction is simple and the tanks are significantly lighter. In Florida, with a high groundwater table, the fiberglass tanks are placed over a trenched out area, filled with water, and allowed to sink into the hole.

The tanks are usually maintained with a high water level. GP tanks, however, which usually have a variable working volume might require a concrete anti-flotation collar. Working volumes vary from 1.1 m^3 (300 gal) at Priest Lake, ID to almost 3.8 m^3 (1,000 gal) at Bend, OR.

Pump Chamber

The septic tank effluent pump chamber can either be an integral component of the septic tank or a separate chamber mounted adjacent to the septic tank. The pump chamber usually contains the effluent pump, on - off controls, a high level control, discharge piping and valves and a means of quick disconnecting the pump from the effluent piping. If the pump chamber is separate from the septic tank, it usually is mild steel with a bitumastic coating. Covers also are steel with a bitumastic coating and are bolted down, but infrequently sealed. The

Figure 19. Septic tanks used in Glide-Idleyld, OR system.

chamber usually has a 7.6 and 10.2 cm (3 or 4 in) inlet from the septic tank and a 2.5 cm, 3.2 cm, or 3.8 cm (1 in, 1-1/4 in or 1-1/2 in) pump discharge pipe diameter. A maximum liquid depth of 0.6 m (2 ft) is provided with pump operation usually commencing when the sewage level is approximately 0.5 m (1-1/2 ft).

The method of mounting the pump within the effluent chamber varies with design. There is a suspended system where the discharge piping is installed through the basin cover and the piping and the suspension rod locate the pump. Since this piping is through the cover a manway must be added to extend the basin cover to ground level. This depth depends on the local frost line and the system is infrequently used. More typical is an effluent pump system where the pump is self-supported in the basin and the discharge piping is connected through the wall of the pump basin. Disconnection between the pump and discharge piping is made possible by either a slide rail type system with a quick disconnect coupling (Figure 20), or a union (Figure 21), or with a pump connected to the discharge pump piping with flexible plastic hose. The union type system is used in General Development Utilities, Florida systems and Priest Lake, ID. The flexible hose connection is used in Glide-Idleyld, OR (Figure 22).

The experimental pressure sewer system at Bend, OR had a fiberglass pump chamber. This system used guiderails for ease

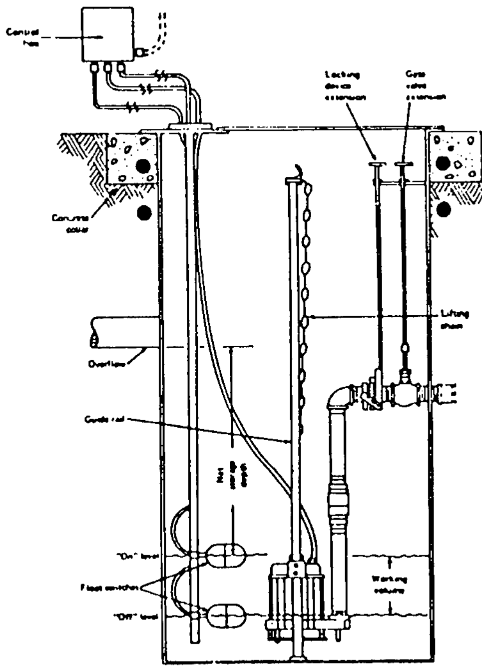

Figure 20. Typical effluent pump guiderail type system.

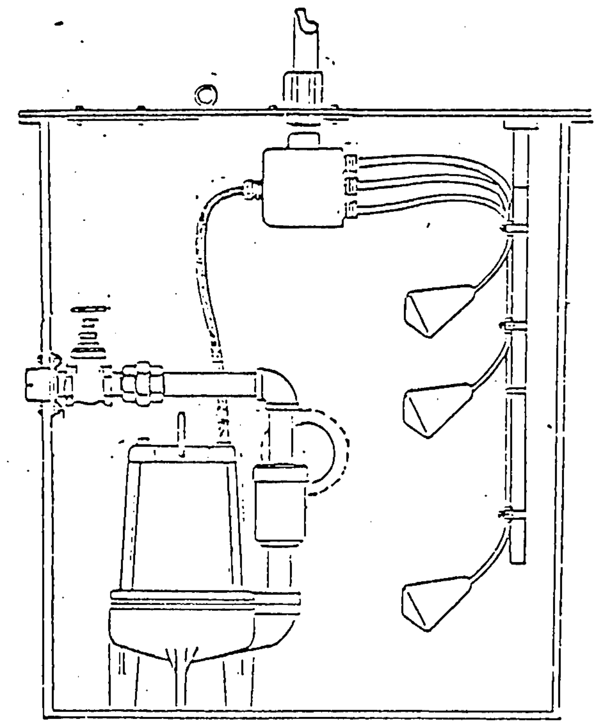

Figure 21. Typical effluent pump union type system.

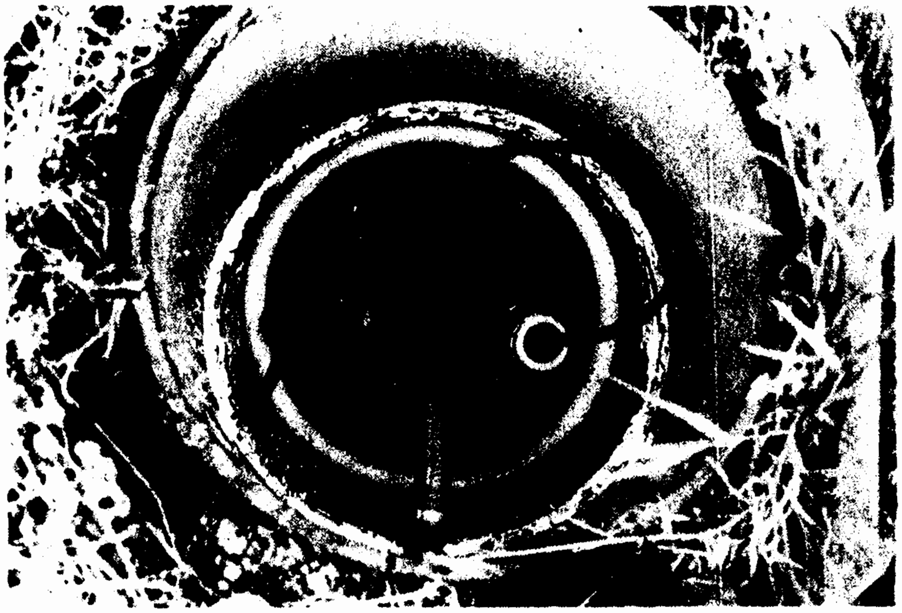

Figure 22. Typical pump chamber in Glide-Idleyld, OR system.

of pump removal. The range of liquid accumulated in the pump chamber to be discharged on each working operation varied from 0.11 - .27 m^3 (30 - 70 gal) in the various systems studied.

Effluent Pumping Equipment

Two types of pressurization devices can transport septic tank effluent to a treatment facility: submerged, non-clog centrifugal sewage pumps manufactured typically by Hydr-O-Matic or Peabody Barnes, and the pneumatic ejector (Figure 23) currently being field tested in various systems by Franklin Research and Clow Corporation. Submersible centrifugal non-clog pumps currently are used in Florida, Priest Lake, ID, and the Glide-Idleyld, OR. The Florida and Priest Lake systems use Hydr-O-Matic sump pumps with varying Hp requirements of 0.25, 0.3, 0.37, 0.75, and 1.5 kw (0.33, 0.4, 0.5, 1 and 2 Hp) with shutoff heads varying from 7.3 to 31 m (24 to 120 ft) at capacities of up to 0.8 m^3/minute (220 GPM). Sizing of pumps depends on the combination of friction and elevation losses to be overcome.

The Port Charlotte and Port St. Lucie Hydr-O-Matic pumps are oil filled Model OSP-33A, usually operating at a discharge capacity between 0.08 and 0.19 m^3/minute (20 and 50 GPM). The

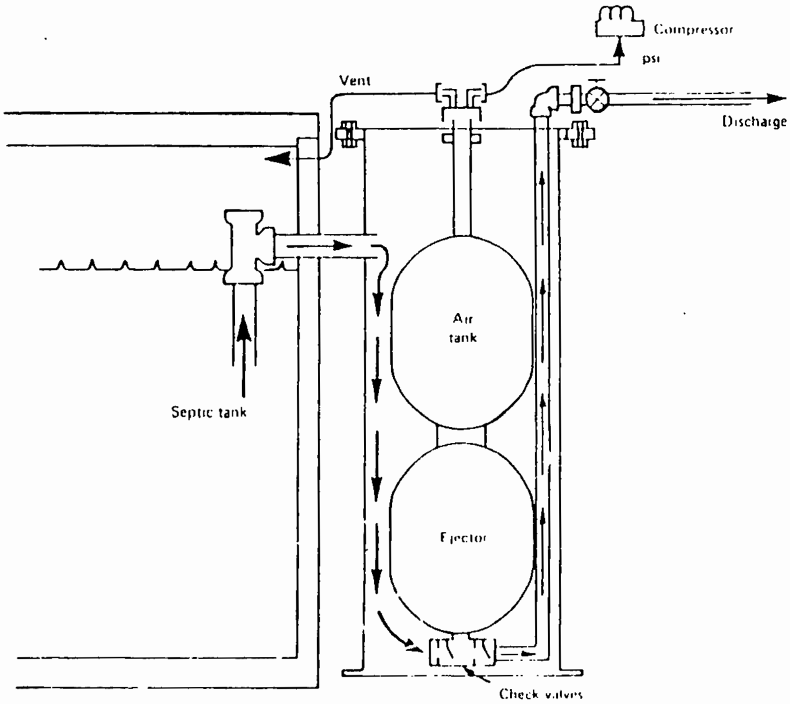

Figure 23. Pneumatic ejector for use in pressure sewer system.

Bend, OR system uses the Peabody Barnes 0.37 kw (1/2 Hp) effluent pump with a similar rating. These pumps presently are manufactured with bronze impellers to reduce corrosion that was evident when original pumps had cast iron impellers. Solids handling capabilities of these pumps are normally 1.9 cm to 5.1 cm (3/4 to 2 in), but because they pump septic tank effluent, 1.3 to 1.9 cm (1/2 to 3/4 in) solids handling capability should be more than sufficient.

The Florida system is evaluating the suitability of an above ground Jabsco effluent pump with a foot valve in the septic tank to maintain suction. This may be an ideal solution for servicing; however, noise reduction must be further investigated because of homeowner complaints of pump operating noise.

Except for some higher head models, most effluent pumps have shutoff heads in the range of under 19.8 m (65 ft). Re-design of these units to produce a higher head at lower flows, along with more plastic components to reduce corrosion and weight, and reduction of solids handling capabilities, may produce a pump that is more suitable for an effluent type system.

GRINDER PUMP ON-LOT FACILITY

Grinder Pump Chamber

All GP manufacturers offer a complete package consisting not only of the pump, but also the pump basin, discharge piping, valving, electrical controls and warning systems (Table 4). Standard basins have the pumps installed by either one of two methods. Either the pump is suspended from or attached to the basin cover and servicing requires a dead lift of the pump cover, or the pump is located on rails and lifted from the basin via a chain. In the second system the discharge flange disconnects from the discharge piping through a slide away coupling. The major disadvantage of the suspended type system is that the top of the basin cover in northern climates must be below frost level. This means an additional manway must be installed up to 1.5 m (5 ft) deep. At this depth, it becomes more difficult to dead lift the pumping unit.

Various manufacturers offer basins as shown in Table 4. Peabody Barnes offers simplex or duplex basins in either the rail system or the suspended model. The simplex is offered in a 0.6 m (2 ft) FRP and the duplex in a suspended 0.9 m by 0.9 m (3 ft by 3 ft) FRP. The simplex rail system is 0.6 m by 1.5 m (2 ft by 5 ft) steel construction and the duplex rail system basin is 0.9 m by 1.5 m (3 ft by 5 ft). Larger sizes are available upon request. Covers are standard steel construction through 1.5 m (5 ft) diameter.

Hydr-O-Matic offers both the suspended and rail type system with the simplex suspended basin 0.6 m by 0.9 m (2 ft by 3 ft) FRP and the duplex suspended pump system in a 0.9 m by 0.9 m (3 ft by 3 ft) FRP manhole. The simplex rail system is offered in a 0.6 m by 1.5 m (2 ft by 5 ft) steel basin and the duplex rail system in a 0.9 m by 1.5 m (3 ft by 5 ft) steel basin. Larger size steel basins are available upon request. Standard steel basin covers are available up through 1.8 m (6 ft) diameter.

Environment/One Company has only a suspended type of basin system. The simplex suspended basin is either a 0.6 m by 0.9 m (2 ft by 3 ft) or 0.9 m by 0.9 m (3 ft by 3 ft) FRP basin. The duplex is a 0.9 m by 0.9 m (3 ft by 3 ft) FRP manhole. Covers are available only in FRP through 0.9 m (3 ft) diameter. Special manways also are offered to bring the basin up to ground surface.

Toran has both the simplex and duplex suspended and rail type systems with the simplex suspended in a 0.6 m by 0.9 m (2 ft by 3 ft) FRP basin and the duplex suspended in a 0.76 m by 0.9 m (2.5 ft by 3 ft) FRP basin. Simplex rail system is a 0.9 m by 1.5 m (2 ft by 5 ft) FRP and the duplex system is a 0.9 m by 1.5 m (3 ft by 5 ft) FRP. Covers are available through a 0.9 m (3 ft) diameter.

TABLE 4. COMPARISON OF GRINDER PUMP AUXILIARY EQUIPMENT

Description	Peabody Barnes	Hydr-O-Matic	Environment/One	Toran	F. E. Meyers
Check Valve	Standard - Ball type with cast body	Standard - Ball type with cast body	Standard - Gravity operated, flapper type with PVC body; also, requires anti-siphoning air release valve; flapper type	Standard - Ball type with cast iron body	Standard - Flapper type
Covers	Standard - Steel thru 60-in diameter	Standard - Steel thru 72-in diameter	Standard - FRP thru 36-in diameter	Standard thru 36-in diameter	Standard - Steel thru 36-in diameter
Basins	Standard - Simplex suspended 2-ft by 3-FRP; duplex suspended 3-ft by 3-ft FRP; simplex rail 2-ft by 5-ft steel; duplex rail 3-ft by 5-ft steel; larger sizes available	Standard - Simplex suspended 2-ft by 3-FRP; duplex suspended 3-ft by 3-ft FRP; simplex rail 2-ft by 5-ft steel; duplex rail 3-ft by 5-ft steel; larger sizes available			Standard - Simplex suspended 2-ft by 3-ft FRP; duplex suspended 30-in by 3-ft FRP; simplex rail 24-in by 5-ft + 78-in; duplex rail 30-in by 5-ft + 78-in
Type of System Available	Simplex suspended; duplex suspended; duplex slide away; simplex slide away	Simplex suspended; duplex suspended; duplex slide away; simplex slide away	Simplex suspended; duplex suspended	Simplex suspended; duplex suspended; simplex rail; duplex rail	Simplex suspended; duplex suspended; simplex rail; duplex rail
Control Panels	Standard - Simplex NEMA 1, 3; duplex 3R optional - NEMA 4 overload protection in panel; uni or duo control	Standard - Simplex NEMA 1; duplex NEMA 3 optional - NEMA 12, 4 overlad protection in panel; uni control only	Control integral part of pump core; overload protection in motor; uni control only	Supply capacitor in junction box and starter if requested; do not furnish complete control panel; uni control only	Standard - Simplex NEMA 1, 3R; duplex - NEMA 1, 3R; overload protection in panel; uni control only
Level Control Switches	Mercury type; simplex system - 2 required; duplex system - 3 required	Mercury type; simplex system - 1 required; duplex system - 3 required	Pressure type located in control housing of pump core	Mercury type; simplex system - 2 required; duplex system - 3 required	Magnetic - Plastic float type; simplex system - 1 required; duplex system - 2 required; alarm - mercury float type
High Water Alarm	Optional - Visual and/or audio; activated by mercury level control	Optional - Visual and/or audio; activated by mercury level control	Standard - Visual jewel alarm activated by pressure switch	Optional - Visual and/or audio activated by pressure switch	Standard - Flashing red light plus buzzer alarm in panel
Approvals	Pump - CSA approved	Pump - CSA approved	Pump - CSA approved; motor - UL approved		
Motor Shaft	Stainless steel	Standard - Ball type		Stainless steel	Stainless steel
Standard Cord Length	30-ft	10-ft	10-ft	10-ft	15-ft

Environment/One Company has only a suspended type of basin system. The simplex suspended basin is either a 0.6 m by 0.9 m (2 ft by 3 ft) or 0.9 m by 0.9 m (3 ft by 3 ft) FRP basin. The duplex is a 0.9 m by 0.9 m (3 ft by 3 ft) FRP manhole. Covers are available only in FRP through 0.9 m (3 ft) diameter. Special manways also are offered to bring the basin up to ground surface.

Toran has both the simplex and duplex suspended and rail type systems with the simplex suspended in a 0.6 m by 0.9 m (2 ft by 3 ft) FRP basin and the duplex suspended in a 0.76 m by 0.9 m (2.5 ft by 3 ft) FRP basin. Simplex rail system is a 0.9 m by 1.5 m (2 ft by 5 ft) FRP and the duplex system is a 0.9 m by 1.5 m (3 ft by 5 ft) FRP. Covers are available through a 0.9 m (3 ft) diameter.

Other manufacturers offering both grinder pumps and basins are F. E. Meyers, and Enpo Cornell. Pneumatic ejector stations are sold by Franklin Research and Clow Corp.; however, these pump systems and basins generally were not used in the systems investigated for this study.

In general, most pump basins are located outdoors. Only two systems investigated, the Country Knolls South Subdivision in upstate New York and Lake Mohawk, OH system had some pump basins located indoors.

It has been recommended that a pump chamber be well sealed, but a pump that uses a pressure switch as its on - off device must have adequate venting of the pump chamber. If the pump chamber is not adequately vented, then a false turn-on signal can be sent to the pump pressure switch if a large inflow of sewage occurs. This has been apparent at Weatherby Lake, MO where failures of the Environment/One pump occurred due to inadequate venting of the pump chamber back through the house plumbing.

Most pump chambers are not installed with overflow devices as some excess storage is provided in the pump chamber. During a power outage water usage would be curtailed due to the inability of the homeowner to use modern convenience appliances. Some systems, however, do utilize an existing septic tank as the overflow device, as in Grandview Lake, IN.

Grinder Pumping Equipment

There are two major kinds of grinder pumps currently installed in existing systems. They are either the semi-positive displacement type manufactured by Environment/One or centrifugal grinder pumps manufactured by Hydr-O-Matic, Peabody Barnes and Toran. Other entrants into the marketplace, such as F. E. Meyers and others have a limited number of pumps in pressure sewer systems.

The Environment/One semi-positive displacement pump uses a large diameter grinder with two removable teeth rotating inside stator rings. Sewage is pumped through a Moyno type stainless steel rotor and rubberized stator or boot. The discharge piping includes the check valve and anti-siphon valve between the pump and the top of the pump basin. The pump is self-contained with a separate dry compartment housing the motor. The motor is protected against running overloads or locked rotor conditions through an automatic reset thermal overload protector. A mechanical seal separates the pumping liquid from the dry motor compartment.

The pump curve of the Environment/One unit has the semi-positive displacement characteristic shown in Figure 24. The semi-positive displacement nature means that with relatively large changes in total dynamic head there are small changes in capacity pumped. The National Sanitation Foundation has determined that pressurization above the 25 m (81 ft) maximum design limit is possible; however, conditions above that level occurring frequently and for long periods can adversely affect the pump. If this pump is used in a slowly growing development, and if maximum design velocity will not be reached for a long period of time, a scouring velocity (usually assumed at 2 ft/second) will not occur until maximum density is reached.

The Hydr-O-Matic Hydrogrind submersible centrifugal pump uses a 1.1 kw or 1.5 kw (1.5 or 2 hp) motor with a capacitor starter in an oil lubricated chamber. A control box is mounted at a separate location outside the pump chamber. Two mechanical seals separate the pumping chamber from the motor compartment. The original cast iron impeller has been replaced by a bronze impeller to reduce deterioration found in earlier models. The grinding mechanism has two cutters. There is an axial cutter followed by a radial cutter that tends to chop stringy materials that passed through the first cutter. These components are all stainless steel.

The Peabody Barnes submersible centrifugal pump is offered in a 1.5 kw (2 hp) capacitor start, oil lubricated model with various voltages available. There is a single mechanical seal on this pump with an extrusion type seal in front of the mechanical seal. The impellers are ductile iron. The grinding mechanism includes a cutter bar followed by an abrader of silicon carbide. The abrader has shattered when trying to wear down metal particles in the sewage. The abrader is being replaced by a metal component.

One of the newer entries into the submersible centrifugal GP market is the Toran pump which has been used at the Sausalito houseboat system at Kappas Marina. This pump is virtually identical to the Hydr-O-Matic pump with the difference being in the secondary cutter mounted perpendicular instead of angled as in the Hydr-O-Matic unit.

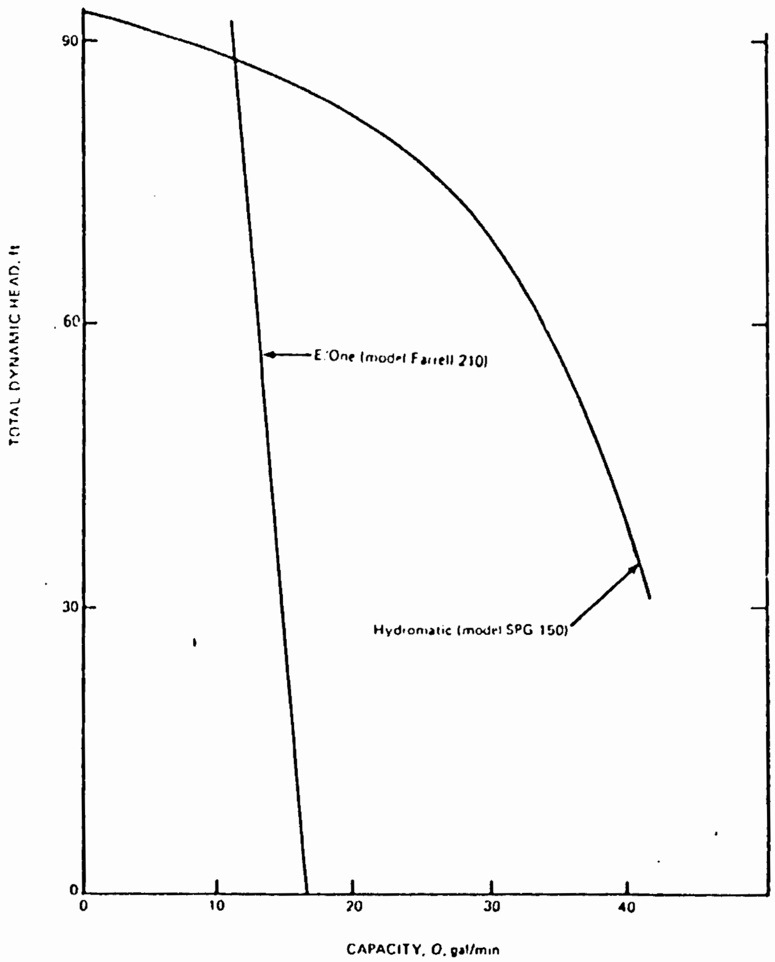

Figure 24. Comparison of characteristics of a semi-positive displacement grinder pump (Environment/One) vs a centrifugal grinder pump (Hydr-O-Matic).

Another entry is the F. E. Meyers pump. One of the significant advances in this pump construction is a seal leak detector that senses moisture between the tandem mechanical seals. When moisture is detected, the pump can be removed for servicing which would include only replacement of the first seal, thus preventing moisture contamination of the main pumping chamber. This maintenance could prevent replacement of a motor costing many times more than replacement of the first seal.

A major advantage of centrifugal grinder pumps is that they have a significantly changing head capacity curve. The capacity increases dramatically with a concurrent decrease in system head. This means that in systems with low densities or low growth rates, scouring velocities would be more frequent than in the flat output of the semi-positive displacement type pump (Figure 24).

Another consideration of the semi-positive displacement vs the centrifugal pump is that in a plugged line situation both pumps would be driven to shutoff head. The maximum pressure that can be developed by the Environment/One pump is significantly greater than a centrifugal pump. This pressure greatly reduces the life of the stator, although it may possibly clear the plug from the pipe. The centrifugal pumps will rotate without discharging and the heat generated would be transferred into the sewage liquid. The Environment/One pump is supposed to be protected against overload pressure by use of a thermal overload protector with automatic reset capabilities. The Environment/One pump may be more suited in conditions where air release valves have been placed incorrectly or are inoperative, because the higher pressure generated by the semi-positive displacement pump may be more suited to pump water against an air entrapment than a centrifugal pump with a limited discharge head. Table 5 provides a detailed comparison of grinder pumps currently offered in the market place.

TABLE 5. COMPARISON OF GRINDER PUMPS

Description	Peabody Barnes	Hydr-O-Matic	Environment/One	Toran	F. E. Meyers
Pump Type	Submersible centrifugal	Submersible centrifugal	Semi-positive displacement (water tight)	Submersible centrifugal	Submersible centrifugal
Motor	2 hp, 3,450 rpm; capacitor start; oil lubricated	1½, 2 hp, 3,450 rpm; capacitor start; oil lubricated	1 hp, 1,725 rpm; capacitor start; thermally protected (auto reset); air cooled	2 hp, 3,450 rpm; capacitor start; oil lubricated	2 hp, 3,450 rpm; capacitor start; oil lubricated
Electrical Voltage/Phase	230/1, 230/3, 460/3, 575/3, 200/1, 200/3	230/1, 230/3, 460/3, 575/3, 200/1, 200/3	230/1	230/1, 230/3, 460/3	230/1, 230/3, 200/3, 460/3, 575/3
Seals	Mechanical type running in oil filled chamber; ceramic and carbon faces with an exclusion type seal in front of mechanical seal	Double tandem mechanical seals with oil chamber between seals; seals have carbon and ceramic seal faces	Mechanical type with a stationary ceramic seal and carbon rotating sealing surface	Double mechanical seals in oil chamber; seals have carbon and ceramic seal faces	Tandem mechanical seals in oil filled chamber; seal leak probe included
Bearings	Thrust bearing is ball type; radial bearing is a sleeve type with permanent lubrication	Upper ball radial and thrust bearing with lower bronze sleeve bearing	Ball bearing	Ball bearing	Upper double ball bearing with lower sleeve bearing
Impeller	Ductile iron - 55 Rockwell C	Bronze	Stator elastomer/ rotor stainless steel	Cast iron	Bronze
Grinder Mechanism	Masticator ring - stainless steel; cutter bar - stainless steel; abrader - No. 8 grit; silicon carbide	Axial cutter - stainless steel; radial cutter - stainless steel; cutter ring - stainless steel	Shredder ring - chrome and steel; cutter bars - stainless steel	Cutter ring - stainless steel; radial cutter - stainless steel	Shredder ring - stainless steel; radial cutter - bars stainless steel
Motor Insulation	Class B	Class B	Class B	Single phase Class B; 3 phase Class F	
Pump Construction	Pump and motor housing made of cast iron; fasteners 18 8 stainless steel	Pump and motor housing made of cast iron; fasteners 8 stainless steel	Core housing cartridge made of PVC; grinder and control housing made of cast iron	Pump and motor housing made of cast iron; fasteners 18 8 stainless steel	Pump and motor housing made of cast iron
Running Amps 230/1	15	12	8	11	
Inlet Shroud Opening Size	2-1/8-in	2-3/4-in	5-in	2-3/8-in	
Pump Performance	Capacities to 39 GPM with heads to 95-ft	Capacities to 48 GPM with heads to 93-ft	Capacities to 16 GPM with normal operating heads to 61-ft	Capacities to 44 GPM with heads to 105-ft	Capacities to 40 GPM with heads to 105-ft
Weight of Pump	130 lbs	125 lbs	134 lbs	75 lbs	70 lbs
Discharge Size	1-¼-in NPT	1-¼-in NPT	1-¼-in NPT	1-¼-in NPT	1-¼-in NPT

OTHER SITE COMPONENTS

Check Valves

Almost all pump companies marketing pressure sewer pumps offer standard check valves with the pumping units. The Peabody Barnes, Hydr-O-Matic and Toran companies offer a ball type check valve with a cast iron body. Environment/One pumps use a gravity operated flapper type check valve with a PVC body. In order to prevent the Environment/One pump from losing its self-priming capabilities, a flapper type anti-siphoning valve, which acts as an air release valve for the pump, is also furnished. Materials of construction for check valves in GP systems are not as critical as those used in STEP systems. General Development uses a plastic ball check valve as well as brass and plastic flapper valves. Brass valves are favored due to their long term

O & M reliability. They have a metal to metal seating face and do not use a resilient seating face.

The quality of check valves has varied considerably. For example, the Klaus houseboat system in Portland, OR originally used brass valves of domestic origin. Because of their lighter weight and thinner hinging device, these valves have been unsuitable for service. The newer type of valves in service are a Red and White brand import valve that is of substantially heavier quality weight and higher price than used previously, but has shown better service history.

Some systems use a backup check valve either in the pumping chamber discharge line or in the service line from the pump to the main. Most system operators find no preference to the location of the check valve in either the vertical or the horizontal mounting. However, the operator at Grandview Lake, IN prefers the ball type valves located in the horizontal position for easier removal for service and the flapper valves located in the vertical position to prevent solids from depositing on the bottom of the seating face. Peabody Barnes, on the other hand, usually recommends the flapper type being installed in the horizontal position and the ball valve in either the horizontal or vertical position.

In addition to a double check valve on Environment/One's pumps, they include an anti-siphon valve. This prevents vacuum conditions on the pump by admitting atmospheric air into the pump discharge line.

Shutoff Valves

Shutoff valves used in the pumping chamber typically are gate valves; however, some systems such as Apple Valley, OH use plug valves. The usualy practice with GP is to utilize a cast iron body shutoff valve. However, in certain conditions the body as well as the turn off wheel have been shown to corrode. Utilization of shutoff valves in STEP systems has precluded the use of cast iron bodies. Bronze is the material of choice as several operators have reported problems with the plastic valves which tend to crack with age or use. Seating of the plastic valves also tends to wear and develops a "set". Brass valves have had a poor service history as well. Admiralty brass tends to lose zinc or dealloy, leaving the copper susceptible to corrosion. Many designers use two shutoff valves for the system: one usually being located in the pumping chamber and the other located between the pump chamber and the main line.

On-lot Piping

Service connections between the on-lot pumping unit and service main vary in size between 2.5 cm and 5.1 cm (1 and 2 in). The most common size is 3.2 cm (1.25 in) inside diameter plastic piping. There are two bases for the selection of this size. Typically, some pumps have used 3.2 cm (1.25 in) size as their standard discharge pipe. When Environment/One developed their unit, they sized the 3.2 cm (1.25 in) pipe based on the headloss and capacity conditions of their pump to deliver a scouring velocity of approximately 0.6 m/second (2 ft/second). For GP, obviously the smaller the size piping, the larger the scouring velocity will be for maintaining a clean pipe, but this will result in a higher friction loss. STEP systems would not be limited by a flushing or scouring requirement, therefore, typically larger service lines would result in a lower friction loss.

Most of the GP installations at Grandview Lake use one inch piping, while in the Horseshoe Bay development 3.2 cm to 5.2 cm (1.25 to 2 in) piping is used. Many of the STEP systems or houseboat solids handling pump systems have 3.8 cm (1.5 in) flexible hose. Examples of some STEP systems are: 3.8 cm (1.5 in) service lines at Priest Lake, ID; 3.2 to 3.8 cm (1.25 to 1.5 in) piping at the General Development Utilities systems in Florida; and the Bend, OR system uses 3.2 cm (1.25 in) piping. Most systems seen have standard 3.2 cm (1.25 in) service lines, using PVC piping (Schedule 40 or SDR 26 lines).

Several systems have been experimenting with the use of polyethylene service lines. For example, the Grandview Lake system has SDR 21 and SDR 13.5 polypropylene and polybutylene service connections. The SDR 13.5 is considered superior. It is more difficult to utilize PVC service lines with brass fittings than service lines with plastic fittings. Harbor Springs, MI where GP are utilized has polyethylene services lines as well as polyethylene mains.

Service taps typically are made under pressure. Common wet tap procedures are used. Cock tapping saddle connections are used with a curb shutoff valve; however, other types of tapping can be used. In the General Development Utilities system in Florida, the wet tap is made with a special tapping saddle which retains the bored out section of main line piping. Saddles and tapping tools for PVC are common to most contractors familiar with PVC underground piping.

Power Supply Requirements

Most effluent pumps are available in 120 volt, single phase; 230 volt, single phase or 230 volt, three phase. Grinder pumps are available in only 230 volt, single phase, or three phase, except for the Environment/One pump which is limited to 230 volt, single phase. Power supply connections are made at the home master electrical panel or just after the meter. A separate disconnect, such as a circuit breaker, is required at the homesite connection. All GP except the Environment/One come with either a NEMA 1 or NEMA 3 cabinet which have their own circuit breaker or a hand-off-automatic (HOA) operating switch. Overload protectors are usually available in the panels. The Environment/One pump is not provided with a panel because the controls are integral with the pump core. The Toran pump has the capacitor supplied in a junction box, if requested. Use of an automatic switch and a nearby control panel greatly simplifies pump servicing since testing is simplified.

Effluent pumps are wired directly from the pump through the control panel. In the General Development Utilities system, a control panel is not used, so the electric feeder line just has a plug-in connection to a home outlet. The plug-in connection is the pump local disconnect. Typically, there is one home on a single effluent or GP, simplifying power supply requirements. Power is supplied from the control panel at a single residence. When a pump unit is shared between residences, other arrangements must be made. In Apple Valley, OH, the first residence on a shared unit supplies the power and a credit of fifty cents per quarter applied to the first pump users bill. If the resident supplying power has service disconnected, a secondary source of power must be provided from the remaining residents on the pump. This is a complicating factor in shared pumps, but this has not been a significant problem.

When a unit must be removed for service, the electric service line and discharge line must be disconnected. Several GP have waterproof disconnects or waterproof junction boxex in the pumping chamber to facilitate pump removal. If an Environment/One pump must be removed for service, the electric service lines must be de-energized and then manually cut. When a new pump is installed in that unit, the electric service lines are reconnected with the use of wire nuts or wire nuts and tape. Separate electric circuits for the pumps and for the controls is recommended at the Glide-Idelyde, OR system to prevent failure of one system from affecting the other (Figure 25).

Control Systems

Many pump manufacturers offer package control systems that include level control switches for activating the pumping units. Many systems also use a high water level sensing device which transmits a signal to an alarm light or horn located either at a nearby control panel, in the kitchen or basement of the resident served.

There are two major types of controls presently being used in pressure sewer pumping units. The earlier systems have a pressure switch which was utilized in the Peabody Barnes GP in a private system near Bend, OR, and is used in the Environment/One GP (Figure 26). Hydr-O-Matic effluent pumps still use a

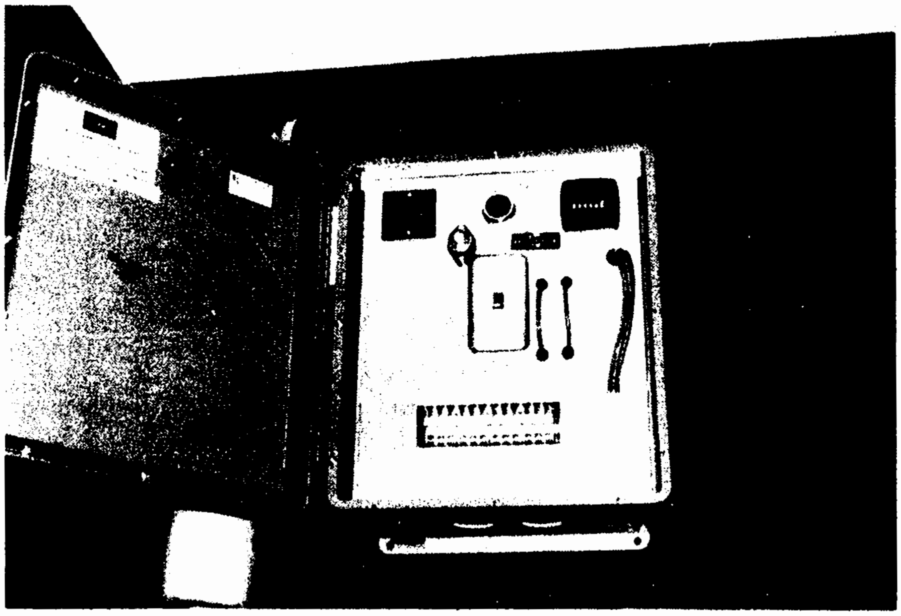

Figure 25. Pump control cabinet for Glide-Idleyld, OR.

pressure switch in the General Development Utilities systems; however, they are changing to the mercury float device. Mercury floats have been used in most pressure sewer systems and are reported to be the most reliable pressure switch. The Environment/One unit utilizes a sensing bell which transmits pressure to a pressure switch. When sufficient pressure forces the diaphragm up against the contact, the circuit is completed. The pressure switch must be vented to allow for movement of the diaphragm. The point of venting usually is at the top of the electrical plug in Hydr-O-Matic units, or through a special vent control device with a water exclusion check valve located in the manway of the Environment/One pump unit chamber.

The mercury float device is a capsule of mercury imbedded in a polyurethane tear drop shaped bulb. When the liquid level rises, the bulb floats and rotates allowing the mercury to complete two electrical contacts. For on - off control, two mercury floats are required; one for turn-on level and one for turn-off. The high level alarm usually requires a third turn-on level. Peabody Barnes is experimenting with a differential mercury float switch which has an angled mercury-containing glass tube inside a polyurethane float. This would permit only

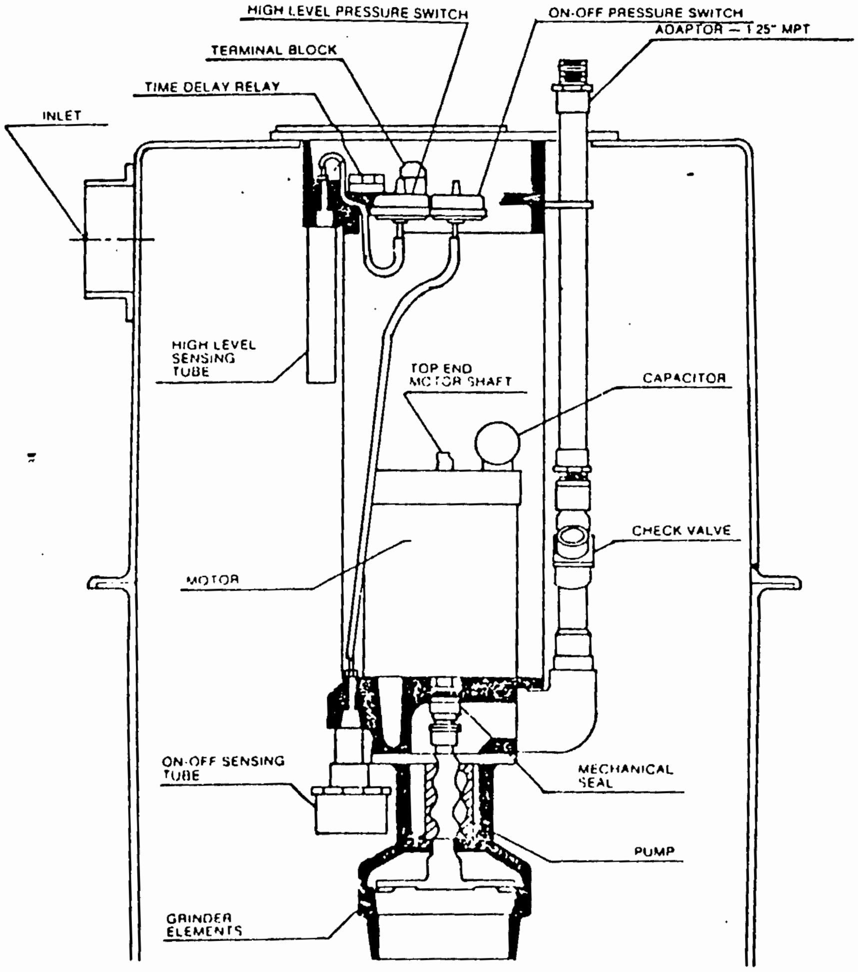

Figure 26. Cut away of Environment/One pump showing pressure sensing bell on lower left with lines running to pressure switches at top center of pump casing.

one mercury float to control the pump on and off levels. Currently under development is a magnetic plastic float which has plastic floats riding on a rod which raises a magnet into contact with a switch case. Usually the switch will not come into contact with the liquid and is found to be impervious to grease accumulation. This type of device is not in current usage in any system investigated, but is planned for usage in the Glide-Idleyld and in the Manila, CA systems. By far the most reliable system utilized is the mercury float system which usually is attached to the discharge pipe or suspended from the top of the pump basin.

The original reason for using the pressure switch was one of economics. Recently the mercury float switch system has been lowered in price to where it is competitive with the pressure switch. Due to the number of service calls required for the pressure switch turn-on device, future systems, with the exception of the Environment/One unit, are being installed with mercury float switches. Special considerations are involved in any system installed in California which has an requirement for explosion proof equipment inside a pressure sewer system manhole or pump basin. From the experience of systems throughout the country, there has been no evidence of the pump basin exploding through the ignition of inflammable gases or gasoline spilled into the pump chamber. This requirement in California has resulted in the planning of intrinsically safe, highly sophisticated, and expensive control circuits in the experimental system in Manila, CA.

Corrosion and Materials of Construction

Corrosion often suggests rusting, or other attack to metals. This report describes corrosion in a broader sense, i. e., any attack from the environment, occuring chemically, biologically or otherwise which destroys a material or hampers its performance. Deterioration of concrete, plastics or metal is included.

Grinder pump and STEP vaults present a corrosive environment from several sources. Inside surfaces are wet, with a part being submerged and the remainder heavy with condensation. Corrosion can occur from constituents in the water supply itself, such as chlorides, as well as from matter in the wastewater. As sewage remains in the vault between pumping cycles, oxygen is depleted from the wastewater and anaerobic conditions develop. Digestion may occur to some degree, first entering the "acid" phase, during which pH declines, presenting corrosive conditions.

Hydrogen sulfide is formed as inorganic sulfur compounds are reduced in the absence of oxygen. H_2S is corrosive in itself and also reacts biologically with thiobacillus bacteria on moist surfaces to form sulfuric acid, H_2SO_4. Corrosion from this can be extreme.

Within the pressure sewer vault, corrosion may attack the pump or the tank itself, whether concrete, fiberglass or some other material. Special attention must be given to mechanical parts and small parts where even slight deterioration can cause failure. Consideration also should be given to equipment exposed to general atmospheric conditions, such as electrical control panels located outside.

Normal means of coping with corrosion problems within pressure sewer vaults are by minimizing conditions conducive to corrosion, and by selecting materials sufficiently resistant to corrosion. Galvanic couples are avoided, and where dissimilar metals are used, they are insulated from each other.

When vaults are well ventilated, the concentration of H_2S is greatly reduced. Designs are preferred where turbulence in the pump vault is minimized, thus releasing less gas. Where possible, flow should enter the vault without falling and becoming aerated. Serious corrosion occurs when sulfide and oxygen and are present simultaneously.

Concern for corrosion may be greatest when an engineer undertakes a custom component design, but the assumption that corrosion matters have been contemplated in package units can sometimes be disappointing. It is best to know the possibilities of corrosion in a given environment and insure that materials selected are suited for the application.

Concern for corrosion is frequently dealt with by a combination of methods, but selection of materials plays a major role. Few materials are completely corrosion resistant, so cost and degree of resistance is weighed against the time required for failure to occur and the significance of the failure. The type of corrosion to be expected also is of importance, whether it is uniform, deep pitting, or crevicing.

Pump casings and impellers normally are made of grey cast iron, a carbon and silicon alloy of iron. In pressure sewer application, iron sometimes becomes plated with ferrous sulfide, iron oxide, and organic matter all cemented together. Normally this is of little significance in the pump's operation; however when a pump remains in the wastewater for some time without operating, such as when the home served is unoccupied, the impeller may become fixed to the volute. Then, when the pump again runs, it may not exert enough starting torque to break loose. Either the fuse or breaker, or the built in thermal overload protects the motor, but a service call is needed. This is an infrequent problem, and one that favors plastics insofar as corrosion is concerned.

Common carbon steel has been used in pressure sewer vaults, and is normally coated or plated. Usually, coated steel has not performed acceptably. Forty steel septic tanks in service were reported on in a study by the Public Health Service (12). The study reported that 70% had holes through the steel, and an average useful life of 7 years was suggested.

Galvanizing (zinc) or cadmium plating often is applied to steel. As with coatings, protection relies on perfect covering, though zinc will cathodically cover small blemishes. Too often, the plating is only cosmetic, as opposed to thicker plating of industrial practice. Generally, plating has not performed well in pressure sewer vaults, but has been satisfactory for items exposed to the atmosphere.

When the properties of steel are required and conditions are quite corrosive, stainless steel may be used. There are many types of stainless steel, generally grouped as martensitic, ferritic, austenitic, or precipitation hardened. Martensitic and ferritic steels are also known as 400 series, and are identified by being magnetic. Type 416 often is used successfully for pump shafts. More delicate parts are best made of austenitic stainless steel, usually 300 series. These are either non-magnetic or slightly magnetic. In a sewage environment, type 316 is favored; it is made more corrosion resistant by the addition of molybdenum. Type 304 also is an excellent material and widely used, though not as corrosion resistant as 316.

Copper alloys are in common use as brass or bronze. Brass is an alloy of copper and zinc, while bronze is copper and tin. Brass is subject to dealloying; the zinc leaches out of the material leaving soft copper. While many bronze alloys are available, a typical one is 85-5-5-5 (copper - zinc - lead - tin), and generally is acceptable for most use. A color may develop on bronze, usually black, silver or green, but is more tarnish than a matter or concern.

Plastics generally have proven to be superb. Some 8 years of experience with plastics in pressure sewer vaults has shown no deteriorating effect on PVC. Some products, however, are hygroscopic and may swell. This can cause mechanical parts to fail. Fiberglass reinforced plastic (FRP) commonly is used to make pressure sewer vaults. Wicking is possible should glass fibers become exposed to moisture. To avoid this, a resin or gel coat is applied to surfaces.

It is well known that sulfuric acid attacks concrete and numerous cases have been cited where the crown or water surface levels of concrete pipes have deteriorated to the point of collapse. Experience with concrete septic tanks has been quite good, however. Some jurisdictions require coating of the soffit of tanks. A study by the Public Health Service was made on concrete septic tanks in field use, ranging in age from one-half to 39 years (12). Of the 150 tanks inspected, 91% were judged to be in good or excellent conditions so far as the concrete was concerned, with some showing spalling at and above the water line.

Gases and Odors

Gases are produced in conventional sewers, force mains, and pressure sewer on-lot facilities. Concern in piping systems is mostly for hydrogen sulfide, owing to its corrosive, odorous and toxic characteristics. The time period required for oxygen to be depleted and production of H_2S to start in force mains usually is about 15 to 30 minutes. Production continues for perhaps 24 hours, or until the sulfate is reduced. Pomeroy (13) has shown that the rate of production is accelerated greatly by anaerobic slimes which coat pipe walls. The same slime would be present in pressure sewer on-lot facilities of both GP and STEP design.

Table 6 outlines characteristics of gases which are of concern in sewage systems. Both methane and hydrogen sulfide are shown to be flammable and may be explosive. Hydrogen sulfide is also very corrosive and oxidizes to form H_2SO_4, sulfuric acid. Hydrogen sulfide is highly odorous and toxic.

When properly vented the tank atmosphere differs insignificantly from normal air. Danger of fire or explosion would be greatest with just the right degree of imperfect ventilation. Pressure sewer vaults must breathe. As flow from the home fills the tank from pump "off" to pump "on" level, gases in the tank atmosphere must be displaced. Air is then drawn in as the liquid level drops while the pump runs.

There are differences among conventional sewer, septic tank systems and pressure sewer systems. In a septic tank drain field installation the liquid level in the tank increases very slightly with flow and it is possible that some gases are drafted to the drain field. These conditions do not exist in pressure sewer design. While a scum mat may exist over septic tank liquids, the authors have never noted any in the vault portion of interceptor tanks used in STEP applications. While conditions are relatively quiescent in septic tanks, some turbulence is caused by pressure sewer pump liberating more gas. Such differences as these should be considered in pressure sewer design.

TABLE 6. CHARACTERISTICS OF COMMON SEWER GASES

Gas	Chemical Formula	Vapor Density (Air = 1)	Class	Common Properties	Physiological Effect	Maximum Safe 60 Minute Exposure (% by Volume in Air)	Flammability Range (% by Volume in Air) Lower Limit	Upper Limit
Methane	CH_4	0.55	Asphyxiant	Colorless, odorless, tasteless	Acts mechanically to deprive tissues of oxygen. Does not support life.	Probably no limit, provided oxygen percentage is sufficient for life.	5.0	15.0
Carbon Dioxide	CO_2	1.53	Asphyxiant	Colorless, odorless, tasteless. When breathed in large quantities may cause acid taste.	Cannot be endured at 10% more than a few minutes even if subject is at rest and oxygen content normal. Acts on respiratory nerves.	4.0 to 6.0		
Hydrogen Sulfide	H_2S	1.19	Toxic	Rotten egg odor in small concentration. Exposure for 2 to 15 minutes at 0.01% impairs sense of smell. Odor not evident at high concentrations. Colorless. Corrosive.	Impairs sense of smell rapidly as concentration increases. Death in few minutes at 0.2%. Exposure to 0.07 to 0.1% rapidly causes acute poisoning. Paralyzes respiratory center.	0.02 to 0.03	4.0	44.0
Nitrogen	N_2	0.97	Toxic	Rotten egg odor in small concentrations. Exposure for 2 to 15 minutes at 0.01% impairs sense of smell. Odor not evident at high concentrations. Colorless. Corrosive.	Physiologically inert.			
Oxygen	O_2	1.11		Colorless, odorless, tasteless. Supports combustion.	Normal air contains 10.93% of O_2. Man can tolerate down to 12%. Minimum safe 8 hour exposure 14 to 16%. below 10% dangerous to life. Below 5 to 7% probably fatal.			

Undesirable sewer gases may be controlled by a wide variety of means. Either the sewage itself or the gases may be treated. Chlorine (Cl_2), hydrogen peroxide (H_2O_2), ozone (O_3), oxygen (O_2), ph adjustment and other chemicals have been used for controlling gas emisssions.

When treatment of gases is required, a practical method is use of a soil filter bed. Typically, this resembles a septic tank drainfield, but is much smaller. Gases are conducted to a perforated pipe bedded in gravel and covered with loam or a mixture of soil and peat moss. Ventilation from the vault to the soil bed has been accomplished mechanically or by the natural escape of gases. For detailed information, reference is made to a paper by Carlson (14) and another by Stone (15).

For homes having an existing drainfield, gases might be vented there. Another option is that a filter bed could be constructed in the same trench as used for the pump discharge or service line. Both of these methods are being used experimentally in the Glide-Idelyld, OR pressure sewer system. Where groundwater is high, such a system cannot be expected to function properly and can be a source of infiltration to the sewer. Mounded construction may be advantageous.

Imperfect ventilation which may allow gases to reach combustible concentrations should be avoided.

While H_2S is highly odorous in small quantities and is heavier than air, this gas is usually dispersed sufficiently when exhausted through the house vent. Complaints of H_2S odors are regularly reported when the vault covers are not sealed. A slight odor is typical when vault covers are lifted from either GP or STEP vaults.

There have been no known fires or explosions, though numerous installations do not use explosion proof electrical equipment. To render installations sufficiently explosion proof at reasonable cost, some designers place the pump "off" level above the top of the pump, keeping it submerged. In some cases, two "off" level controls are used to insure that the pump remains entirely below the liquid, and explosion proof controls are sometimes used. When wiring is placed in a conduit between the pump vault and electrical control panel, a conduit seal is necessary.

Workmen normally need not enter pressure sewer vaults, so poisoning or suffociation is not likely. Some dizziness has been reported when a workman breathes the gases by lowering his head into the vault. Designs are preferred where such action is neither necessary nor possible.

SECTION 6

DESIGN OF OFF-LOT FACILITIES

GENERAL

This section presents a compendium of various engineer's designs and operator's modifications as they relate to pressure sewer system design. Piping hardware selection is detailed as well as engineering design considerations for applying the hardware to a functioning system.

After a preliminary analysis of the number of homes and character of the community, the system is layed out with branches having the shortest runs and fewest changes in direction. Langford and others (3, 5, 16) suggest attempting to keep a positive head on all pumps. Positive head will prevent: 1) air plating of grease and solids on the lining of the pipe, 2) large air accumulations at high points and 3) siphoning of pumps. Langford also suggests that precise topographical surveys of an area to be served are not as critical in a pressure sewer system compared to a gravity system.

Various methods exist to layout pressure sewers. For example, Ken Durtschi designed the Priest Lake, ID system by determining the elevation of each pumping unit and assigned a suitable pump with a substantial safety factor to each location. Basically, he discounted velocity as an important design consideration within his system. Pipe sizes were determined by an estimate of the number of homes pumping at any one time. The Weatherby Lake, MO grinder pump system used data from rural water systems according to the equation:

$$X = Y^{0.515}$$

where X = number of customers drawing water at any one time

Y = total number of customers connected to the system.

This analysis assumes all water used would be transported to the waste system. Grandview Lake, IN used a similar peak water demand curve and returned 80% of that peak to the sewer with a C factor of 130. On the basis of that system, they presently are designing new systems using 70% of the peak water demand with a new minimum velocity of 0.61 m (2 ft) per second rather than the previous velocity of 0.3 m (1 ft) per second.

Environment/One suggests designing the system for the maximum number of pumps operating at any one segment based on previous research work done by the firm (18). Pumps at any one segment are assumed to pump at 0.69 liters/second (11 GPM). The friction headloss is determined in any one segment based on the velocity of sewage in that segment when the maximum statistical number of pumps are operating. Static elevation is then added to the line segment and is accounted for by the greatest difference in elevation between that pump segment and the discharge elevation.

There are several computer programs used for designing a pressure sewer system. General Development Utilities in Florida has a computer analysis that included pump curves in the computer program and simulated development levels which translate into population density and velocities (19, 20). One Hydr-O-Matic representative in the Houston, TX area has developed an analysis for sizing pressure sewer lines which tend to downsize mains in order to increase velocity to a point consistent with maximum scouring conditions and total head delivered by the pump.

Bowne (21) has designed STEP systems with centrifugal pumping units. His analysis incudes a determination of the number of homes to be served and the peak flow from those homes. Then the profile of the system is analyzed with hydraulic grade lines of various sizes that are estimated to be suitable for the system. The graphical analysis shows by inspection the correct pipe size (Figure 27). Positive pressure throughout the system is maintained by a pressure sustaining valve. This pressure sustaining valve adds additional head and changes the hydraulic grade line as shown. Individual pumping units are then selected at each individual location consistent with head to be pumped against and desired flow rate into the system.

PIPE

Various types of pipe material have been used in existing pressure sewer systems including various ratings of PVC, polyethylene and galvanized. Most systems use PVC piping exclusively. For example, pressure sewer mains in Albany, NY utilized PVC Type 1 Schedule 40 pipe with PVC DWV fittings (3). Grandview Lake uses SDR-26 pipe as do those of General Development, Priest Lake and Weatherby Lake pressure sewer systems. In this investigation PVC SDR-26 pipe was observed to be the most frequently used piping component. Schedule 40 pipe is the most expensive PVC pipe. Its pressure rating for 5.1 cm (2 in) pipe

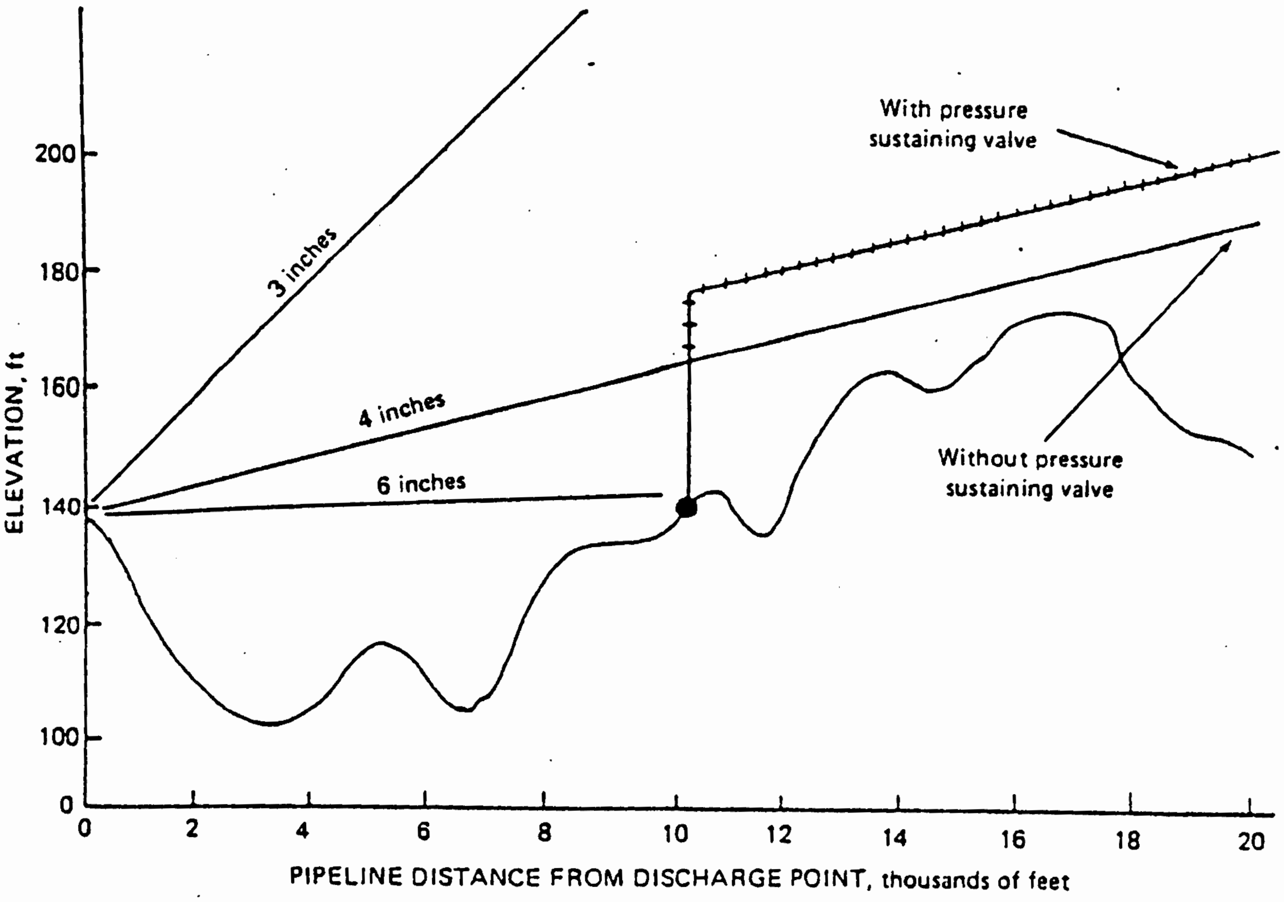

Figure 27. Pipe sizing procedure.

1,920 kPa (277 psi) and for 7.6 cm (3 in) pipe is 1,820 kPa (263 psi). Schedule 40 pipe is unusual in that its pressure rating varies with size. SDR 26 pipe has a pressure rating of 1,041 kPa (150 psi), whereas SDR 21 is 1,388 kPa (200 psi). These pressure ratings are valid up to a temperature of 22.8°C (73°F) and at higher temperatures than this, the pressure rating is substantially reduced. There usually is a safety factor rating in the piping systems. For example, SDR-26 pipe can withstand in excess of four times its nominal pressure rating.

Slip jointing offers a potential expansion and contraction area which solvent weld piping systems do not. Usually the slip joint piping system results in a much tighter system with fewer leaks. Mechanical jointing, which results in a compression fit, has experienced a sufficiently high degree of success in water system construction.

There are several reasons why pipe locator systems are used in pressure sewer systems. They serve to warn contractors working on other underground utilities that a pressure sewer system is nearby, thus preventing a possible break in the pressure sewer line. They also serve to help the utility company locate a broken pressure line and speed repairs. Also, the locator system serves to differentiate between water, gas or other underground utilities so a tap will not be made into the wrong line.

There are various types of pipe locator systems available. One system used in Glide-Idelyde, OR and in Grandview Lake, IN consists of physical sign posts announcing the presence of underground pressure sewer lines. Another system, also in Glide-Idelyde, uses a toning wire, which is sensitive to a metal locator, placed above the pressure sewer line. A third method, not currently in use in any pressure sewer systems but used in sewage force mains and by over 1,200 electric, water, gas, telephone and CATV companies and utilities, is the Terra Tape system manufactured by Griffolyn Co. of Houston, TX. It is an inert bonded layer of plastic with a metallic foil core. The manufacturer claims the tape to be highly resistant to anything encountered in the soil. This tape, when buried approximately 0.3 to 0.46 m (1 to 1.5 ft) below the surface and parallel to the pipe line, provides detection by all pipe locators. It provides positive dig-in protection from accidental discovery by other utilities excavating. This system is available at a cost of approximately $0.03 to $0.05 per meter ($0.01 to $0.015 per ft).

Often, locator pins are laid on top of valve structures to locate the valves by a metal detector. These locator pins usually are sections of reinforcing steel rods that are placed 0.3 to 0.6 m (1 to 2 ft) below the soil surface. Another system used to locate pressure sewer lines is to color code the pipe to identify whether it is a water or sewer line. Various pressure sewer systems, including General Development Utilities in Florida, Grandview Lake, IN and others use various colors such as brown PVC, green PVC or red striped PVC to denote the line as a sewer. The Pennsylvania Dept. of Environmental Resources requires underground sewer coding by color.

Another method of pipe location is to have a very detailed set of as-built plans so the operator can tell quickly where and at what depth a pressure sewer line is located.

AIR RELEASE VALVES

Air release valves should be located at high points on the pressure sewer line. The function of the air release valve is to permit accumulated air and gases produced to be released from the piping system so pressure buildups at the high points can be avoided. When an air release valve operates, allowing accumulated air to be discharged, flow resistance and headloss decreases. If a pump has sufficient head and capacity, it is possible for the velocity of the liquid to carry accumulated air from the high points down the piping system and eventually out at the discharge point; however, this frequently is not possible and a line may become airlocked.

Two major types of air release valves are available. One is an automatic air release valve which will automatically purge the high point of air without an attendant operating the system (Figure 28). This valve is located in a small manhole. The second type is a manual air release valve. It is nothing more than a valve located on a riser connected to the main line piping system. The manual air release valve is significantly less expensive than an automatic one, but frequent operation may offset capital savings. The automatic air release valve, on the other hand, does require some minimal maintenance to assure that grease has not accumulated inside the mechanism preventing automatic operation. Operators report typical cleaning schedules of two times per year.

Pressure sewer system operators suggested the desirability of using more air release valves than were included in their designs. For example, in Texas at the Lake LBJ MUD, manual air release valves are located at major high points in the line. However, the operator suggested more air release valves are needed because the velocity of sewage in the pressure mains changes the point at which the air accumulates. The higher the velocity in the mains, the further downstream from the high point the air accumulates. The same observation was made at Grandview Lake, IN. It is interesting to note that for manual air release valves operated in Texas, the operator often finds between twenty seconds and a minute of high pressure air is released during manual purging. At the General Development Utilities, the operator often can disconnect the service and work on it for several minutes with only air coming out from the connection. Large volumes of air may be minimized if a pressure sustaining device is used to keep liquid from draining out of the lines. This is especially true for those portions susceptible to gravity flow during low flow conditions when air may replace the liquid volume.

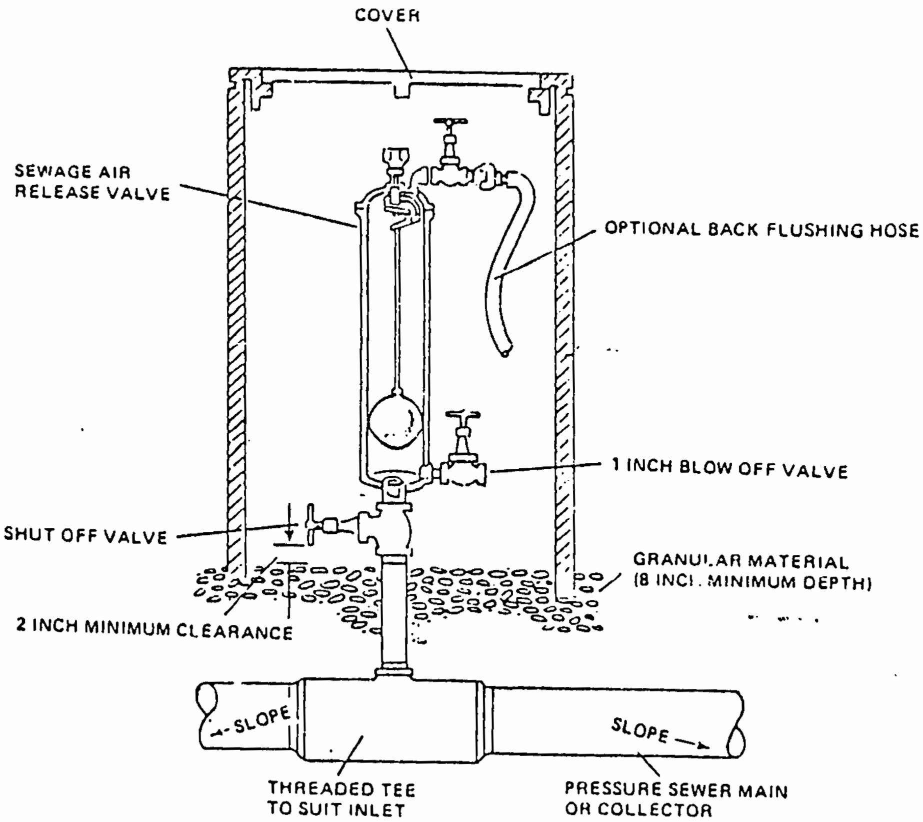

Figure 28. Automatic air release valve schematic.

IN-LINE SHUTOFF VALVES

A number of pressure sewer systems use in-line shutoff valves in the mainline piping. There are various reasons for including shutoff valves in the piping system. At the ends of the lines, a shutoff valve is included prior to a cleanout to allow for ease of cleanout access without causing sewage spills.

Valves are used in the Apple Valley system in order to route the piping system from a loop to linear layout. These valves usually are operated at intervals between six months and a year. Valves also may be located at intermediate inline cleanout locations to provide both access and bypassing for a broken sewage line segment. Fully ported valves used in these situations are either gate valves, which are most typical; or less frequently, plug valves, as used at Apple Valley. These valves have cast iron bodies even in STEP systems . Corrosion does not seem to be a significant factor with inline valves in contrast to basins where the corrosive atmosphere attacks the outside surface of cast iron valves.

CLEANOUTS

Virtually every pressure sewer system has cleanouts of one type or another. Cleanouts allow blockages in the line to be removed; provide access for flushing the lines; and provide access for bypassing a segment of line that may be temporarily out of service. There are various types of cleanouts. An in-line cleanout is usually located at changes of direction or at confluences of pipes. It is installed with a cleanout facing in one or both directions (Figure 29). There is an end of line cleanout (Figure 30) and there are service line cleanouts where two or more service lines are connected together. Cleanout facilities almost always are located in meter boxes or in small manholes.

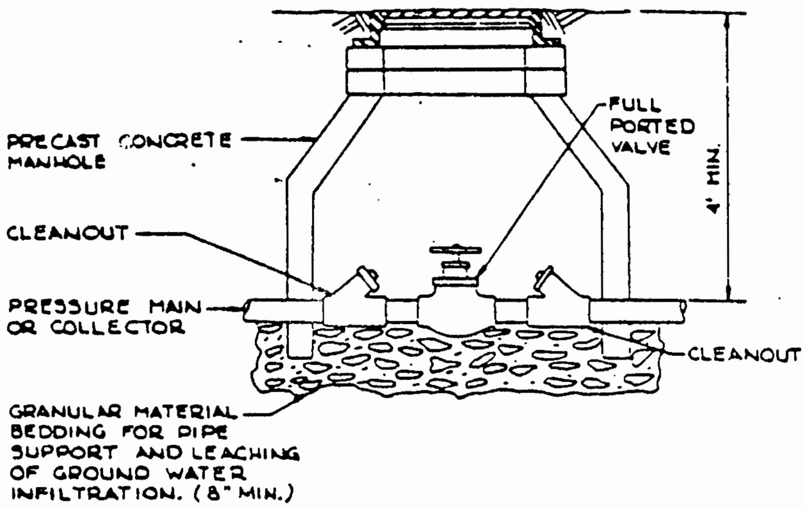

Figure 29. Valve box cleanout at Harrison, ID.

The spacing of cleanout facilities never has achieved a concord. Kreissl's (3) report recommends 122 m (400 ft) to 183 m (600 ft) maximum separation. However, in actual systems this spacing recommendation is uncommon. Cleanouts only are found on the ends of lines, at confluences of major lines, and at changes in pipe line sizing.

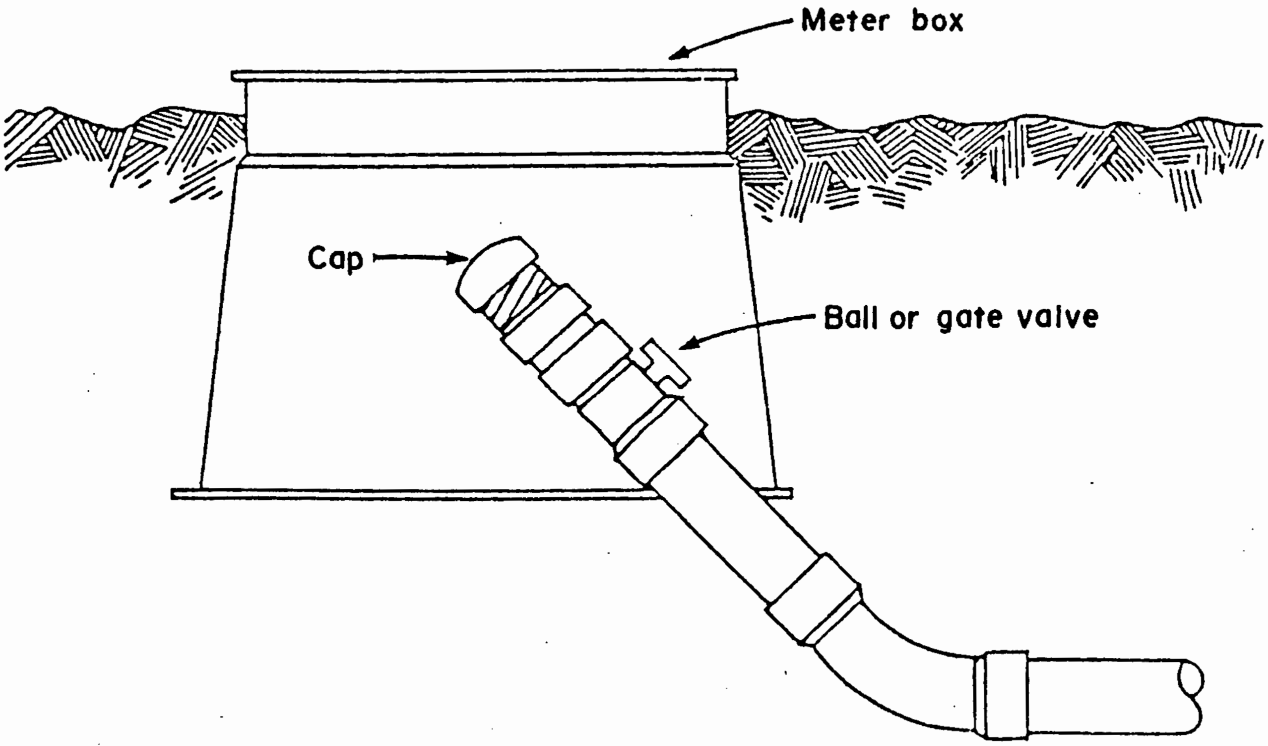

Figure 30. Terminal cleanout.

An example of an unusual type of cleanout facility is located in the Country Knolls South pressure sewer system at Ballston Spa, NY. End of line cleanouts are brought to an above grade position and finished with a cap sticking out of the ground, although construction plans called for a below grade line cleanout. According to the system operator, the cap has blown out several times, possibly due to freezing conditions. A disadvantage is accessibility to vandalism. On the other hand, the cleanout is easily located.

An ancillary design concept to a cleanout connection is a flushing station. Flushing stations are used at Grandview Lake, IN and the Lake LBJ MUD at Horseshoe Bay, TX. The advantage of a flushing station is that it can automatically pump large volumes of water through mains in order to clean out accumulated solids and grease. At the Grandview Lake system there are 3.8 m^3 (1,000 gal) holding tanks with 0.56 kw (0.75 hp) centrifugal pumps, actuated by timers and stopped by low level float switches, flushing the mains with septic tank effluent. Several similar facilities were provided at Lake LBJ, although they used potable water with an air gap. The relative advantage of the Grandview Lake system was that it did not add additional water to the treatment facility. The H-O-A switches and timers which control the flushing station can be set to operate during low flow periods.

VELOCITY

Liquid velocity in pressure sewers is inextricably tied to overall system design: i.e., nominal pipe diameter, number of homes, and number of contributing units. There are two major concerns in determining overall velocity: scouring and grease accumulation, providing the contributing pumping units have sufficient head to overcome the friction loss developed.

Scouring velocity in mains has been presented both by Hobbs (22) and by Flaniga, et. al. (23) for the minimum scouring velocity for 5.1 cm to 20.3 cm (2 in to 8 in) plastic lines. Battelle considered transport of sand using the equation:

$$V_S = d^2/2,$$

where V_S = the minimum scouring velocity in feet per second

d = the minimum inside pipe diameter in inches.

In that study, sewage that was tested had grease concentrations ranging from 15 to 365 mg/l, which approximated conventional sewage. However, these tests were performed without lengthy periods of flow or no - flow which could radically affect the sand transport capability if a grease sand matrix were found adhering to the piping system.

Grease accumulations in pressure sewers have been noticed at ends of lines and, in some systems, in service lines and throughout the mains. Grease accumulation adds to friction losses by two mechanisms. First, an increasingly rough surface lowers the coefficient of friction. Second, a decrease in the effective open area of the pipe occurs, thus increasing friction loss for the same liquid flow rate. Grease accumulation problems are less of a concern in STEP systems than GP systems.

PRESSURE

Pressure developed in any force main is related directly to elevation and friction loss requirements. Friction loss will vary with time, presence of air, amount of grease and solids plating, and the type of pump in service (e.g. semi-positive displacement or centrifugal.) If a semi-positive displacement pump is used, then greater heads can be developed to overcome friction loss. A centrifugal pump develops only its shutoff head, while the semi-positive displacement pump continues to develop substantial amounts of head over its design head.

Pressures seen in GP and STEP systems depend on the static lifts of the system. For example, General Development Utilities systems in Florida, are in very flat terrain, typically operate at heads less than 7.6 m (25 ft). Some of the systems in more mountainous terrain, such as in Priest Lake, ID, operate over elevation ranges in excess of 60 m (200 ft). If elevations to be overcome are greater than the capability of the pumping unit, then intermediate lift stations are required. Pressures in virtually every pressure sewer system have been less than 625 kPa (90 psi) and more than 69 kPa (10 psi). The 625 kPa (90 psi) figure was encountered during abnormal pumping conditions due to accumulations of air at high points with inoperative or nonexistent air release valves.

FUTURE SYSTEM USAGE

Many existing pressure sewer systems have been installed with a substantially lower number of initial users than their ultimate full-flow capacity. In some second home developments, in fact, such systems have been installed and operated with as few as 5 or 10% of the ultimate number of connected homes. Questions frequently encountered during the design phase include: Should the designer plan the piping system for the entire ultimate development or phase piping sizing to account for future development? A corollary question is: If an area has sufficient capacity to sewer all potential customers within a service area, how can additional inputs beyond the existing sewer area best be handled?

There are many ways to account for growth. For example, the Apple Valley sewers in Mount Vernon, OH are partially gravity and pressure. Areas served by pressure are lakefront properties. These areas have looped pressure sewers and feed back into a common gravity manhole. During the initial low density contribution to the piping system, valves are operated such that the entire flow of the pipe may be clockwise or counterclockwise. This will enable all contributing units to flow through the same pipe segment. The system has valving so that if a valve at the far end of the loop were shut then half of the contributing units would flow to one segment of the loop and half would flow down the remaining segment thus doubling the capacity of the line without significantly increasing the initial capital cost.

Another alternative for future development is to install the lines at their ultimate capacity, but to account for possible grease buildup during low or inactive flow periods by installing flushing stations at the ends of lines. This is accomplished at Lake LBJ MUD at Horseshoe Bay, TX.

Another alternative is to install parallel lines, with one of a smaller size and one of slightly larger size. When ultimate development occurs both lines would be used. The disadvantages are the significant increase in the construction cost and identification of service connections to both lines. Another alternative to accomodate future growth is to plan for parallel lines, but construct the second line as the need arises.

SECTION 7

CONSTRUCTION REQUIREMENTS

ON-LOT

On-lot facilities consist of the service line, pumping unit valves and main connection. Frequently, pump systems have designs which permit low intensities of labor input for complete construction. General Development Utilities have simplified on-lot installation by using a fiberglass tank and an effluent pump which draws power through a plastic conduit plugged into an outside receptacle.

Proper construction of on-lot facilities are important to the overall system success. For example, loose joints between the home and pumping unit often can account for significant infiltration into the pressure sewer system. Loose joints also may allow sand and silt to enter the pumping unit. Frost depth should be considered. In a shallow installation in a northern climate, severe problems may develop from freezing. This situation was encountered at Weatherby Lake and solved by the installation of styrofoam cutouts. The location of the pumping unit on-lot is dependent on maintenance, power supply and aesthetics which must be addressed in any proposed installation.

OFF-LOT

Unlike gravity sewers, some latitude is permitted in laying pressure sewer pipe, but good jointing techniques are essential. Careful bedding is an essential requirement to the piping system. Bedding with approved granular material usually is specified. Care also must be taken in backfilling to prevent sharp rocks or crushed stone from scouring the pipe.

Normal depth of pipe installation is no less than water main burial for the same location. Pipe has been buried as shallow as 0.45 m (1.5 ft) in Florida installations. Usual practice is to secure the pipe at every change in elevation or direction by the use of thrust blocking.

Various systems have different requirements for pressure testing of the pipe. Typically, air or water testing for a period of 30 minutes to 2 hours has been practiced. The leak test usually is performed at approximately 1,041 kPa (150 psig); however, other pressures such as 694 and 868 kPa (100 and 125 psig) has been used.

Although solvent weld piping has been in common practice in water systems for numerous years, push-tight joints on PVC piping have become an acceptable practice due to ease of installation, low leakage, and provisions for expansion and contraction. Solvent welds must be performed on a dry, clean pipe surface and not during wet or very humid conditions. Bedding and pressure tests would be similar to the requirements for water main installations for the same kind and class of pipe.

SECTION 8

OPERATION AND MAINTENANCE

GENERAL

As with any complex mechanical system, pressure sewer systems require rigorous O & M. Some tasks are required daily, weekly, monthly, semi-annually, annually or at longer intervals for continued proper operation. Effective preventive maintenance has been found desirable in reducing the frequency of emergency breakdown maintenance in pressure sewer systems.

This section is divided into tasks relating to O & M for each of the on-lot components and those dealing with requirements of the piping system components.

The relative reliability of each system can be inferred by analyzing a parameter called the "Mean Time Between Service Calls" (MTBSC). This parameter, measured in years, determines the mean time interval each component can last without a service call for either repair or replacement. For example, if a system had 400 pumps and each year 100 pumps required breakdown maintenance, then 25% of the pumps required service in a one year interval. The MTBSC then is the reciprocal of the fraction of pumps requiring service, or an MTBSC of 4 years.

Similar data is presented for most of the systems investigated, where either detailed records were available, or where the operator exhibited significant recollection to estimate these parameters.

One of the greatest demands on an operator's time in a pressure sewer system is his supervision and coordination of on-lot facility installations. Operators from Horseshoe Bay, TX; Weatherby Lake, MO; Apple Valley, OH; Florida systems; Idaho systems and other reported that they spend between 10 and 33% of their time on this activity.

Inspection trips to various pressure sewer installations revealed that recordkeeping generally is deficient. Most opinions of operators are subjective and are based upon limited data. In many cases, information given during interviews is contradictory. For example, where operators are of the opinion that the system is performing well, service calls are understated when compared to what documentation is available. The reverse often is true when the operators are dissatisfied with system performance.

The problem of securing objective data is compounded for hybrid systems, or those with several different pump manufacturers. Frequently no distinction is made between the types of systems or the kinds of pumps serviced.

In this report attempts were made, wherever possible, to segregate O & M information into distinguishable components. Although potentially biased, pump manufacturers tended to be good sources of more detailed information.

PUMPING SYSTEMS

Effluent Pumps

STEP systems at Port Charlotte and Port St. Lucie, FL, and at Coolin and Kalispell, ID, include over 841 pump installations. The Florida locations are important because of the duration of operation; one area has been in operation since 1970. In Idaho, the more than 588 pumps represent a sizable system. Experience at these locations has been good and is expected to improve because many early problems have been identified and corrected. For example, at the Florida locations most pump service calls were for pumps installed in the first three years. Specifically, 11 out of 15 calls at Port St. Lucie were for pumps installed in the first two years. Initially, Hydr-O-Matic SP33, 1/4 hp pumps were used. Subsequently, it was shown that pumps with oil-filled motor cavities (Hydr-O-Matic OSP-33a) performed more reliably. Since 1974, at Port Charlotte, only 6 pump-related service calls have been reported for the 62 installed systems.

The oil-filled motor cavities caused problems at Idaho because leakage resulted in failures of the capacitor-relay starter switch. Such problems were categorized as non-pump related and accounted for over 75% of operational problems. Leakage problems have been corrected.

Installation problems can account for a significant percentage of system failures. Twenty percent of the service calls for pumps are ascribed to faulty installation at Port St. Lucie. Likewise, in Idaho, poor wiring discovered at installation or shortly thereafter was significant. As effluent pump installations become more numerous, it is reasonable to expect that installation reliability will increase.

The Florida systems originally used pressure switches for level controls. Nearly 20% of service calls at Port St. Lucie were related to pressure switch failures. Even though these switches have an average life of 4 years and cost approximately $15.00 to replace, some are being replaced by the more reliable mercury float level switches.

A difficulty encountered in assessing STEP system reliability is inherent in the manner in which service records are kept. Problems with pumps are not necessarily reflective of the total scope of system problems. For example, of the 191 units installed at Port St. Lucie, maintenance records are fully available for only 87. These records indicated 58 service calls during a 5 year period; however, maintenance personnel report about 5 to 8 service calls per month. Hence, assuming an average of 6 service calls per month for the 5 year period (360 calls), roughly 16% were judged to be pump related. This figure compares well with data from the Idaho systems where 12% (30 out of 250 service calls in a 2 year period) of calls were due to pumps.

Table 7 shows an approximate distribution of types of O & M problems at Port St. Lucie, along with potential remedies. At all locations, a service call is made when the alarm light is on and/or the toilets flush slowly.

The Idaho installations problems could be observed at other systems located in rural areas. Frequently low voltages are encountered leading to increased pump currents and thence pump overheating. Overheating in turn causes the two, 220 v fuses to blow out and a failure signal occurs. Although the remedy is simple - fuse replacement, the process is time consuming and over a long term could conceivably be damaging to the pumps.

Pumps can become air bound when the pump vent hole becomes plugged. The electrical cords and air vent lines are bundled in Florida. In the event of a kink in the vent line, repair is not possible, and the entire bundle must be replaced. This is an arduous task. Likewise, the bundles cannot be extended, but rather must be totally replaced.

Preventive maintenance plays a major role in reducing system difficulties. Originally, the Florida systems scheduled preventive maintenance calls every three years. These are now performed annually. Reduced service calls are attributed, in part, to more frequent preventive maintenance. The Idaho system also schedules one preventive maintenance call per year, at which time the pumps and chambers are hosed to remove buildup of oils, greases and scale.

Table 8 summarizes some of the important O & M characteristics for the Florida and Idaho STEP systems. Parameters in-

TABLE 7. SERVICE CALLS AT PORT ST. LUCIE, FL

Approximate % of Total Service Calls	Problem	Remedy
20	Installation: a) Couplings blow off b) Mercury float switch improperly adjusted c) Inadequate electrical installation	a) Reattachment b) Readjustment c) Rewiring
10	Nothing wrong	
10	House plumbing, pipes clogged	Usually a plumber's snake is sufficient
10	Frozen impeller - when part-time residents leave and pump is not in use scale builds up on bridges from impeller to pump body	Manual rotation of impeller to break scale
20	Pressure switch	Replace with mercury float switch, new pressure switch or relieve kink in breather tube
10	Electrical system	Call electrician
10	Pump clogged, can also be caused by scale	Refurbish pump
10	Air lock (because of gas accumulation or air entrapment)	Retap pump vent hole

TABLE 8. SUMMARY OF EFFLUENT PUMP MAINTENANCE RECORDS

Location	Number of Installations	Years of Operation	Number of Service Calls	Mean Time Between Service Calls
Port St. Lucie	191	5	58[1]	3.6 yr
Port Charlotte				
Section 18	29	8	15	6.3 yr
Section 54	33	6	15	7.7 yr
Coolin	356	5	30[2]	37.4 yr[3]
Kalispell	232	4	30[2]	37.4 yr[3]

[1]Based upon records for 87 pumps.

[2]Pump related service calls.

[3]Based upon past two years of experience for pumps only.

cluded are: number of installations, years of operation, number of service calls and MTBSC. While these figures are estimates, based upon records available, they do give an indication of overall system reliability.

Grinder Pumps (Semi-Positive Displacement)

Of the almost 100 pressure sewer installations in the country, GP systems clearly predominate. As described in earlier sections, GP are either semi-positive displacement or centrifugal types. Various operational and maintenance problems are associated with each type of pumps; however, one general class of problem with the semi-positive displacement pump has been reported at every system visited. Moreover, this problem comprised a very significant proportion of all system failures. Hence, this problem - boot failure - will be discussed in some detail.

Figure 31 shows the five basic modes of boot failure, causes of which are explained below. Tearing of the rubber skirt can occur during short and periodic dry running of the pump stator. This can be caused by failure of the pressure switch to shut down pump operation after the chamber has been evacuated. If the pump runs continuously when dry, then the boot core can burn out.

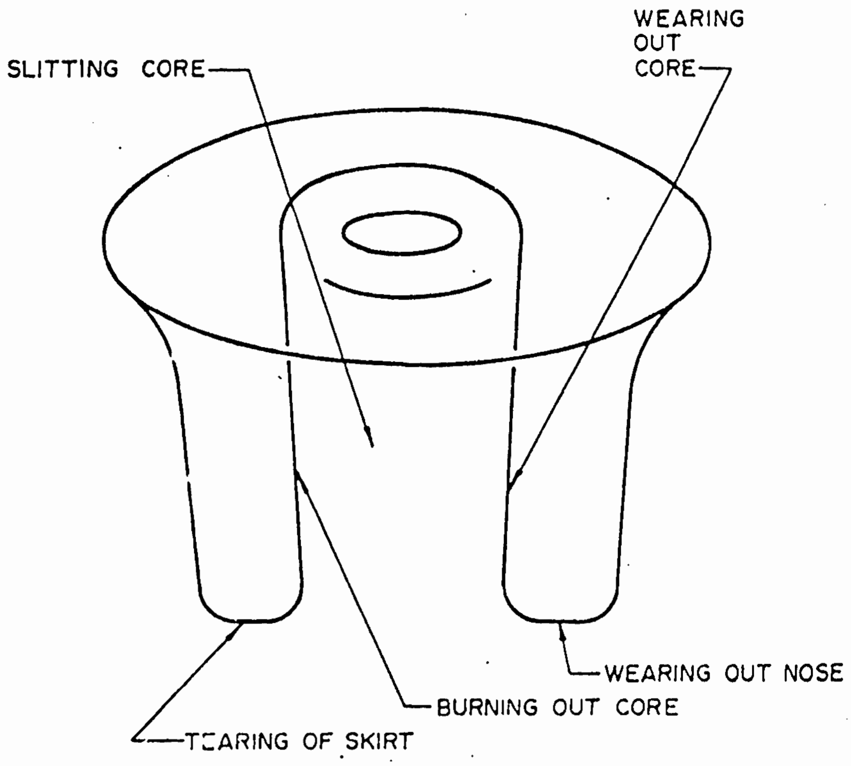

Figure 31. Boot failure mode.

Another common failure mode occurs when the boot core is worn out. This occurs when abrasives such as sand, plaster or egg shells routinely enter the pump chamber. This problem can be minimized by reducing the presence of abrasives through instruction of householders, installation of grit traps, or improving the durability of the boot.

Core splitting can occur when over pressures of up to 694 kPa (100 psi) are repeated for long periods. In most cases, this less frequently observed problem can be minimized by careful attention to overall system design and prevention of grease buildup in service lines and mains. Finally, the wearing out of the core nose is indicative of the end of boot useful life. This problem is not regarded as normal and should not occur for many years.

In its own evaluation of failure rates, the manufacturer of the semi-positive displacement pumps has shown that inadequate level switches caused boot failure at a rate three times that of other pumps. Where they corrected the level switch problems, boot failures dropped drastically.

Typically at Horseshoe Bay, with about 50 service calls per year, 75% of problems are ascribed to pressure switches with another 10% attributed to boot failures from unknown causes.

The Lake Mohawk system also reports a high percentage of service calls due to boot problems. Over 56% (98 of 174) of service calls have been so categorized. During 1977, 85% of 80 service calls were for boot failures. It takes two hours for one man to replace a boot, unless it is too deep for one man to pull the pump; then two men are needed.

Country Knolls South, one of the first semi-positive displacement pump installations, reports 13,224 pump-months of service. For this period, 391 pump repairs were reported. Boot problems account for 64% of repair calls. Boot replacement takes from 1 to 1.5 manhours. Environment/One tested 20 selected pumps at this site by recording boot failures before and after raising the turn off level and readjusting the time delay relays. These 20 pumps originally had the highest rate of boot failures in the development. After modifications, no failures were reported for the 13 month period to date.

The Sausalito, Kappas Gate 6 facility has 50 to 55 semi-positive displacement pumps. The local pump representative reported only 5 boot failures in two years. Replacement takes about one manhour. Boot replacement at Weatherby Lake also is reported to take one manhour. These problems represent about 39% of all service calls. There was significant improvement in performance of the semi-positive displacement pumps at Weatherby Lake when the manufacturer replaced the time delay relay. In the older configuration the time delay relay switched on at 30 cm (12 in) and off at 14 cm (5.5 in). In the new edition, the switch is on at 43 cm (17 in) and off at 30 (12 in) which is similar to modifications made in the Country Knolls South test. Clearly, this should be helpful in protecting the boot because if the pump continues to run, the boot will remain immersed, thus eliminating the dry running problems.

The manner in which maintenance records are kept can lead to misinterpretation and erroneous diagnosis of problems. For example, previous sections have shown that boot failures can result from several primary causes. At Lake Mohawk it was claimed that 85% of service calls were boot failures. Only 5% are attributed to pressure switch or time delay relays, when in fact these may be the primary cause of boot failures.

Table 9 shows a distribution of service calls for two large semi-positive displacement pump locations, i.e. Country Knolls South (355 units) and Weatherby Lake (362 units), as reported by Environment/One Corporation.

TABLE 9. DISTRIBUTION OF SERVICES CALLS[1]

Country Knolls South		Weatherby Lake	
Problem	Percentage	Problem	Percentage
Boot failure	64	Boot failure	39
Time delay relays	7	Boot replacement, unknown cause	10
Sensing bell plugged with grease	7	Frozen discharge line	11
Bearings	3	Pressure switch:*	
		Failure	7
		Overflow	8
		Stuck	1
Centrifugal switch	3	Circuit breaker off	6
Unknown	16	Discharge check valve leak	6
		Jammed grinder	3
		Unknown	9
	100		100

*Now obsolete

[1]From data reported by Environment/One Corp.

Weatherby Lake service personnel have constructed a pump test center for troubleshooting their semi-positive displacement pumps. A breakdown of the types of service calls the system experienced is included in Table 10.

TABLE 10. TYPES OF SERVICE CALLS - WEATHERBY LAKE, MO

	Number of Service Calls	% of Category	% of Total Service Calls	MTBSC for Category (years)
Installation				
Pump and Piping Installation	3	100	0.9	198
Electrical				
Circuit Breaker	22	37.9	6.2	
Wiring	16	27.6	4.5	10.2
Horn Switch	20	34.5	5.6	
Total	58		15.9	
Pump				
Core Replaced - Damaged or Unknown Noise	19	12.2	5.4	
Core Replaced	2	1.3	0.6	
Jammed Grinder	1	0.6	0.3	
Motor Failure	3	1.9	0.9	
Pressure Switch	12	7.7	3.4	
Mechanical Seal	1	0.6	0.3	
Shaft Seized	7	4.5	2.0	
Stator	104	66.7	29.3	
Time Delay Relay	1	0.6	0.3	
Cracked Housing	1	0.6	0.3	
Vibration	2	1.3	0.6	
Repaired for Unspecified Reason	3	1.9	0.9	
Total	156		44.3	3.8
Piping				
House Service Line Broken or Blocked	11	29.7	3.1	
Check Valve Leaked	7	18.9	2.0	
Frozen Discharge Line	19	51.4	5.4	
Total	37		10.5	16.0
Other				
Pump Tank Frozen	2	2.0	0.6	
Lock on Tank Lid	1	1.0	0.3	
Corrosion	1	1.0	0.3	
Nothing Wrong	10	9.9	2.8	
Vent Tank	87	86.1	24.5	
Total	101		28.5	5.9
Total Service Calls	355			
Pump Months of Service	7,124			
MTBSC Total				1.7

Table 11 shows a comparison of repair labor and costs for several semi-positive displacement systems.

TABLE 11. SEMI-POSITIVE DISPLACEMENT PUMP SYSTEM REPAIR LABOR AND COSTS

Location	Repair or Service	Labor (manhours)	Cost ($)
Country Knolls South	Control system	1 - 2	
	Boot replacement	1 - 1.5	
	Motor	3 - 8	
	Seal	3 - 8	
	Capacitor	3 - 8	
	Rotor	3 - 8	
	Bearings	3 - 8	
Kappas Gate 6	Boot replacement	1	50
Weatherby Lake	Boot replacement	1	
	Pressure switch	0.7	
	Time delay relay	1	
	Vent kit	0.3	
	Clean stopped line from house to pump	0.2	
	Electrical	0.3 - 1	
	Pump overhaul parts:		
	Motor		192
	Switch		120
	Time delay relay		8
	Seals		30
	Boot		20
	Small seals, bolts, nuts, etc.		9
	Labor - (4 hrs)		25
	Total		217
Lake Mohawk	Boot Replacement		
Point Venture	Boot Replacement		

Grinder Pumps (Centrifugal)

One of the most commonly observed problems for centrifugal grinder pumps is air binding and locking. Such problems have been documented at Seabrook, TX; Apple Valley, OH; and Grandview, IN. Typical of the mode of repair is the procedure undertaken at Apple Valley. The pumps are removed, shook and then replaced. Such problems are most often seen at new pump installations.

At Horseshoe Bay 3 centrifugal grinder pumps served 60 condominiums, a clubhouse and restaurant. After 3 1/2 years of use, there were no failures. Sixty centrifugal pumps have been operating for a year at Horseshoe Bay. Only one service call is reported and this was related to poor pump installation. Manufacturing problems observed within two days after installation were evident at Seabrook. Two of 16 pumps needed motor service.

Seabrook reports the following types of problems:

1. Two electrical control panel malfunctions, repaired by an electrician within 30 minutes.

2. One capacitor burn out.

3. One pump burn out.

4. One outage of unspecified cause.

At Apple Valley 55 service calls have been reported for the centrifugal grinder pumps since October, 1974. Currently, there are 51 pump installations. The operator claims that all but 4 or 5 service calls have been caused by grease on the fixed arm float switches. Other service calls were related to skinning of electrical wiring during installation causing a short circuit; lightning; and defective wiring. The pressure sewers discharge into a gravity system. The estimated division of operation and maintenance between the pressure and gravity systems is 15 and 85%, respectively.

Table 12 shows labor and cost estimates for repair of centrifugal grinder pumps.

TABLE 12. CENTRIFUGAL GRINDER PUMP REPAIR LOCAL LABOR AND COST ESTIMATES

Repair	Parts	Part Cost ($)	Labor (hrs)	Labor ($)
Abrader Failure[1]	Abrader	43		
	Impeller	75	1	16 - 18
	Cutter	19		
Seal failure[1]	Seal	19	3 - 4	48 - 72
	Motor	337		
Other repairs[2]	Pump refurbishing		0.3	
	Storage tank cleaning		1	
New unit*[1]	Motor (2 hp)	741		
	Starter and control panel	175		

*Discounts: 25% for contractors
25% + 20% for wholesalers

[1]Peabody Barnes, Sausalito System (Bay Area, CA, May, 1978 costs)
[2]Hydr-O-Matic, Seabrook System

Valves

The most serious problem with valves is corrosion. At both of the Florida installations inspected, Port Charlotte and Port St. Lucie, the cast iron and brass valves corroded quickly. Experience has shown that bronze valves, now used at both Florida systems, provide satisfactory results.

Every system using cast iron valves has noted corrosion problems. Some other systems also have had trouble with brass check valves. For example, the Klaus system in Portland has replaced all of the original brass check valves with heavy duty bronze valves.

Although several facilities reported no valve difficulties, larger and older systems had some of the following types of problems: grease plugs in-service line check valves; frozen check valves; leaking check valves; and leaking air release valves. Periodic flushing should prevent the formation of grease plugs. In general, proper gasket and valve installation can overcome most leakage problems.

ODOR ABATEMENT

Odor problems have been documented at several locations. The most commonly observed location for odor problems is at lift stations. Several novel methods have been used to overcome the odor problems. For example, odors from the lift stations at Kalispell are vented to a drainfield for soil scrubbing. At the Klaus system when odors are found, the remedy involves resetting the levels or timers on the pumps for more frequent intervals. For the Klaus system, odors are a presumptive indicator of pump difficulties. Weatherby Lake adds hydrogen peroxide at three lift station locations. About 0.06 m^3/day (15 gal/day) of 35% hydrogen peroxide is used for odor control.

Port Charlotte has the capability to add chemicals for odor control, e.g. ozone or chlorine can be added at the pump station before the treatment plant. However, odor abatement is rarely used. In fact, the sister system, Port St. Lucie, has no odor control capabilities.

At the Apple Valley system, pressure sewers discharge to a gravity collection system. Odors have been noted near one manhole in particular; however, there is no conclusive evidence that the odor results from the pressure sewers.

CORROSION

Corrosion problems appear to be most severe in Florida installations. Difficulties with valves have been cited previously. In addition, steel clamps on pipes in pump chambers corrode quickly. This problem has been cured by using all stainless steel bands throughout. Corrosion in Florida is characterized by hard scale formation.

Some observations at other locations include:

1) Horseshoe Bay, TX - Lids on the pump canisters corroded. The remedy involved using PVC or fiberglass for replacement lids.

2) Kalispell, ID - Most evidence of corrosion was at lift stations. Presumably, this is because of the higher concentrations of hydrogen sulfide at that location.

3) Klaus System, Portland, OR - No corrosion has been noted in the piping system, only at lift stations.

4) Bend, OR - Within 1 month, steel covers on septic tank pump chambers showed substantial corrosion, even though painted. After 12 months, the corrosion had not spread noticeably.

The conclusion is that septicity and associated formation of hydrogen sulfide greatly accelerates corrosion. Where possible, steps should be taken to minimize hydrogen sulfide concentrations. If such measures are not possible or effective, then remedies must be related to design or substitution of suitable materials of construction.

OTHER PROBLEMS

The following discussion cites problems not covered elsewhere. Such problems, while unique to specific locations, could conceivably occur in multiple sites.

Horseshoe Bay, TX

Pump servicing is complicated by the weight of pumps. The Environment/One pumps weigh more than 45 kg (100 lbs) and the Hydr-O-Matic about 32 kg (70 lbs). This is difficult for one person to handle, and requires two people for chambers in locations with difficult access.

Port Charlotte and Port St. Lucie, FL

In certain locations, nylon screens have been used between the septic tanks and pumps as an experiment to determine if screens can prevent wedging of large objects between impellers and the pump housing. Screens clog because of large floatable objects (presumably grease globules) and especially because of cigarette filters. There is a serious questions of whether the screens caused more problem than they were designed to overcome.

Klaus System, Portland, OR

One of the biggest problems in this system is misuse by homeowners. Maintenance personnel have found garbage in the pump chambers, and have removed sponges, shorts, sanitary napkins, toys and balls from jammed pumps. Additionally, build up in service lines require flushing about every six months.

Weatherby Lake, MO

This system has had poor experience with its alarm system. Eleven horn or switch problems were reported in 1977. The system has both light and horn alarms.

PIPING SYSTEMS

Preventive Maintenance

In general, the systems investigated had the capability to flush pressure sewer lines, but most systems were flushed daily only after a line was clogged. It may be presumed that such is the case because system operators either believed that such maintenance is unnecessary or because of lack of information on preventive maintenance.

Table 13 summarizes information on piping system preventive maintenance functions.

Breakdown maintenance, however, may not be the most cost-effective solution for piping system maintenance. Many instances of impaired hydraulic capacity due to grease buildup in lines have been documented. Hence, running to failure could lead to more expenditures than would be encountered if preventive maintenance were utilized.

The automatic flushing stations at Point Venture involve submersible pumps in a water chamber controlled by an electronic timer. At Apple Valley, flushing connections are available at various locations. Some systems flush through cleanouts.

TABLE 13. PIPING SYSTEM PREVENTIVE MAINTENANCE

Location	Maintained By	Flushing Frequency	Other Maintenance
Horseshoe Bay	Municipal Utility District	Two weeks/year; also automatic flushing stations	
Point Venture	Development operator	Four automatic flushing stations	
Apple Valley	County	Annually	Quarterly installation checks
Country Knolls	Development operator	At breakdown	
Port Charlotte	Development operator	At breakdown	Septic tank pumping
Port St. Lucie	Development operator	At breakdown	Septic tank pumping
Kalispell	Development operator	At breakdown	Septic tank pumping
Klaus	Homeowner	As needed	
Kappas	Homeowner	None	
Grandview Lake	Homeowner	At breakdown	Septic tank pumping

Examples of preventive maintenance utilized in several systems include:

1) Apple Valley - In-line shutoff valves are manually operated once or twice a year and direction of flow is changed at about the same frequency for looped service lines and mains.

2) Klaus System - Pipe flushing uses river water. For example, it takes about two hours to flush about 1,200 feet of pipe. Lift stations are inspected every two weeks with routine maintenance occurring monthly.

3) Grandview Lake - For installations where a septic tank is involved, homeowners pump septic tanks about every 3 to 4 years.

Malfunctions/Other Problems

Most piping system problems can be categorized as construction and installation related, leaks and breaks, and frozen lines. In the first instance, problems occur when lines are not installed at the proper depth and structural damage results when there is poor pipe bedding; and when dirt or other foreign objects enter the lines during installation.

Leaks and breaks appear to be more frequent for dockside and houseboat systems, which should be expected. This happens when there is insufficient compensation to overcome shifting from wakes and tides. At the Kappas system, six breaks were reported for 35 installations over a two year period. Repairs took 10 to 15 minutes. Twice main dock lines came apart because of shifting and no hub fittings on the ABS pipe. Also, problems on the connections between flexible hoses and rigid pipes have been eliminated by installing a 90° elbow with a quick disconnect fitting.

Other difficulties include clogging of lines because of air and solids buildup, and solids accumulation at line ends. In the latter case, the solids are soft and appear to be saponified grease.

SYSTEM COMPARISONS

An estimator of the total operation and maintenance efforts involved in the STEP, GP and solids handling pump systems is presented in Table 14. The majority of the information available is in pump reliability, expressed as the MTBSC. Estimates of overall system performance were obtained for only one of each type of system, and may not provide a true indicator of system reliability, including piping problems such as leaks, freezing or air locks. Pump maintenance requirements are thought to be over estimated, with actual operating pumps now yielding a longer MTBSC than presented. This reflects the effect of various and continual modifications made by pump manufacturers to their units.

TABLE 14. MEAN TIME BETWEEN SERVICE CALLS FOR ALL TYPES OF PRESSURE SEWER SYSTEMS

System Name	System Type	Year Started	Overall System	Environment/One	Hydr-O-Matic	Peabody Barnes	Toran
Port Charlotte, FL Section 54	STEP	1970			7.7		
Port Charlotte, FL Section 18	STEP	1970			6.3		
Port St. Lucie, FL	STEP	1972			3.6		
Priest Lake, ID	STEP	1974	2.4		19.6		
Apple Valley, OH	GP	1973			1.5		
Seabrook, TX	GP	1977			5.6		
Sausalito, CA Houseboats	GP	1976		10.4	10.0	1.8	No Failures
Point Venture, TX	GP	1972		1.2			
Weatherby Lake, MO	GP	1975	1.5	3.8			
Schenectady, NY Campbell Avenue	GP	1973		7.5			
Lake Cavalier, MO	GP	1976		9.8			
Horseshoe Bay, TX	GP	1972		1.6			
Country Knolls, NY	GP	1973		2.8	No Failures		
Lake Mohawk, OH	GP	1974		3.0			
Lake of the Pines, PA	GP	1976		3.5			
Quaker Lake, PA	GP	1976		6.4			
Portland, OR Houseboats	Solids Handling	1968	3.6			5.8	
Sausalito, CA Houseboats	Solids Handling	1975				1.0	

SECTION 9

TREATMENT

GENERAL

Characterization and treatability of pressure sewer wastewater typically has been one of the most neglected aspects of the entire pressure system concept. One of the most notable benefits of a pressure sewage collection system is the veritable absence of infiltration and inflow within the closed piping system. However, there is the possibility of some infiltration and inflow if there are leaky or poorly inspected joints between the house and pumping unit, or if water enters the pumping unit basin or septic tank through cracks or misfitted joints.

Approximately half of the pressure sewer systems transport sewage to their own treatment facility. Many of the systems have treatment facilities that combine the pressure collected sewage with sewage from other areas served by gravity. Of the sites visited in this study, Country Knolls South, Horseshoe Bay, part of Port Charlotte, Grandview Lake, Coolin and Kalispell, Lake Mohawk, and the Glide-Idelyde have their own treatment facilities fully dedicated to treating 100% pressure collected wastewater.

The major difference between GP and STEP system wastewater is that GP system sewage has more concentrated BOD, SS and other characteristics than gravity collected sewage; whereas STEP system wastewater has lower concentrations compared to gravity collected sewage. However, there may be some individual parameters that do not adhere to this generalization. Also, in STEP systems, septage must be pumped out on a regular basis and the treatment and disposal of this material must be taken into account. For a further discussion of the treatability and state of the art concerning this material, see reference (32).

WASTE CHARACTERISTICS

Grinder Pump Sewage

Grinder pump sewage contains from moderate to strong wastewater when compared to conventional gravity sewage. It is typically 25 to 50% stronger than in domestic gravity collected sewage. Grinder pump sewage also produces more finely divided solids (smaller particles) than a communitor in a conventional treatment facility. Kreissl's (3) report indicates potential for large variations in flows at a sewage treatment plant serving a community that only has pressure sewers. This large variation in flow has not been seen in any sewage treatment plant visited during the course of this report.

The appearance of very fine particulate matter in GP sewage is a consequence of the effective grinder mechanism in the pumps. A disadvantage associated with this very finely ground sewage may be that the solids tend to settle out more slowly than they do in conventional gravity sewage. Figure 32 compares the South Pearl Street GP sewage collected in the Albany pressure sewer system study with gravity collected sewage in tests at the Battelle Laboratories' pilot plant. Better removals for comminuted gravity collected sewage compared to pressure collected sewage from a GP system are shown at various overflow rates.

Grinder pump sewage exhibits consistently higher organic loadings than gravity collected sewage. The average influent BOD_5 of typical municipal wastewater is reported to be about 200 mg/l by General Development Utilities in Table 15, while the systems in Table 16 report a mean BOD_5 of 255 mg/l with a range of 93 mg/l to 690 mg/l. Similarly, General Development Utilities reports typical municipal wastewater contains 200 mg/l SS, while the systems in Table 16 report a mean SS of 264 mg/l, with a range from 60 mg/l to 1,080 mg/l.

STEP System Sewage

STEP system sewage also has little or no infiltration or inflow as a result of the tight piping system. Removal characteristics of the septic tank result in lower average concentrations of organic loading than conventional gravity sewer systems. A recent EPA report lists typical septic tank effluent as 100 - 180 mg/l BOD_5, SS removal of 70 - 90% and grease removal of 70 - 90% in septic tanks. While these numbers reflect excellent removals, many similar systems show significantly lower removals for all these parameters. It has been observed and reported that there is some conversion of solid BOD_5 into soluble BOD in the septic tank (5). This liquification is reported to be intermittent and may be accompanied by gas production.

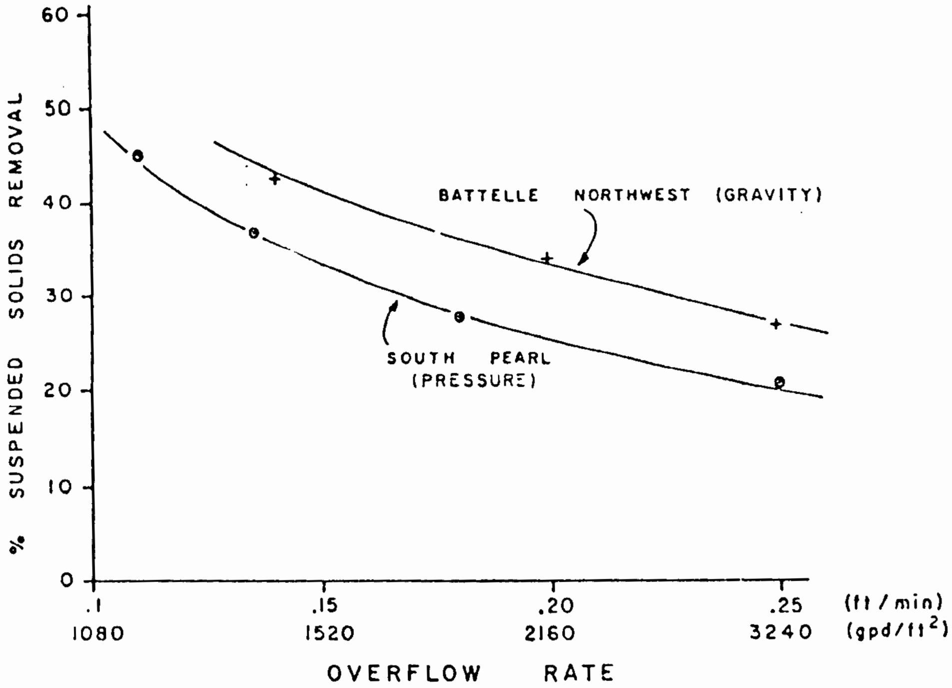

Figure 32. Percent suspended solids removal vs overflow rate.

TABLE 15. MUNICIPAL HOUSEHOLD SEWAGE CHARACTERISTICS, ALBANY, NY

Parameter mg/l	Albany Project (8)	Typical Municipal Waste (35)	Typical Municipal Waste (36)	Typical Municipal Waste (37)	Household Wastes With Grinder (6)	Household Wastes Without Grinder (6)
BOD_5	180	210		200	490	435
SS	200	200		200	480	380
Total Solids	700	600		700		
COD	400	350	143	500	910	710
Ammonia N	11	12	16.1	25	81	64
TKN mg, N/l	31	33	18.3	40	105	84
Total P mg, P/l	11	24			57	61
Ortho PO_4			22.8			
Alkalinity			122	100		
Grease	40	14		100	89	65

TABLE 16. GRINDER AND SOLIDS HANDLING PUMP SEWAGE CHARACTERISTICS

Parameter (mg/l)	Grandview Lake, IN (1976 - 1977) Influent Mean	Range	Ward System Bend, OR Influent Mean	Range	Lake Mohawk Malvern, OH Influent Mean	Range	Albany, NY Influent Mean	Range	Phoenixville, PA Influent Mean	Range	Grandview Lake, IN Influent Mean	Range
BOD_5	309	264 - 328	234	135 - 315	155	93 - 188	330	216 - 504	146	104 - 198	360	180 - 690
SS	234	181 - 290	225	128 - 367	102	60 - 168	310	138 - 468	248	108 - 514	467	145 - 1,080
Total Solids							681	526 - 928				
COD							855	570 - 1,450	393	311 - 524	558	460 - 707
Ammonia N	43.6	42.6 - 45.3					51	34 - 68			35	17 - 70
$NO_2 + NO_3$, mg N/l	7.28						0.1	*			6.3	5 - 7
TKN							80	41 - 144	59	36.3 - 74.1		
Total P							15.9	7.2 - 49.3	11.5	5.8 - 19		
Ortho PO_4	23.2	14.1 - 36.6					8.7	1.3 - 17.9	2		31	23 - 37
Alkalinity							198	185 - 209	288	188 - 360		
Grease							81	31 - 140				
pH		6.3 - 6.8						7.1 - 9.7		7.2 - 8.3		

*NO_3 only

Influent concentrations for various parameters are shown on Table 17 (24). Only the Gulf Cove plant in the Port Charlotte area treats exclusively STEP sewage. Limited data is available in many systems as frequently only grab samples are taken. Composite sampling techniques and recorded flow information is generally not available.

TABLE 17. STEP SYSTEM SEWAGE CHARACTERISTICS*

Parameter (mg/l)	Port Charlotte Lakeshore Circle Effluent Holding Chambers	Port St. Lucie Suburbanaer Project	Port St. Lucie Septic Tank Effluent	Port Charlotte Gulf Gulf Cove STP Through 1975 Influent	Port Charlotte Gulf Gulf Cove STP Through 1975 Effluent
BOD_5	135	206	92.5	123	6.9
SS	97	44	107	102	14.3
Total Solids	537	600	706	834	583
COD		320			
Ammonia N		42	31.7		0.79
NO_2 + NO_3, mg N/l		0.01		0.01	1.00
TKN		51		5.55	1.08
Total P				7.83	7.26
Ortho PO_4		29			
Alkalinity		335			
Grease			14.7		
pH	7.2	7	7.5	7.2	
Dissolved Oxygen					
Sulfide					

*Reference 24.

GRINDER PUMP TREATMENT PLANT DESIGN AND PERFORMANCE

As previously noted, the finely ground solids associated with GP sewage have been known to reduce the efficiency of primary clarifiers in various systems. If primary settling tanks are used, possibly more settling time and surface area should be allocated to systems treating only GP sewage in order to achieve the same removal of settleable materials as with gravity sewage. However, treatment facilities such as the Lake LBJ MUD at Horseshoe Bay and Lake Mohawk system, both of which have their own sewage treatment plants, find no difficulty in removing SS even with a design based on conventional influent characteristics.

With a higher organic loading per unit volume in GP sewage treatment systems, treatment kinetics may dictate a higher mixed liquor SS concentration is needed to achieve the same removals as would be observed in a system treating gravity sewage.

No treatment plant operator, either verbally or in reports, mentioned any problems with variation in flows at the treatment plant in pressure sewer systems. Sewage from a GP system also has been noticed to be anaerobic when entering the treatment facility.

Systems to date have not exhibited any difference in treatability where loading characteristics did not differ between GP vs gravity sewage. Effective treatment was found at conventional treatment facilities at Horseshoe Bay, at the Ward system in Bend, OR, and at the Lake Mohawk, OH tertiary plant utilizing Hydroclear sand filter units which exhibited excellent and consistent removals. It can be concluded that GP waste offers no barriers to conventional biological treatment and any biological treatment facility can, with minor modifications, accomodate pressure sewage loadings.

STEP SYSTEM TREATMENT PLANTS

Due to the limited use of STEP systems throughout the country, only one STP exclusively treats STEP system wastewater. This is an extended aeration plant located in the Port Charlotte area called Gulf Cove. Influent concentrations at this facility typically are slightly lower than conventional gravity collected sewage. However, wide variations have been observed. Lower concentrations than the mean are due to recirculation of effluent into an influent pipe line. Significantly higher concentrations, of at least an order of magnitude have been observed, but their causes are undocumented.

Since septic tanks remove a large portion of the SS and a significant portion of the BOD_5, plants may exhibit a lack of adequate solids for treatment. In the case of the Gulf Cove plant, sludge is frequently trucked in from other facilities in order to supply enough biomass for continual treatment.

TREATMENT FACILITY O & M CONSIDERATIONS

General

Most treatment facilities treating either GP or STEP system wastewaters have O & M considerations or requirements in direct relationship to the sophistication and type of facility. Small treatment systems generally have infrequent operator attention similar to serving a conventional gravity sewered area. Typical maintenance tasks include: wasting of sludge; oiling and greasing equipment; and recording plant information. Lagoon systems are typically less labor intensive than a mechanical system. More sophisticated treatment facilities, which may include chemical addition or tertiary treatment as well as larger systems which accept pressure sewer waste, require significantly more operator attention and management to insure continuously effective treatment.

Maintenance requirements are low for small communities having treatment plants in a pressure sewered area. At Horseshoe Bay, TX, the operator estimated 20 hours per week are spent in operation. The operator reports approximately half of his time is spent maintaining the aeration equipment at the aeration tanks and the other half spent on the tertiary facilities at this 379 m^3/day (0.1 MGD) facility. Operational problems include odors (present only during high humidity and temperature conditions) and some corrosion at the lift stations and in the chlorine contact tanks.

At Lake Mohawk, the operator reports approximately 55 hours per month are spent on the treatment system, of which about 10 hours per month are spent at the lift station leading into the plant, and the remaining 45 hours at the plant. This plant consists of a 379 m^3/day (100,000 GPD) Environment/One batch type treatment unit and an additional 379 m^3/day (100,000 GPD) activated sludge extended aeration type unit. Both units feed into Hydroclear filters, then to a chlorine contact tank. In this system, most of the 45 hours per month of labor is spent maintaining and operating the Environment/One batch type unit.

Lagoons

Data is currently unavailable on STEP sewage treatment lagoons. For example, the two systems at Kalispell Bay and Coolin, ID accept pressure collected waste from STEP units. These two cell aerated lagoons usually are operated in a facultative mode without aeration during winter. Because the area experiences a net evaporation, these basins act as non-overflow containment lagoons. At some point in the future influent flows will exceed the evaporative capacity and an existing spray irrigation system on nearby woodlands will be placed into use. At this time there is no information on the effect or desirability of spraying lagoon treated STEP sewage treatment.

Small Scale Treatment

In this report, most pressure sewer systems served 100 or more homes. For cost-effective smaller treatment facilities, consideration should be given to having several homes served by a community disposal field or subsurface alternative. Where community facilities are employed a maintenance program may more readily be instituted. A properly trained maintenance staff results in better system performance and relieves homeowners of duties they may be ill-suited to accomplish.

A number of community alternatives exist, such as drainfield disposal, sand mounds and sand filters. Mounds are used in areas where a conventional soil absorption field is unsuitable due to either slowly permeable soils, excessively permeable soils, shallow soils over bedrock or seasonally high groundwater. (26) The seepage system is built above natural ground in a mound of sand which serves to distribute the effluent over a large area. Dosing and pressure distribution principles are used and laterals are small diameter perforated pipe. Properly applied mound systems have proven very satisfactory.

Several designs of sand filters have been used to treat septic tank effluent, most notably the intermittent sand filter (ISF) and the recirculating sand filter (RSF). Effluent from sand filters may be irrigated or disinfected and discharged to receiving streams. The ISF is a sand bed of generally 0.61 to 1.0 m (2 to 3 ft) depth, receiving septic tank effluent with the filtrate collected by underdrains. A typical size is based on 1.2 l/m^2 (5 gal/day-ft^2) and normally two are used to allow a resting period. A common maintenance frequency of raking or removing the top sand is at about six month intervals, though this and effluent quality will vary depending on the sand size used. Effluent BOD and SS normally are in the order of 10 mg/l and 5 mg/l, respectively. Work by Sauer (27) and others (26) contains more detailed information.

To reduce odors and extend the length of filter runs, Hines and Favreau developed the RSF (28). This consists of a recirculation tank and open filter of coarse sand. Effluent is dosed onto the filter by a pump in the recirculation tank. The pump is activated by a timer and provides about a 4:1 recirculation rate. The sand bed is 1 m (3 ft) deep and is sized for 0.12 m^3/day-m^2 (3 gal/day-ft^2). Both the recirculation rate and sizing are based on the flow from the septic tank. Maintenance of the sand bed consists of removing the top 2.5 cm (1 in) of sand yearly. Hines reports BOD_5 and TSS to average 5 mg/l and 6 mg/l, respectively, following RSF treatment, (29) and this has been buttressed by other experience. (30)

SECTION 10

COSTS

CAPITAL COSTS

General

Use of pressure sewer systems has been promoted due to a potential cost advantage in certain areas where gravity sewers tend to be significantly more expensive. These areas include: low density development areas that are unsuitable for on-site disposal; hilly terrain where steep gravity sewer cuts or numerous lift stations would be required; lakefront community developments where a gravity sewer serving lakefront lots would have to be laid at an elevation below the lake level; areas with rock close to the ground surface; areas with high groundwater tables; areas where significant shoring and dewatering would be required for installation of a gravity sewer system; and second home or low growth developments where lots sales and home development are slow and initial capital costs can be reduced.

Various communities either have estimated the cost of or have installed pressure sewer systems for far less than a conventional gravity alternative. In Central Chautanqua, NY, a pressure sewer alternative would cost $1,200,000 vs $2,600,000 for gravity (4). The Grandview Lake estimate was $10,000 per home for gravity sewers vs $2,000 per home for pressure sewer systems. In Saratoga, NY, a small area was estimated to cost $100,000 to sewer by gravity yet the area was served by GP for only $20,000. In the Priest Lake, ID communities, approximately $12,000,000 would have been spent for gravity sewers vs an approximate installed cost for pressure sewers of $1,000,000 including treatment. In the Glide-Idelyde system Bowne estimated a present worth of $4,700,000 for the gravity alternative vs $2,400,000 for the pressure sewer alternative. Golf View Estates, IN estimated a gravity sewer system would cost $2,100 per lot vs a pressure sewer system cost of $1,550 per lot. In the General Development Utilities, FL, one area of Port Charlotte serving 1,517 lots by gravity would cost $3,500,000 vs an effluent pump system costing $1,200,000. Coincident with the General Development Utilities savings in collection systems, there was a concurrent savings (1977 dollars) of $164,910.00 for the STP. The reason for this savings is the reduction in infiltration and inflow from a tight piping system, and a lower wastewater strength due to the septic tanks removing a portion of the organic loads.

Other alternatives are available besides a complete pressure sewer system. For example, in Lake Lakengren, OH, a complete gravity system was estimated to cost $3,810,000; however, a combined gravity and pressure sewer system, where the pressure sewers served only those areas that were difficult to be served by gravity, would cost an estimated $3,117,000. Some other systems reported only the cost of the pressure sewer alternative. Diamond Head development near Tulsa, OK is an estimated cost of $1,500 per unit including collection lines and $2,300 per unit including treatment. The Gulf Cove area in Port Charlotte was estimated to cost $15,000 for 25 to 30 homes for collection.

Kreissl (3) reported seven unidentified municipalities with reported savings from 34 to 83% over a gravity system. Per lot costs averaged in the range of $2,000 to $3,000 with some relationship to the size of the development, that is, the more units on the development, typically the greater the savings. Kreissl's analysis, however, did not take into account specific regions of the country, labor rates, geological or hydrological conditions.

On-lot Capital Costs

Kreissl reported on-lot equipment costs range from $700 to $1,500 for GP pumping units alone, whereas GP packages cost from about $1,400 to $2,000 including the pump, basin, control panel (where applicable), level controls, valves and piping (3). Installation costs are an additional $300 to $700. Effluent pumps frequently cost as much as $500. One manufacturer (33) estimates the price of a union-type system as $841 and the rail-type at $1,089. A fiberglass basin and pump cost approximately $1,279, or $1,118 with a concrete basin. This includes the basin, pump, controls, level controls, valves and piping. Installation costs for the total system would be between $1,000 and $2,000 (33) Bowne estimates a STEP system price of $450 for the septic tank, $150 for the pump vault, $250 for the effluent pump, $150 for electrical work, and $400 for installation, for a total cost of $1,325 (3). Installed costs range from $1,875 if the unit is located inside the house and $1,990 if the unit is installed outdoors. Typical installation costs at Apple Valley after the pump package has been purchased, are detailed in Table 18. A summary of on-lot facility construction costs are shown in Table 19. A summary of piping system construction costs, both estimated and actual, are shown in Table 20.

TABLE 18. TYPICAL INSTALLATION COST OF SIMPLEX PUMP UNIT

Backhoe	4 hours @	$15.00/hour	$ 60.00
Shop Preparation	2 hours @	6.00/hour	12.00
Man Hours Installation	18 hours @	6.00/hour	108.00
1¼-inch Force Main (average)	150 feet @	0.75/foot	112.50
3 - 12 electric wire (average)	75 feet @	0.14/foot	10.50
½-inch conduit (average)	17 feet @	0.17/foot	2.89
½-inch clamps	2 @	0.07/each	0.14
30 amp Box	1 @	12.75/each	12.75
Breaker	1 @	8.40/each	8.40
Electric Fittings (box)	3 @	0.15/each	0.45
Greenfield Fittings	2 @	1.90/each	3.80
ABS 4-inch Pipe	2 feet @	1.25/each	2.50
Water Plug	1 gallon @	4.90/gallon	4.90
4 - 6-inch Rubber Seals	2 @	3.70/each	7.40
4-inch Plug (sewer)	1 @	2.40/each	2.40
Discharge 1¼-inch Galvanized Adapter Plastic to Steel	1 @	1.13/each	1.13
Stainless Steel Clamps	4 @	0.60/each	2.40
2½-inch Saddle	1 @	7.80/each	7.80
1-inch Corporation Stop	1 @	11.12/each	11.12
3-inch Brass Nipple	1 @	1.46/each	1.46
1¼-inch Galvanized Coupling	1 @	1.35/each	1.35
1¼-inch Galvanized Adapter	1 @	1.13/each	1.13
Granular	8 tons @	3.20/ton	25.60
			$ 400.62

This does not include the cost of pump or controls.

*Hydr-O-Matic Simplex Pump unit at Apple Valley, OH.

Treatment Plant Costs

Construction costs for facilities treating pressure collected sewage are not significantly different than those facilities treating conventional gravity collected sewage. The aerated lagoon system at Grandview Lake was constructed during the 1974 to 1977 period at a total estimated cost of approximately $80,000 ($15,000 for excavation and earthwork and $65,000 for equipment). A Neptune Microfloc tertiary treatment facility at Horseshoe Bay had an initial capital cost of $190,000 in 1973 to treat 3,000 m^3/day (560 GPM). No plant design changes were made to accomodate the pressure collected GP sewage. A STEP treatment system at Priest Lake cost $65,000 in 1971. The Harrison, ID treatment facility uses a lagoon system for treating effluent pumping system wastewater and cost approximately $90,000.

TABLE 19. ON-LOT FACILITY CONSTRUCTION COSTS

Item	Phoenixville, PA	Grandview Lake, IN	Apple Valley, OH	Lake Lakengren, OH	Lake LBJ MUD, TX	Port Charlotte, FL	Glide, OR	Bend, OR	Portland, OR	Priest Lake, ID	Point Venture, TX	Weatherby Lake, MO	Kinnelon, NJ	Bottle Bay, ID	Seabrook, TX	Harrison, ID
Type	GP	GP	GP	GP	GP	STEP	STEP	STEP	Solids	STEP	GP	GP	GP	STEP	GP	STEP
Year	1971	1969	1975	1973	1975	1977	1975	1975	1978	1973	1973	1972	1974	1975	1976	1977
CCI	1,581	1,269	2,212	1,895	2,212	2,577	2,212	2,212	2,693	1,895	1,895	1,753	2,020	2,212	2,401	2,577
Total On-lot	2,050		1,582	2,000		727	1,325	1,336	1,800	672 - 899	1,350 - 1,500		2,120	902 - 992		1,300 - 1,400
Grinder Pump	900	1,000 - 1,500	1,182		1,200							1,061	1,150		987 - 1,897	
Effluent Pump								166 - 229		230 - 425				421 - 511		400 - 500
Solids Handling Pump									295 - 320							
Service Line 2.5 cm (1 in)/1m		2.07														
Service Line 3.2 cm (1.25 in)/1m					5.12								16.4			
Service Line 3.8 cm (1.5 in)/1m		3.12			5.18				16.9	4.3			16.73	5.25	3.28	12.47
Service Line 5.1 cm (2 in)/1m					5.31											
Gate Valve 3.2 cm (1.25 in)					29				15					12		
Check Valve 3.2 cm (1.25 in)					9				11					26		
Corporation Cock and 7.6 cm (3 in) clamp		20				25										
Corporation Cock and 10.2 cm (4 in) clamp						25										
Corporation Cock and 15.2 cm (6 in) clamp						50										
Wye for Double Service					22.5											
Pressure Service Connection		250								56			80	70		

TABLE 20. PIPING SYSTEM CONSTRUCTION COSTS

Item	Phoenixville, PA	Grandview Lake, IN	Apple Valley, OH	Lake Lakengren, OH	Lake LBJ MUD, TX	Port Charlotte, FL	Glide, OR	Bend, OR	Portland, OR	Priest Lake, ID	Point Venture, TX	Weatherby Lake, MO	Kinnelon, NJ	Bottle Bay, ID	Seabrook, TX	Harrison, ID
Type	GP	GP	GP	GP	GP	STEP	STEP	STEP	Solids	STEP	GP	GP	GP	STEP	GP	STEP
Year	1971	1969	1975	1973	1975	1977	1975	1975	1978	1973	1973	1972	1974	1975	1976	1977
CCI	1,581	1,269	2,212	1,895	2,212	2,577	2,212	2,212	2,693	1,895	1,895	1,753	2,070	2,212	2,401	2,577
PVC Pipe/Meter (unspecified size)	6.56	4.11						12.3				13.63				
5.1 cm (2 in) PVC/Meter					4.1					3.84			17.39			13.12
6.4 cm (2.5 in) PVC/Meter			4.27	9.02						4.13						
7.6 cm (3 in) PVC/Meter					4.63	4.33	13.12		14.76	4.17			20.34	10.17	3.28	14.76
10.2 cm (4 in) PVC/Meter					5.22	4.99	16.40		32.81	4.59				13.62		16.40
10.2 cm (4 in) ABS/Meter			12.63													
15.2 cm (6 in) PVC/Meter			9.02	13.12	10.43	6.96	22.97			17.72						18.04
20.3 cm (8 in) PVC/Meter					12.11		32.81									
25.4 cm (10 in) PVC/Meter					20.14		39.37									
30.5 cm (12 in) PVC/Meter					23.92		49.21									
5.1 cm (2 in) Valve, installed					70				33	45						
6.4 cm (2.5 in) Valve, installed			150							58						
7.6 cm (3 in) Valve, installed					71	136			55	70				250		
10.2 cm (4 in) Valve, installed					96	186			125	129				275		
15.2 cm (6 in) Valve, installed					113	209				149						
20.3 cm (8 in) Valve, installed					155											
25.4 cm (10 in) Valve, installed					274											
Cleanout (inline)					37.5	100 - 150										
Cleanout (terminal)	350		125													200
Manual Air Release Valve		125				120				118						
Auto Air Release Valve	350	200			317									620		
Lift Station						44,125				11,289				4,900 - 11,066		75
Flushing Hydrant			330							103	220		150	260		
Auto Flushing Station					3,381											
Evacuation Station										155				260		
Concrete Blocking/m^3					5,586											
Rock Excavation/m^3					18.31								26.16			
Rock Hauling/m^3					0.65											
Seeding/m^2					0.02											

OPERATION AND MAINTENANCE COSTS

On-lot Facilities

Maintenance is required to keep pumps or their ancilliary components in operating condition. Leckman (17) has estimated $4 to $8 per month is necessary per GP for O & M. Dounoucos (33) has estimated between 1.4 and 2% of the on-lot capital costs should be allocated to annual O & M. Bowne (5) has reported GP service contracts cost between $48 to $60 per year; however, at Grandview Lake service contracts cost in excess of $180 per year. A charge of $9 per lot is made for O & M at Apple Valley. In addition, a $15 per quarter user fee is charged to those lots connected to the system. This fee is placed into a fund to repair on-lot and piping system components. Golf View Estates has a $6 per month service charge.

O & M costs of effluent pumps are estimated to cost significantly less than GP, principally because there are fewer moving parts. Bowne estimates nearly one half of the planned $9.50 monthly charge will be allocated to maintenance of the pumps and interceptor tanks (21). Of the $50 per year fee for the effluent pump maintenance, approximately $20 per year is allocated to a fund for pump replacement only and the remaining $30 per year is for maintenance calls and pumping of the septic tank at approximately ten year intervals. Typical pump overhaul costs are presented in Table 21.

TABLE 21. PUMP OVERHAUL COSTS

	Part	Cost
1.	Motor	$ 120.00
2.	Pressure Switch	8.00
3.	Time Delay Relay	30.00
4.	Seals	20.00
5.	Boot	9.00
6.	Small Seals, Nuts, Bolts	5.00
		$ 192.00 plus four hours labor

For a new installation, the total less cost of pump core is $200.00 material, plus $800.00 labor.

Electrical Costs

Pressure sewer systems use electrical energy to transport wastewater to its point of disposal. For example, at the Albany, NY and Phoenixville, PA experimental pressure sewer systems, EPA reports an electrical usage of 0.264 kw hours/m^3 (1 watt hour/gal) to transport the collected sewage (3). This equals $0.27/month/residence at $.043/kw hour (assuming each residence has four persons each using 0.2 m^3/day (50 gal) per capita per day). Grinder pumps are less efficient in transporting sewage than an effluent pumping system, since a GP will use 1.1 to 1.5 kw (1 1/2 to 2 hp), whereas an identical effluent pump will use between 0.25 and 0.75 kw (1/3 and 1 hp) to produce the same head and flows. This is due to the energy used to drive the grinding mecharism. Bowne estimates a 0.25 kw (0.33 hp) effluent pump unit can be operated at about $0.10/month in his area of Oregon (21). Another EPA report estimates both grinder and effluent pump cost roughly $0.20/month for power (3).

At General Development Utilities, system operators estimate the cost of operation at $1.33 unit/year ($0.05/kw hour). At the Apple Valley system, if two or more homes share one GP, the home supplying power receives a deduction of $1.50 per quarter. The other home(s) on the line pays the full amount. Table 22 summarizes various typical annual power consumption and costs.

TABLE 22. TYPICAL ANNUAL POWER CONSUMPTION OPERATING COSTS

Appliance[3]	Average Wattage	Estimated kwh Consumed Annually	Cost @ $0.044/kwh
Grinder Pump[1]	1,121	100	4.43
Effluent Pump[2]	247	27	1.18
Oven - Microwave	1,450	190	8.42
Oven - Self Cleaning	4,800	1,146	50.77
Range with Self Cleaning Oven	12,200	1,205	53.38
Refrigerator/Freezer (frostless 14 ft^3)	615	1,829	81.02
Washing Machine - Automatic	512	103	4.56
Water Heater - Standard	2,475	4,219	186.90
Air Conditioner - Room	1,566	3,445	152.61
Television - Solid State Color	200	440	19.49
Waste Disposer	445	30	1.33
Trash Compactor	400	50	2.22
Coffee Maker	894	106	4.70

[1]Kinnelon, NJ.
[2]General Development Utilities, FL.
[3]Appliances except for pumps from Electric Energy Associates, 1973.

Piping Systems

Piping system O & M costs are by far overshadowed by the maintenance efforts and costs associated with maintaining and repairing on-site pumping units. As a comparison, gravity sewer systems have been reported by the EPA to cost approximately \$0.23 to \$0.26/m (\$0.07 to \$0.08/ft) per year which is equivalent to \$248/km/year (\$400/mile/year) (3). Bowne has established some costs for maintaining rural water supply systems using small diameter PVC piping (21). (These costs are assumed to be equivalent to those encountered in pressure sewer system piping.) These costs are approximately \$62 per km/year (\$100 mile/year). This number reflects automatic air release valves rather than manual air release valves, since manual valves require more operator attention. Grinder pump systems require more attention and therefore experience a higher O & M cost per LF than effluent pumping systems due to grease buildup problems.

The Sausalito pressure sewer system, using GP to serve houseboats, indicates the only problems are flexible hoses breaking and flexible connectors between rigid pipe lengths occasionally cracking. These costs plus those associated with maintaining lift stations are recovered by allocating \$2.00/month/user from the monthly moorage fee to an O & M account.

Other malfunctions with buried piping include: vehicles may run off the shoulder of roads and run over shallowly buried PVC piping, causing breaks; grease plugs; and infrequently reported stoppages and leaks. Since these occurrences are sporatic and highly variable with regard to the amount of time required to repair, costs are difficult to obtain and categorize.

Treatment Plants

In Apple Valley, OH, the mechanically aerated treatment plant with micro strainers treats mostly gravity collected sewage and has an estimated charge of \$83.32/lot/year. Country Knolls South plant, using an Environment/One physical-biological-chemical treatment plant, had a labor charge of \$1,000/month, a power bill of \$800/month, and chemical usage of \$800/month. Customer charge was \$40/year for treatment. The General Development Utilities' Gulf Cove plants in Florida have an extended aeration facility serving 25 to 30 homes. The facility initially cost \$5,000 in 1972 with a plant operation cost of \$0.15/m^3 (\$0.56/1,000 gal). An additional treatment plant at one of the General Development Utilities will service 1,517 lots and treat 790 m^3/day (208,500 GPD) less sewage using an effluent pump system compared to a gravity designed system. This will save an estimated \$42,635 in treatment costs. Of this amount, \$6,800 is directly associated with energy savings. The lagoon system at Priest Lake, ID, had O & M costs of \$8,600/year in 1971.

SECTION 11

MANAGEMENT IMPLICATIONS

GUIDANCE AND REGULATORY RESTRICTIONS

Existing or approved pressure sewer systems have been found in at least 30 of the 50 states. Every state contacted indicated a willingness to consider the installation of a pressurized sewer system.

Requirements vary from state to state, such as California which requires consultants to review options for providing an "intrinsically safe" environment in the pumping chamber, in accordance with the National Fire Protection Association (NFPA), the National Electric Code (NEC) and California OSHA. One California state official believed "intrinsically safe" components will result in a 50% increase in on-site component costs. This requirement is intended to reduce the risk of explosion from hazardous material spillage. Local codes not only affect plumbing work, but also affect electrical work. Certain areas have requirements for separate circuits for pumps as well as controls and may also have requirements for approved wiring, underground conduits, local disconnects and types of connections between the pump and household service.

Texas endorsed pressure sewer systems early in their history and emphasized thirteen items in their design review: the number of pumps on at any one time; scouring velocity; flushing requirements; cleanouts; air release valves; bypassing of line segments in the case of leaks or ruptures; alarms; quality power being available in an area; holding tank capacity; reliability of the pumping unit; backflow devices; the supplementation of the gravity system as opposed to a complete pressurized sewer system; and the encouragement of a good management system.

Several states have various levels of permits. For example, in Virginia there is an experimental permit whereas in Texas there are three permit levels: unconditional, conditional and limited approval. Originally, pressure sewer systems were given the limited approval classification. As systems prove reliability, become more standardarized and regulatory officials become familiar with their existence, pressurized sewer systems can be expected to gain an increased standing with regulatory agencies.

SYSTEM ORGANIZATION MODELS

In the course of this study, system management models investigated fell into the three major categories. Under one model the entire pressure sewer system, regardless of treatment, is controlled by a unit of government. The controlling unit may be a sewer district, municipal utility district, a city, a county or other similar government organization. Under this type of management, all variations of ownership may exist. For example, in most instances, the entire facility, including the on-lot pumping facilities and the transportation pipe network, is owned by the governmental unit. Under some governmental unit organizations, the pipeline is owned by the government unit, but the homeowner owns the on-lot facilities, as in the Lake LBJ MUD, Texas. At Lake LBJ MUD if the pump malfunctions it is the responsibility of the homeowner to obtain service for the unit.

Another option exists if the district owns the entire system including on-lot facilities, and utility workers maintain the on-lot facilities as well as the piping system. This type of system is evident in Glide, OR; Apple Valley, OH; and Seabrook, TX. A subcategory under this system, is Seabrook, where there are both GP units and gravity served residences in the city. Those on the pressure sewer system pay a higher monthly user charge than those served by gravity. In Apple Valley the same type of mixture occurs, but both gravity and pressure system users pay identical monthly user fees. Another option under a governmental unit organization model would be to have the district contract for O & M labor. This is done in the Priest Lake systems in Idaho, and Weatherby Lake, MO. At the Priest Lake system, the operator places a bid for his services at the beginning of the year, whereas in the Weatherby Lake system the operator charges the district on a per service call basis, but the operator is treated as a city employee.

A second major category of organization is to have a private utility company own and operate the system. For example, Country Knolls South near Albany, NY, owns and maintains the pressure sewer system, but the individual users who have purchased the pumping units pay the service company at the rate of $11/service call. General Development Utilities Company, also a private organization, owns the on-lot facilities and service is included in the monthly user fee. Lake Mohawk, OH, operates in the same manner, as Environment/One holding the service contract, and a local independent repair organization charges Environment/One on a per call basis. Environment/One accepts responsibility for maintaining the system on a per month user sponsibility for maintaining the system on a per month user charge basis that is fixed for a five year period. At the Country Knolls South development, a private utility owns the piping system and the individual owns the pumping unit. Similarly, the houseboat systems in Portland, OR and Sausalito, CA an individual owns the mainline piping systems and the users own their own pumps. When an individual needs pump maintenance, he is free to contact anyone to repair his unit, but usually has service performed by the local service representative. The homeowner pays the repair charge directly to the service organization of his choice.

The third major category of organization model is where a cooperative or homeowners' association maintains the piping system with the individual owning and maintaining the pump units. There is an elected homeowners association board which oversees the system and deals with calls from the homeowners. When the piping system needs repair, the homeowners call the association who in turn call the local contractor. When the individual needs repair on his pump unit, he is free to call the local service organization for individualized service, or have the service organization perform the needed repairs on a maintenance contract. This management scheme is used at Grandview Lake, IN.

All system operators interviewed during the course of the study suggest an overall comprehensive management system offering perpetual maintenance on the complete system with emergency service charges built into the monthly user fee.

OTHER MANAGEMENT TASKS

Operators report preventive maintenance to be an important task in pressure sewer systems. Management scheduling should include preventive maintenance, although it occurs in less than 10% of existing pressure sewer systems. The most detailed preventive maintenance programs occur in the Port Charlotte and Port St. Lucie systems and Apple Valley, OH. Preventive maintenance may require up to 30 minutes per unit twice a year and include hosing down of the units and checking the pump operation. It can offer the advantage of reduction in breakdown service calls and act as an excellent public relations tool to the serviced community. In order to prevent carry-over of solids from septic tanks, preventive maintenance is highly desired in the STEP system where pumping of the septic tank is a required maintenance item. The pumping interval varies from three to ten years. Another preventive maintenance function is the pulling and storing of pumps from homesites with temporary or seasonal residence. This function would reduce "stuck pump" problems of seasonal residents when they return to use their units.

There also is a need for continual education of the users of a pressure sewer system, since the operators frequently have reported pumping units clogged with extraneous material. Several systems offer guidelines in regular newsletters sent out to homeowners or placards designed to be located in the basement of homes. These guidelines offer suggestions as to the use of the system, including refraining from pouring grease into the kitchen sink. Homeowners involved in an "unconventional" sewer system have a desire to be kept continually informed as to the sewer system's condition. At Weatherby Lake a periodic homeowner's newsletter always includes some information about the system operation, expenses, or other informative details. All the operators interviewed under this project agreed that this type of approach is beneficial in winning consumer acceptance when coupled with an all inclusive maintenance organization.

REFERENCES

1. Detailed Housing Characteristics (HC 1-B), 1970 Census Bureau of the Census, U. S. Dept. of Commerce, Washington, DC, 1972.

2. Cooper, I. A. and J. W. Rezek, "Septage Disposal In Wastewater Treatment Facilities" in Individual Onsite Wastewater Systems, N. McClelland, Ed., Ann Arbor Science Publishers, Ann Arbor, MI, 1977.

3. Kreissl, J. F., "Alternatives For Small Wastewater Treatment Systems - Status of Pressure Sewers Technology", U. S. EPA, Technology Transfer EPA-625/4-77-011, Volume 7, Oct. 1977.

4. Wall Street Journal, Monday, July 26, 1976, Volume CLXXXVIII No. 17, pp 1 and 10.

5. Bowne, W. C., "Sewerage Study for the Glide-Idleyld Park Area, Douglas County, Oregon", Douglas County Dept. of Public Works, Dec., 1975.

6. American Society of Civil Engineers, Combined Sewer Separation Using Pressure Sewers, U. S. Dept. of the In- terior, Federal Water Pollution Control Administration, FWPCA Report No. ORD-4, 1969.

7. Clift, M. A. "Experience With Pressure Sewerage," Journal of Sanitary Engineering Division, American Society of Civil Engineers, 94, 5, 849 - 865, 1968.

8. Carcich, I. G., L. J. Hetling, and R. P. Farrell, A Pressure Sewer Demonstration, U. S. EPA, Report No. R2-72-091, 1972.

9. Mekosh, G. and D. Ramos, Pressure Sewer Demonstration at the Borough of Phoenixville, Pennsylvania, U. S. EPA, Report No. R2-73-270, 1973.

(continued)

10. Hendricks, G. F. and S. M. Rees, Economical Residential Pressure Sewage System With No Effluent, U. S. EPA, Technology Series, Report No. EPA-600/2-75-072, Dec., 1975.

11. Gray, Glen C., "Environmental Constraints Challenge Designers Of Shoreline Community Near Kansas City, Missouri", Professional Engineer, June, 1975, pp 42 - 44.

12. Weibel, S. R., Straub, C. P. and Thomas, J. R., "Studies on Household Sewage Disposal Systems, Part 1", U. S. Public Health Service, 1949.

13. Pomeroy, R. D., "Process Design Manual for Sulfide Control in Sanitary Sewerage Systems", U. S. EPA, Technology Transfer Publication, 1974.

14. Carlson, D. A., and Leiser, C. P., "Soil Beds for the Control of Sewage Odors", Journal Water Pollution Control Federation, 38, 829.

15. Stone, R., Newton, L. C. and Rowlands, J., "Wastewater Pumping Station Designed to Avoid Odor Problems", Journal Public Works, Jan., 1975.

16. Langford, R. E., "Effluent Pressure Sewer Systems", presented at 1st WPCF Annual Conference, Philadelphia, PA, Oct. 2 - 7, 1977.

17. Leckman, J., "Pressurized Sewer Collection Systems", prepared for Illinois Institute of Environmental Quality, 1972.

18. Environment/One Corporation, "Design Handbook for Low Pressure Sewer System", Third Edition, 1973, Schenectady, NY, 20 pp.

19. Mendez, L. A., "South Gulf Cove Suburbanaer Sewage Collection System Hydraulic Analysis", General Development Utilities Co., Miami, FL, Project No. 355-0944-72, April, 1977, 6 pp.

20. Mendez, L. A., "Appendices and Exhibits to Suburbanaer Sewerage Processing System", General Development Utilities Co., 1977, 58 pp.

(continued)

21. Bowne, W. C., "Pressure Sewer Systems", prepared for Douglas County, OR, 1974.

22. Hobbs, M. F., "Relationship of Sewage Characteristics to Carrying Velocity", Report No. R-2598 to American Society of Chemical Engineers, 1967.

23. Flaniga, L. J. and R. A. Cudnik, "Review and Considerations for the Design of Pressure Sewer Systems", performed by Battelle's Columbus Laboratories for Hydr-O-Matic Pump Division, Wylain, Inc., 1974.

24. Kloser, P. C. and H. E. Schmidt, "The Suburbanaer Pressure Sewer System Three Year History Gulf Cove Areas, Port Charlotte, Florida", General Development Utilities, Inc., Jan., 1976.

25. Bluem, R. A., and L. A. Mendez, "The Surburbanaer Sewerage Processing System Compared with A Conventional Gravity System in Plat Units 79 and 101 and a Portion of Unit 37, Port Charlotte, Florida", prepared for General Development Utilities, Inc., by General Development Engineering, Miami, FL, 1977, 22 pp.

26. Otis, R. J., Boyle, W. C., et al, "Alternatives for Small Wastewater Treatment Systems, On-Site Disposal", U. S. EPA Technology Transfer, 1977.

27. Sauer, D. K., "Intermittent Sand Filtration of Septic Tank and Aerobic Unit Effluents under Field Conditions", master's thesis, Department of Civil and Environmental Engineering, University of Wisconsin, Madison, WI, 1975.

28. Hines, M. and Favreau, R. E., "Recirculating Sand Filter: An Alternative to Traditional Sewage Absorption Systems", Proceedings of the National Home Sewage Disposal Symposium, Proc. American Society of Agricultural Engineers, 175, Dec., 1974.

29. Hines, M., "The Recirculating Sand Filter: A New Answer For an Old Problem", Proceedings of the Illinois Private Sewage Disposal Symposium, Champaign, IL, 1975.

(continued)

30. Bowne, W. C., "Experience in Oregon with the Hines-Favreau Recirculating Sand Filter", Douglas County, OR, Engineer's Office, Roseburg, OR, 1977.

31. Troyan, J. and D. P. Norris, "Alternatives for Small Wastewater Treatment Systems - Cost Effectiveness Analysis", U. S. EPA, Technology Transfer, EPA-625/4-77-011, Volume 3, Oct., 1977.

32. Cooper, I. A. and J. W. Rezek, "Septage Management", U. S. EPA, Technology Transfer EPA-625/ 4-77-011, Volume 2, Oct., 1977.

33. Langford, R. E., "Overview of Hardware for Pressure Sewer Systems", Peabody Barnes Pump Co., Mansfield, OH, May 2, 1977, 27 pp.

34. Dounoucos, A., "Sanitary System Construction Costs Turn Engineering Attention to Alternate Solutions", Professional Engineer, 44, 8, 1974.

35. Benett, E. R., K. D. Linstedf and J. Felton, "Comparison of Septic Tank and Aerobic Treatment Units", Paper presented at Rural Environmental Engineering Conference, Warren, VT, 1973.

36. Metcalf and Eddy, Wastewater Engineering Collection Treatment and Disposal, McGraw Hill, 1972, 231 pp.

37. Carcich, I. G., L. F. Hetling and R. P. Farrel, "Pressure Sewer Demonstration", Journal of Environmental Engineering, Division A.S.C.E., 100, No. 1, pp. 25 - 40, 1974.

38. Eblan, J. E. and L. K. Clark, "Pressure and Vacuum Sewer Research and Development Project, City of Bend, Oregon", U. S. EPA Grant No. 5803295, (at press).

EXISTING RESIDENTIAL PRESSURE SEWER SYSTEMS.

SYSTEM	YEAR	SYSTEM TYPE	MANUFACTURER(S)	CONNECTIONS PRESENT	CONNECTIONS ULTIMATE	TREATMENT	% PRESSURE AT TREATMENT	ENGINEER
1. Apple Valley, OH	1973	G.P.	Hydromatic	51	225	Tertiary STP	10	M. M. Schirtzinger & Assoc., Ltd. Chillicothe, OH
2. Diamond Head Tulsa, CK	1972	G.P.	Hydromatic	188	188	Secondary STP	100	K. N. Cox & Assoc., Tulsa, CK
3. Chickasaw Pt. Fair Play, SC	1974	G.P.	Hydromatic Environment/One	60	742	Lagoons - Spray Irrigation	100	Gary See
4. Souther Hills Estates Sellersbrug, IN	1973	G.P.	Hydromatic Environment/One	23	225	Lagoon	100	Paul Moffat, KY
5. Strongsville, CH	1974	G.P.	Hydromatic	18	20	Gravity Sewers	Very Small	Joe Molner
6. Thunderhead Lake Unionville, MC	1974	G.P.	Hydromatic	25	300	Lagoon	75	N. E. Isaacson, Reedsburg, WI
7. Bogulusa, LA	1976	G.P.	Hydromatic	30	30	Gravity Sewer	Very Small	Dyer & Moody, Baker, LA
8. Rome City, IN	1976	G.P.	Hydromatic	120	140	Tertiary	70	John R. Snell Engineers, Lansing, MI
9. Harbor Springs, MI	1975	G.P.	Hydromatic	84	2,200	Gravity Sewer	Very Small	Williams & Works, Grand Rapids, MI
10. Lake Lakengren, OH	1975	G.P.	Hydromatic	80	300	Secondary STP	15	M. M. Schirtzinger & Assoc., Ltd. Chillicothe, OH
11. Grandview Lake, IN	1970	G.P.	Environment/One Hydromatic	150	350	Lagoon	100	Freese & Abplanalp, Franklin, IN
12. Lake Meade, PA	1977	G.P.	Hydromatic	600	750	Secondary STP	80	Buchart-Horn, Lewisburg, PA

SYSTEM	YEAR	SYSTEM TYPE	MANUFACTURER(S)	CONNECTIONS		TREATMENT	% PRESSURE AT TREATMENT	ENGINEER
				PRESENT	ULTIMATE			
13. Lake LBJ M.U.D., Horseshoe Bay, TX	1972	G.P.	Environment/One Hydromatic	200	4,000	Tertiary STP	100	Bennet Coulson Engineers, Houston, TX
14. New Landings of the Delta Queen, Dixon, IL	1973	G.P.	Environment/One	12	2,200	Tertiary Batch STP	100	Willard Hoffman Engineers, Dixon, IL
15. Rose Blanche, New Foundland, Canada	1977	G.P.	Environment/One	60	60	Secondary STP Planned	20	James F. McLaren Ltd, Toronto, Ontario, Canada
16. Cuyler, NY	1976	G.P.	Environment/One	43	60	Community Septic System	100	John McNeil, Homer, NY
17. Port Charlotte, FL	1970	S.T.E.P.	Hydromatic	62	1,600	Secondary STP	100	General Development Utilities Engineers, Miami, FL
18. Port St. Lucie, FL	1972	S.T.E.P.	Hydromatic	191	1,000+	Gravity Sewer	Very Small	General Development Utilities Engineers, Miama, FL
19. Arrowhead Estates, TX	1974	G.P. Variety (Deflector type)	Eco-Systems	10	100+	Secondary STP	Small	Bidds & Mathews, Wichita Falls, TX
20. Glide-Idleyld, OR	1977	S.T.E.P.	Peabody Barnes	600	2,300	Secondary STP	100	Parametrix, Inc., Eugene, OR
21. Bend, OR (EPA)	1976	S.T.E.P.	Peabody Barnes	11	11	Secondary STP	Very Small	C & G Engineers, Salem, OR
22. Juniper Utilities, Co., Bend, OR	1970	Solids Handling	Peabody Barnes	400	1,800	Secondary STP	100	Parametrix, Inc., Eugene, OR

SYSTEM	YEAR	SYSTEM TYPE	MANUFACTURER(S)	CONNECTIONS PRESENT	CONNECTIONS ULTIMATE	TREATMENT	% PRESSURE AT TREATMENT	ENGINEER
23. Portland, OR Houseboat Systems	1968	Solids Handling	Peabody Barnes	700	700	Varies	Varies	Klaus Pump & Equipment Portland, OR Also Others
24. Coolin, ID	1974	S.T.E.P.	Hydromatic	356	356+	Lagoon	100	K. A. Durtschi & Assoc. Coeur D'Alene, ID
25. Kalispell Bay, ID	1974	S.T.E.P.	Hydromatic	232	232+	Lagoon	100	K. A. Durtschi & Assoc. Coeur D'Alene, ID
26. South Seas Plantation, Captiva, FL	1977	G.P.	Hydromatic	33	60	Secondary STP	10	Johnson Engineers, Fort Meyers, FL
27. Point Venture, TX	1972	G.P.	Environment/One	37	175	Secondary STP	90	Assoc. Engineers, Houston, TX
28. Weatherby Lake, MO	1975	G.P.	Environment/One	362	900	Gravity Sewer	Very Small	Larkin & Assoc., Houston, TX
29. Saratoga, NY	1972	G.P.	Environment/One	10	10	Gravity Sewer	Very Small	City Engineer, Saratoga Springs, NY
30. Country Knolls South, Clifton Park, NY	1973	G.P.	Environment/One	355	500	Gravity Sewer	Very Small	Standard Engineering, Albany, NY
31. Golfview Estates,	1971	G.P.	Environment/One	50	114	Gravity Sewer	Very Small	Environmental Control Products, Jeffersonville, IN
32. San Angelo, TX	1976	G.P.	Environment/One	160	1,250	Secondary STP	100	Water Dept., City of San Angelo, TX
33. Kappas Marina Gate 6, Sausalito, CA	1976	G.P.	Environment/One Hydromatic Peabody Barnes Toran	82	82+	Gravity Sewer	Very Small	E. Beattie, Sausalito, CA

SYSTEM	YEAR	SYSTEM TYPE	MANUFACTURER(S)	CONNECTIONS PRESENT	CONNECTIONS ULTIMATE	TREATMENT	% PRESSURE AT TREATMENT	ENGINEER
34. Kappas Marina Gate 6½, Sausalito, CA	1975	Solids Handling	Peabody Barnes	35	35+	Gravity Sewer	Very Small	E. Beattie, Sausalito, CA
35. Quaker Lake, PA	1976	G.P.	Environment/One	110	145	Lagoon	100	Milnes Engineers, Tunkhannock, PA
36. Cavalier Lake, MS	1976	G.P.	Environment/One	81		45,000 GPD A.S.		Reynolds Engineers, Inc. Jackson, MS
37. Black Butte, OR	1976	S.T.E.P.	Peabody Barnes	60	450	Secondary Treatment	10	Century West Engineers, Bend, OR
38. Wexford County, MI	1978	G.P.	Hydromatic	225	225+	Gravity Sewer	15	John R. Snell Engineers, Lansing, MI
39. Lake Winona, PA (Stony Hollow)	1976	G.P.	Peabody Barnes	40	4,000	Extended Aeration	100	Edward C. Hess & Assoc., Stroudsburg, PA
40. Mast Hope, PA	1976	G.P.	Peabody Barnes	150	1,000+	Extended Aeration	100	Edward C. Hess & Assoc., Stroudsburg, PA
41. Bottle Bay, ID	1977	S.T.E.P.	Peabody Barnes	100	200	Lagoon	100	K. A. Durtschi & Assoc., Coeur D'Alene, ID
42. Montgomery City M.U.D. 6, Woodlands, TX	1975	G.P.	Environment/One	25	25	Gravity Sewer	Very Small	S & B Engineers, Houston, TX Hild Engineers, Houston, TX
43. Winter Green Resort, Nelson & Augusta Cities, VA	1975	G.P.	Environment/One	50	250	Tertiary STP	45	Willey & Wilson, Lynchburg, VA

SYSTEM	YEAR	SYSTEM TYPE	MANUFACTURER(S)	CONNECTIONS PRESENT	CONNECTIONS ULTIMATE	TREATMENT	% PRESSURE AT TREATMENT	ENGINEER
44. Lake Monticello, Fluvanna City, VA	1975	G.P.	Environment/One	60	200	Secondary STP	20	Gilbert Clifford & Assoc., Fredericksburg, VA
45. Beaver Lake, OH	1973	G.P.	Environment/One	70	1,800	Secondary STP		Hendrick, Cox & Assoc. Cleveland, OH
46. Lake Mohawk, Malvern, OH	1974	G.P.	Environment/One	200	1,700	Tertiary STP	100	Friedl & Harris, Inc., North Canton, OH
47. Pewaukee Lake, WI	1976	G.P.	Environment/One	50				Strand Assoc., Madison, WI
48. Lake of the Woods, Indianapolis, IN	1977	G.P.	Hydromatic	20	120			
49. Condo Project, Indianapolis, IN		G.P.	Hydromatic	30	100			
50. Campbell Ave. System, Schenectady, NY	1973	G.P.	Environment/One	23	23	Secondary STP	Very Small	City Engineers Office, Schenectady, NY
51. Limestone Hills Sewer District, Fayetteville, NY	1973	G.P.	Environment/One	12	12	Secondary STP	Very Small	Calo Cerino & Spina, Liverpool, NY
52. Hassenplug Project, WV		G.P.	Environment/One					Hassenplug Assoc., Pittsburg, PA
53. Elks Club, Huntington, WV		G.P.	Environment/One					Hassenplug Assoc., Pittsburg, PA
54. Harrison, ID	1978	S.T.E.P.	Peabody Barnes	120	131	Lagoon	100	URS Engineers, Spokane, WA

SYSTEM	YEAR	SYSTEM TYPE	MANUFACTURER(S)	CONNECTIONS PRESENT	CONNECTIONS ULTIMATE	TREATMENT	% PRESSURE AT TREATMENT	ENGINEER
55. Cooper Communities, Bentonville, AR	1978	S.T.E.P.	Peabody Barnes	75	20,000	Extended Aeration	100	Blaylock, Threet & Assoc., Little Rock, AR
56. Busch Properties, Williamsburg, VA	1975	G.P.	Environment/One	20				Langley McDonald & Overman, Virginia Beach, VA
57. Seabrook, TX	1977	G.P.	Hydromatic	10	115	Gravity Sewer Secondary STP	Very Small	Bayshore Engineers, Deer Park, TX
58. Lake of the Pines, PA	1976	G.P.	Environment/One	13				
59. Saw Creek, PA		G.P.	Environment/One	70				Edward C. Hess & Assoc., Stroudsburg, PA

	System	Engineer
60.	Vacation Village, Pennsylvania	Ebeco Associates, Hagelton, PA
61.	Fairfield Glade, Tennessee	Thomas Swafford, Fairfield Glade, Tennessee
62.	Girard Homes, California	Sanders & Assoc., Mountain View, California
63.	The Summit, Virginia	Gilbert Clifford & Assoc., Winchester, Virginia
64.	Alexandria Bay, Minnesota	McCombs - Knutson Associ., Minneapolis, Minnesota
65.	Orion Lake, Michigan	Hubbel, Roth & Clark, Bloomfield Hills, Michigan
66.	Fallen Leaf Lake, California	Clair Hill & Assoc., Reading, California
67.	Toronto Island, Canada	James F. MacLaren Ltd, Willowdale, Ontario, Canada
68.	Lake Mitchell, South Dakota	Schmacher Engineering, Mitchell, South Dakota
69.	Wood Creek Resort, Texas	Candill, Rowlett & Scott, Houston, Texas
70.	Rose Blanche, New Foundland, Canada	James F. MacLaren, Willowdale, Ontario, Canada
71.	West Vancolver, Canada	Greater Vancouver Sewer & Drainage District, Vancouver, Canada
72.	Friendswoods, Texas	Engineering Science, Austin, Texas
73.	North River Development, Alabama	Gilbreath, Foster & Brooks, Inc.
74.	Ulster, New York	J. Kenneth Frasier & Assoc., Ronssolaer, New York
75.	Fairfield Bay, Arkansas	Graver & Graver, Little Rock, Arkansas
76.	Groton, Connecticut	Hayden, Harding & Buchanan, Boston, Massachusetts
77.	DeGray Lake, Arkansas	U. S. Army Corps of Engineers, Vicksburg, Mississippi
78.	Trails End, Goshen, Kentucky	Goshen Utilities, Goshen, Kentucky