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The Iowa Department of Natural Resources

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Alternative Collection Systems Technology Assessment and Design Guidance

Iowa Department of Natural Resources

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NOTICE

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MSA
PROFESSIONAL SERVICES
TRANSPORTATION • MUNICIPAL
DEVELOPMENT • ENVIRONMENTAL
www.msa-ps.com

5075 East University Avenue, Suite E
Pleasant Hill, Iowa 50327-7001
Phone: (515) 263-8882

We would like to acknowledge the following individuals for contributing to the completion of this manual:

CONTRACT PROJECT OFFICERS:

Satya Chennupati, Iowa Department of Natural Resources
G. Brent Parker, Iowa Department of Natural Resources
Jason Miller, MSA Professional Services, Inc.

AUTHORS:

Pat Morrow, MSA Professional Services, Inc.

OTHER CONTRIBUTING REVIEWERS:

Gabriel Lee, Iowa Department of Natural Resources
Wayne Farrand, Iowa Department of Natural Resources
Terry Kirschenman, Iowa Department of Natural Resources
Jim Carroll, United States Department of Agriculture, Rural Development
Gil Hantzsch, MSA Professional Services
Jason Miller, MSA Professional Services
Doug Wilcox, MSA Professional Services

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EXECUTIVE SUMMARY

Application

Alternative wastewater collection systems have been developed to provide cost-effective solutions for wastewater collection and conveyance. Alternative Collection systems have developed centered around changing the motive force (e.g. pumping) or changing the character of the wastewater collected so that construction and operating costs can be reduced. The most common alternatives used are pressurized sewers using septic tank effluent pumps (STEP) or low-pressure sewers (LPS), and septic tank effluent gravity (STEG) sewers that are small diameter sewers that convey septic tank effluent through a gravity sewer main.

Performance

The advantages of alternative collection systems considered in this document are a reduction in installation costs through the use of almost exclusively smaller diameter pipes, usually buried just below the frost penetration depth. The cost effectiveness of these systems is enhanced when any of the following are present:

- Hilly terrain;
- High groundwater; or
- Shallow bedrock.

When properly constructed, alternative collection systems may experience reduced infiltration and inflow as compared to conventional sewers due to the construction methods surrounding plastic piping. The reduction of infiltration and inflow, coupled with attenuation of peak flows in the septic tanks or grinder pump vaults enable the use of smaller collection system piping and reduced loading to downstream treatment processes.

Disadvantages of the systems considered in this document arise from the uncertainties in operation and maintenance costs of using septic tanks and / or LPS or STEP vaults located at each service connection, usually on private property. In addition, the corrosive nature of wastewater that can turn septic requires special collection and treatment system design considerations that differ from conventional gravity collection systems. Furthermore, alternative collection systems are not designed to receive significant amounts of infiltration and inflow. Poorly constructed building sewers, septic tanks, or pump vaults and improperly assembled collection system piping can result in failed systems if high groundwater is present.

Recommended Design Parameters

STEP Collection Systems

- All wastewater and gray water sources shall be served, including sources located within basements.
- Properly sized and constructed septic tanks with effluent filters located prior to discharge;
- Watertight septic tanks sized for a minimum of 2 x daily flow for septic tanks services individual wastewater sources, community based septic tanks may require larger sizes;
- Septic tank sludge shall be removed as needed;
- Minimum 1.25-inch service laterals;
- Isolation valve and redundant check valve at each service connection;
- Typical 2-inch pipe diameter for mains;
- Tracer wire shall be installed with all mains;
- Isolation valves placed at intersections;
- Minimum design flow (based upon water use),

Minimum design Flow	
Population Equivalents Served	**Equation**
Less than 100	$Q_{gpm} = 0.15 * Pop + 15$
Between 100 and 250	$Q_{gpd} = 4.2 * 100$ gpcd * Pop

- Minimum velocity of 1 ft/s,
- Required Hazen-Williams C = 120;
- Higher C factors for initial construction may need to be evaluated;
- All pumps shall be non-overloading over their entire curve;
- Flushing connections spaced every 600 – 1300 feet along mains;
- Air release valves shall be installed at high points;
- Careful placement of air release valves shall be considered when incorporating centrifugal pumps.

LPS Collection Systems

- All wastewater and gray water sources shall be served, including sources located within basements;
- Watertight LPS pump vaults;
- 24-hour storage volume or emergency generator compatible;
- Minimum 1.25-inch service laterals;
- Isolation valve and redundant check valve at each service connection;
- Minimum 2-inch pipe diameter for mains;
- Tracer wire shall be installed with all mains;
- Isolation valves placed at intersections;
- Minimum design flow (based upon water use);

Minimum design Flow	
Population Equivalents Served	**Equation**
Less than 100	$Q_{gpm} = 0.15 * Pop + 15$
Between 100 and 250	$Q_{gpd} = 4.2 * 100 \text{ gpcd} * Pop$

- Minimum velocity of 2 ft/s,
- Required Hazen-Williams C = 120;
- Higher C factors for initial construction may need to be evaluated;
- Flushing connections are required;
- Air release valves shall be installed at high points;
- Careful placement of air release valves shall be considered when incorporating centrifugal pumps.

STEG Collection Systems

- All wastewater and gray water sources shall be served, including sources located within basements.
- Properly sized and constructed septic tanks with effluent filters located prior to discharge;
- Watertight septic tanks sized for a minimum of 2 x daily flow for septic tanks services individual wastewater sources, community based septic tanks may require larger sizes;
- Septic tank sludge shall be removed as needed;
- Minimum 4-inch service laterals;
- Check valve on each service connection if back flooding is possible;
- Positive gradient mains are required;
- Minimum 4-inch mains;
- Minimum design flow (based upon water use);

Minimum design Flow	
Population Equivalents Served	**Equation**
Less than 100	$Q_{gpm} = 0.15 * Pop + 15$
Between 100 and 250	$Q_{gpd} = 4.2 * 100$ gpcd * Pop

- Minimum velocity of 1 ft/s based on Kutter's formula, n = 0.013;
- Design flow should be carried at a depth of no more than 0.50 of pipe diameter;
- Flushing connections are required;

I. INTRODUCTION

A. Scope

The Iowa Department of Natural Resources (DNR) has commissioned this manual in order to broaden the number of sewage collection system options considered for Iowa's small rural communities. With the adoption of this manual and acceptance of the technology constraints herein, it is the intent of the DNR to provide design guidance for alternate wastewater collection systems. Further, when used by owners and/or designers, this manual is intended to significantly reduce the investment of time and research to supply enough supporting data and design information for approval by the regulatory agency.

This manual is intended for use by Owners, Consulting Engineers, DNR Review Engineers and associated DNR personnel, as well as funding source personnel to provide a common minimum threshold for design for the use of alternative collection systems within Iowa. The design approach contained within this manual should be construed as a minimum basis of design. Nothing within this manual should be construed or viewed as eliminating additional alternative systems, or alternative design approaches with respect to transport of wastewater, provided adequate justification and data from actual installations is submitted.

B. Background

Use of alternative wastewater collection systems should be considered when justified by unusual terrain or geological formations, low population density, difficult construction, or other circumstances where alternative wastewater collection systems would offer an advantage over a conventional system. Alternative wastewater collection systems include pressurized or gravity sewers carrying septic tank effluent, pressurized sewers carrying raw wastewater from grinder pumps, and combinations thereof. Pressurized septic tank effluent pumping systems are termed STEP systems, and gravity flow septic tank effluent systems are termed STEG systems. Pressurized systems conveying grinder pump effluent are commonly termed Low Pressure Systems (LPS). Alternative wastewater collection systems are comprised of both on-site (septic tanks, pumps, pump tanks, valves, service laterals) and off-site components (collector mains, force mains, clean-outs, manholes, vents, and lift stations).

Ownership of the components in an alternative collection system is typically taken over by the municipality, or utility (public or private) so as to ensure that regular maintenance is performed. Homeowner maintenance is occasionally implemented, but a central authority should coordinate maintenance activities and record keeping. General easement agreements are needed to permit access to on-site components, such as septic tanks, STEP pump units, GP units, and control panels located on private property.

C. Terminology

Definitions of some terms used in this evaluation report are as follows:

ADW	Average Dry Weather Flow Rate. ADW is average daily flow when groundwater is at or near normal and a runoff condition is not occurring. The period of measurement for this flow should extend for as long as favorable conditions exist up to 30 days, if possible
AWW	Average Wet Weather Flow Rate. AWW is the daily average flow for the wettest consecutive 30 days for mechanical plants, or for the wettest 180 consecutive days for controlled discharge lagoons
Biochemical Oxygen Demand	The biochemical oxygen demand (BOD) of domestic and industrial wastewater is the amount of molecular oxygen required to stabilize the decomposable matter present in water by aerobic biochemical action.
Infiltration	The water entering a sewer system (including service connections) from the ground, through such means as, but not limited to, defective pipes, pipe joints, connections, or manhole walls. Infiltration does not include, and is distinguished from, inflow.
Infiltration/Inflow	The total quantity of water from both infiltration and inflow without distinguishing the source.
Inflow	The water discharged into a sewer system (including service connections) from such sources as, but not limited to, roof drains, cellar, yard and area drains, foundation drains, cooling water discharges, drains from springs and swampy areas, manhole covers, cross connections from storm sewers and combined sewers, catch basins, storm water, surface runoff, street wash waters, or drainage. It does not include, and is distinguished from, infiltration.

MWW	Maximum Wet Weather Flow. MWW is the total maximum flow received during any 24 hour period when the groundwater is high and a runoff condition is occurring.
PHWW	Peak Hourly Wet Weather Flow Rate. PHWW is the total maximum flow received during one hour when the groundwater is high, runoff is occurring and the domestic, commercial and industrial flows are at their peak.
Reserve volume	The volume of storage provided between the pump "ON" level and the high water alarm level in the tank.
Sanitary Sewer	A sewer intended to carry only sanitary or sanitary and industrial wastewater, from residences, commercial buildings, industrial plants, and institutions.
Storage volume	The volume of storage between the pump "OFF" and the top of the septic tank. A minimum storage volume of corresponding to 24 hours of storage shall be provided. Tanks without 24 hours of storage shall be installed with a power transfer switch with an emergency generator plug or other device for allowing emergency power connection, or shall have storage volume provided with a separate vessel (State of Washington, 2006)
Suspended Solids	Those solids that either float to the surface of, or are suspended in water, sewage, or industrial waste which are removable by a laboratory filtration device.
Working volume	The volume of storage provided by the distance between the pump "ON" and the pump "OFF" switch.

Abbreviations of some terms used in this report are as follows:

AARV	Automatic Air Release Valve
$_CBOD_5$	carbonaceous five-day biochemical oxygen demand
cfs	cubic feet per second
CTH	county trunk highway
DNR	Department of Natural Resources (State of Iowa)
EDU	Equivalent Dwelling Unit
EPA	Environmental Protection Agency (Federal)
gpcd	gallons per capita per day
gpd	gallons per day
gpm	gallons per minute
HRT	hydraulic retention time
I/I	infiltration/inflow
IV	Isolation Valve
lb/day	pounds per day
lb/cap/d	pounds per capita per day
LPS	Low Pressure Sewer (Grinder Pumps)
MARV	Manual Air Release Valve
MG	million gallons
MGD	million gallons per day
mg/l	milligrams per liter
msl	mean sea level
PMS	Pressure Monitoring Station
STEG	Septic Tank Effluent Gravity
STEP	Septic Tank Effluent Pump
TKN	Total Kjeldahl Nitrogen
TSS	total suspended solids
WWTF	Wastewater Treatment Facility

II. COLLECTION PIPING

A. Process Description

Small diameter sewers used in alternative collection systems differ from conventional gravity collection systems because large solids are either removed in a septic tank or broken down in the pumping station before they are transported through the collection system. In the case of STEP and STEG systems, approximately 70 to 90% of the solids, fats, grease, and oils are retained in the septic tank and relatively solids-free effluent is conveyed through the collection system. In contrast, LPS systems using grinder pumps grind the solids in the wastewater prior to conveying through the pressure sewer. In either case, a lack of large solids within the system allows the use of smaller diameter pipes. Pressurized systems (STEP and LPS) may follow the surface contour of the land.

B. Design Flow Determination

With respect to the design of small diameter alternative collection systems, design flows are the maximum flow rates expected to occur once or twice per day, and are used to size the gravity or pressure sewer mains (EPA, 1991). Typically, design flow equations used in alternative collection system design define the design flow as an event that lasts about 15 minutes. The minimum design flow equations contained within EPA's published literature are based upon water use.

Alternative collection systems are not meant to receive large amounts of I/I. Therefore, the design of these systems must incorporate methods and materials to eliminate infiltration and inflow. I/I can occur in non-pressurized portions of the collection system, such as the building sewer and the connection to the septic tank or grinder pump vault. Therefore, it is prudent to make an allowance for I/I when adopting a peak design flow, based on the extent of I/I control given to the project and the conditions present (EPA, 1991). Furthermore, a new collection system constructed to serve existing homes in an area of high groundwater could be impacted by sources of inflow such as basement sumps and foundation drains.

1. Minimum Design Flow Determination (Based on Water Use)

In order to determine design flows for an alternative collection system, two different methodologies are to be used, based upon population being served. The current wastewater facilities design standards identify minimum flow rates and applicable peaking factors based upon population. However, these peaking factors are only applicable to population equivalents greater than 100. For those population equivalents less than 100, alternative means for determining the design flow are provided.

a) *Collection Systems Serving less than 100 people*

For systems serving a population of less than 100 people, the minimum peak flow used in the pipeline design for alternative systems shall be equal to or greater than the following:

Equation 1. $Q_p = 0.5 * EDU + 15$ (State of Washington, 2006), or
Equation 2. $Q_p = 0.15 * P + 15$ (State of Washington, 2006)

Where:

Equation 1
Q_p *is the peak flow in gpm (based on water use);*

EDU is the equivalent number of dwelling units, typically 3.0 capita per single family dwelling (Iowa Wastewater Facilities Design Standards); and

The constant of 15 gpm is used to account for the flowrate from one or more EDUs discharging at the collection system extremities

For example, a system containing 33 EDUs would have a minimum design peak flow of 32 gpm (0.5 * 33 EDUs + 15 = 32 gpm) based on Equation 1.

Equation 2
Q_p *is the peak flow in gpm (based on water use);*

P is the design population; and

The constant of 15 gpm is used to account for the flowrate from one or more EDUs discharging at the collection system extremities

Similarly, if the community in the above example contained 3.0 capita per EDU, the design population would be 100 capita. The minimum design flow would then be 30 gpm (0.15 * 100 people + 15 = 30 gpm), based on Equation 2.

The assumptions of this manual were based upon populations of 25, 100 and 250 people. Therefore the design flow for 25 people is equal to 18.75 gpm.

b) Collection Systems Serving 100 people or more

For systems serving population equivalents of more than 100 people, the current IDNR design standards stipulate that a flow rate be computed assuming 100 gpcpd, with a conservative peaking factor of 4.4 applied. Therefore the design flowrate for 100 people is 30 gpm, and the design flowrate for 250 people is 76gpm.

C. IDNR Background and Requirements

Under the assumptions and constraints of this manual, the DNR is the jurisdictional entity that provides oversight and approval of wastewater treatment system design and operation. As defined within §567 IAC 64, the DNR provides that oversight through the issuance of permits to construct and NDPES operational discharge permits. These permits must be obtained and authorized before any wastewater treatment system can become operational.

In conjunction with Alternative Collection Systems, the DNR will review and issue a construction permit for all of the following components (if applicable):

- Septic Tanks and pump stations;
- Pumps;
- Valves;
- Force mains;
- Gravity Sewer Mains; and
- Miscellaneous appurtenances.

The DNR will require review of a single property unit lateral for new collection systems leading to alternative collection system components in order to receive a permit to construct.

The reader of this manual is directed to review the requirements, as outlined within §567 IAC 64 for the currently enforced rules and regulations regarding wastewater construction and operation in Iowa. Current rules and regulations regarding site separation distances, materials of construction, design parameters and other regulated parameters are applicable to the proper design and construction of alternative wastewater collection systems.

III. SEPTIC TANK EFFLUENT PUMPING

Septic Tank Effluent Pump (STEP) sewer systems have replaced failing septic tanks or been installed as the primary collection system for new residential developments in numerous communities across the United States. STEP systems have also been installed in numerous locations in Iowa. Some examples of communities operating collection systems served entirely or in part by STEP systems include, but are not limited to: Marathon, Ainsworth, Mystic, and Westchester. Typically, communities choose alternative systems over conventional systems based on lower costs and better suitability to local soil conditions.

This section discusses the application of small diameter effluent sewers that are pressurized throughout the system. Situations where septic tank effluent flows by gravity to a gravity collection system are discussed under STEG systems.

A. Collection System Overview

Collection system layout is similar for all alternative collection systems. Figure 3-1 provides a typical layout of the plan and profile views of a STEP collection system, where treatment of the wastewater occurs at a central treatment facility.

1. Isolation Valves

Isolation Valves (IVs) are placed throughout the system. As indicated in the figure, isolation valves are placed upstream of where two mains intersect and at the terminal end of the system to facilitate the future extension of the main. They are also needed at railroad crossings, bridge crossings, waterway crossings, both sides of areas of unstable soil, and long force-main lengths.

2. Flush Connections

Flush connections (sometimes called clean outs) are also frequently installed. In the case of STEP systems, flush connections are recommended. The purpose of installing flush connections is to provide an access point for injecting high-pressure water to clean the system, or to provide an access point for launching a pipe cleaning pig. Typical locations are upstream of where the forcemain increases in diameter and on the terminal end of the main. Typically, pigging is only needed to remove debris that entered the collection system during construction (EPA, 1991).

3. Automatic Air Release Valves

Automatic air release valves (AARVs) are needed at all highpoints within the system. As practiced in water main installations, installation of AARVs at highpoints prevents the entrapment of air in the system, which ultimately reduces capacity of the system. The manufacturers of air release valves and pumping equipment should be consulted for review of air release valve placement.

In accordance with the Iowa wastewater design standards, Air Release valves are required at all high points in the force main to relieve air locking.

Because the effluent in STEP systems is septic (anaerobic) the off gas from release valves is odorous and can be a nuisance if the valves are located near residential areas. For this reason, air release valves are often vented through carbon or soil filters. Manual air release valves are often used in locations that are readily accessible or are not expected to require frequent operation.

4. Service Line Connections

Connections to the service lines from individual homes are made using service saddles, tees, or tapped couplings. The method of connection is often dependent on the timing of installation of homes compared to installation of the pressure main. Regardless of timing, a means of isolation and redundant backflow prevention are required on all service lines. Location of isolation valves varies, but are frequently placed in paved areas with appropriate valve boxes to prevent damage by snow plowing or lawn mowing.

5. Flow Metering

Flow meters (often Doppler or transit time acoustic meters) installed on individual branches can provide valuable information pertaining to per capita wastewater generation, infiltration and inflow, and system capacity. Smaller systems of the type considered in this design manual often elect to avoid the cost of permanent structures in favor of using portable meters. Permanent meters (typically magnetic flow meters) may be installed for systems requiring flow measurement for sewage billing purposes, but are not required.

6. Pressure Monitoring Stations

Pressure monitoring stations (PMSs) are recommended in STEP systems due to the required practice of providing a check valve on the service line. Pressure monitoring stations consist of an access vault to the collection piping that includes a threaded tap and pressure gauge for reading system pressure. PMS's are beneficial for the characterization of operating conditions within the pressure sewer and identifying areas where air-induced headloss may be occurring.

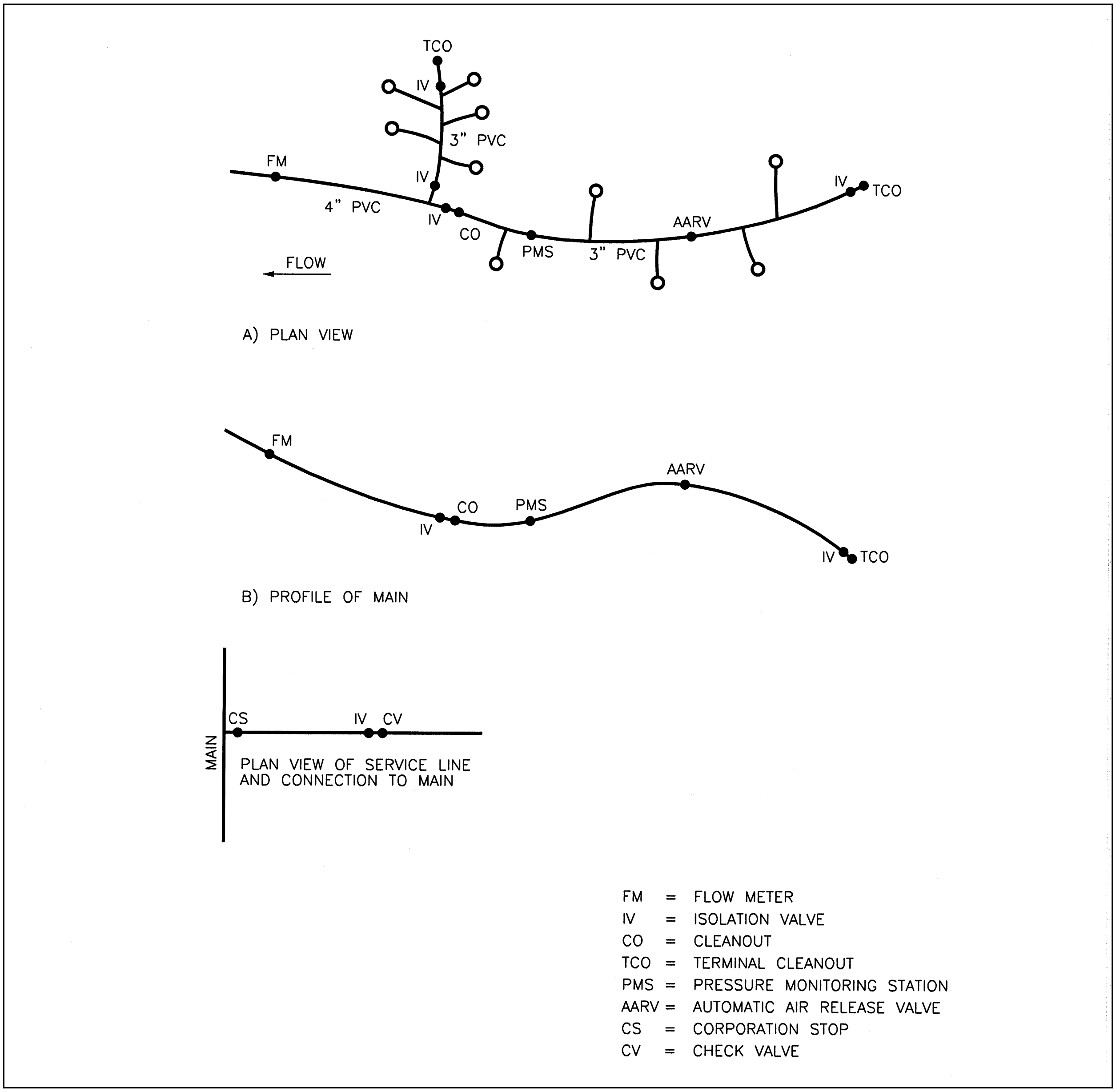

Figure 3-1 Collection System Appurtenances (EPA, 1991).

B. Description of System Components

In Septic Tank Effluent Pump (STEP) systems, wastewater from the user flows into a watertight septic tank to capture solids. The septic tank provides the primary treatment of the wastewater in the system. It holds the wastewater long enough to allow solids to settle out (forming sludge) and oil and grease to float to the surface (as scum). The liquid effluent from the septic tank flows into a pump vault containing a pump and control devices. The pump vault provides storage due to the working volume between the pump on and pump off liquid levels. Additional storage volume provided between the pump on and high water alarm allows for the conditions where the flow generation exceeds the capacity of the pump.

Preassembled STEP packages are available through various pump manufacturers. Included with the packages are the necessary components for a complete system, such as pump, pump vault, pump vault piping and valves, level floats or switches, control panel, junction box, alarms, and associated equipment. Septic tanks can be manufactured and provided with all of the package components, or they can be manufactured separately. Often, pump manufacturers will contract with a concrete tank supplier if pre-cast septic tanks are used. The use of a pre-assembled system is sometimes considered to be advantageous to the design engineer, manufacturer, and system end user. This not only allows for a simplified approach to the design of STEP system components, but also facilitates a single source of responsibility. Though simplified, however, it is of paramount importance that the engineer works closely with the potential suppliers of the STEP units during the design of the system to ensure that the system components will meet or exceed all system requirements.

Providing packaged STEP components may result in concerns that competitive pricing will be negatively impacted. For this reason, individual components of the STEP systems have been designed and specified by application engineers, which are then constructed by the owner or the contractor's supplier. Cost savings may be realized under this approach, but extreme care should be used to avoid the provision of inferior 'generic' components. When this occurs, components often do not fit properly (such as a pump within a pump vault), pumps may not meet the system head and flow conditions used for the design of the system, or materials provided are not properly resistant to the corrosive environment of septic tanks.

In some cases component STEP systems are designed and specified in an effort to produce a superior collection system that is custom made to suit the particular project. According to the EPA, this approach has had limited success. It has been successful only in projects where prototypes were fully developed, tested, and refined over a period of time, or where the design engineer had considerable experience with pressure sewer technology.

Pumps used in STEP systems are not designed to function in the presence of troublesome solids such as hard solids, plastics, rags, sanitary napkins, and stringy material. Though different designs of STEP pumps are able to pass some troublesome solids better than others, a certain degree of homeowner cooperation is needed to prevent these troublesome solids from ever entering the pump vault. Though centrifugal pumps may pass larger solids (some up to 2-inches in diameter), these solids may pass into the collection system and cause blockages or hamper the operation of check and isolation valves. To help prevent these solids from leaving the septic tank and contacting the pump or entering the collection system, strainers or filters are required.

Figures 3-2 through 3-4 depict common configurations of STEP system equipment. All approaches are widely used for STEP systems, and selection of the configuration is often dictated by local sanitary codes, design preferences, equipment and installation costs, and available lot size. STEP pumps may also be located in a separate pump vault located downstream from the septic tank, as shown in Figure 3-5.

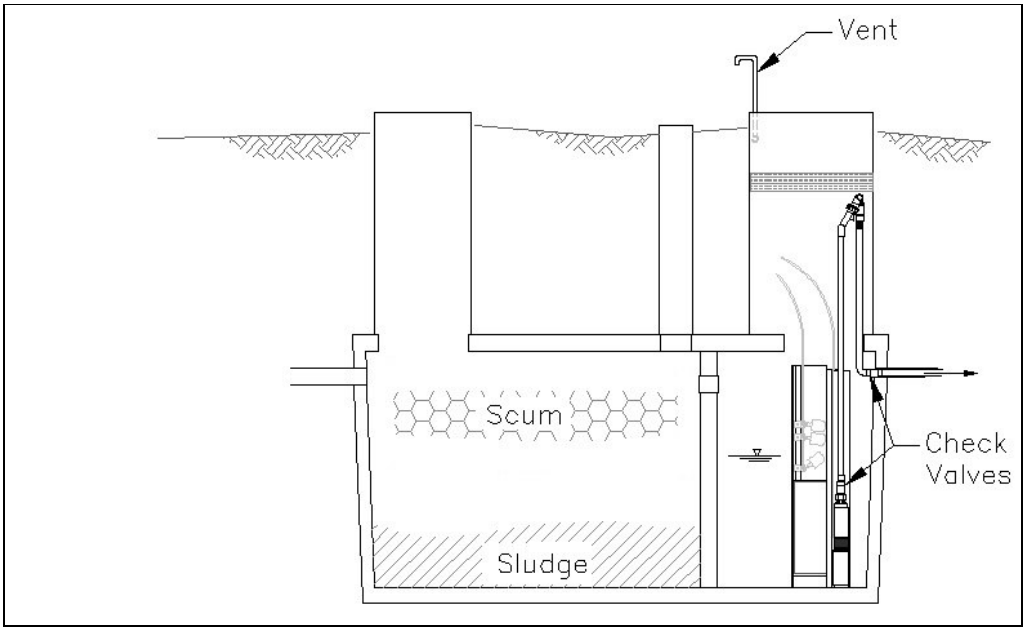

Figure 3-2 Two-compartment septic tank with turbine-style (Orenco, Inc.) pump.

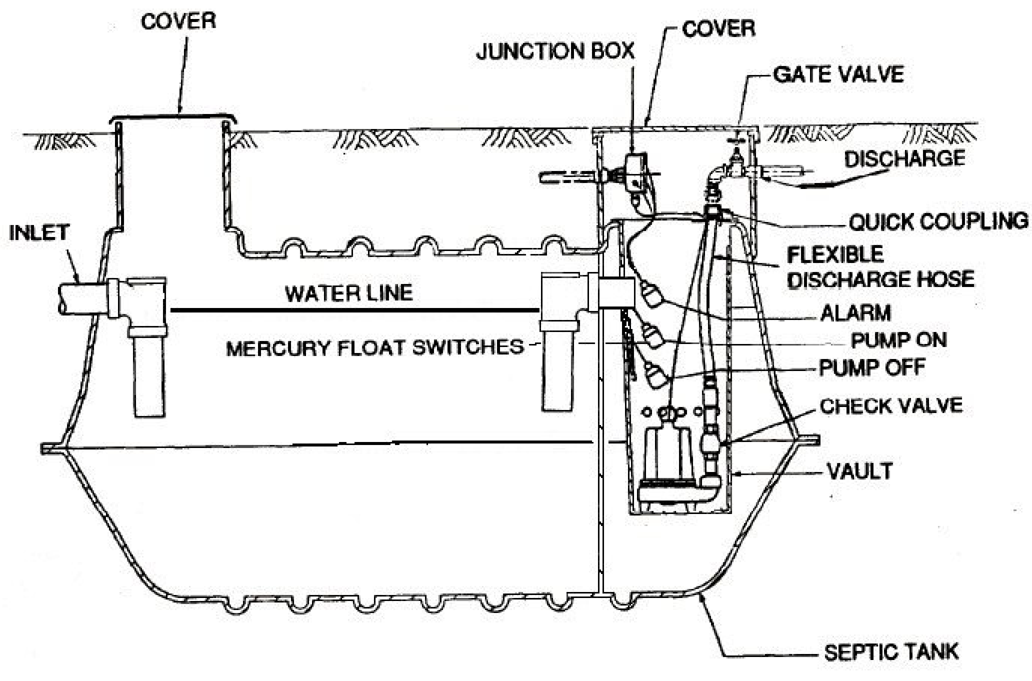

Figure 3-3 Centrifugal STEP pump and internal pump vault (EPA, 1991)

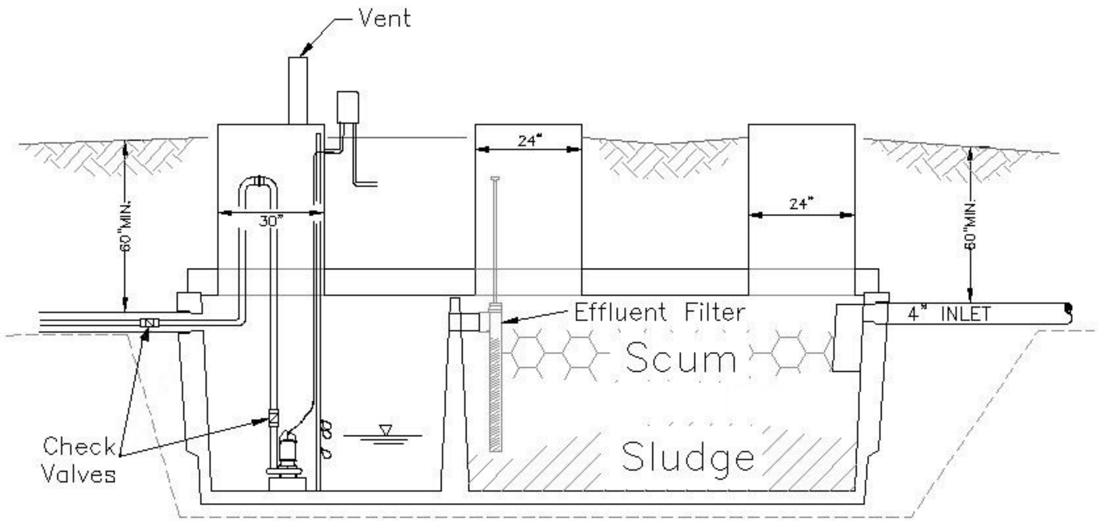

Figure 3-4 Centrifugal STEP pump and integral pump vault.

As shown in Figures 3-2 through 3-4, the effluent pump in a STEP system is typically placed on a block riser just above the vault floor elevation or is suspended within the tank. The pump discharges to a small diameter pipe typically made of PVC flexible piping, which then rises vertically until making a U-shape near the ground surface within the access riser. Quick connects shall be provided, in addition to a check valve and gate (shutoff) valve accessible from the ground surface. Pump Off, Pump On, and High Water Level switches are provided in the pump vault, with the level switch wires and pump power cable terminating in a junction box.

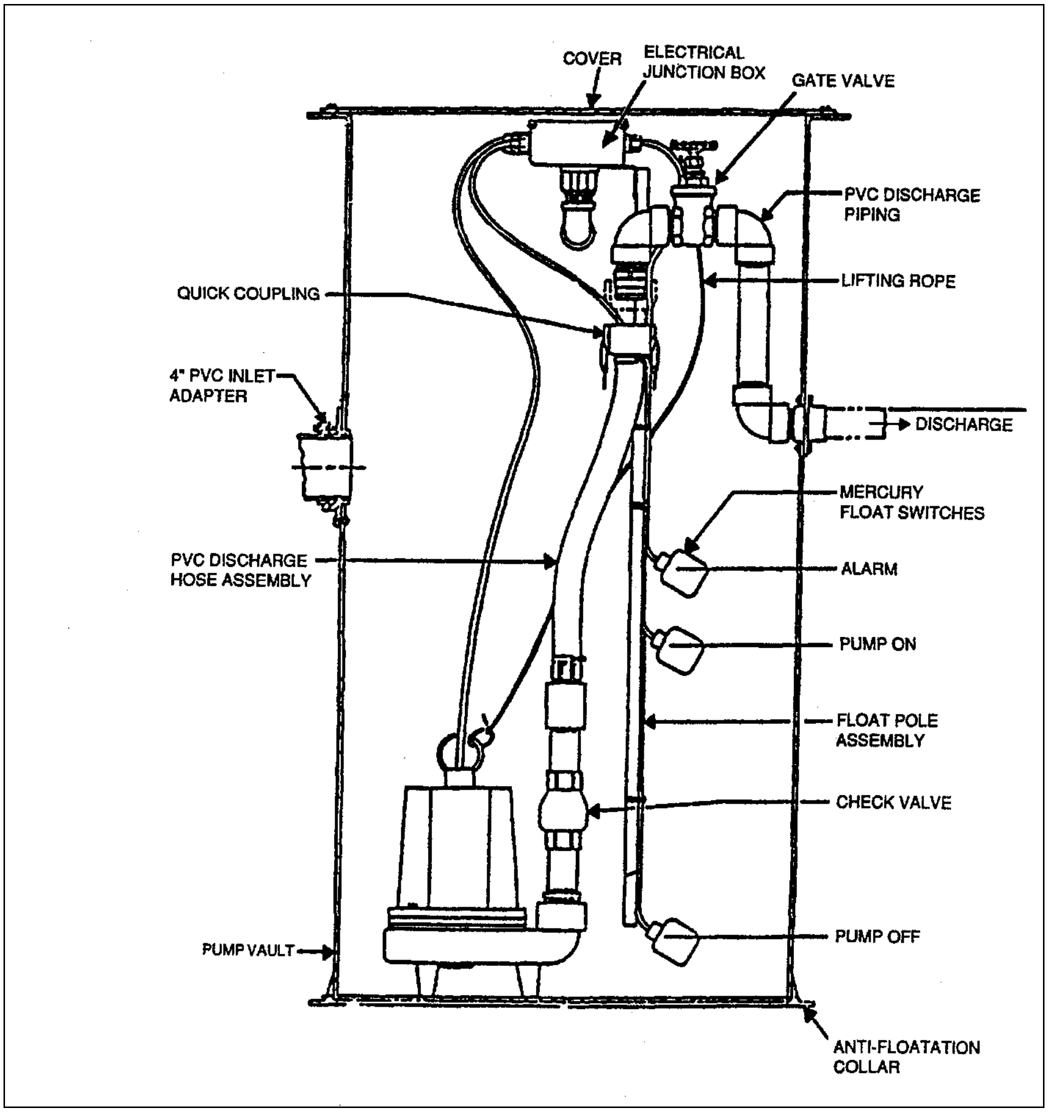

Figure 3-5 Centrifugal STEP pump in external vault. (EPA, 1991).

Pumping characteristics vary depending on the type of pump and the manufacturer. In STEP systems, centrifugal pumps and turbine pumps are most commonly used. Progressive cavity pumps have also been used in STEP systems, but their use is more common in grinder pump applications. Turbine pumps have been preferred in some applications due to their relatively constant discharge rate at various head conditions. If turbine pumps are used, however, the pump vault must be configured to include an effluent filter. In addition, the effluent acts as cooling water as it travels past the motor prior to entering the pump. Typical curves for discharge versus head conditions for various pump designs can be obtained from pump manufacturers.

Figure 3-6 provides discharge versus head conditions for centrifugal, positive displacement, and turbine pumps (EPA, 1991).

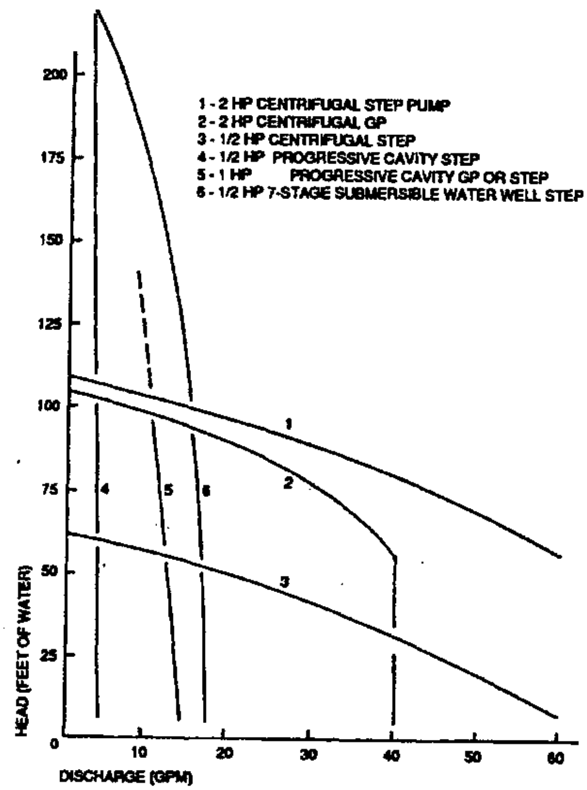

Figure 3-6 Discharge curves for pumps used in pressure sewers (EPA, 1991)

C. Materials of Construction

Structurally sound and watertight tanks are an absolute necessity in all pressure sewer applications. The installation of inferior tanks has resulted in severe leakage or groundwater infiltration, deformation of the tank, and collapse. Excessive flows caused by infiltration and inflow have resulted in failed pressure sewer applications. Poor quality tanks that collapse or deform require costly removal and replacement.

Pump vaults are typically constructed from reinforced concrete, fiberglass reinforced polyester (FRP), high density polyethylene (HDPE), low density polyethylene (LDPE), or polyvinyl chloride (PVC). FRP vaults are most common, with a typical thickness of approximately ¼ inch. If PE tanks are used and intended to provide structural support, they must be thicker than FRP because PE is more flexible.

Septic tanks are most commonly constructed of reinforced concrete, FRP, and PE. Reinforced concrete tanks should conform with the requirements of Chapter 69 of the Iowa Administrative Code. Due to the importance of watertight design in a pressure sewer application, the reuse of existing septic tanks from an on-site system is not recommended without a rigorous evaluation of each tank. In cases where component systems are designed and tanks are provided by entities other than the pump manufacturer, tank construction must be scrutinized to assure that all components will fit together. Quality control of the tank manufacturing process is critical.

Due to the corrosive atmosphere present in STEP septic tanks and pump chambers, all equipment, piping, and fasteners such as hose clamps must be suitably corrosion resistant. For metal components, austenitic stainless steel of Type 316 or type 304 is required. Type 416 or other martensitic stainless steels are not acceptable. For plastic components, PVC, ABS, and PE are recommended due to their resistance to corrosion by H_2S. Nylon is degraded by H_2S and is not acceptable.

D. Design Guidance – STEP Collection Systems

1. Required Pumping Rates

Required pumping rates for STEP systems should not be confused with the peak flow expected to occur in the dwelling. Since the purpose of the STEP pump is to discharge effluent at a rate such that the water level in the septic tank does not reach the high water level alarm and also to prevent backups with a high degree of confidence, pumping rates are established that utilize the reserve volume provided in the septic tank.

Pumping rates will be lower than design flow rates used for sizing the collection system mains, because design flow rates do not incorporate any attenuation of flows due to the reserve volume of the septic tank.

The **reserve volume** is defined as the volume of storage provided between the pump "ON" level and the high water alarm level in the tank.

The **working volume** is the volume of storage provided by the distance between the pump "ON" and the pump "OFF" switch.

The **storage volume** is the volume of storage between the pump "OFF" and the top of the septic tank. A minimum storage volume of corresponding to 24 hours of storage shall be provided. Tanks without 24 hours of storage shall be installed with a power transfer switch with an emergency generator plug or other device for allowing emergency power connection, or shall have storage volume provided with a separate vessel (State of Washington, 2006).

Various pumping rates have been recommended for STEP systems, and in all cases the recommended pumping rate is a function of the reserve volume in the septic tank Recommendations of a minimum pumping rate of 10 gpm at a reserve volume of 25 gallons, and a minimum pumping rate of 5 gpm at a reserve volume of 50 gallons have been made (WEF MOP 12, 1984).

A minimum pumping rate of 2.6 gpm for a tank reserve volume of 50 gallons has been recommended (EPA, 1991). This is based upon the results obtained from the work of Jones, who performed a 1% regression analysis of his peak flows. That regressive analysis corresponded well to the peak flows determined by both the ASCE and Bennett. ASCE found a peak flow of 26 gallons over a 4-minute period that would be expected to occur twice per year, in addition to a flow of 46 gallons occurring over a 2-minute period (corresponding to the simultaneous discharge of a bathtub and clothes washer) having a high probability of occurrence, while Bennett determined a flow of 60 gallons over a 7-minute period.

Figure 3-7 provides the flows determined by ASCE and Jones' regression analyses. Figure 3-8 uses the 1% regression line from Figure 3-7 and indicates the required pumping rates needed at various tank reserve volumes. In Figure 3-8, the curves were based upon the <1% regression curve in Figure 3-7, and are calculated according to the following equation:

$$Q = \left(\frac{V - S}{t} \right)$$

Where,

Q = minimum required pump discharge rate (gpm)
V = Volume of peak wastewater flow from the home (gallons)
S = Storage volume between pump on and alarm condition (gallons)
t = Time (minutes)

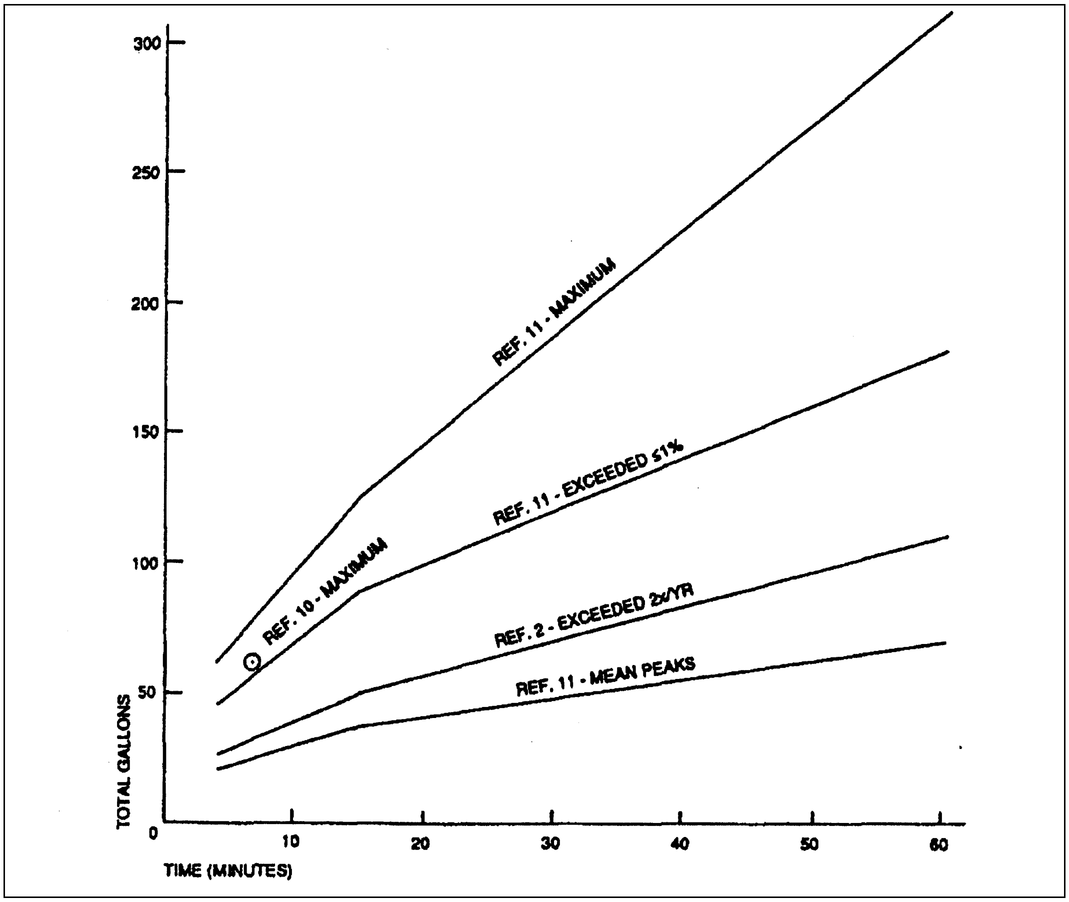

Figure 3-7 Wastewater flows for a single residence (EPA, 1991).

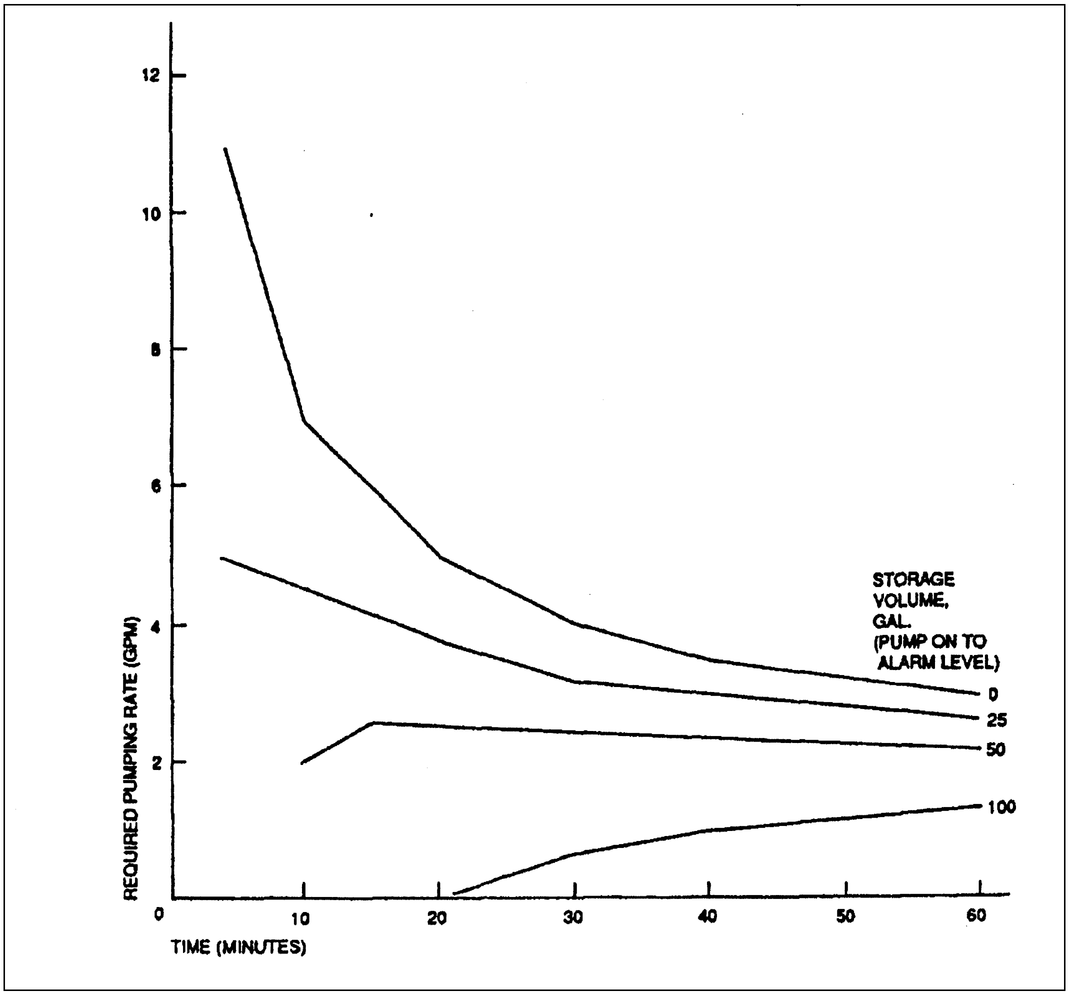

Figure 3-8 Required pumping rates based Reference 11, <1% regression

Therefore, based on the curves shown in Figure 3-8, a minimum pumping rate of 5 gpm is suitable for STEP pumping systems, having a reserve volume greater than 25 gallons.

2. Collection System Flow Considerations

Conventional gravity collection systems have historically been designed to maintain "self-cleaning velocities" of 2-3 ft/s at least once or twice per day. Self-cleaning velocities are velocities required to transport solid materials with the water to avoid buildup and clogging. STEP systems, however, are relatively free of solids and do not need to maintain the traditional self-cleaning velocity of 2-3 ft/s. For design purposes, a minimum velocity of 1 ft/s shall be used.

The Hazen-Williams, Manning, or Kutter's Equation can be used for the calculation of headloss in pressure sewer applications.

Hazen-Williams: $V = 1.318CR^{0.63}S^{0.54}$

Manning: $V = \frac{1.486}{n}R^{2/3}S^{1/2}$

Kutter's: $V = C_K\sqrt{RS}$

Where,

V = velocity, ft/s
C = Hazen-Williams flow coefficient (120)
C_K = Chezy's roughness coefficient, where:

$$C_K = \frac{k_1 + \frac{k_2}{S} + \frac{k_3}{n}}{1 + \frac{n}{\sqrt{R}} * \left(k_1 + \frac{k_2}{S}\right)}$$

R = hydraulic radius (for pressure pipes, R = D/4)
S = slope of energy grade line
n = Manning or Kutter's flow coefficient

The most commonly used equation in pressure sewer design (applicable to STEP systems) is the Hazen-Williams Equation. C factors identified for PVC pipe range from C = 140 to C = 160, with a typical value of 150 (Crites & Tchobanoglous, 1998; WEF MOP No. FD 12, 1986), to C = 130 to C = 140 (US EPA, 1991, 2002).

The current Iowa standards require a C value of 120. Therefore analysis shall be completed using a C Factor of 120. Analysis should also be performed to confirm performance with higher C factors that could be observed after initial startup.

3. <u>STEP Force mains</u>

a) *<u>Configuration and Layout</u>*

STEP pressure sewer systems are typically configured in a branched pattern because the arrangement enables easily predictable velocities in the mains. The disadvantage of a branched arrangement is that the system lacks redundancy, so users upstream from a disturbance to the collection system are without service.

Pumping “uphill” is usually the preferred practice. Uphill pumping occurs when all pumps and all portions of the pressure sewer collection system and service lines are at an elevation lower than the point of discharge. “Downhill” pumping may be unavoidable in some cases, or may be preferred for site-specific reasons. When downhill situations are present, air enters the pipeline and two-phase flow (air and water) will be present.

Pumping both “uphill” and “downhill”, or two-phase flow, results in high turbulence and headloss in the system, and can diminish capacity if air release valves are not properly installed and located. Downhill portions of the collection system should be short, steeply inclined and distinct, which may require rerouting of mainlines in the proposed layout. If this cannot be achieved, standpipes or pressure-sustaining control valves can be used to elevate the static grade line and ensure that the mains in these areas remain full of effluent throughout pumping. This allows air release valves to function properly. The use of standpipes and the location of air release valves may need to be evaluated in downhill pumping applications (WEF MOP 12, 1986).

Another option for situations where downhill pumping cannot be avoided is to oversize the downhill portion of the main to accommodate gravity flow conditions. In this arrangement, automatic air release valves would be placed at the upstream highpoint and the downstream static water elevation.

b) Sizing Recommendations

Refer to Table 3-1 for approximate sizing of effluent sewer mains and the characteristics of flow based on the design assumptions. For most systems considered in this design manual, a 2-inch diameter PVC pipe would suffice. However, pump manufacturers’ recommendations should also be considered for the proper specification and sizing of system piping. Given the fact that plastic pipe is most often used for the main line installations; mechanisms for future location of the sewer line (including tracer wire) shall be included with the sewer main.

The use of 2-inch pipe should be compared to 3-inch pipe in terms of overall project costs (materials, labor, and installation). Depending on the availability of 3-inch pipe, the increase in material costs (3-inch pipe costs roughly double the cost of 2-inch pipe) may be offset by reduction in labor cost through the use of gasketed joints instead of solvent welded joints. The added benefit of 3-inch pipe is that the capacity of the system is greatly increased.

Sophisticated pipe selection charts and computer programs are available for more complicated effluent sewer systems. The use of pump manufacturers’ computer programs specific to the type of pumping equipment to be used is recommended to provide additional hydraulic analysis.

Because the wastewater in a STEP system is relatively free of solids, design velocities will typically range from 1 to 5 ft/s. Generally speaking, design friction headloss values of 0.5 to 1.5 ft/100 ft are targeted to avoid unnecessarily high pressures in the mains (Crites & Tchobanoglous, 1998). This enables the STEP pumps to remain within the 0.5 – 2.0 hp range, depending on the type of pump used. If turbine pumps are used in the system, the pump discharge will remain near the design discharge rate over a wide range of head conditions. If centrifugal pumps are used in the system, head pressures have a much greater effect on the discharge rate of the pump.

Table 3-1
STEP Forcemain Size and Flow As a Function of Design Population

EDUs	Design Population	Qp (gpm)	Pipe Size[a] (inches)	Headloss[b] (ft/100 ft)	Velocity (ft/s)
8	25	19	2	0.8 +/-	1.7
33	100	30	3	0.3 +/-	1.2
83	250	76	3	1.7 +/-	3.1

a. Nominal diameter.

b. Head loss is based on C=120 and the inside diameter of class 200 PVC pipe

c) *Site Conditions*

Due to the ability of pressure sewers to be installed at shallower depths than conventional systems, pressure sewer mains are often selected when groundwater or bedrock is present near the ground surface.

Poor soils are often present when groundwater is high. Imported granular pipe zone backfill is needed to surround the piping when material excavated from the trench is unsuitable.

d) *Pipe Location*

Typically, pressure sewers are not located under roadways. The preferred location of mains is adjacent to the roadway (often in the ditch right of way), running roughly parallel so that the location of the non-metallic pipes can be easily anticipated. Placement of a toning cable or metalized marker tape with the main aids in future location and shall be required.

Some municipalities, however, prefer to locate mains underneath the roadway, to protect them from damage caused by future excavation. This is not recommended, however, unless the ditch or right of way area is subject to significant erosion or is otherwise problematic for installation, such as shallow bedrock.

In all cases, pipes should be buried to at least the winter frost penetration depth. To avoid freezing when buried below frost penetration depth.

In areas where high bedrock is present, insulated and heat-traced pipes are generally buried near the surface at a minimal depth.

e) Pipe Materials

(1) PVC

The most common PVC mains are iron pipe size (IPS) 200 psi working pressure rated standard dimension ratio (SDR) 21 or standard dimension ratio (SDR) 26 which is rated for 160 psi. Even though operating pressures in the mains may be much lower than the working pressure rating, the use of lower rated pipe is not recommended. Thinner wall pipe is more likely to be seriously damaged during installation, and may not have the strength to withstand the pressures created during pigging.

When PVC mains larger than 8 inches are used, AWWA C-900 pipe is sometimes specified due to the availability of proper fittings (EPA, 1991).

(2) HDPE

Though PVC is the most widely used type of pipe for effluent pressure sewers, HDPE has also been used. Fused-joint HDPE has the advantage of minimizing the number of joints, and it has been selected for visual identification in contrast to PVC water mains. HDPE has also been used for lake and stream crossings. If HDPE is selected, SDR 11 is most often used.

f) Isolation Valves

Isolation valves are used on pressure sewer mains much as they are on water mains. Resilient-wedge gate valves, plug valves, and occasionally ball valves are used. Isolation valves should be located at all intersections (on each upstream branch), railroad crossings, bridge crossings, waterway crossings, both sides of areas of unstable soil, and long force-main lengths. The design interval between isolation valves along straight runs of force main varies. Suggested spacing for isolation valves is similar to the placement of flushing connections, having recommended intervals of 600 – 1,300 ft (EPA, 1991, State of Washington, 2006).

Standard AWWA bronze gate valves have been used, but those having a resilient wedge and closing on a smooth bore have been found to close more tightly (EPA, 1991).

Mainline isolation valves are necessary for isolating sections of lines during line breaks or other emergencies. They usually remain in either their open or closed position until an emergency arises.

g) Flushing Connections and Clean-Outs

Accumulation of grease and solids will reduce the system capacity by increasing friction losses. Pipeline cleaning is most commonly accomplished by hydraulic flushing at velocities of greater than 3 ft/s. Some installations incorporate pipeline pigging, which is introducing a bullet-shaped 2 lb/cu ft polyurethane foam device, or pig, into the line at a flushing connection or clean-out and forcing it through with water or air pressure. Typically, a cleanout and pipeline can accept a polyurethane pig that is 2 inches larger than the diameter of the pipeline being cleaned, thus a 4-inch pig can be launched into a 2-inch pipeline. The exterior of a cleaning pig is normally coated with a plastic material in a spiral or criss-cross design to aid in scrubbing the pipe's inner walls. Retrieval of the pig occurs at the downstream flushing connection.

Flushing connections should be located at strategic points in the collection lines. They shall be located at the ends of mains, where the diameter of the main changes, at major changes in direction, and approximately every 600 to 1,300 feet along straight runs.

Figures 3-9, 3-10, and 3-11 provide details of acceptable flushing connections. Single flush connections are used at the terminal ends of a main and on each branch, and are adequate for launching and retrieving pipeline pigs, whereas dual-flush connections are used at all major branch intersections.

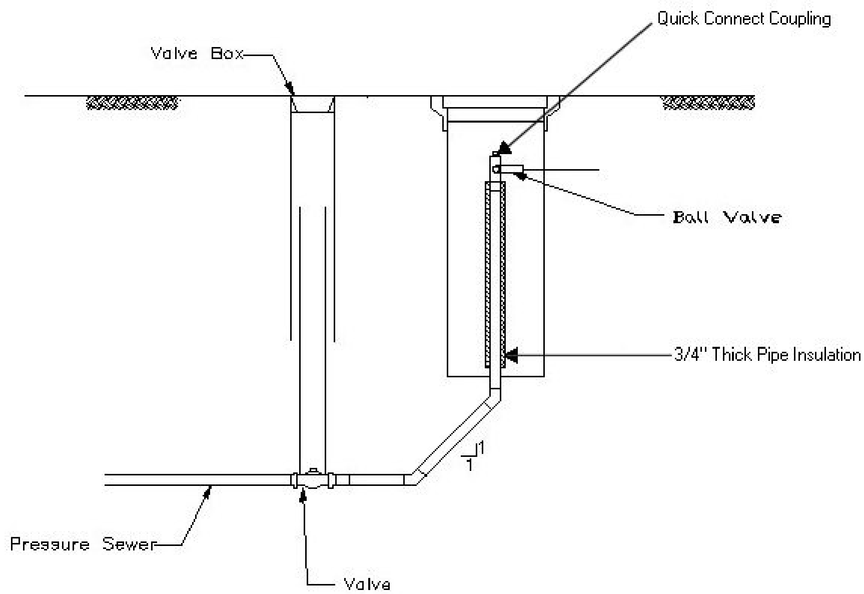

Figure 3-9 Typical single-flush connection

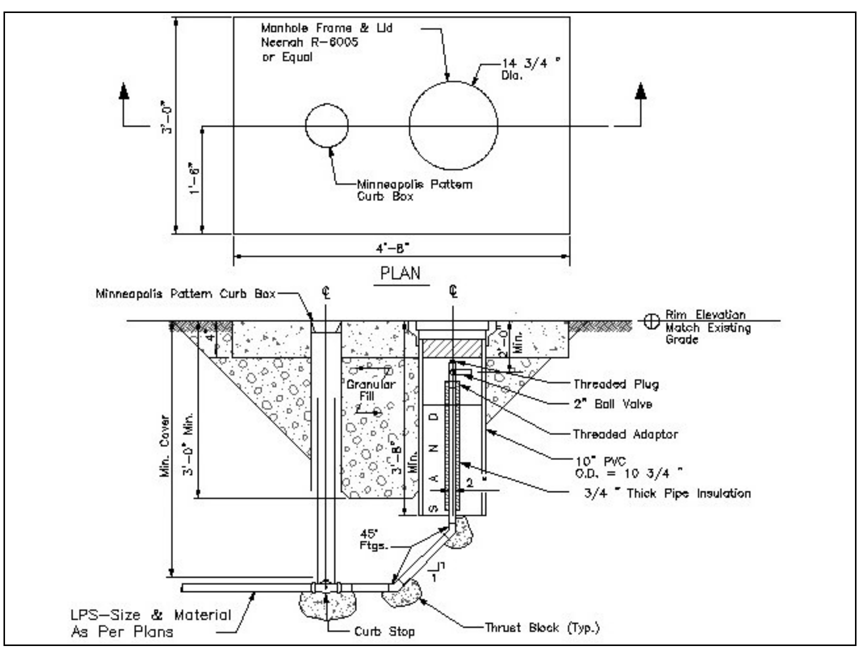

Figure 3-10 Typical single-flush connection.

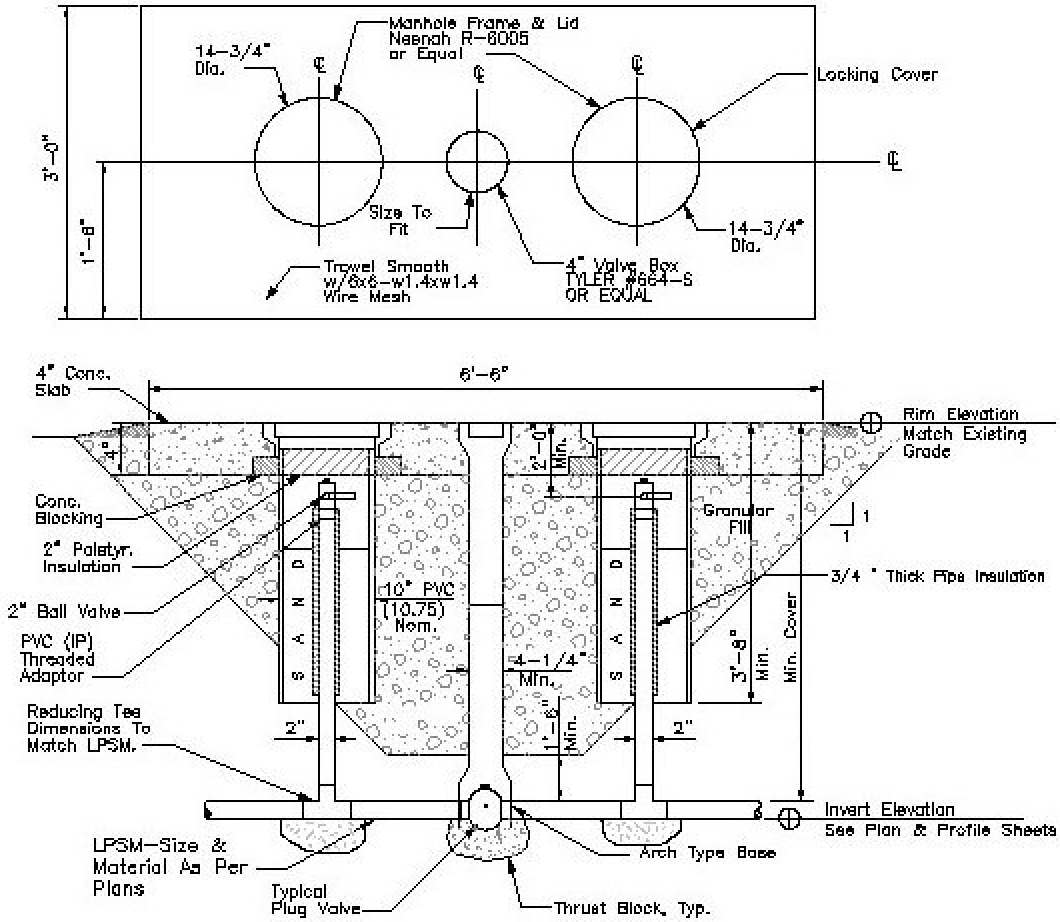

Figure 3-11 Typical dual -flush connection.

In effluent collection systems, septic tanks remove 70 to 90 percent of the greases, oils, fats and solids. Properly designed, installed and maintained systems of this type have demonstrated little or no need for line cleaning. Pigging in effluent sewers is most commonly required to purge a system of dirt and debris that gets into the open lines during initial installation or during repair operations, though other options for cleaning construction debris are also available.

h) *Air Relief Requirements*

Careful placement of air release valves is necessary to avoid the buildup of air and gases within the system, as their presence will diminish the system's hydraulic capacity. Air release valves must be located at all critical high points and at the high point on pressure sustaining devices where it's necessary to keep the system purged of air.

Air release valves should be automatic where air and gas pockets are persistent. Manual valves that are vented periodically can be used in areas where gas and air entrainment is less severe.

Automatic air release valves provided must be designed for operation with wastewater. Potable water system air release valves often foul and become inoperable, and may not be made of corrosion-resistant materials.

Because the air released by these valves will be odorous and contain hydrogen sulfide, the valves and their enclosures must be constructed of corrosion-resistant materials. Vaults must also be insulated to prevent freezing, and should be equipped with an activated carbon filter impregnated with sodium hydroxide.

i) Pressure Sustaining Requirements

High points must be carefully evaluated to determine where pressure sustaining is necessary. A minimum pressure must be sustained to minimize the tendency for air and gasses to coalesce at high points and restrict the system hydraulic capacity. Pressure sustaining equipment is designed to maintain upstream static pressures in those portions of the system higher in elevation than the discharge point, where the pressure is insufficient to maintain full flow (see Figure 3-9). Roll seal valves that use a predetermined hydro-pneumatic pressure to establish the upstream static pressure are most commonly used.

Figure 3-12 provides a schematic for the application of air release and pressure sustaining valves (Crites and Tchobanoglous, 1998). Air release valves are typically placed at a point 5-ft below the elevation of the downstream static hydraulic grade line (See Figure 3-12*b*). If a line is oversized to allow for gravity flow, an air release valve is used at both the high point and at a point 5-ft below the static hydraulic grade line (Figure 3-12*c*).

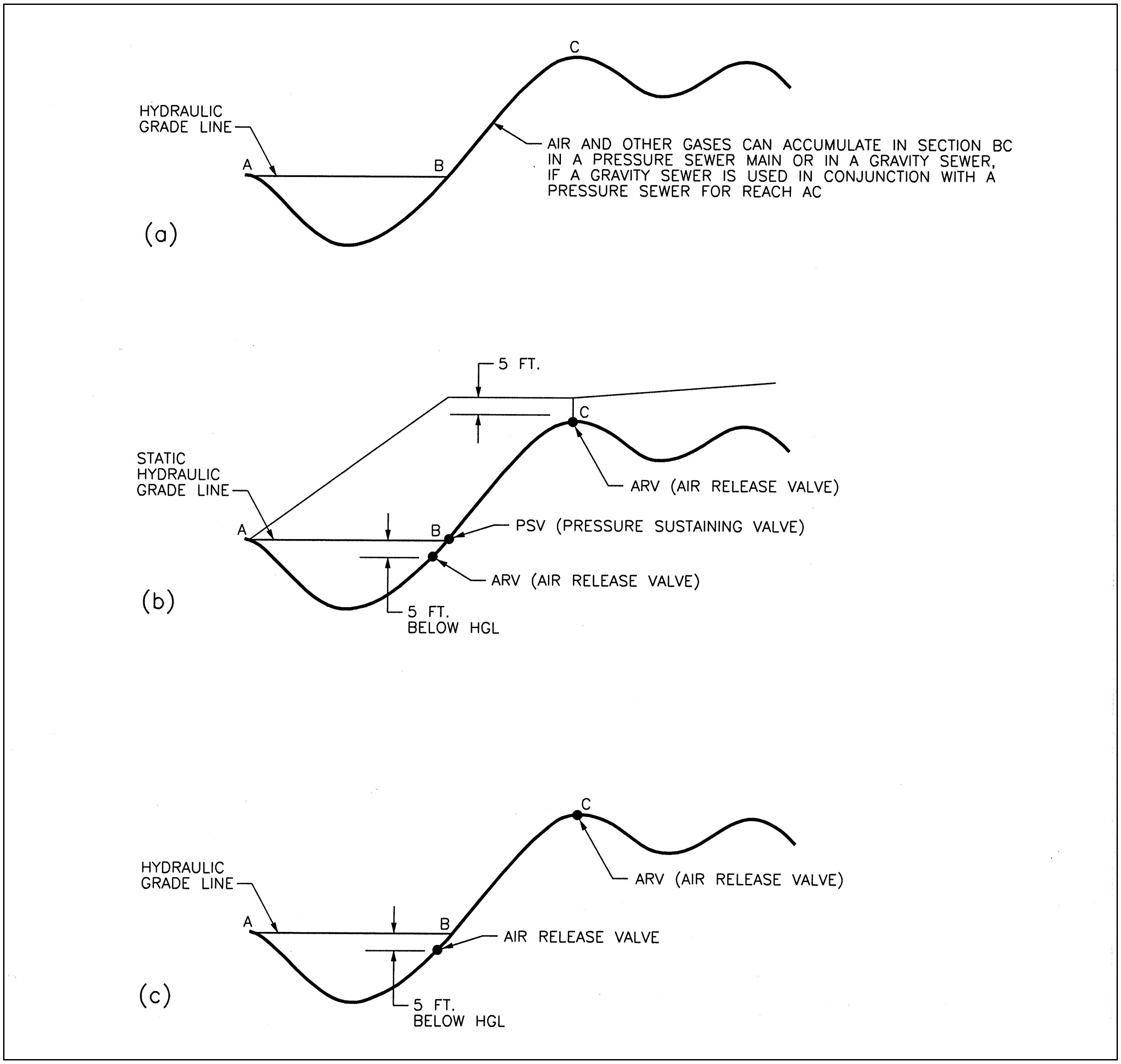

Figure 3-12 Application of air release and pressure sustaining valves (Crites & Tchobanoglous, 1998).

j) Thrust Restraints

Thrust blocks should be used with pressure sewer mains in the same fashion as they are commonly used in water mains. Thrust blocks enable the system to withstand hydrostatic pressure testing. They also prevent damage to the system caused by high flows and pressures generated during pipeline pigging.

k) Flow Metering

On systems where permanent flow metering is needed, magnetic flow meters are the most common method of metering pressure sewer flows. Flow measurement is often necessary if the collection system carries wastewater generated by users located in different districts or municipalities. Portable flow meters used for periodic system monitoring and evaluation are typically of the doppler or transit time acoustic variety.

4. STEP Service Lines

a) Location

Pressure sewer service lines should be isolated from the potable water lines and wells to reduce the possibility of cross contamination. They should also be distant from other buried utilities if possible, due to the possibility of damage caused by the subsequent excavations for maintenance or repair of those utilities. Refer to Chapter 12.5.8. of the Iowa Department of Natural Resources Design Standards for isolation requirements.

Service lines should be buried below the frost penetration depth. The use of continuous tracer tape or wire is recommended.

b) Sizing

Service lines for STEP systems are commonly 1.25 inches in diameter.

c) Pipe Materials

Schedule 40 or Schedule 80 PVC is most commonly used for service lines because of its durability. Schedule 40 and Schedule 80 PVC have a thicker wall than other pressure classes in the 1.25-inch size, which helps to prevent damage resulting from construction activities. Due to the small diameter, solvent welding is the required method for joining pipes together.

d) Connection to the Main

Service lines are connected to the forcemain using either a service saddle or a tee. Tees can be used if the service line location is precisely known when the forcemain is being placed. If the main is already in service, a service saddle is used to make the wet tap. A corporation stop is typically used at the service saddle.

Wyes are not recommended for connection to the main. They are not hydraulically superior to tees, and they are not available in pressure-rated PVC.

e) Service Line Valves

Isolation valves are needed to isolate the service line from the main. Typically, either ball valves or gate valves are used for this purpose. The isolation valve (or curb stop) on the service line is often located at the edge of the road right of way. PVC ball valves with PVC loaded EPDM stem seals, micro-finished PVC ball, and self-adjusting ball seat are commonly used.

It is required to place a redundant check valve next to the isolation valve. The check valve is necessary to prevent the pressurized wastewater in the main from entering the pump vault should the check valve on the pump fail. Placement of the check valve next to the isolation valve allows the check valve to be located, since the isolation valve will have a valve box riser to the ground surface. A check valve next to the isolation valve is not needed when a redundant check valve is provided in the pump chamber. Regardless of location (at the isolation valve or within the pump vault), all systems must have a redundant check valve.

Check valves used on service lines are typically tee or wye pattern PVC swing check valves with working pressures of 150 psi.

Figure 3-10 provides a typical detail for the connection of a STEP system to the forcemain.

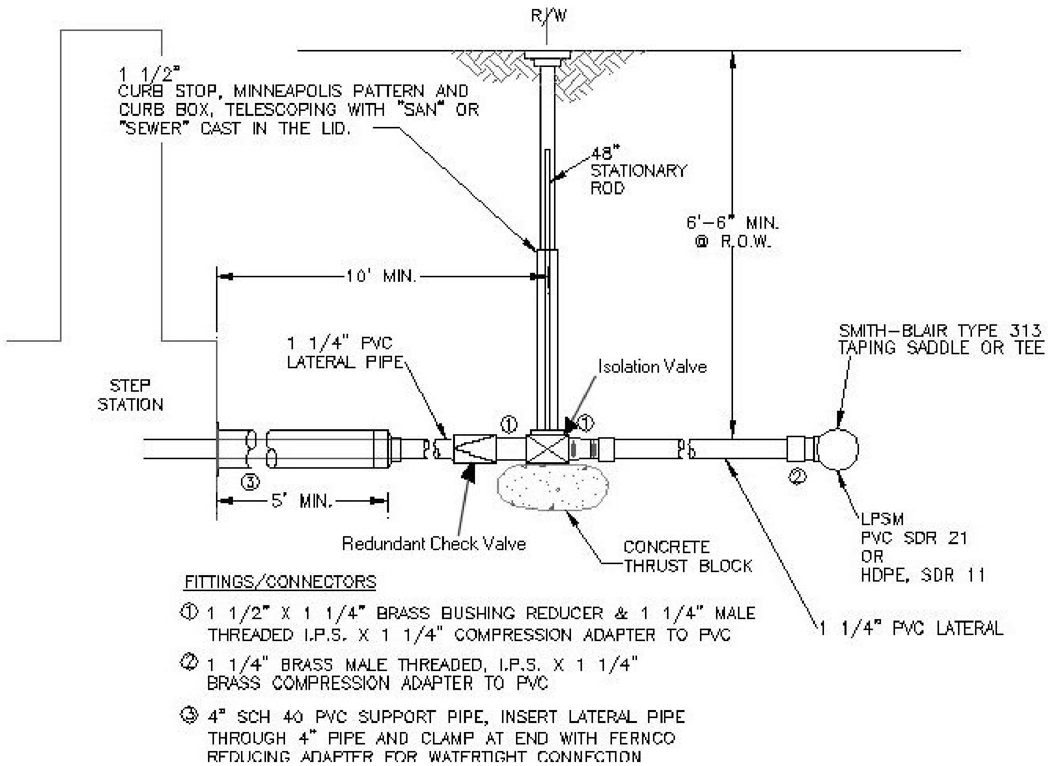

Figure 3-13 Typical STEP vault connection to forcemain.

E. Design Guidance

1. Septic Tanks

The minimum detention volume in the septic tank shall be as follows:

V = 2.0 * Q (Residential Applications)

Where,
V = Liquid volume
Q = Peak daily flow for the structure being served

The working volume is the volume of storage provided by the distance between the pump "ON" and the pump "OFF" switch. The working volume shall be greater than the difference between the peak influent flow and discharge of the effluent pump over a period of time estimated to be the peak duration (State of Washington, 2006).

The storage volume is the volume of storage provided by the distance between the pump "OFF" and the top of the septic tank. The storage volume provided shall be a minimum of 150 gallons, or 24 hours detention, whichever is greater.

Additional design guidance and detailed information pertaining to the sizing, construction, and effluent characteristics of septic tanks is provided in Appendix A.

2. Pump Selection

Pumps having a minimum 24-hour run dry capability without water lubrication are recommended, as are designs that allow circulation of effluent for motor cooling and to prevent air bind. Considerations should be made to protect against thrust in an effort to increase pump life. Pump motors must be rated for continuous use and frequent cycling, at least 100 cycles per day. The motor cable must be suitable for Class 1, Division 1 and 2 applications. Lightweight pumps facilitate easy removal and maintenance.

The most common pump types used in STEP systems are centrifugal pumps and multistage turbine pumps. Horsepower required depends on the system conditions, but pumps ranging from 0.5 to 2.0 hp are most common.

Pumps used in pressure sewers should be capable of running at shutoff head conditions. Shutoff head conditions can be produced in the collection system after a substantial power outage, when many of the pumps within the system energize simultaneously. Shutoff head conditions also occur if a mainline isolation valve is closed for maintenance purposes or curb stop is inadvertently left in the closed position.

If the installation of the pump is such that the liquid level in the pump tank is higher than the hydraulic grade line of the main, siphoning can occur when the pump has shut off. In some cases, siphoning can result in air-binding of pumps. Anti-siphon valves must be provided if siphoning could occur.

Most centrifugal effluent pumps will handle solids up to 0.75 inches in diameter. If a turbine pump is used, effluent filters are mandatory because the pumps cannot handle solids larger than 1/8-inch in diameter. The use of effluent filters is recommended in all systems, however, regardless of the type of effluent pump used.

Pumps should be UL and CSA listed for use with septic tank effluent.

a) Flow Rates

The pumping rate provided in a STEP system depends upon the pump type used. When a centrifugal effluent pump is used, the discharge from the pump will vary over a larger range flows than if a turbine pump is used. Figure 3-14 provides the discharge versus head relationships for a typical centrifugal pump and a turbine pump. Because turbine pumps offer more consistent flow rates over a large range of head conditions, they are preferred by many engineers for effluent pumping applications.

When pumping from a pump vault that is located inside of the septic tank, the pumping rate should be slow enough to allow maximum settlement of solids, adequate fat, grease and oil retention, and an efficient power rating, but not so slow that the pump's run-time is excessive. The ideal discharge rate for a single-family residential effluent sewer pump with a pump vault located internally to the septic tank is 5 gpm. Where system pressures are low, and turbine pumps are used, flow controllers are commonly used to keep the discharge rate below 9 or 10 gpm.

In the Glide, Oregon STEP system's original design, pumps for single-family dwellings were meant to discharge 10 gpm with sufficient lift to accommodate the system's ultimate hydraulic gradient. However, the system has never operated above 25 percent of its designed capacity. As a consequence of the flat performance curve of the centrifugal effluent pumps installed in the system, actual pumping rates often exceed 60 gpm. At these rates solids are passed into the system, increasing maintenance costs (Orenco, Inc. 2006). At a lower pumping rate of 4 to 6 gpm, the contents of the septic tanks are barely disturbed and the solids carryover is minimized.

In systems where the effluent pump chamber is physically separated from the septic tank, maintaining a lower flow rate is not as critical, since the operation of the pump will not induce turbulence in the septic tank that could re-suspend sludge. Effluent filters also aid in the prevention of solids entering the system, regardless of whether turbulence occurs.

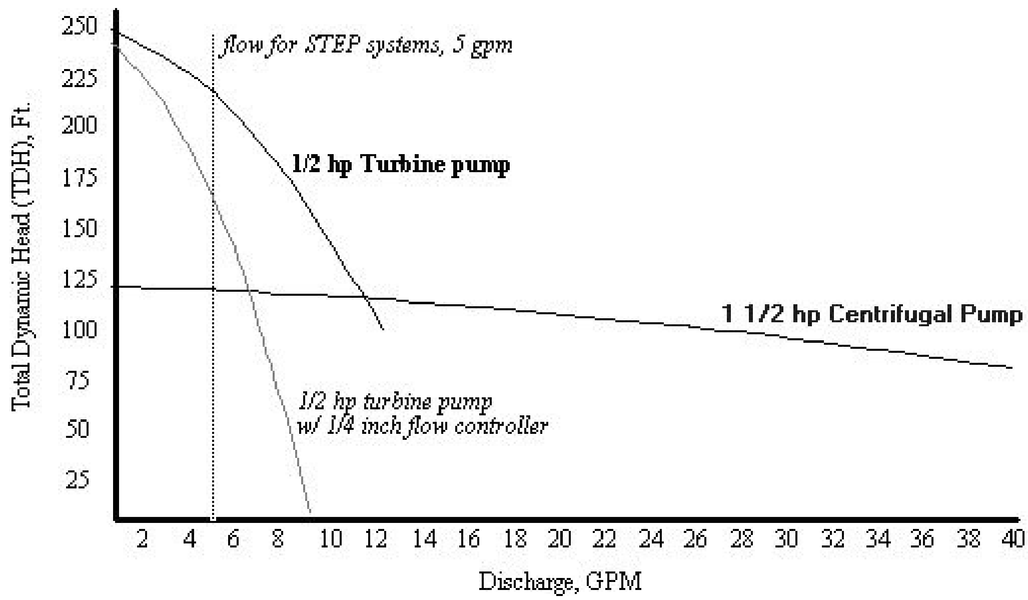

Figure 3-14 Typical pump conditions (Courtesy of Orenco, Inc.)

Pump selections can be made after the energy gradient for the collection system has been established. The selection is made by determining the total dynamic pumping head (TDH) in feet of pressure. The friction losses in the discharge assembly (h_{hv}) and service line (h_l) are computed based on the pump discharge rate, and then added to the pressure head in the main (h_p) and the static head (h_e) based on the elevation of the water level in the septic tank (or pumping chamber if separate).

b) Controls

A fiberglass-enclosed panel is typically provided to control the pump(s). Panels should be NEMA, UL or CSA listed, be provided with current limiting circuit breakers with thermal magnetic tripping characteristics, HOA (hand, off, automatic) switch, audible and visual alarm, silence relay, and fused alarm circuit separate from the pump circuit.

Panels should be located in an area that is not objectionable.

(1) Simplex / Duplex

In residential applications serving a single family, simplex pump stations are most common. Due to the reserve capacity present in septic tanks, redundancy is not needed.

If a duplex station is installed, alternation between the two pumps is recommended.

(2) RTM's/Event Counters

Run time meters and event counters are considered optional for residential applications with simplex pump units. In contrast, they should be provided with all duplex stations.

Though optional, many design engineers and utilities recommend the installation of RTMs and event counters, because they can aid in troubleshooting the collection system. For example, in the case where higher flows are observed in the pressure sewer than anticipated, the RTMs at each residence can be used to identify pumps with excessive run times. Excessive run times (compared to the average runtimes in the system) can be due to differing head conditions, but are often due to leaking septic tanks or cross connections that allow significant amounts of clearwater to the collection system.

(3) Alarms

The control/alarm panel should be located on the side of the house at a height that is convenient and accessible for maintenance. It should be close to and in sight of the pump and out of the direct sun and rain. At lease one alarm must be provided on the house control panel that is audible and also has a visual (light) alarm indication. Some installations incorporate a remote signal in the house that is fed from the outside alarm.

All installations must be supplied with a high water alarm. A high liquid level in the tank activates an alarm light and a buzzer, which may be silenced by pressing the illuminated PUSH TO SILENCE button on the top of the control panel. The alarm light stays on until the high level condition is corrected and then the alarm circuit automatically resets.

When an alarm occurs, the user calls the phone number on the panel cover. An operator should be on-call 24 hours in order to respond to line breaks or treatment plant problems that require immediate attention; on-site problems, however, can usually be responded to during convenient work hours, usually within 24 hours of the call.

"Smart panels" now available sound alarms when the water level is too low (leaking tank) and when too much water is passing through the system (stuck toilet valve). They can also dose at predetermined times, regardless of varying inflows, in order to reduce the collection system's hydraulic gradient.

3. Electrical Requirements

Effluent pumps used in STEP systems are typically either 115 Volt or 230 Volt, single phase. When the panels are wired, it is common to provide 230 Volt power to the panel with a neutral. Although this is more costly, it allows pumps of either voltage to be run from the panel.

Junction boxes are provided to connect the control panel wiring to the pump and float switch wiring. In commercial STEP packages, the junction box is usually included in the riser for the pump vault. Junction boxes must remain watertight so that the electrical connections inside them are not damaged by corrosion.

Power is usually obtained from an available circuit in the user's existing circuit breaker. If the STEP system is a retrofit installation, modifications to the homeowner's electrical system are sometimes needed before the system can be operated. This situation can lead to unexpected costs, especially in older residences that may not comply with current electrical standards.

F. Collection System Operation and Maintenance Information

1. Operational Concerns

a) Testing

It is important to adhere rigorously to all hydrostatic testing procedures and requirements. Mains should be tested at or near the working stress rating for the pipe materials. Allowable AWWA leakages should be the maximum, not to be exceeded. Zero leakage should be the goal.

b) Freezing

During extended periods of cold weather, exposed portions of the STEP collection system may be subject to freeze damage. Underground components are normally buried below the frost line. In extremely cold climates where frost depth is great, underground components may be protected by insulation or heating tape. Risers should be backfilled with pea gravel to prevent frost heave from separating the riser from the tank. Bridge crossings and air release valve locations are especially susceptible to freezing. Continuous water movement inhibits the freezing process, so as long as the system maintains even a slight flow, mainlines shouldn't freeze. If for any reason, however, the system must be shut down during freezing conditions, all bridge crossings should be drained and all air release valve assemblies should be protected with appropriate insulation.

c) *Odors and Corrosion*

The odor typically associated with domestic wastewater processes is the rotten egg aroma of hydrogen sulfide (H_2S). While such odors can originate from many sources, not always sewer related, the natural inclination of the public is to blame them on the public sewerage system. Responding to odor complaints, nevertheless, is a maintenance responsibility.

Odors originating from a sewage spill or pipe break are usually easy to trace. A leaking manual air release valve (MARV), or a very active automatic air release valve (AARV), is a likely place for odors to originate because of the expelling of air and sewer gases. Soil absorption beds or carbon filters are useful to prevent complaints in these cases.

Sulfate ($SO4^{2-}$) is naturally present in most raw water sources between 40 and 80 mg/L; although, depending on the water supply, it may vary from 5 to 500 mg/L. In an enclosed sewerage line it may only take 15 or 20 minutes for the microbial activity, relative to the strength of the waste streams biochemical oxygen demand (BOD), to completely deplete its dissolved oxygen (DO). As soon as the dissolved oxygen (DO) is depleted, the microorganisms (sulfur bacteria) begin stripping oxygen from the next available source, which is usually the dissolved sulfate, leaving sulfide ions (S^{2-}) free to form molecules of hydrogen sulfide (H_2S, HS^-). Microbes will also strip oxygen from nitrites (NO_2), nitrates (NO_3) and other sources, when available, and in preference to sulfate especially if less energy is required to break the molecular bond. Nitrate injection, in the form of sodium nitrate ($NaNO_3$), is a measure that is sometimes considered effective for reducing the amount of hydrogen sulfide a system generates. Hydrogen sulfide odors can be detected in concentrations as low as 0.00025 mg/L; however, the average threshold of annoyance is expected to about 0.04 mg/L.

A STEP forcemain should not discharge into a gravity sewer without provisions for addressing either the odor or corrosion problems. Many articles are presented annually in professional journals and other publications describing new and old methods of dealing with sulfide problems. Chemical addition (Bioxide, Thioguard, etc) and aeration methods are available to prevent hydrogen sulfide odor and corrosion issues. In the case where a STEP forcemain discharges into a conventional liftstation or treatment facility wetwell, the discharge should utilize a drop inlet, where the septic effluent discharge is made below the water surface. This reduces the amount of turbulence that leads to the liberation of hydrogen sulfide. Because the structure receiving the septic effluent is typically constructed of concrete, the application of a corrosion resistant coating is recommended. Commercial coating formulations are readily available that protect the concrete from attack by sulfuric acid.

d) Main Line Flush connections

Main line flush connections should be exercised at least annually. Occasionally, a leaking valve allows air and gas to collect at the flush connection, since it is a high point in the system. Periodic exercising allows this gas to be vented and prevents deterioration of system performance.

e) Extended Power Outages

Following a power outage, it is likely that nearly all pumps in the system will energize simultaneously. The hydraulics of the system will be such that some centrifugal pumps will discharge and others will not, since they will be operating at shutoff conditions. However, once the bulk of downstream pumps de-energize, upstream pumps will re-start (if necessary) and begin pumping.

If turbine effluent pumps are installed in the system, the hydraulics of the system will balance so that even the most remote pumps will still discharge 1 or 2 gpm into the collection system. The reserve storage in the tanks is normally about 150 gallons, which typically allows up to 24 hours of normal water usage. Power outages of 9 to 12 hours are infrequent and generally considered the worst condition to allow for; most disruptions last no longer than a couple of hours.

Turbine effluent pumps are constructed with a 1/8" diameter by-pass orifice in the discharge head that allows 3 gpm to circulate when the pump is operating near its shut-off head. These pumps are capable of operating at shut-off, continuously, for several days without damage to the motor or liquid end. In extreme conditions, where history has shown that long power outages are frequent, the most effective way to allow for extended power outage is to substitute 1,500-gallon tanks for the standard 1,000-gallon tanks.

f) Main Line Isolation Valves

Because inactive valves may not operate when needed, an exercising program should be established to open and close each valve once or twice annually. Difficult to operate valves should be exercised even more frequently. Because valves do occasionally stick, operators should be ready to respond to an emergency condition.

g) Air Relief Valves

Air release valves should be inspected annually or more frequently, depending on their performance. Manual air release valves should be bled off as often as necessary to keep large air pockets from developing. If maintenance of a manual valve becomes too expensive, an automatic one should replace it. To scrub odors, vent all automatic air release assemblies through soil beds or activated carbon filters. In grinder systems, which are more susceptible to grease buildup, air release valves require more frequent cleaning than is necessary in effluent sewers.

Monitoring air release valves requires routine visits to each location. All valves, automatic and manual, should be vented manually and the conditions reported using one of the five conditions tabulated below. Depending on the type of valve and elevation relative to the energy grade line, conditions (1) and (5) are ideal.

1. No air -- effluent only
2. Minor air --small bubbles
3. Continuous air -- large air pockets (1 min. or more)
4. Vacuum -- air drawn into the system
5. Passive -- no air, vacuum, or effluent

Condition 1, no air -- effluent only, is representative of those air release locations below static or energy grade lines (refer to as-built drawing for relative elevations) where no air or gas is accumulating or where the accumulation is being properly released by an AARV.

Condition 2, minor air, can usually be expected where an adequately monitored MARV is located.

Condition 3, continuous air -- large pockets of air, indicates excessive accumulation of gas or air. The problem may indicate (a) insufficient monitoring of a MARV, (b) the need to convert the location to an AARV, or, (c) if the station has an AARV, mechanical malfunction of the valve. An AARV should be bled by opening the blow-off valve beneath the AARV body. This process should be repeated for two additional days. If air continues to escape after several days of manual bleeding, the AARV should be replaced or repaired.

Condition 4, vacuum, indicates that siphoning is occurring. Locations that are subject to siphoning are those with elevations above the energy grade line (refer to as-built drawings). These are usually at the beginning of gravity sections, e.g. the top of standpipes, and should always be handled with AARVs. Condition 4 may be the result of an AARV with a plugged orifice or mechanical apparatus that is frozen shut. In either case, movement of air back into the system is restricted and repair or cleaning of the mechanism is required. If condition 4 is encountered at a MARV location, it indicates a drop in pressure and the need for a check of downstream hydraulic pressures.

Condition 5, passive, is typical of AARV locations that are above the static or energy grade lines and at which air is being properly expelled.

Back-flushing or cleaning of automatic air release valves should be scheduled according to each location's priority rating and usually should be performed at least once a year. Operators may find that certain locations require service more frequently than others.

2. Maintenance Concerns

a) Main Line Flushing

In the case of a STEP collection system, flushing of main lines is rarely needed, because the effluent is relatively free of solids. Rather than determine a flushing schedule solely based on the calendar year, it is recommended that the pressure in each branch of the system be monitored. Increased pressures in areas of the mains could be an indication of air entrainment or the need for flushing.

b) Pressure Monitoring

Pressure monitoring stations should be established and periodically monitored to check system performance, especially with regard to effects of air binding or siphoning, or to determine a system's operating capacity or the need for pigging. Several sites throughout the system, generally at strategically located air release assemblies, should be set up for pressure recording.

Annual review of the pressure monitoring reports and comparison of those results with design hydraulics will help establish if or when cleaning is necessary. Amperage draws from operating pumps may also be used to determine if head conditions have increased, indicating the presence of air or the need for flushing.

c) Record Keeping

Accurate record keeping is essential to the successful operation and maintenance of any small diameter, low-pressure sewer system. Records of pigging and flushing operations should be maintained in a central location where all responsible staff may access the information.

G. STEP System Operation and Maintenance Information

Routine operation and maintenance requirements for STEP systems are minimal. Small systems that serve 300 or fewer homes do not usually require a full-time staff (EPA, 2002). WEF Manual of Practice No. FD-12, "Alternative Collection Systems" contains a fairly extensive discussion of the operation and maintenance requirements of STEP systems.

To avoid abuse of a systems septic tanks that can lead to operation and maintenance concerns, cooperation of users is essential. Users of the system must be properly educated, and a list of Do's and Don'ts should be provided to patrons and updated regularly. Orenco Systems, Inc., a leading researcher and manufacturer of STEP system components, offers the following recommendations:

> "Users should be warned against disposing inappropriate solid-waste into the sewer. Tampons, cigarette butts, Handy Wipes, disposable diapers, prophylactics, rags, plastics, excessive grease, petroleum oils, cutting oils, coffee grounds, egg shells, kitty litter (clay), chemicals, water softener backwash, and any non-biodegradable substances should be disposed in trash containers at approved solid or hazardous waste sites. The best practice is not to discharge anything into a septic system that is poisonous or that may inhibit the digestive abilities of its working microbes. An excellent guideline is not to dispose anything into the tank, with the exception of toilet tissue and mild detergents, that hasn't first been ingested. A simple educational program tailored to encourage homeowners' compliance can cure most septic tank problems and reduce the need for premature septage pumping."

1. <u>General Preventative Maintenance</u>

Annual preventative maintenance suggested by Overton, as included in WEF Manual of Practice No. FD-12, "Alternative Collection Systems" recommends the following sequence for the annual inspection of STEP systems:

1. Remove pump, check intake, suction plate, and pump body for corrosion; cleat pump.
2. Exercise valves.
3. Return pump and test.
4. Test alarm system.
5. Check sludge and scum in septic tank.

2. Pumps and Pump Vault

There is very little preventative maintenance practical to accomplish at most pumping units (EPA, 1991). The pumps and ancillary components are not routinely removed from the pump vaults. Service calls generally involve responding to electrical control problems or pump blockages. Mean time between service calls (MTBSC) data vary greatly, but values of 4-10 years for both Grinder (LPS) and STEP units are reasonable estimates for quality installations (EPA, 2002).

Typical routine maintenance activities involve the demonstration of proper system function. Pumps should be actuated using the "Hand" function, and also checked for operation when the "Pump On" float is actuated. Voltage and amperage readings are recorded while the pump is operating, and checked against the full-load amperage draw of the pump. Initiation of audio and visual alarms is also checked by manually actuating the high-level alarm float switch.

The number of spare pumps on hand varies depending on the municipality operating the system. A typical standard, however, is that a quantity of 5% of the total number of pumps in the system be on-hand at any given time. Replacement requirements for pumps vary, but a typical life of an effluent turbine pump is 250,000 cycles.

3. Sludge Management

Disposal of collected septage from the septic tanks used in STEP systems is probably the most complex aspect of the operation and maintenance of a STEP system. It is recommended that the removal of septage be organized by local authorities and performed at regular intervals by qualified contractors. Due to the location of the septic tanks on private property, easement agreements are essential for an effective sludge management program (EPA 2000).

Most residential STEP systems make use of 1,000 gallon or 1,500 gallon septic tanks. The best method for removal of septage is to remove it when it begins to encroach on the clear space within the septic tank. Because the accumulation of sludge varies considerably between installations, a sludge removal schedule should be adopted for conservative purposes in conjunction with inspections.

Onsite design manuals may encourage frequent pump-outs as a precautionary measure when an inspection program is not in effect, however, longer intervals are usually justified, particularly if an effluent filtering device is in place. The pump-out interval must be within a range that is affordable and provides adequate long-term solids retention for ensuring thorough digestion. Intervals that are too short not only retard digestion, but force users to pay significantly more for service and pumping. The initial additional cost for a larger prefabricated tank is usually insignificant, especially when compared to the present worth value of long-term maintenance.

4. Security and Access

Security and access to on-site components of a STEP system should be for qualified maintenance personnel only. Typically, access to the risers over the septic tank and the pump vault is restricted by through the use of tamper-proof bolts or chains and padlocks. Control panels shall be padlocked.

5. Odors

A pump failure or a disconnected discharge hose may cause odors originating at on-lot facilities. Occasionally an odor's source may be the building sewer, which is generally considered the responsibility of the property owner. Intermittent odors may be elusive and difficult to isolate, requiring the property owner's cooperation in tracking down the source. Odors originating in the septic tank are typically vented through the roof vent connected to the building sewer. Improper venting can lead to localized residential odor problems, and in most cases, improper house venting has been a major contributor (EPA, 1991).

6. Septic Tank and Pump Vault Effluent Filters

Manufacturers recommend that the filters be cleaned once every two to three years, assuming the filters have significant surface area to prevent excessive cleaning frequencies. Manufacturer recommendations indicate that effluent filters are usually cleaned as part of the annual maintenance visit for the on-site components. Experience with effluent filters has shown that more frequent cleaning is often necessary.

7. Freezing

Freezing is not common for onsite components. If the components are located in areas expected to receive high traffic in the winter, which could allow frost to penetrate further than normal, insulation may be added.

Risers for tanks should be backfilled with pea gravel to prevent frost heave from separating the riser from the tank.

8. Alarm Conditions

The most common alarm is the “High Water Alarm”. In the case of an alarm, the users would typically go to the panel and silence the alarm. After silencing the alarm, the user would call the phone number on the panel cover, and maintenance crews would then respond.

9. Valve Exercising

Annual exercising of the valves in a STEP system is recommended.

H. Cost Estimates

Due to the extreme variably of local markets for labor and materials, it is not possible to estimate universally the cost of construction and operation of STEP systems. Cost differentials are significant across local geographies and economies. Therefore the reader of this manual is advised to consult local markets for specific data.

1. Capital Costs

A major determinant in the overall cost of a project is its size. The larger the project, the greater the benefit from economies of scale. Therefore the reader of this manual is advised to consult with knowledgeable individuals for specifics relating to costs of construction for a particular project.

a) Capital Cost Estimating Spreadsheet

The next page details a typical cost estimating spreadsheet for estimating overall capital costs for a STEP system. The spreadsheet identifies major components of the proposed construction and allocates units for each component. Upon completion of a standard design, actual units of installation may be inputted into the spreadsheet. Costs per unit must be obtained from local sources due to the aforementioned extreme variability in local markets.

Table 3-2
STEP System Capital Cost Estimating Sheet

Item	Quantity	Units	Unit Cost	Total Cost
Onsite Sanitary Sewer System Abandonment or Removal		EA		
Equipment (Use if Individual Components Specified)				
Septic Tanks		EA		
Effluent Filters		EA		
Pump Vaults (Internal or External)		LS		
Pumps		EA		
Spare Pumps		LS		
Control & Alarm Panels, Level Switches		EA		
Supplemental Electrical Cable (25-foot length)		EA		
Installation, Complete		LS		
Equipment (Use if Package STEP Units Provided)				
Septic Tanks		LS		
Simplex STEP Pumpstations, Complete		LS		
Duplex STEP Pumpstations, Complete		LS		
Supplemental Electrical Cable (25-foot length)		LS		
Installation		LS		
4" PVC Building Sewer		LF		
1-1/4" Service Laterals		LF		
2" Main		LF		
3" Main		LF		
4" Main		LF		
5" Main		LF		
1-1/2" Curb Stop and Box, Check valves, Isolation Valves		EA		
Imported Granular Backfill		CY		
Valve/Tee Manhole		EA		
Single Flush Connection, Complete		EA		
Dual Flush Connection, Complete		EA		
Manual Air Release Station, Complete		EA		
Automatic Air Release Station, Complete		EA		
Pressure Sustaining Station, Complete		LS		
Flow Meters, Complete		EA		
Pressure Monitoring Station, Complete		EA		
Surface Restoration		LS		
Erosion Control		LS		
Traffic Control		LS		
Electrical (10%)		LS		
Mob./Demob., Bonding/Ins. (7%)		LS		
Subtotal				
Capital Contingencies (25%)				
Subtotal				
Engineering (20%)				
Legal and Administrative (5%)				
Total Estimated Capital Cost				

Table 3-3
STEP System O&M Costs

Operation and Maintenance Costs	Qty	Units	Unit Cost	Annual Cost
Sludge Removal		tanks		
Pump Replacement		pump		
Equipment Maintenance, Repair, and Replacement				
Labor		hours/yr		
Electric Power		kWh		
Annual O & M Cost				

2. Annualized Costs

a) *Operations and Maintenance Cost Estimating Spreadsheet*

A spreadsheet showing the major operations and maintenance cost line items and unit costs that could be anticipated is shown in Table 3-3.

b) *Significant Assumptions*

(1) Sludge Removal

Sludge removal should be assumed, with an annual amount built into the budget.

(2) Pump Replacement

Replacement costs for pumps varies depending on the type of effluent pumps installed in the system and the quantity purchased. Equipment manufacturers of the specified pumping equipment should be contacted during the formulation of the cost estimate for current prices.

(3) Power

Power costs will vary across the state, but a rate of $0.10 per kWh should be used to estimate annual power costs for the all pumps. Power cost for the pumps can be calculated by multiplying the total number of pumps times the average running time, and converting horsepower into kilowatts as per the following formula:

Annual Power Cost =
(Np)(T%)(24 hours)(HP)(0.75)($0.10)(365)

Where:
Np = Number of pumps
T% = Percent daily run time
HP = Horsepower of each pump

If horsepower of pumps installed in the collection system varies, the calculation must be repeated for each horsepower present in the system.

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(4) Equipment Maintenance and Replacement

An annual set-aside for equipment replacement should be built into the budget. The amount set aside should be based on the original cost of the equipment, and prorated out over the expected design life of the equipment.

(5) Labor

The estimated cost for labor should be based on the total compensation for the operating staff, including any benefits, plus any administrative salaries for meetings, billing, etc. The estimated hours needed should include the provision for periodic maintenance such as mainline flushing, pressure monitoring, routine inspections of collection system and on-site components, and service calls.

IV. SEPTIC TANK EFFLUENT GRAVITY

Septic tank effluent gravity (STEG) systems are an economical method of collecting and transporting partially treated wastewater to a treatment facility. The systems consist of two basic elements: a watertight septic (septic) tank and a network of plastic piping leading to a treatment site. The septic tank, often a conventional septic tank, provides pretreatment, removing most settleable and floatable solids from the wastewater. Wastewater flows by gravity through the network of small diameter plastic piping to a treatment site. Shallow collection lines at minimum grade follow the contours of the ground surface. However, inflective (flowing "uphill") gradients are not permitted, so excavations may be deeper if the collection lines are installed through a hill and dale.

Approximately 250 STEG systems have been financed in the United States by the EPA Construction Grants Program. Many more have been financed with private or local funding. These systems were introduced in the United States in the mid-1970s, but have been used in Australia since the 1960s. Examples of Iowa communities operating collection systems served entirely or in part by STEG systems include, but are not limited to: Harvey, Greenville, St. Mary's, Portsmouth, and Westchester.

This section discusses the application of small diameter effluent gravity sewers. Occasionally, STEP units are required if the hydraulic gradient of the collector main exceeds the gravity flow potential of an individual connection.

A. Description of System Components

1. <u>Collector Mains</u>

Collection system layout for STEG collection systems is similar to conventional gravity sewers, using a branched layout. However, pipe diameters are smaller, and self-cleaning velocities are not required. The collector mains convey the septic tank effluent to the central treatment facility. The mains are most commonly constructed of 4-inch PVC pipe (SDR 35 or SDR 21) or larger. Gasketed joints are utilized for joining pipe sections.

2. <u>Manholes and Cleanouts</u>

Hydraulic flushing is usually adequate to keep the mains free of debris, since the septic tank effluent that is being conveyed is relatively free of gross solids. Cleanouts are commonly used, and to a lesser extent manholes, to provide access to the collector main. Similar to STEP systems, cleanouts are constructed and recommended. Typical cleanout locations are upstream of where the collector main increases in diameter, on the terminal end of the main, every 400 – 1,000 feet on long pipe runs, and at minor junctions within the main. Cleanouts are favored over manholes, which should be used sparingly, because they can be a significant source of infiltration, inflow, and sediment (EPA, 1991).

3. Vents

Vents are needed to maintain free flow within the system. Due to the continuously negative gradients considered in this design manual, all collector mains should vent through the individual house connections as long as the service lateral is not trapped.

4. Service Lines

The service line conveys the effluent from the septic tank to the collector main by gravity. Typically, the service lines are constructed of PVC and are the same size as the collector main. Ductile iron pipe is not permitted. Service lines that have invert elevations that are close to the hydraulic grade line in the collector main are often supplied with a check valve to prevent backflow.

5. Septic Tanks

In Septic Tank Effluent Gravity (STEG) systems, wastewater flows into a watertight septic tank to capture solids. The septic tank provides the primary treatment of the wastewater in the system. It holds the wastewater long enough to allow solids to settle out (forming sludge) and oil and grease to float to the surface (as scum). The tank also provides flow attenuation due to the large reserve volume. Septic tank effluent filters are required on STEG septic tanks.

6. Surge Chambers

Surge chambers are installed downstream of septic tanks in systems that are expected to exhibit high peak-to-average flow ratios (such as a commercial installation) or if a section of the service area is being pumped to a gravity collection line from a lift station. They have also been installed as retrofit applications for systems with high peaking factors. Surge chambers equalize the flow and occasionally incorporate flow-modulating orifices. Typical residential STEG collection systems do not incorporate surge chambers in their operation.

7. STEP Units and Lift stations

STEP units are installed in the STEG collection system when individual residential connections are lower in elevation than the collector main. STEP stations have also been used in the collector main in the same fashion as a conventional lift station, lifting the effluent to a higher elevation and allowing the re-establishment of gravity flow at the new elevation. When used as a collector main lift station, corrosion by H_2S can be a problem. As a result, a wet well/dry well arrangement is often used to isolate the corrosive wastewater from the pumping components, allowing easier access and reducing overall corrosion problems.

B. Materials of Construction

Structurally sound and watertight tanks are an absolute necessity in small diameter effluent gravity sewer applications. The installation of inferior tanks has resulted in severe leakage or groundwater infiltration, deformation of the tank, and collapse. Excessive flows caused by infiltration and inflow have resulted in failed sewer applications. Poor quality tanks that collapse or deform require costly removal and replacement.

Septic tanks are most commonly constructed of reinforced concrete, FRP, and PE. Reinforced concrete tanks should conform with the requirements of Chapter 69 of the Iowa Administrative Code. Due to the importance of watertight design in a pressure sewer application, the reuse of existing septic tanks from an on-site system is not recommended without a rigorous evaluation of each tank. Quality control of the tank manufacturing process is critical.

C. Design Guidance – STEG Collection Systems

1. Collection System Flow Considerations

Conventional gravity collection systems have historically been designed to maintain "self-cleaning velocities" of 2-3 ft/s at least once or twice per day. Self-cleaning velocities are velocities required to transport solid materials with the water to avoid buildup and clogging. STEG systems, however, are relatively free of solids and do not need to maintain the traditional self-cleaning velocity of 2-3 ft/s. Studies have shown that the remaining solids which enter the collector mains and any slime growths that develop within the sewer are easily carried when the flow velocity is 0.5 ft/s or higher. However, for design purposes, a minimum velocity of 1 ft/s shall be used (EPA, 1991).

Each segment of the gravity sewer shall be analyzed by Kutter's formula to determine if the pipe is of adequate size and slope to handle the peak design flow.

All pipes for gravity systems must carry the design flow at a depth of no more than 0.50 of the pipe diameter. All sewers shall be designed and constructed to give average velocities when flowing full of not less than 1.0 ft/s based on Kutter's formula using an "n" value of 0.013.

Kutter's: $$V = C_K \sqrt{RS}$$

Where,

V = velocity, ft/s
C_K = Chezy's roughness coefficient, where:

$$C_K = \frac{k_1 + \frac{k_2}{S} + \frac{k_3}{n}}{1 + \frac{n}{\sqrt{R}} * \left(k_1 + \frac{k_2}{S} \right)}$$

R = hydraulic radius (for pressure pipes, R = D/4)
S = slope of energy grade line
n = Kutter's flow coefficient, Requirement: 0.013

The Iowa Department of Natural resources requires a Kutter's n value of 0.013 for all plastic piping used in alternative collection systems.

Design depths of flow allowed in the sewer mains have either been half full or full. Most older systems designed with uniform gradients have used half-full conditions to dictate changes in pipe size. When flow exceeds half-full, the next larger pipe size is selected (EPA, 1991).

2. <u>Collector Mains</u>

a) <u>Configuration and Layout</u>

STEG effluent sewer systems are typically configured in a branched arrangement similar to conventional gravity systems.

The gradient of mains must be sufficient to provide enough slope that peak flows are conveyed. However, a constant gradient is not necessary, so the gradients can follow the ground surface gradient if inflective gradients are avoided and a minimum velocity of 1 ft/s is maintained.

b) <u>Pipe Location</u>

Typically, the sewers are not located under roadways. The preferred location of mains is adjacent to the roadway (often in the ditch right of way), running roughly parallel so that the location of the plastic pipes can be easily anticipated. Placement of a toning cable or metalized marker tape with the main aids in future location.

Some municipalities, however, prefer to locate mains underneath the roadway, to protect them from damage caused by future excavation. This is not recommended, however, unless the ditch or right of way area is subject to significant erosion or is otherwise problematic for installation, such as shallow bedrock.

Occasionally, mains are constructed on both sides of the street to avoid pavement crossings, though directional boring underneath the road is more common if pavement restoration is to be avoided. Because existing homes typically have septic systems in the back yard, collector mains have been located along the back property lines to avoid re-routing building sewers, and take advantage of collecting wastewater from an entire block with one collector. However, this limits future access to the collector main and should be evaluated carefully.

Installation depth of the collector mains is determined by the elevation of the septic tank outlet invert elevations, frost depth, or trench loading. Pipes must be buried to at least the winter frost penetration depth, to avoid freezing.

In areas where high bedrock is present, insulated and heat-traced pipes are generally buried near the surface at a minimal depth.

c) <u>Sizing Recommendations</u>

The diameter of STEG collection system piping must be determined through hydraulic analysis. Piping size will vary according to the number of connections. Pipes used in gravity collection systems shall have a minimum diameter of 4-inches.

d) <u>Pipe Materials</u>

(1) PVC

SDR 35 is most common for effluent gravity sewer applications. SDR 26 may be specified for road crossings or where water lines are within 10-ft.

If the system contains multiple STEP units, only SDR 26 or 21 should be used for the affected segment of collector mains because of pressurizing requirements and the compatibility of pipe fittings (EPA, 1991).

(2) HDPE

Though PVC is the most widely used type of pipe, HDPE has been successfully used. Fused-joint HDPE has the advantage of minimizing the number of joints, and it has been selected for visual identification in contrast to PVC water mains. HDPE has also been used for lake and stream crossings.

e) Manholes and Clean-Outs

Pipeline cleaning can be accomplished by hydraulic flushing.

Cleanouts should be located at strategic points in the collection lines. Cleanouts are typically located at the ends of collector mains, where the diameter of the main changes, at major changes in direction, minor junctions, and approximately every 400 to 1000 feet along straight runs (EPA, 1991).

If manholes are used, their use is generally restricted to only major junctions. The interiors of manholes should be coated with epoxy or other chemical resistant coating to prevent corrosion of the concrete, and have gas-tight covers. Manhole construction should be such that infiltration and inflow potential are minimized.

Typical details for cleanouts used in STEG systems are included in Figures 4-1 and 4-2.

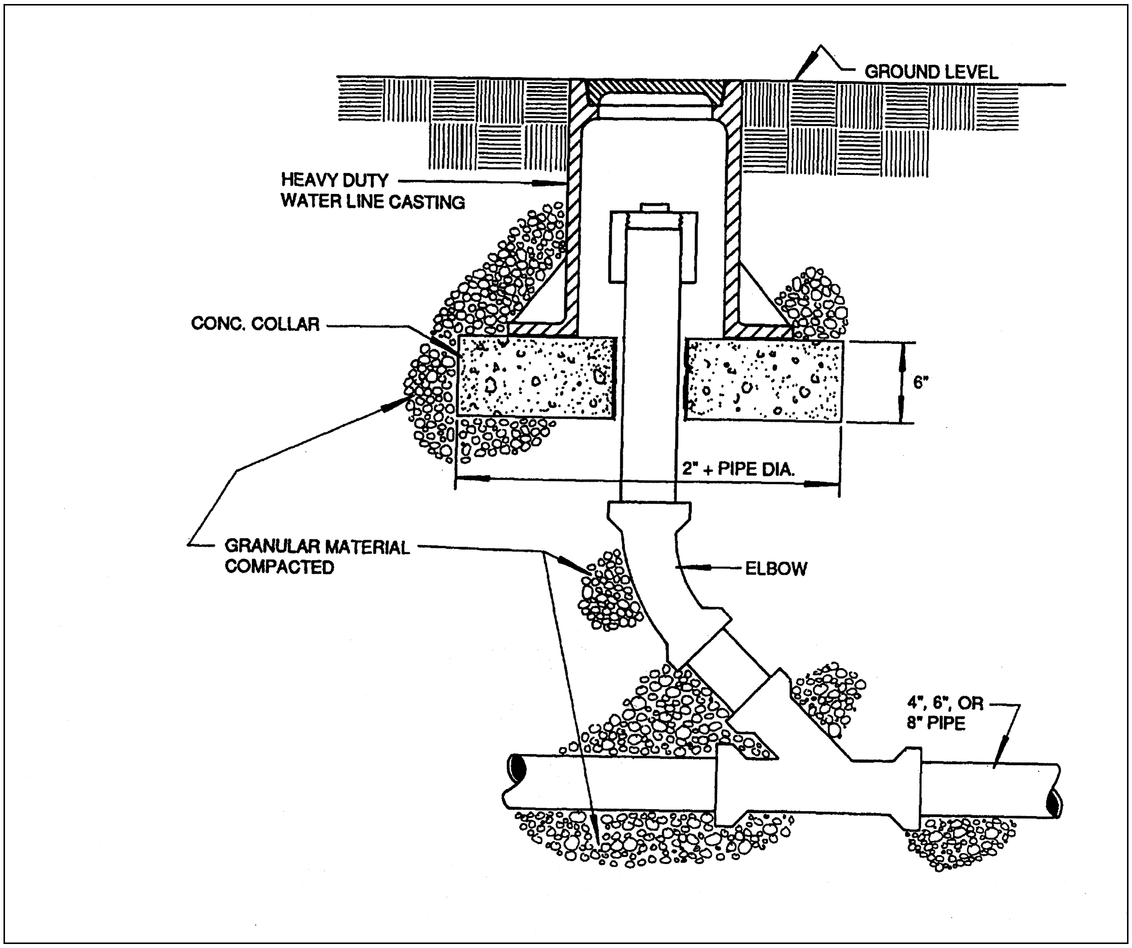

Figure 4-1 Typical STEG cleanout detail (EPA, 1991)

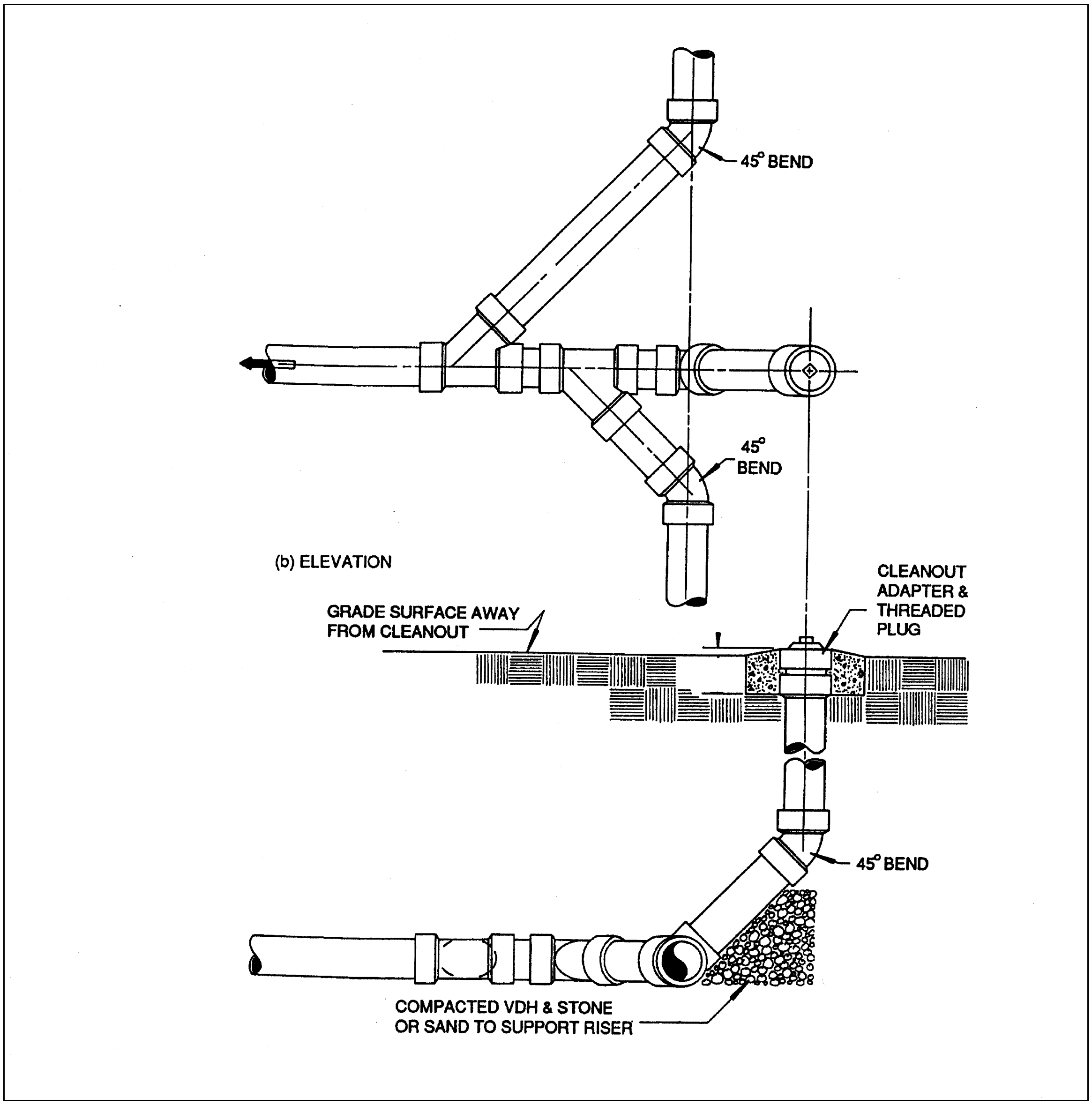

Figure 4-2 Typical STEG cleanout detail (EPA, 1991)

3. STEG Service Lines

a) *Location*

Service lines for STEG systems are commonly located near and parallel to property lines. Depending on the preference of the municipality or local authority, service lines may be located under paved areas to decrease the probability of future damage by excavation.

Effluent sewer service lines should be isolated from the potable water lines to reduce the possibility of cross contamination. They should also be distant from other buried utilities if possible, due to the possibility of damage caused by the subsequent excavations for maintenance or repair of those utilities.

Service lines must be buried to at least the winter frost penetration depth, to avoid freezing. The use of continuous tracer tape or wire is recommended to aid in future pipe location.

b) Sizing

Service lines for STEG systems are shall be a minimum of 4-inches in diameter, and shall not exceed the diameter of the collector main to which it is connected.

c) Pipe Materials

SDR-35 PVC pipe is commonly used for service lines. Ductile iron shall not be used.

d) Connection to the Main

Service lines are usually connected to the forcemain using a tee or wye.

D. Design Guidance

1. Septic Tanks

A discussion of septic tank configuration, location, sizing, and design is included in Appendix A. The discussion included therein is applicable to the septic tanks used for gravity flow effluent sewers. Septic tank effluent filters are required on STEG septic tanks.

E. Collection System Operation and Maintenance Information

Operation and maintenance for STEG systems will be essentially identical to the non-electrical O&M requirements of STEP systems. Refer to Sections 3.F. and 3.G. for operation and maintenance of STEG systems.

F. Cost Estimates

Due to the extreme variably of local markets for labor and materials, it is not possible to estimate universally the cost of construction and operation of STEG systems. Cost differentials are significant across local geographies and economies. Therefore the reader of this manual is advised to consult local markets for specific data.

1. Capital Costs

A major determinant in the overall cost of a project is its size. The larger the project, the greater the benefit from economies of scale. Therefore the reader of this manual is advised to consult with knowledgeable individuals for specifics relating to costs of construction for a particular project.

a) *Capital Cost Estimating Spreadsheet*

The next page details a typical cost estimating spreadsheet for estimating overall capital costs for a STEG system. The spreadsheet identifies major components of the proposed construction and allocates units for each component. Upon completion of a standard design, actual units of installation may be inputted into the spreadsheet. Costs per unit must be obtained from local sources due to the aforementioned extreme variability in local markets.

Table 4-1
STEG System Capital Cost Estimating Sheet

Item	Quantity	Units	Unit Cost	Total Cost
Onsite Sanitary Sewer System Abandonment or Removal		EA		
Equipment (Use if STEP Stations Present, Individual Components Specified)				
Septic Tanks		EA		
Effluent Filters		EA		
Pump Vaults (Internal or External)		LS		
Pumps and Spare Pumps		LS		
Control & Alarm Panels, Level Switches		LS		
Supplemental Electrical Cable (25-foot length)		LS		
Installation, Complete		LS		
Equipment (Use if STEP Stations Present, Package Stations Specified)				
Septic Tanks		EA		
Simplex STEP Pumpstations, Complete		LS		
Duplex STEP Pumpstations, Complete		LS		
Supplemental Electrical Cable (25-foot length)		EA		
Installation		LS		
Equipment (STEG Units)				
Septic Tanks		EA		
Effluent Filters		EA		
Installation, Complete		LS		
4" PVC Building Sewer		LF		
1-1/4" Service Laterals		LF		
1-1/2" Curb Stop and Box, Check valves, Isolation Valves		EA		
4" Service Laterals		LF		
4" Main		LF		
6" Main		LF		
8" Main		LF		
10" Main		LF		
4" Tees, Check valves		EA		
Imported Granular Backfill		CY		
Valve/Tee Manhole		EA		
Single Flush Connection, Complete		EA		
Dual Flush Connection, Complete		EA		
Manual Air Release Station, Complete		EA		
Surface Restoration		LS		
Erosion Control		LS		
Traffic Control		LS		
Electrical (10%)		LS		
Mob./Demob., Bonding/Ins. (7%)		LS		
Subtotal				
Capital Contingencies (25%)				
Subtotal				
Engineering (20%)				
Legal and Administrative (5%)				
Total Estimated Capital Cost				

Table 4-2
STEG System O&M Costs

Operation and Maintenance Costs	Qty	Units	Unit Cost	Annual Cost
Sludge Removal		tanks		
Pump Replacement		pump		
Equipment Maintenance, Repair, and Replacement				
Labor		hours/yr		
Electric Power		kWh		
Annual O & M Cost				

2. Annualized Costs

a) Operations and Maintenance Cost Estimating Spreadsheet

A spreadsheet showing the major operations and maintenance cost line items and unit costs that could be anticipated is shown in Table 4-2. The spreadsheet has been developed to account for the potential presence of STEP units within the STEG collection system.

b) Significant Assumption

(1) Sludge Removal

Sludge removal should be assumed, with an annual amount built into the budget

(2) Equipment Maintenance and Replacement

An annual set-aside for equipment replacement should be built into the budget. The amount set aside should be based on the original cost of the equipment, and prorated out over the expected design life of the equipment.

(3) Labor

The estimated cost for labor should be based on the total compensation for the operating staff, including any benefits, plus any administrative salaries for meetings, billing, etc. The estimated hours needed should include the provision for periodic maintenance such as mainline flushing, pressure monitoring, routine inspections of collection system and on-site components, and service calls.

V. LOW PRESSURE SYSTEMS

Low Pressure Sewer (LPS) systems have been installed as the primary collection system in numerous communities across the United States. Examples of Iowa communities operating collection systems served entirely or in part by LPS systems include, but are not limited to: Diamond Head/Lake Dexter, Maxburg, Rock Falls and the Rural water districts of SIRWA and Xenia. The City of Mystic also used a combination of STEP and LPS stations to discharge to a gravity collection system. Typically, communities choose alternative systems over conventional systems based on lower costs and better suitability to local soil conditions.

This section discusses the application of small diameter pressure sewers using grinder pumps. In an LPS system, sewage flows to a vault where a grinder pump grinds the solids into smaller particles and discharges the sewage into a pressurized pipe system. LPS systems do not require a septic tank but usually require more horsepower than STEP systems because of the grinding action. The situation where the effluent from grinder stations is discharged under pressure to a gravity portion of a collection system is also discussed in this section.

A. Collection System Overview

Collection system layout is similar for all pressure sewer systems (STEP and LPS). Figure 5-1 provides a typical layout of the plan and profile views of a LPS collection system, where treatment of the wastewater occurs at a central treatment facility.

1. <u>Isolation Valves</u>

Isolation Valves (IVs) are placed throughout the system. Isolation valves are placed upstream of where two mains intersect and at the terminal end of the system to facilitate the future extension of the main. They are also needed at railroad crossings, bridge crossings, waterway crossings, both sides of areas of unstable soil, and long force-main lengths.

2. <u>Flush Connections</u>

Flush connections (sometimes called clean outs) are required. Flush connections are occasionally needed because the wastewater within the piping contains solids that may build up over time if scouring velocities are not present. The purpose of installing flush connections is to provide an access point for injecting high-pressure water to clean the system, or to provide an access point for launching a pipe cleaning pig. Typical locations are upstream of where the forcemain increases in diameter and on the terminal end of the main. Pigging may also be needed to remove debris that entered the collection system during initial construction or connection of new grinder stations.

3. Automatic Air Release Valves

Automatic air release valves (AARVs) are needed at all highpoints within system if the discharge location (central treatment facility) is located at an elevation higher than the remainder of the system. As practiced in water main installations, installation of AARVs at highpoints prevents the entrapment of air in the system, which ultimately reduces capacity of the system. Frequently, grinder pump effluent has been in the force main for extended periods of time, resulting in anaerobic conditions.

In accordance with the current Iowa Wastewater Design Standards, air release valves are required at all high points in the force main to relieve air locking.

Like STEP systems, grinder pump effluent can be assumed to be anaerobic and potentially odorous if subjected to turbulence, where gases such as H_2S are generated (EPA, 2002). As a result, the off gas from release valves is frequently odorous and can be a nuisance if the valves are located in near residential areas. For this reason, air release valves are often vented through carbon or soil filters.

4. Service Line Connections

Connections to the service lines from individual homes are made using service saddles, tees, or tapped couplings. The method of connection is often dependent on the timing of installation of homes compared to installation of the pressure main. Regardless of timing, a means of isolation and redundant backflow prevention is required at all service lines. Location of isolation valves varies, but are frequently placed in paved areas with appropriate valve boxes to prevent damage by snow plowing or lawn mowing.

5. Flow Metering

Flow meters (often Doppler or transit time acoustic meters) installed on individual branches can provide valuable information pertaining to per capita wastewater generation, infiltration and inflow, and system capacity. Smaller systems of the type considered in this design manual often elect to avoid the cost of permanent structures in favor of using portable meters. Permanent meters (typically magnetic flow meters) may be installed for systems requiring flow measurement for sewage billing purposes.

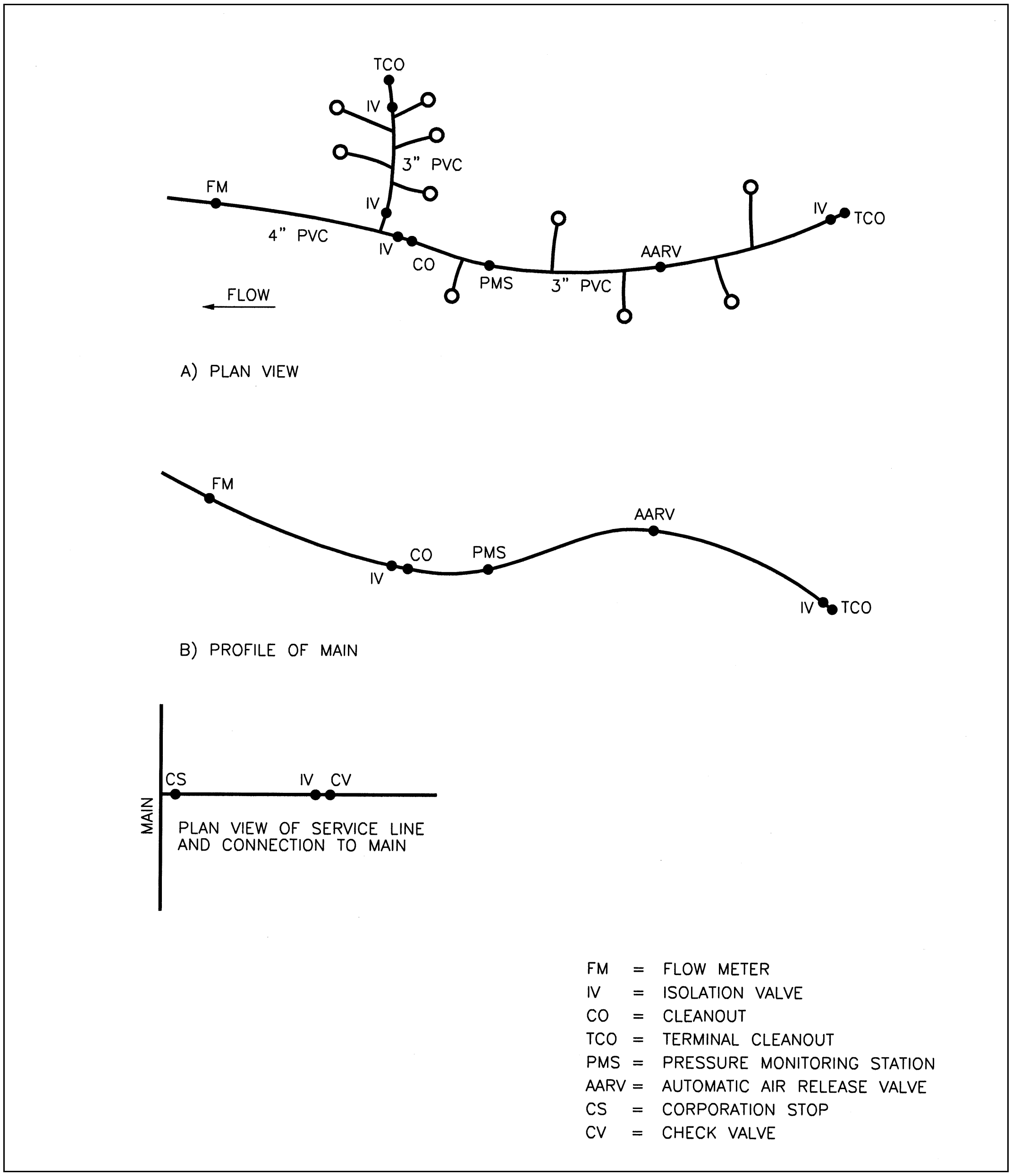

Figure 5-1 Collection System Appurtenances (EPA, 1991).

6. <u>Pressure Monitoring Stations</u>

Pressure monitoring stations (PMSs) are recommended in LPS systems due to the required practice of providing a check valves on the service line. Pressure monitoring stations consist of an access vault to the collection piping that includes a threaded tap and pressure gauge for reading system pressure. PMS's are beneficial for the characterization of operating conditions within the pressure sewer and identifying areas where air-induced headloss may be occurring.

B. Description of System Components

In LPS systems, wastewater flows into a vault containing a grinder pump. The grinder pump grinds the solids contained in the wastewater as it pumps the sewage to the collection system. Some degree of user cooperation should be encouraged to prevent the discharge of troublesome solids (hard solids, plastics, rags, sanitary napkins, and stringy material) to the pumping unit. Once these materials enter the pump vault however, grinder pumps have been capable of routinely handling small plastics, wood, rubber, and light metal objects without jamming the grinder or clogging the pump or piping system.

The pump vault of a grinder station does not provide primary treatment (settling) of the raw sewage. In addition, fats, oils, and grease are not retained in the vault, but are ground with organic material and conveyed to the central treatment facility.

Preassembled LPS packages are available through various pump manufacturers. Included with the packages are the necessary components for a complete system, such as pump, pump vault, pump vault piping and valves, level floats or switches, control panel, junction box, and associated equipment. Typically, grinder vaults are constructed of HDPE or FRP. The use of a preassembled system is sometimes considered to be advantageous to the design engineer, manufacturer, and system end user, because the manufacturer has refined the pump packages based on previous experience. This not only allows for a simplified approach to the design of on-site components, but also facilitates a single source of responsibility for the on-site components. Though simplified, however, it is of paramount importance that the application engineer works closely with the potential suppliers of the grinder units during the design of the system to ensure that the system components will meet or exceed all system requirements.

Providing packaged LPS components may result in concerns that competitive pricing will be negatively impacted. For this reason, individual components of the LPS systems have been designed and specified by application engineers, which are then constructed by the owner or the contractor’s supplier. Cost savings may be realized under this approach, but extreme care should be used to avoid the provision of inferior ‘generic’ components. When this occurs, components often do not fit properly, pumps may not meet the system head and flow conditions used for the design of the system, or materials provided are not properly resistant to corrosion.

In some cases component LPS systems are designed and specified in an effort to produce a superior collection system that is custom made to suit the particular project. According to the EPA, this approach has had limited success. It has been successful only in projects where prototypes were fully developed, tested, and refined over a period of time, or where the design engineer had considerable experience with pressure sewer technology.

Figures 5-2 and 5-3 depict typical simplex grinder stations.

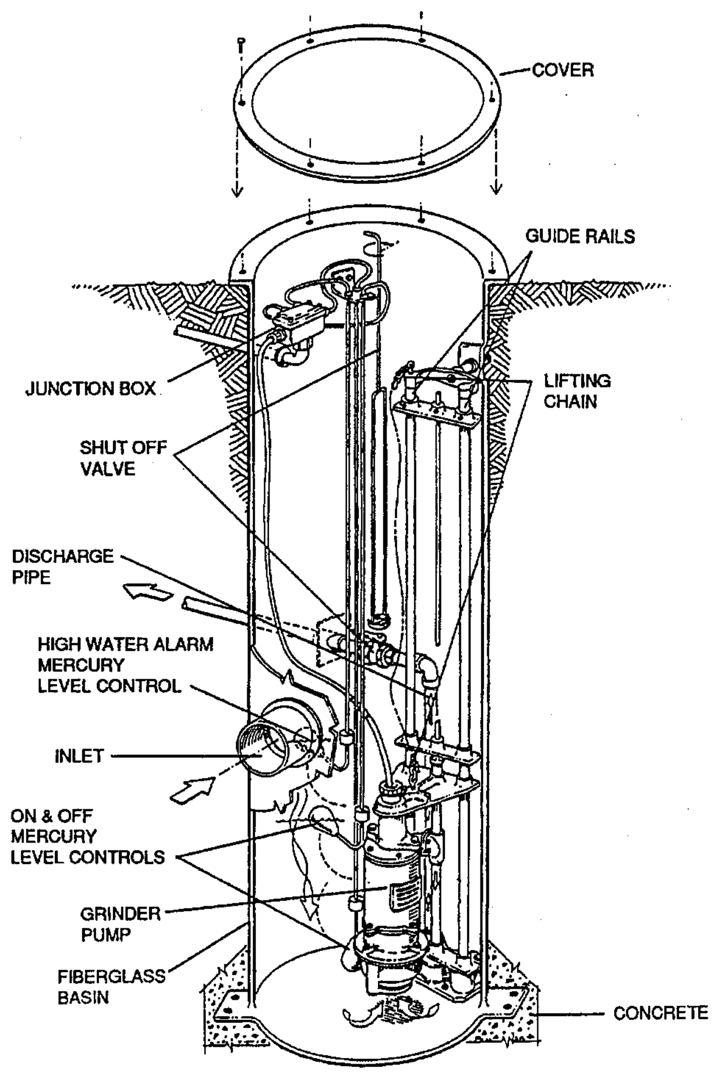

Figure 5-2 Typical Centrifugal Grinder Pump installation (Courtesy F.E. Myers/Pentair Water).

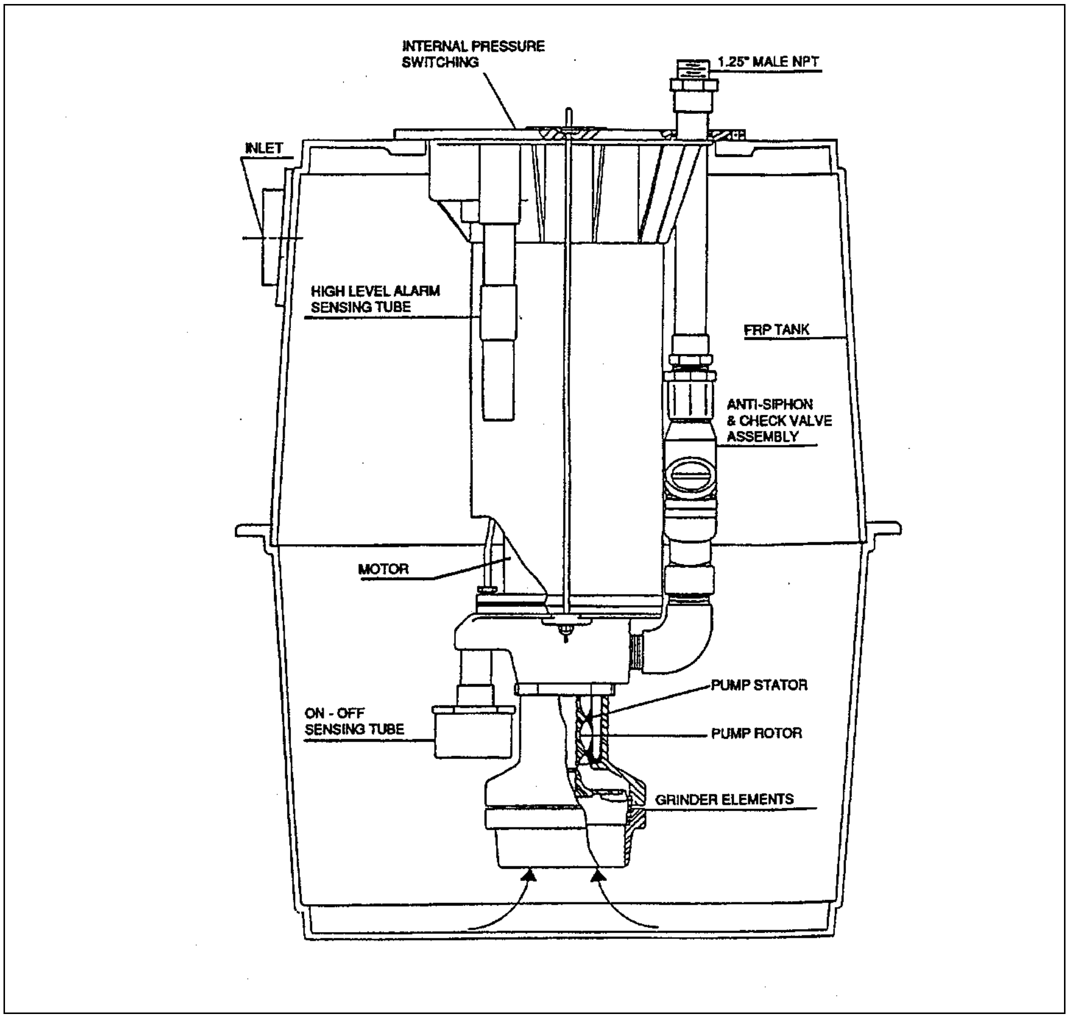

Figure 5-3 Typical Progressing Cavity Grinder Pump(Courtesy E/One).

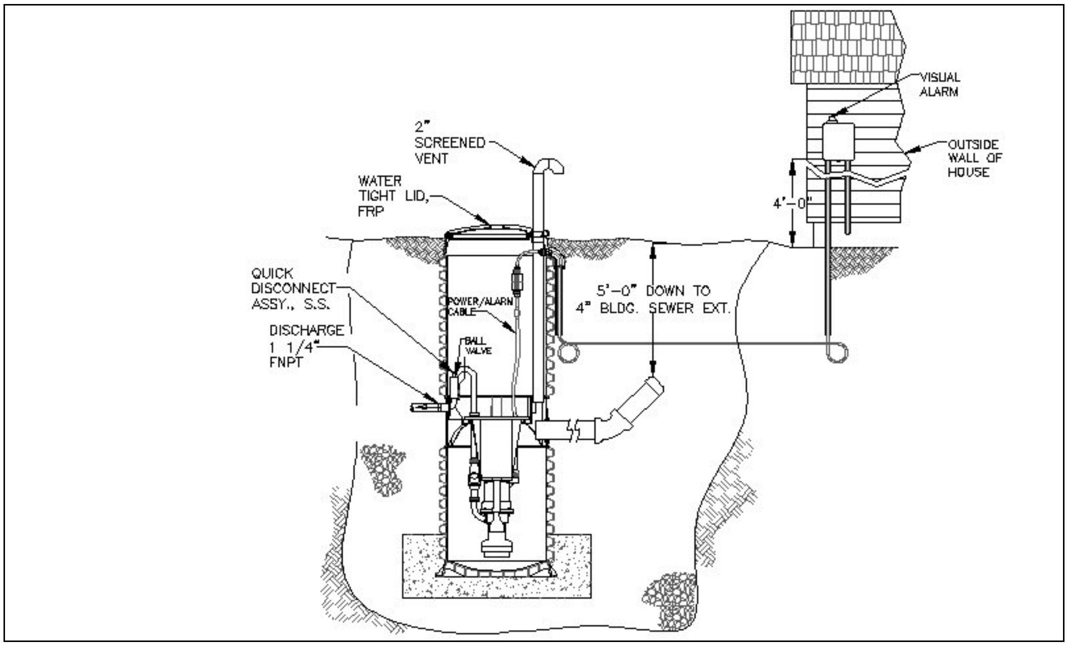

Figure 5-4 Typical Progressing Cavity Grinder Pump installation (Courtesy E/One).

As shown in Figures 5-2, 5-3, and 5-4, the grinder pump is suspended from the pump vault. Pumps may be removed using a lifting chain or guide rail system. The pump discharges to a small diameter pipe typically made of PVC, which then rises vertically until making a U-shape within the access riser. Quick connects may be provided and multiple check valves are required. An isolation (shutoff valve) accessible from the ground surface must also be provided. Pump Off, Pump On, and High Water Level switches are provided in the pump vault, with the level switch wires and pump power cable terminating in a junction box.

Pumping characteristics vary depending on the type of pump and the manufacturer. Progressive cavity pumps and centrifugal pumps have been commonly used in grinder applications. Progressive cavity pumps possess a relatively constant discharge rate at various head conditions. Figure 5-4 provides discharge versus head conditions for various pump designs.

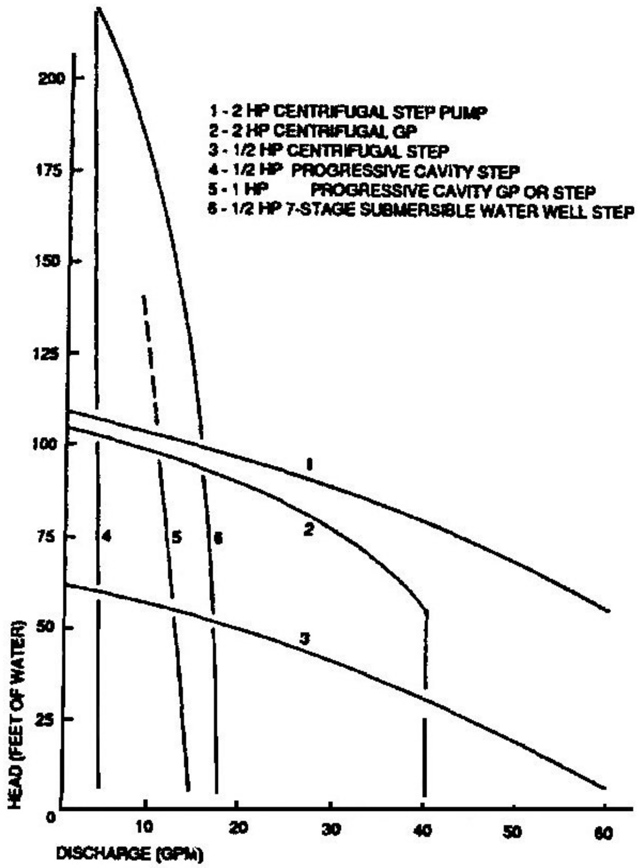

Figure 5-5 Typical discharge curves for pumps used in pressure sewer systems (EPA, 1991)

C. Materials of Construction

Structurally sound and watertight tanks are an absolute necessity in all pressure sewer applications. The installation of inferior tanks has resulted in severe leakage or groundwater infiltration, deformation of the tank, and collapse. Excessive flows caused by infiltration and inflow have resulted in failed pressure sewer applications. Poor quality tanks that collapse or deform require costly removal and replacement.

Grinder pump vaults are typically constructed from fiberglass reinforced polyester (FRP), high density polyethylene (HDPE), steel, or concrete. The typical thickness of FRP vaults provided by pump manufacturers is approximately ¼ inch. If HDPE vaults are used and intended to provide structural support, they must be thicker than FRP. The nominal thickness of HDPE grinder vaults is ½ inch.

Due to the corrosive atmosphere present in grinder pump vaults, all equipment, piping, and fasteners such as hose clamps must be suitably corrosion resistant. For metal components, austenitic stainless steel of Type 316 or type 304 is required. Type 416 or other martensitic stainless steels are not acceptable. For plastic components, PVC, ABS, and PE are recommended due to their resistance to corrosion by H_2S. Nylon is degraded by H_2S and is not acceptable.

In cases where a preassembled pumping package is provided from a manufacturer with considerable experience with pressure sewers, acceptable materials are nearly always provided. If component systems are constructed, the engineer must pay strict attention to material specification, selection, and provision.

D. Design Guidance – LPS Collection Systems

1. Collection System Flow Considerations

LPS collection systems must be designed to maintain "self-cleaning velocities" of 2-3 ft/s at least once or twice per day. Self-cleaning velocities are velocities required to transport solid materials with the water to avoid buildup and clogging.

The Hazen-Williams, Manning, or Kutter's Equation can be used for the calculation of headloss in pressure sewer applications.

Hazen-Willimams: $V = 1.318 C R^{0.63} S^{0.54}$

Manning: $V = \dfrac{1.486}{n} R^{2/3} S^{1/2}$

Kutter's: $V = C_K \sqrt{RS}$

Where,

V = velocity, ft/s
C = Hazen-Williams flow coefficient
C_K = Chezy's roughness coefficient, where:

$$C_K = \frac{k_1 + \frac{k_2}{S} + \frac{k_3}{n}}{1 + \frac{n}{\sqrt{R}} * \left(k_1 + \frac{k_2}{S}\right)}$$

R = hydraulic radius (for pressure pipes, R = D/4)
S = slope of energy grade line
n = Manning or Kutter's flow coefficient

The most commonly used equation in pressure sewer design (applicable to STEP systems) is the Hazen-Williams Equation. C factors identified for PVC pipe range from C = 140 to C = 160, with a typical value of 150 (Crites & Tchobanoglous, 1998; WEF MOP No. FD 12, 1986), to C = 130 to C = 140 (US EPA, 1991, 2002).

The current Iowa standards require a C value of 120. Therefore analysis shall be completed using a C Factor of 120. Analysis should also be performed to confirm performance with higher C factors that could be observed after initial startup.

2. LPS Forcemains

a) Configuration and Layout

LPS pressure sewer systems are typically configured in a branched pattern because the branched arrangement enables easily predictable velocities in the mains. The disadvantage of a branch arrangement is that the system lacks redundancy, so users upstream from a disturbance to the collection system are without service.

Looped systems are typically not utilized for LPS systems because scouring velocities become unpredictable and difficult to maintain.

Pumping "uphill" is usually the preferred practice. Uphill pumping occurs when all pumps and all portions of the pressure sewer collection system and service lines are at an elevation lower than the point of discharge. "Downhill" pumping may be unavoidable in some cases, or may be preferred for site-specific reasons. When downhill situations are present, air enters the pipeline and two-phase flow (air and water) will be present.

Pumping both "Uphill" and "Downhill", or two-phase flow, results in high turbulence and headloss in the system, and can diminish capacity if air release valves are not properly installed and located. Downhill portions of the collection system should be short, steeply inclined and distinct, which may require rerouting of mainlines in layout. If this cannot be achieved, standpipes or pressure-sustaining control valves can be used to elevate the static grade line and ensure that the mains in these areas remain full of effluent throughout pumping. This allows air release valves to function properly. Standpipes and the location of air release valves in downhill pumping conditions (WEF MOP 12, 1986).

Another option for situations where downhill pumping cannot be avoided is to oversize the downhill portion of the main to accommodate gravity flow conditions. In this arrangement, automatic air release valves would be placed at the upstream highpoint and the downstream static water elevation.

b) Sizing Recommendations

Refer to Table 5-1 for approximate sizing of LPS mains and the characteristics of the flow under various design assumptions for per capita flow rates and the number of people per EDU. For most systems considered in this design manual, a 2-inch diameter (class 200) PVC pipe would suffice. However, pump manufacturers' recommendations should also be considered for the proper specification and sizing of collection system piping.

Because solids are present in the wastewater in an LPS system, design velocities will typically range from 2 to 5 ft/s. Generally speaking, design friction headloss values of 0.5 to 1.5 ft/100 ft are targeted to avoid unnecessarily high pressures in the mains. This enables the LPS pumps to remain within the 1.0 – 2.0 hp range, depending on the type of pump used.

The use of 2-inch pipe should be compared to 3-inch pipe in terms of overall project costs (materials, labor, and installation). Depending on the availability of 3-inch pipe, the increase in material costs (3-inch pipe costs roughly double the cost of 2-inch pipe) may be offset by reduction in labor cost through the use of gasketed joints instead of solvent welded joints. The added benefit of 3-inch pipe is that the capacity of the system for future expansion is greatly increased. However, 2-inch pipe may be needed in LPS systems to maintain self-cleaning velocities.

To determine the ultimate effect on line sizing, evaluate all conditions including high static pressure and long pipe runs. When it becomes apparent that these other conditions significantly affect the hydraulics, divide the system into segments and use the next size larger where necessary. The use of pump manufacturers' computer programs specific to the type of pumping equipment to be used is recommended to provide additional hydraulic analysis.

If progressing cavity grinder pumps are used in the system, head pressures will have little affect on the design discharge rate of the pump. If centrifugal pumps are used in the system, head pressures have a much greater effect on the discharge rate of the pump.

Table 5-1
LPS Forcemain Size and Flow As a Function of Design Population

EDUs	Design Population	Qp (gpm)	Pipe Size[a] (inches)	Headloss[b] (ft/100 ft)	Velocity (ft/s)
8	25	19	2	0.8 +/-	1.7
33	100	30	2	2.0 +/-	2.7
83	250	76	3	1.7 +/-	3.1

a. Nominal diameter.

b. Head loss is based on C=120 and the inside diameter of class 200 PVC pipe

The remaining force main and service line design considerations for LPS systems are similar to the discussion provided in Section 3 pertaining to STEP systems. Refer to Section 3 for the complete discussion.

Figure 5-6 provides a detail for the connection of a grinder station service line to the LPS main.

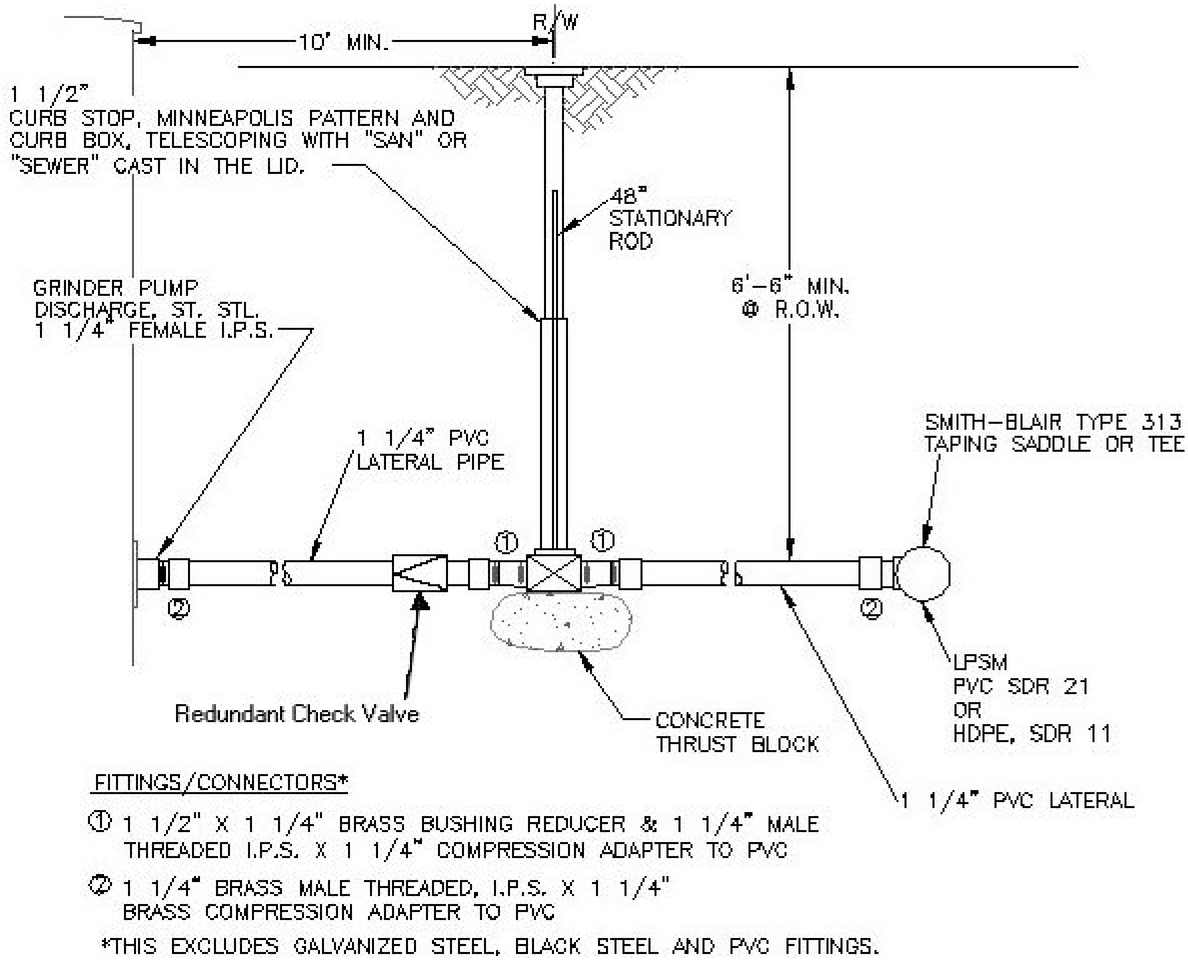

Figure 5-6 Typical curb-stop connection of a grinder station

E. Design Guidance – LPS

Grinder pump vaults receive raw wastewater and pulverize it as it is discharged to the collection system.

1. Grinder Station Location and Access

Location of the tank should be considered carefully. The most economical location for the grinder station is in the basement of the building it will serve. If there is risk of damage to items located in the basement level, an outdoor installation should be considered. Outdoor installations are often required when municipalities perform the operation and maintenance of the grinder stations. If located outdoors, access to the interior of the home is not needed for repairs or routine maintenance to the grinder station.

In an existing dwelling the exit point of the building sewer will many times dictate the location of the station. In the case of a new development the designer will have many more options available. In either case every effort should be made to locate the tank so that it is easily accessible by maintenance crews. Locking devices must be provided to prevent unauthorized tampering or access to the tank.

2. Volume Sizing Requirements and Required Pumping Rates

Required pumping rates for LPS systems should not be confused with the peak flow expected to occur in the dwelling. Since the purpose of the LPS pump is to discharge effluent at a rate such that the water level in the grinder pump vault does not reach the high water level alarm and also to prevent backups with a high degree of confidence, pumping rates are established that utilize the reserve volume provided in the grinder pump vault.

Pumping rates will be lower than design flow rates used for sizing the collection system mains, because design flow rates do not incorporate any attenuation of flows due to the reserve volume of grinder pump vault.

Grinder pump vaults rarely have reserve volumes greater than 50 gallons, so their pumping rates need to be higher. Note that in Figure 3-7, the term "Reserve Volume" was defined as the volume provided between the "Pump On" and "Alarm" floats. In popular residential simplex grinder pump vaults with internal diameters of 24 inches, this volume typically ranges from 12 – 15 gallons. Based upon this reserve volume, Figure 3-7 indicates a pumping rate greater than 11 gpm is needed.

If the liquid level rises above the crown of the incoming building sewer, ventilation through the roof vent of the home is interrupted. For this reason, some grinder pump installations provide a vent through the cover of the vault to provide ventilation under this condition.

If the grinder pump malfunctions, or in the case of a power outage, water use may still occur for a short period of time. Information provided by a manufacturer of grinder pumps indicates that 7.5 hours of emergency storage capacity (storage volume) above the normal "pump on" level is provided in a 70-gallon residential unit if the water level increases to the crown of the inlet pipe.

In the above example, the amount of available storage capacity was based on 4 people per grinder station, and 1.54 gallons per hour per person, the actual measured flow for a one-year period at the Albany Demonstration Project (Environment One, 2004). Furthermore, the 7.5-hour storage capacity was deemed to be adequate for 97% of the power outages experienced in the United States between 1968-1972. The need for emergency maintenance in the case of a power outage is therefore minimized. However, the allowable response time due to a pump malfunction is considerably less than if a large septic tank was used.

Most grinder pump vaults are provided as package units directly from the manufacturer. As a result, sizes vary depending on the pump performance characteristics and the dimensions necessary for installation of their equipment. Typical diameters of single-family grinder stations range from 24 to 36 inches, and are available in heights ranging from 5 to 13 feet. The height of the package grinder stations depends on the cover required over the inlet sewer and discharge piping.

3. <u>Site Conditions</u>

In areas where groundwater is present near the surface, precautions must be taken to prevent the tank from "floating" to the surface. Various methods have been used to counteract buoyancy, and are discussed in the paragraphs that follow.

The most common method of anti-flotation for grinder pump stations is the construction of a concrete ballast that is properly secured to the tank. If this method is employed, sufficient time must be provided for the concrete to cure before completing the backfilling. Ballasts should be provided based upon the buoyancy calculated for the site conditions and manufacturer's recommendations.

Provision of a minimum depth of cover can also be employed. The minimum cover depths should be based upon an evaluation of the groundwater elevation, and site-specific soil conditions.

4. Pump Selection

The most common pump types used in LPS systems are centrifugal grinder pumps and progressing cavity grinder pumps. Horsepower required depends on the system conditions, but pumps ranging from 1.0 to 2.0 hp are most common.

Pumps having a minimum 24-hour run dry capability without water lubrication are recommended, as are designs that allow circulation of effluent for motor cooling and to prevent air bind. The motor cable must be suitable for Class 1, Division 1 and 2 applications. Lightweight pumps facilitate easy removal and maintenance.

Pumps used in pressure sewers should be capable of running at shutoff head conditions. Shutoff head conditions can be produced in the collection system after a substantial power outage, when many of the pumps within the system energize simultaneously. Shutoff head conditions also occur if a mainline isolation valve is closed for maintenance purposes or curb stop is inadvertently left in the closed position.

If the installation of the pump is such that the liquid level in the pump tank is higher than the hydraulic grade line of the main, siphoning can occur when the pump has shut off. In some cases, siphoning can result in air-binding of pumps. Anti-siphon valves must be provided if siphoning could occur.

a) Flow Rates

The pumping rate provided in a LPS system depends upon the pump type used. When a centrifugal grinder pump is used, the discharge from the pump will vary considerably depending on the head conditions present. At high heads, centrifugal pumps will operate near shut off conditions. At low heads, the pumps will draw the most horsepower and run toward the right of their performance curve. When multiple pumps, at multiple elevations operate simultaneously, the analysis becomes more detailed (EPA, 1991). The difference in pump discharge rate versus head conditions was previously illustrated in Figure 5-4.

Centrifugal pump selections can be made after the energy gradient for the collection system has been established. The selection is made by determining the total dynamic pumping head (TDH) in feet of pressure. The friction losses in the discharge assembly (h_{hv}) and service line (h_l) are computed based on the pump discharge rate, and then added to the pressure head in the main line (h_p) and the static head (h_e) based on the elevation of the water level in the grinder pump vault. Progressing cavity grinder pumps provide a relatively constant flow rate at nearly all head conditions expected for pressure sewers, making the pump selection process less involved.

$$TDH = h_e + h_p + h_l + h_{hv}$$

b) Controls

A fiberglass-enclosed panel is typically provided to control the pump(s). Panels should be NEMA, UL or CSA listed, be provided with current limiting circuit breakers with thermal magnetic tripping characteristics, HOA (hand, off, automatic) switch, audible and visual alarm, silence relay, and fused alarm circuit separate from the pump circuit.

(1) Simplex / Duplex

In residential applications serving a single family, simplex pump stations are most common. Redundant pumps are typically not required or necessary.

If a duplex station is installed, alternation between the two pumps is needed.

(2) Run Time Meters / Event Counters

Run time meters and event counters are considered optional on for residential applications with simplex pump units. In contrast, they should be provided with all duplex stations.

Though optional, many design engineers and utilities recommend the installation of RTMs and event counters, because they can aid in troubleshooting the collection system. For example, in the case where higher flows are observed in the pressure sewer than anticipated, the RTMs at each residence can be used to identify pumps with excessive run times. Excessive run times (compared to the average runtimes in the system) can be due to differing head conditions, but are often due to leaking grinder pump vaults or cross connections that allow significant amounts of clearwater to the collection system.

(3) Alarms

The control/alarm panel should be located on the side of the house at a height that is convenient and accessible for maintenance. It should be close to and in sight of the pump and out of the direct sun and rain. At lease one alarm must be provided on the house control panel that is audible and also has a visual (light) alarm indication.

Some installations incorporate a remote signal in the house that is fed from the outside alarm.

All installations must be supplied with a high water alarm. A high liquid level in the tank activates an alarm light and a buzzer, which may be silenced by pressing the illuminated PUSH TO SILENCE button on the front of the control panel. The alarm light stays on until the high level condition is corrected and then the alarm circuit automatically resets.

When an alarm occurs, the user calls the phone number on the panel cover. An operator should be on-call 24 hours in order to respond to line breaks or treatment plant problems that require immediate attention. The amount of emergency storage volume available should be evaluated on a site-specific basis. Maintenance personnel will become familiar with response times needed for grinder pump failures, and will usually need to respond within 8 hours of the high water alarm.

"Smart panels" now available sound alarms when the water level is too low (leaking tank) and when too much water is passing through the system (stuck toilet valve). They can also dose at predetermined times, regardless of varying inflows, in order to reduce the collection system's hydraulic gradient.

5. Electrical Requirements

Centrifugal pumps used in LPS systems are typically 230 Volt, single phase, and are 2 hp or larger. A junction box is provided to connect the control panel wiring to the pump and float switch wiring. In commercial LPS packages, the junction box is usually included in the riser for the pump vault. Junction boxes must remain watertight so that the electrical connections inside them are not damaged by corrosion.

Progressing cavity pumps used in LPS systems are typically 230 Volt, single phase, but can be operated at 115 Volt in the case of an older home that does not have adequate wiring for 230 Volt. Pump activation is provided by a trapped air system integral to the pump core, and no level floats are required.

Power is usually obtained from an available circuit in the user's existing circuit breaker. If the LPS system is a retrofit installation, modifications to the homeowner's electrical system are sometimes needed before the system can be operated if 230 V centrifugal pumps are installed. This situation can lead to unexpected costs, especially in older residences that may not comply with current electrical standards.

F. Collection System Operation and Maintenance Information

1. Operational Concerns

   a) Testing

The testing of LPS systems does not differ than the discussion included in Section 3 pertaining to STEP collection systems. Refer to Section 3 for the discussion of this topic.

b) Freezing

The freezing of LPS systems does not differ than the discussion included in Section 3 pertaining to STEP collection systems. Refer to Section 3 for the discussion of this topic.

c) Odors and Corrosion

The odor typically associated with domestic wastewater processes is the rotten egg aroma of hydrogen sulfide (H_2S). While such odors can originate from many sources, not always sewer related, the natural inclination of the public is to blame them on the public sewerage system. Responding to odor complaints, nevertheless, is a maintenance responsibility.

Odors originating from a sewage spill or pipe break are usually easy to trace. A leaking manual air release valve (MARV), or a very active automatic air release valve (AARV), is a likely place for odors to originate because of the expelling of air and sewer gases. Soil absorption beds or carbon filters are useful to prevent complaints in these cases.

Sulfate ($SO4^{2-}$) is naturally present in most raw water sources between 40 and 80 mg/L; although, depending on the water supply, it may vary from 5 to 500 mg/L. In an enclosed sewerage line it may only take 15 or 20 minutes for the microbial activity, relative to the strength of the waste streams biochemical oxygen demand (BOD), to completely deplete its dissolved oxygen (DO). As soon as the dissolved oxygen (DO) is used-up the microorganisms (sulfur bacteria) begin stripping oxygen from the next available source, which is usually the dissolved sulfate, leaving sulfide ions (S^{2-}) free to form molecules of hydrogen sulfide (H_2S, HS^-). Microbes will also strip oxygen from nitrites (NO_2), nitrates (NO_3) and other sources, when available, and in preference to sulfate especially if less energy is required to break the molecular bond. Nitrate injection, in the form of sodium nitrate ($NaNO_3$), is a measure that is sometimes considered effective for reducing the amount of hydrogen sulfide a system generates. Hydrogen sulfide odors can be detected in concentrations as low as 0.00025 mg/L; however, the average threshold of annoyance is expected to about 0.04 mg/L.

A grinder force main should not discharge into a gravity sewer without provisions for addressing either the odor or corrosion problems. Many articles are presented annually in professional journals and other publications describing new and old methods of dealing with sulfide problems. Chemical addition (Bioxide, Thioguard, etc) and aeration methods are available to prevent hydrogen sulfide odor and corrosion issues. In the case where a grinder station forcemain discharges into a conventional liftstation or treatment facility wetwell, the discharge should utilize a drop inlet, where the potentially septic effluent discharge is made below the water surface. This reduces the amount of turbulence that leads to the liberation of hydrogen sulfide. Because the structure receiving the effluent is typically constructed of concrete, the application of a corrosion resistant coating is recommended. Commercial coating formulations are readily available that protect the concrete from attack by sulfuric acid.

d) Main Line Flush connections

Main line flush connections should be exercised at least annually. Occasionally, a leaking valve allows air and gas to collect at the flush connection, since it is a high point in the system. Periodic exercising allows this gas to be vented and prevents deterioration of system performance.

e) Extended Power Outages

Following a power outage, it is likely that nearly all pumps in the system will energize simultaneously. The hydraulics of the system will be such that some centrifugal pumps will discharge and others will not, since they will be operating at shutoff conditions. However, once the bulk of downstream pumps de-energize, upstream pumps will re-start (if necessary) and begin pumping.

If progressing cavity pumps are installed, the high back pressure experienced for some pumps would cause the automatic thermal overload protectors to trip after a few minutes of operation. In the mean time, the pumps remaining energized would be able to clear the contents of their vaults. After one or two minutes, the pumps that tripped due to thermal overload would have cooled and be able to restart. The system backpressure would have been reduced and the group would be able to operate normally.

The reserve storage in the grinder vaults will vary depending on the manufacturer. Popular residential grinder stations have an emergency storage volume (the volume of storage between the pump "OFF" and the top of the grinder pump vault) of roughly 70 gallons, which typically allows up to 7-9 hours of normal water usage. Power outages of 9 to 12 hours are infrequent and generally considered the worst condition to allow for; most disruptions last no longer than a couple of hours.

In extreme conditions, where history has shown that long power outages are frequent, the most effective way to allow for extended power outages is to install holding tanks adjacent to the grinder stations. The holding tanks should be installed such that they begin receiving flow when the sewage elevation in the grinder station reaches the invert of the building sewer inlet of the grinder station. Depending on the number of grinder stations in the system, the sharing of portable emergency generators can also be used in lieu of the construction of holding tanks.

f) Main Line Isolation Valves

The exercising of mainline isolation valves in LPS systems does not differ than the discussion included in Section 3 pertaining to STEP collection systems. Refer to Section 3 for the discussion of this topic.

g) Air Relief Valves

LPS systems are more susceptible to grease buildup, so air release valves may require more frequent cleaning than is necessary in effluent sewers. The need for accelerated cleaning schedules and the necessary intervals between cleaning will become apparent after the system is operational.

The remaining discussion for air relief valves in LPS systems does not differ than the discussion included in Section 3 pertaining to STEP collection systems. Refer to Section 3 for the discussion of this topic.

2. Maintenance Concerns

a) Main Line Flushing

In the case of an LPS collection system, flushing of main lines is rarely needed because self-cleaning velocities are maintained at least once or twice a day. Rather than determine a flushing schedule solely based on the calendar year, it is recommended that the pressure in each branch of the system be monitored. Increased pressures in areas of the mains could be an indication of air entrainment, grease buildup, or solids deposition.

b) *Pressure Monitoring*

The discussion of pressure monitoring in LPS systems does not differ than the discussion included in Section 3 pertaining to STEP collection systems. Refer to Section 3 for the discussion of this topic.

c) *Record Keeping*

Accurate record keeping is essential to the successful operation and maintenance of any small diameter, low-pressure sewer system. Records of pigging and flushing operations should be maintained in a central location where all responsible staff may access the information.

G. LPS Operation and Maintenance Information

Routine operation and maintenance requirements for STEP systems are minimal. Small systems that serve 300 or fewer homes do not usually require a full-time staff (EPA, 2002).

To avoid abuse of a system's grinder stations that can lead to operation and maintenance concerns, cooperation of users is essential. Users of the system must be properly educated, and a list of "Do's and Don'ts" should be provided to patrons and updated regularly. Orenco Systems, Inc., a leading researcher and manufacturer of STEP system components, offers the following recommendation, which would also be applicable to prolonging the life of grinder pumps and increasing the length of time between service calls: "Users should be warned against disposing inappropriate solid-waste into the sewer. Tampons, cigarette butts, Handy Wipes, disposable diapers, prophylactics, rags, plastics, excessive grease, petroleum oils, cutting oils, coffee grounds, egg shells, kitty litter (clay), chemicals, water softener backwash, and any non-biodegradable substances should be disposed in trash containers at approved solid or hazardous waste sites."

1. General Preventative Maintenance

The annual preventative maintenance previously discussed for STEP systems would be applicable for LPS stations also, with a few modifications. The following sequence is recommended for annual maintenance visits:

1. Remove pump, check intake, suction plate, and pump body for corrosion; cleat pump.
2. Exercise valves.
3. Return pump and test.
4. Test alarm system.
5. Check sludge, scum, and grease accumulation in grinder vault.
6. Remove grease buildup from level floats or pump.
7. Add enzymes, if enzymes are routinely added to the system.

2. Pumps and Electrical

There is very little preventative maintenance practical to accomplish at most pumping units (EPA, 1991). The pumps and ancillary components are not routinely removed from the pump vaults. Service calls generally involve responding to electrical control problems or pump blockages. Mean time between service calls (MTBSC) data vary greatly, but values of 4-10 years for both Grinder (LPS) and STEP units are reasonable estimates for quality installations (EPA, 2002).

Typical routine maintenance activities involve the demonstration of proper system function. Pumps should be actuated using the "Hand" function, and also checked for operation when the "Pump On" float is actuated. Voltage and amperage readings are recorded while the pump is operating, and checked against the full-load amperage draw of the pump. Initiation of audio and visual alarms is also checked by manually actuating the high-level alarm float switch.

The most common electrically related problems involved mercury float switches that either malfunctioned, became tangled, or became inoperable due to grease buildup (EPA, 1991). When heavy grease buildup is present, maintenance staff will occasionally provide the homeowner with enzymes for grease removal.

Most wear-related problems with pumps stemmed from the disposal of coffee grounds, eggshells, kitty litter, and other abrasive compounds by the end user. The primary failure item on progressive cavity pumps is the wearing of the stator (boot) resulting from repetitive dry running due to malfunctioning level switches, or the pumping of abrasives. Common wear items on all grinder pumps are the seals and cutter mechanisms. Frequency of replacement varies depending on the characteristics of the waste stream.

The number of spare pumps on hand varies depending on the municipality operating the system. A typical standard, however, is that a quantity of 5% of the total number of pumps in the system be on-hand at any given time. Replacement frequency for grinder pumps will vary depending on the application and the wastewater practices of the user. Manufacturers indicate that a grinder pump will last 10 to 20 years with proper O&M (WEF, 1986).

3. Odors

A pump failure or a disconnected discharge hose may cause odors originating at on-lot facilities. Occasionally an odor's source may be the building sewer, which is generally considered the responsibility of the property owner. Intermittent odors may be elusive and difficult to isolate, requiring the property owner's cooperation in tracking down the source. Odors originating in the septic tank are typically vented through the roof vent connected to the building sewer. Improper venting can lead to localized residential odor problems, and in most cases, improper house venting has been a major contributor (EPA, 1991).

H. Cost Estimates

Due to the extreme variably of local markets for labor and materials, it is not possible to estimate universally the cost of construction and operation of LPS systems. Cost differentials are significant across local geographies and economies. Therefore the reader of this manual is advised to consult local markets for specific data.

1. Capital Costs

A major determinant in the overall cost of a project is its size. The larger the project, the greater the benefit from economies of scale. Therefore the reader of this manual is advised to consult with knowledgeable individuals for specifics relating to costs of construction for a particular project.

a) Capital Cost Estimating Spreadsheet

The next page details a typical cost estimating spreadsheet for estimating overall capital costs for a LPS system. The spreadsheet identifies major components of the proposed construction and allocates units for each component. Upon completion of a standard design, actual units of installation may be inputted into the spreadsheet. Costs per unit must be obtained from local sources due to the aforementioned extreme variability in local markets.

Table 5-2
LPS System Capital Cost Estimating Sheet

Capital Costs

Item	Quantity	Units	Unit Cost	Total Cost
Onsite Sanitary Sewer System Abandonment or Removal		EA		
Equipment (Use if Individual Components Specified)				
Pump Vaults		EA		
Pumps		EA		
Spare Pumps		LS		
Control & Alarm Panels, Level Switches		LS		
Supplemental Electrical Cable (25-foot length)		LS		
Installation, Complete		LS		
Equipment (Use if Package LPS Units Provided)				
Pump Vaults		EA		
Simplex LPS Pumpstations, Complete		EA		
Duplex LPS Pumpstations, Complete		EA		
Supplemental Electrical Cable (25-foot length)		LS		
Installation		LS		
Portable Generators		LS		
4" PVC Building Sewer		LF		
1-1/4" Service Laterals		EA		
Service line isolation and check valves		EA		
2" Main		LF		
3" Main		LF		
4" Main		LF		
5" Main		LF		
1-1/2" Curb Stop and Box, Check valves, Isolation Valves		EA		
Imported Granular Backfill		CY		
Valve/Tee Manhole		EA		
Single Flush Connection, Complete		EA		
Dual Flush Connection, Complete		EA		
Manual Air Release Station, Complete		EA		
Automatic Air Release Station, Complete		EA		
Pressure Sustaining Station, Complete		EA		
Flow Meters, Complete		EA		
Pressure Monitoring Station, Complete		EA		
Surface Restoration		LS		
Erosion Control		LS		
Traffic Control		LS		
Electrical (10%)		LS		
Mob./Demob., Bonding/Ins. (7%)		LS		
Subtotal				
Capital Contingencies (25%)				
Subtotal				
Engineering (20%)				
Legal and Administrative (5%)				
Total Estimated Capital Cost				

Table 5-3
LPS System O&M Costs

Operation and Maintenance Costs	Qty	Units	Unit Cost	Annual Cost
Pump Replacement		pump		
Equipment Maintenance, Repair, and Replacement				
Labor		hours/yr		
Electric Power		kWh		
Annual O & M Cost				

2. Annualized Costs

a) *Operations and Maintenance Cost Estimating Spreadsheet*

A spreadsheet showing the major operations and maintenance cost line items and unit costs that could be anticipated is shown in Table 5-3.

b) *Significant Assumptions*

(1) Pump Replacement

Replacement costs for pumps varies depending on the type of grinder pumps installed in the system and the quantity purchased. Equipment manufacturers of the specified pumping equipment should be contacted during the formulation of the cost estimate for current prices.

(2) Power

Power costs will vary across the state, but a rate of $0.10 per kWh should be used to estimate annual power costs for the all pumps. Power cost for the pumps can be calculated by multiplying the total number of pumps times the average running time, and converting horsepower into kilowatts as per the following formula:

Annual Power Cost =
(Np)(T%)(24 hours)(HP)(0.75)($0.10)(365)

Where:
Np = Number of pumps
T% = Percent daily run time
HP = Horsepower of each pump

If horsepower of pumps installed in the collection system varies, the calculation must be repeated for each horsepower present in the system.

(3) Equipment Maintenance and Replacement

An annual set-aside for equipment replacement should be built into the budget. The amount set aside should be based on the original cost of the equipment, and prorated out over the expected design life of the equipment.

(4) Labor

The estimated cost for labor should be based on the total compensation for the operating staff, including any benefits, plus any administrative salaries for meetings, billing, etc. The estimated hours needed should include the provision for periodic maintenance such as mainline flushing, pressure monitoring, routine inspections of collection system and on-site components, and service calls.

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