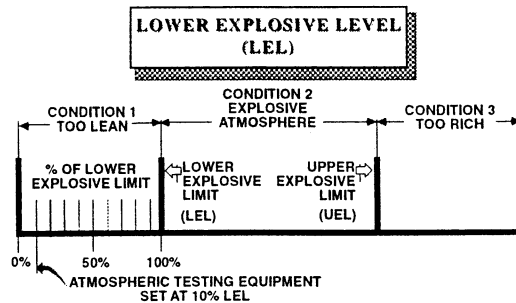
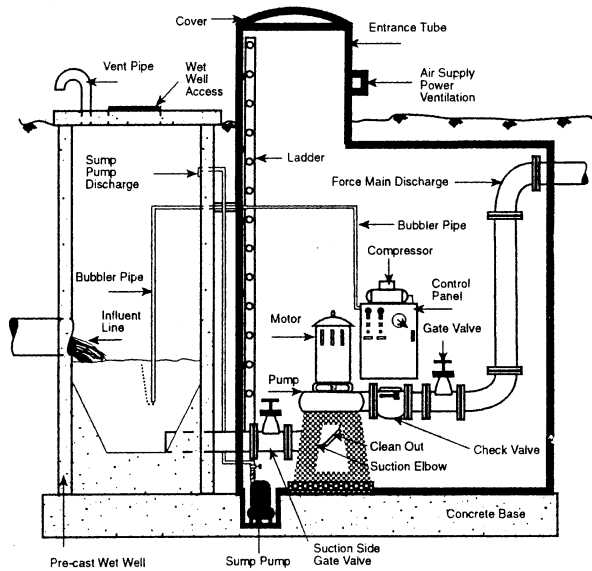


Basic Wastewater Collection Systems

**Minnesota Pollution
Control Agency**

**Water Quality
Division**

**Training and
Information
Management
Unit**



THREE ATMOSPHERIC CONDITIONS CAN EXIST
 1. TOO LEAN TO SUPPORT COMBUSTION
 2. MIXTURE JUST RIGHT, EXPLOSION OCCURS
 3. MIXTURE TOO RICH TO SUPPORT COMBUSTION

Basic Wastewater Collection Systems

**Prepared by:
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Rick Arbour & Associates, Inc.
for:
Minnesota Pollution Control Agency
Water Quality Division
Training and Information Management Unit**

**Second Edition
1995**

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Rick Arbour**

Acknowledgments

The Operator Training Unit (OTU) of the Minnesota Pollution Control Agency has been at the forefront of Collection Systems Training since the early 1970's, long before the majority of other states recognized the need for training in this area. As a result, they have developed and shared resources, not only in Minnesota, but throughout the country. Many of the programs they have developed have become models for other agencies and organizations and are or have been distributed by the National Environmental Training Association, the Water Environment Federation and the California Water Pollution Control Association, to name a few.

The leadership and foresight of the OTU has benefited thousands of operators throughout the country. That leadership continues with the development of this manual, which will be used as the basis for a 2 1/2 day Basic Collection Systems Seminar. While there is some risk of omitting someone's name, I would like to thank those I have worked closely with over the years and who I feel were instrumental in providing the OTU leadership. These include Emily Armistead, Russ Degerstedt, Steve Duerre, Gene Erickson, Del Haag, Deb Lindlief, Dwayne Nelson, and Bill Sexauer, as well as the unseen and unrecognized support staff at the OTU.

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The California State University, Sacramento Field Study Training Program, Operation and Maintenance of Wastewater Collection Systems, Volumes 1 and 2, Fourth Edition, was used as a resource for this manual. The collection system information contained in the 2 volumes that comprise this course has been refined over the years, under the direction of Dr. Ken Kerri, and is now the most comprehensive resource available on the topic of Collection Systems Operation and Maintenance. I strongly encourage anyone who is pursuing a career in collection systems to enroll in the training program. The course is offered in two parts corresponding to each volume and the cost to enroll is \$30 per manual or \$60 to complete both volumes. Additional information is available from:

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INTRODUCTION

It is historical fact that the development of civilization is closely tied to the development of sanitary sewer systems and sanitary water supplies.

Prior to the development of potable water and sanitary sewer systems, infectious diseases, carried by contaminated water systems, prevented many civilizations from developing.

Wastewater collection systems, a recent term for sanitary sewer systems, are therefore as important as having adequate potable water supplies. Unfortunately, wastewater collection systems have not received the same amount of attention as water supply systems or Treatment Plants.

In the past 20 years, we have focused on developing potable water supplies and treating wastewater.

In the US and Canada, construction of waste treatment plants became a priority, since in many cases, the collection system had been installed, sometimes over a hundred years ago. Because plants were not built, the sewers were allowed to discharge directly into streams, lakes and oceans.

In the 70's, most of the financial resources were directed at plant construction. It is only the last ten years or so that wastewater collection systems have been recognized as needing to be included as part of environmental issues.

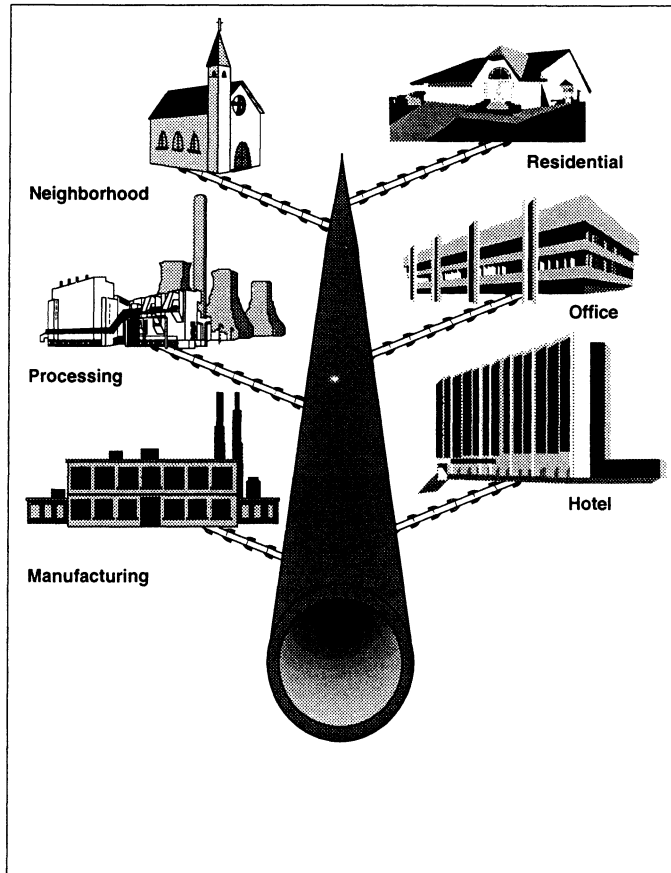
As we have recognized the need to improve operation and maintenance of collection systems, which are complex and require specialized skills and knowledge, there is far more emphasis today on collection systems than in the past.

What Is a Wastewater Collection System?

Collection systems collect the used water generated from homes and businesses and convey it to a wastewater treatment plant.

Wastewater Collection Systems

This definition is really an oversimplification for a very complex system. Let's take a look at what a collection system really does in the community.



Wastewater collection systems transport domestic, commercial and industrial wastes to the wastewater treatment plant in the community for treatment prior to discharging into lakes, streams or rivers. The collection system may also be known as a sanitary sewer collection system, since it is transporting sanitary wastes. Because of contributions to the wastewater flow from inflow and infiltration, which will be discussed in later chapters, wastewater usually carries some surface and ground water. In the past, some wastewater collection systems

were designed to carry both sanitary and storm water flows, in which case the system is referred to as a combined sewer overflow system (CSO) since it combines both sanitary and storm water in the collection system. Combined sewers generally are not being designed today since storm water has been recognized as having high pollutant loads which can pollute the surface waters where they discharge directly. The Environmental Protection Agency, in fact, has implemented a storm water regulation that requires communities to address this problem with storm water. In addition, most cities in the United States are either separating their sanitary and storm water sewer systems or providing treatment for much of the combined flow rather than bypassing the combined flow during wet weather as was the case in the past.

Collection systems are very complex networks that include the following components:

- ◆ Gravity sewers, in which flow is conveyed by gravity.
- ◆ Force mains, in which the flow is conveyed via a pump station.
- ◆ Pump stations and pumping equipment.
- ◆ Special structures such as manholes, valve vaults, meter stations, diversion structures and siphons.

Operation and Maintenance of Wastewater Collection Systems.

Communities invest a significant amount of money when they are constructing their wastewater collection system. In fact, it is usually such an expensive proposition that bonds are sold to finance the project over several years. If the collection system, once it is constructed, is to perform as intended, that is, convey the wastewater in a manner that protects public health and safety and the environment, then adequate operation and maintenance must be per-

Wastewater Collection Systems

formed on the system. The lack of maintenance on the system results in cumulative effects. Initially there may be a few blockages and overflows and over time the consequences of inadequate operation and maintenance are severe and can include:

- ◆ Blockages occurring in the mainline sewer that result in back ups into homes, businesses and other customers that are connected to the wastewater collection system. This usually results in, at a minimum, the agency having to pay for clean up and repair/replacement costs of the damage. It can also result in law suits that can potentially cost your agency tens of thousands of dollars.

- ◆ Bypassing raw sewage from the collection system or pump station as a result of system failures into surface or subsurface waters that are used for recreation and/or water supply. Here again, the consequences can range from water contamination and beach closings to violations of the Clean Water Act that can result in fines from state and federal regulatory agencies in the tens of thousands or hundreds of thousands or even millions of dollars.

- ◆ Street collapse. Inadequate operation and maintenance affects other utilities and frequently the transportation system when the system fails. Large voids under the street created by collection system mainline sewers that are leaking can result in large scale street collapses that not only can result in injury and death to the public, but extensive property damage to streets and adjacent buildings and foundations as well. Because other underground utilities are normally in close proximity to the wastewater collection system, water service, electrical service, telephone, cable TV service can also be disrupted.

- ◆ Experience has shown that inadequate operation and maintenance of the wastewater collection system over the long term is actually several times more costly than the cost of a systematic program of operation and maintenance on the system on a scheduled basis. Not only is the performance of the wastewater collection system affected, but the life of the collection system network can be reduced significantly and require capital rehabilitation or replacement before its intended life.

Operation and maintenance of the wastewater collection system can be thought of therefore, as protecting the capital investment the community has made in the wastewater collection system so that it performs its intended function and can be utilized efficiently throughout the planned life of the system.

The work that operators do varies it varies from agency to agency. In some cases they may take care of pump stations. In some cases they have only larger trunk sewers.

In general, they are responsible for the proper operation and maintenance of a system defined by their agency or company. To accomplish this they:

- ◆ Operate a wide variety of equipment
- ◆ Perform system inspections
- ◆ They clean lines and remove stoppages
- ◆ Repair lines, equipment and facilities
- ◆ Perform preventive, corrective and emergency maintenance.

Collection system operators are employed by cities,

The Role of a Collection System Operator

Wastewater Collection Systems

counties, regulatory agencies, contractors and sanitation districts.

Operation and maintenance of collection systems will continue to increase in importance as new regulations are implemented. This will require new skills and knowledge.

In order for the collection system operator to increase skills to keep pace with technology, professionalism must also increase.

Formal training and certification programs play a big role in the developing the knowledge and skills needed for one of the most important jobs in the community.

Collection system operators are directly responsible for public health and safety and protection of the environment. Therefore, we play an important role in the community.

The role of the collection system operator has changed drastically in the last several years through the development of modern technology.

In the past, much of our work required that we actually enter sewers in order to perform many of the tasks. With new equipment and systems, much of this has been eliminated.

It is now far more important for the collection system operator to understand the concepts of collection systems and have a thorough understanding of the equipment utilized for operating and maintaining them.

Collection System Salaries

Historically collection system operators have been among the lower paid utility workers. In agencies where the level of professionalism has increased and certification programs have been implemented,

collection system operators can expect wages on par with other utilities, such as water and wastewater treatment plant operators.

Employers are now, more than ever, recognizing the need for qualified collection system operators and it is expected this will continue in the future.

Why Collection System O&M?

Preventive maintenance is talked about, but seldom practiced by some agencies. Decades of neglect, or grossly inadequate maintenance of some systems, are two reasons why wastewater collection systems now require over 42.9 billion dollars worth of rehabilitation and upgrading between now and 2010 and at a time when the economy can ill afford the cost .

There are multiple reasons why collection systems throughout the US are in such poor shape

- ◆ Wastewater collection systems were engineered with inadequate flow capacities for the area served or for the unexpected population growth.
- ◆ Poor design.
- ◆ Collection systems were not installed as designed. Problems are caused by faulty construction, poor inspection and low-bid short cuts.
- ◆ Little thought was given to the fact that sewers, although made of permanent material, could be considered only as permanent as the joint.
- ◆ Earth movement, vibration from traffic, settling of structures and construction disturbance (all occur from time to time) require a flexible pipe material or joint that can maintain tightness, yet joints were made rigid.

Wastewater Collection Systems

- ◆ Not enough scientific knowledge existed or was available to designers about potential damage to pipe joints by plant roots. Although root intrusion into sewers was age-old, it was assumed that if the joint was watertight, it would be root tight.
- ◆ People did not realize that roots would be attracted by moisture and nutrient vapor unless the joints were vapor tight (which means airtight).

Roots can enter a pipe joint or walls microscopically (through extremely small holes or cracks); thus, open or leaking joints are not necessary for root intrusion in collection systems.

Collection system environments are ideal for root growth. In this environment, roots enter, expand and open joints and cracks.

Root growth is a principal cause of pipe damage that allows INFILTRATION, INFLOW (I/I) and EXFILTRATION. This creates a major concern for because of wastewater treatment plant overload and groundwater pollution.

Local taxpayers have invested more money in underground sewers than in all the structures above ground owned by their local government. Why has this great taxpayer investment been so grossly neglected? Because it is out of sight, and so, out of mind.

Some cities spend more money repairing and replacing sidewalk sections because of earth movement and tree-root damage, than on preventive maintenance of wastewater collection systems.

Many collection systems are maintained by a department charged with street, sidewalk, storm drain, and sometimes water utility maintenance.

Money is usually spent where the taxpayer can see it, especially when the budget is inadequate for the total need. How often do you see a sign. “Your tax dollar is at work cleaning and repairing your sewer?”

Problems that can develop include groundwater infiltration into the sewer, possible flotation of the sewer, or structural failure of the sewer or joint.

Most communities cannot afford to construct new sewers and wastewater treatment plants to meet regulations if the wastewater collection system is subject to excessive inflow and infiltration.

Consequently municipalities must reduce I/I to the extent that is cost effective and properly maintain the wastewater collection system to comply with regulations.

Reducing infiltration/inflow is good practice because it allows the collection system to handle greater quantities of wastewater.

Negligence and vandalism are also sources of collection system problems.

Vandals may place objects such as rocks and tree branches in manholes, causing blockages.

Contractors repaving roads have allowed material to enter manholes. Any material in a sewer will slow the flow and allow other solids to settle.

Fortunately there exist today properly designed, constructed, operated and maintained collection systems that can serve as examples of how the job should be done.

Leakage should not be a problem in properly constructed and maintained sewers.

Wastewater Collection Systems

Operation and maintenance of wastewater collection systems on a trouble or emergency basis has been the usual procedure and policy in many communities and districts.

Planned operation and preventive maintenance of the collection system has been delayed or omitted, in spite of desires by collection system operators.

Municipal officials tended to neglect collection systems as long as complaints were not excessive.

To please constituents, officials often demanded street and sidewalk repair be done by collection system crews, but seldom have they ever demanded preventive work on collection systems.

Why Have Collection Systems?

First we should consider why we have wastewater collection systems and then I think we will understand why we should take care of them. Collection systems were built to remove diseases that man comes in contact with when he lives surrounded by other people and their wastes. Roman and other early civilizations built drains and aqueducts to carry away their wastes

Wherever large population centers developed, a means of waste handling and removal was needed

In 1888, Dr. McVail reviewed the Methods and Objectives of Preventive Medicine. Three basic lines of defense were outlined as constituting the preventive measures

They were

- ◆ sanitation (cleanliness),

- ◆ inoculation (vaccination for protection against diseases), and

- ◆ isolation (keeping sick people away from healthy people)

Sanitation was considered the most important of the three. Also emphasized was the need for a good environment suitable for humans.

Comparisons of Collection Systems

You will find city and county officials that will know the cost of each building and their total building budget. Bridges and parks are obvious and everyone can see neglect, but you will find few city and county officials who know for sure how many feet of sewers they have and the number of man-holes in their system.

Few cities or agencies have correct maps of their wastewater collection system or of the connections to the system.

Officials become aware of sewers mainly when the service is inadequate, a stoppage occurs, the system fails, or odors are produced.

We know how many pumping plants are in the collection system, where the wastewater treatment plants we have are located, and the number of people we think it takes to operate and maintain them. Numbers of operators will vary from city to city, but you will find some agreement

Unfortunately officials often forget or neglect adequate inspection during construction, and fail to budget adequately for personnel and equipment requirements for the proper operation and maintenance of collection systems. Consider comparisons of collection systems with highways, traffic signals and railroad crossings.

- ◆ Highway and Street Comparison
- ◆ Traffic Signal Comparison

Wastewater Collection Systems

◆ Railroad Crossing Comparison

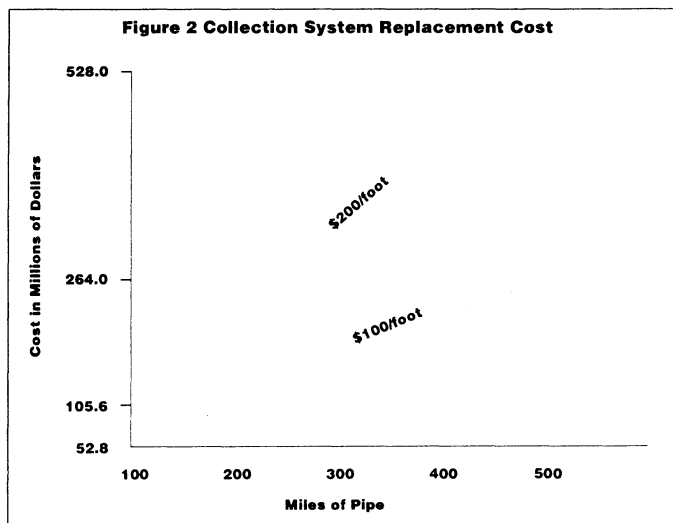
The same thing happens when you have a manhole that is in the roadway and causes a bump, or the manhole cover rattles and keeps someone awake. They're interested in your collection system for the first time. Not quite so; just in the manhole that caused the bump or rattle.

You will find that the underground collection system won't draw much attention from anyone until the flow starts coming out of a manhole or some other low overflow point, such as a basement drain or shower drain in a home.

The Cost of Wastewater Collection Systems

When collection systems are installed, they sometimes cost significantly more than the cost of the wastewater treatment plant.

If for some reason, the collection system fails in, let's say, twenty years, the cost per foot for replacement could be as much as ten times its original cost.



In some locations the replacement is practically

impossible and extremely expensive because of the crowding of other utilities, and the fact that everything is going underground now makes this even more of a problem.

The collection system is a capital asset that the community has invested heavily in. Let's examine the replacement costs of a collection system using \$100/foot and \$200/foot. In a small system of 100 miles, the investment ranges from \$52.8 million dollars at \$100/foot to \$105.6 million dollars at \$200/foot.

We need to begin to operate and maintain the collection system as a business including asset management. Instead of looking at O&M as overhead, we should consider it a value added activity which means we are adding value to the original investment, by maintaining capacity and extending its useful life.

If the collection system is considered an asset, then we need to consider life cycle cost, both as a design parameter and as a guide to O&M needs. The life cycle cost of a piece of equipment or system is the entire cost over its lifetime. Life cycle cost has two components, acquisition cost and ongoing costs. The acquisition cost is a onetime cost for the initial purchase. Ongoing costs are those costs that occur continuously for O&M such as energy, repair, component replacement, and rehabilitation from the time the system is started until the end of its useful life.

The ratio of life cycle costs to acquisition costs can cover a wide range depending on the equipment or system. The US Navy for example, uses a ratio of 2.5 for its capital ships. A 1970 study done on consumer products showed ratios from 1.9 to 4.8. Another way to consider this ratio is that the ongoing costs to operate and maintain are 1.9 to 4.8 times the original acquisition cost.

While this type of analysis is common in private sector maintenance programs, it is not common in public sector collection systems O&M management. O&M budgets for collection systems to provide the level of maintenance necessary to protect the capital investment and minimize failures that are O&M related are usually severely underfunded.

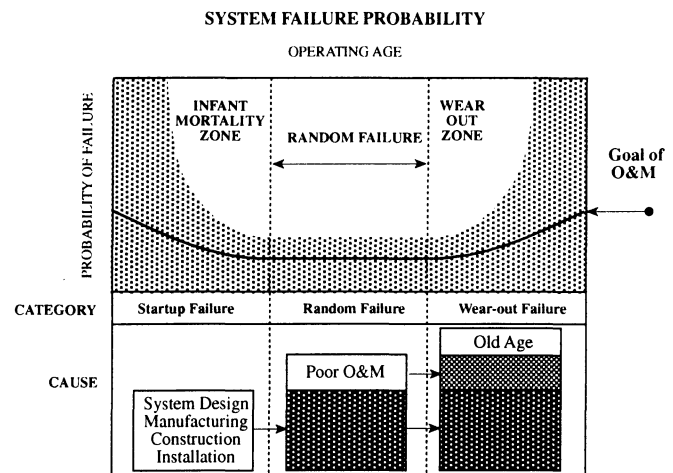
Why Operation and Maintenance of the Wastewater Collection System?

What Is Operation and Maintenance?

Collection systems means sewers, pipelines, conduits, pumping stations, force mains, and all other facilities used for the collection of wastewater from individual service connections to facilities to provide treatment prior to discharge to the environment. The primary purpose of collection systems is to convey wastewater in a manner that protects the public's safety and health and the environment, by operating and maintaining the system so that overflows and bypasses are minimized.

Raw sewage transmits polio, cholera, tuberculosis, typhoid, Weil's disease, tetanus, hepatitis and a wide variety of other diseases. In addition, the discharge of raw sewage has a detrimental effect on the environment. The performance of the wastewater collection system is critical to the health and safety of the community and the surrounding environment and the performance goal for the system is to "keep it in the pipe."

If we are going to reduce O&M related failures, we need to make major changes in the way we operate and maintain collection systems. To do that we need to know what factors affect collection equipment and systems, and what the effect is on collection system performance. The failure rate of a piece of equipment, a pump for example, or a system such as a gravity sewer as a function of its age, is illustrated in the following figure.



The probability of failures occurring is high during start-up, stabilizes once into the O&M period and begins to increase as the useful life is reached. Start-up failures are caused by errors in;

- ◆ Design,
- ◆ manufacturing,
- ◆ construction, and installation.

Unfortunately, many of these errors carry over into the O&M period and affect the performance of the system. A pump that is installed in a station with inadequate Net Positive Suction Head available is an example of a design problem that is nearly impossible to rectify once construction is complete. Hydrogen sulfide production and the resulting odor and corrosion problem would be another.

During the O&M period of the system, failures occur as a result of operational errors and inadequate maintenance of the system, in addition to the cumulative problems from the start-up phase. Finally, increases in premature failures that are costly to repair begin to increase, signalling the end of the useful life of the equipment or system. The

Wastewater Collection Systems

cumulative effect of the failures are;

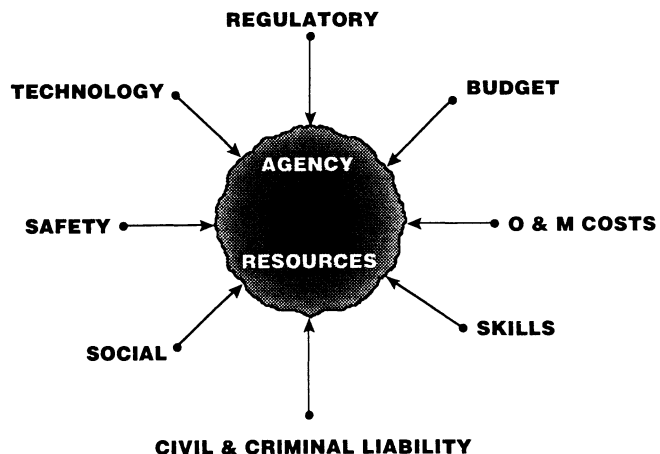
- ◆ Substandard performance such as bypasses, overflows, reliability and equipment availability,
- ◆ higher O&M costs, (reactive maintenance is always more costly than proactive maintenance),
- ◆ reduction of the useful life of the system and equipment, and
- ◆ higher rehabilitation/replacement costs.

Operation and maintenance of a wastewater collection system can be defined as O&M activities that result in conveying wastewater safely and efficiently. The results of the activities are the protection of public health and safety and the environment.

Collection System Operation and Maintenance In The 90's And Beyond

Now let's look at the elements that affect an O&M program:

So far, we have discussed collection system O&M from a past history perspective. Now let's take a look at collection system O&M in the future.



All public agencies resources are facing increasing pressure from external sources. The effect of these pressures will require those of us responsible for O&M to do a better job of managing our resources more effectively. These pressures are:

- ◆ Regulatory – More federal, state and local regulations.
- ◆ Budget – Reduction of federal and state money.
- ◆ O&M Costs – Rising costs of O&M.
- ◆ Skills – Reduction of skills in the labor pool.
- ◆ Civil and Criminal Liability – Fines and jail time for O&M staff.
- ◆ Social – ADA, EEO.
- ◆ Safety – More regulations and enforcement.
- ◆ Technology – Increased use of technology in collection systems.

Summary

Those responsible for collection system O&M, are in a better position than anyone else in an agency to manage resources.

We Operate A Wide Range of Equipment

- ◆ Jet machines
- ◆ Rodders
- ◆ Combination machines
- ◆ Bucket machines

Wastewater Collection Systems

- ◆ Pickup trucks
- ◆ Dump trucks
- ◆ Backhoes
- ◆ Generators
- ◆ Compressors
- ◆ Pump stations
- ◆ TV Inspection equipment
- ◆ Grouting equipment

We Are Responsible For

- ◆ Capitol investment
- ◆ Public health
- ◆ Environment
- ◆ Operating expenses
- ◆ Emergencies

We Need A Broad Range of Knowledge and Skills

- ◆ Safety - Survival
- ◆ Electrical
- ◆ Mechanical
- ◆ Hydraulics
- ◆ Construction

- ◆ Design

Our Jobs Require

- ◆ Planning
- ◆ Teamwork
- ◆ Thinking on our feet
- ◆ Decision making

Because of the importance of collection systems, there will be increased opportunities for anyone choosing to work in this field. The work will become even more interesting, challenging and rewarding for those who are prepared professionally to take advantage of the opportunities.

DESIGN AND COMPONENTS

Persons responsible for the operation and maintenance of wastewater collection systems usually are not the ones responsible for the design, construction and inspection of these systems. A basic knowledge of the components of collection systems, their purpose, and how engineers design the systems will help you do a better job. At the same time, such knowledge will enable you to discuss design, construction and inspection with engineers.

Collection system operators who know how and why wastewater collection systems work, should and will be consulted by design engineers for the purpose of improving the design and construction of future systems.

Understanding the design and construction of the system you will be responsible for operating and maintaining also will assist you in determining the correct action to take when the system fails to operate properly. In some emergency situations you may be called upon to design and to construct small, temporary portion of the wastewater system you are maintaining.

The purpose of a wastewater collection system is to collect and convey the wastewater from a community's homes and industries. The water carries the wastes in the form of either dissolved or suspended solids.

Purpose

Wastewater collection systems must be properly designed and constructed to provide a water velocity of around 2.5 feet per second. Velocities which are too high or too low can be detrimental to the operation and maintenance of a collection system.

The collection system conveys the wastewater and solids to a treatment plant where the pollutants are removed before the treated wastewater is discharged to a body of water or onto land.

Wastewater Collection Systems

The wastewater in collection systems is usually conveyed by gravity utilizing the natural slope of the land.

Wastewater pumps are used when the slope of the land requires lifting the wastewater to a higher elevation for a return to gravity flow.

Pumps and other mechanical equipment require extensive maintenance and costly energy to operate so their use should be avoided whenever possible.

Thus the location and design of the components of a collection system are strongly influenced by the topography (surface contour) of its service area. In some instances, where the topography is unfavorable for a gravity collection system, a pressure or vacuum collection system may be used.

Collection system operators need to recognize the differences between the sanitary wastewater collection systems described above, a similar storm water system, and a combined storm and wastewater collection system.

A storm water collection system conveys water resulting from runoff of rainfall and snow melt from buildings and surrounding unpaved and paved areas to a natural watercourse or body of water, usually without treatment.

This system also conveys excess water supplied to urban areas for irrigation and surface cleaning.

A combined wastewater and storm water collection system conveys a combination of these waters to a treatment plant.

Occasionally an excessively heavy rain or cloud burst may produce flows which exceed the wastewater treatment plant's capacity.

The excess flow may be diverted to specially designed holding tanks or lagoons for storage until the high flows recede.

The stored water is then returned to the plant for proper treatment. In a few older communities with combined wastewater collection systems, provisions are usually made to relieve the collection system and treatment plant by diverting the excess flow and providing partial treatment plus disinfection before discharging the flow to water or onto land.

Quantity of Wastewater

The amount of wastewater that a collection system will convey is determined by careful analysis of the present and probable future quantities of:

- ◆ residential, commercial and industrial wastewater.
- ◆ anticipated groundwater INFILTRATION and surface water INFLOWS produced in the service area.
- ◆ The sanitary sewers that make up a collection system are usually designed to convey the peak flow from all of these sources.

Design Period

Ideally a wastewater collection system should be designed to convey the estimated peak flow from its service area when the area has reached its maximum population and has been fully developed commercially and industrially.

However, it is not always economically feasible to construct some of the major sewers in a system large enough to convey the ultimate peak flow from its service area.

Under these circumstances the sewers are designed to convey peak flows that are estimated to occur within an appropriate design period, generally

Wastewater Collection Systems

Design Flows

ranging from 10 to 30 years.

Provisions should be made when planning a collection system to provide for expansion of the system before the actual flows become greater than the design flows.

Once the design period has been determined, design flows that will occur during the period are calculated based on the estimated population, per capita wastewater discharge and industrial and commercial wastewater discharges that will occur at the end of the period.

The following information is provided to show you how a design engineer calculates needed flow capacities.

It will also be useful to you, as the system operator, in predicting and managing the increasing flows that accompany commercial and residential development in your service area.

Population estimates can sometimes be obtained from a planning agency that has data covering the collection system's service area. If such information is not available, population estimates are made by using the most appropriate method.

Suitable methods for making the estimates include an arithmetic increase per year, uniform percentage growth rate based on recent census periods, graphical comparison with the growth of other similar but larger cities, and graphical extension of past growth.

Domestic wastewater flow is calculated by multiplying the estimated population in the collection system service area by the per capita flow factors.

Typical per capita flows from residential sources

Design and Components

range from 70 to 100 gallons per day per person.

Wastewater flows from commercial and industrial areas are usually estimated in terms of gallons per day per acre, based on the type of development and measured flows from similar existing developments.

Estimation of flows from a proposed unsewered industrial area can be very difficult. Industrial discharges vary widely due to the types of manufacturing processes used by the industries.

Information from local zoning commissions regarding the types and sizes of industries expected and permitted to use the area can be very helpful.

Typical sewer capacity allowances for commercial and industrial areas are outlined in Table 2.1

Wastewater Collection Systems

Table 2.2 shows ranges of average flows for several different types of commercial establishments.

Table 2.1 Sewer Capacity Allowances for Commercial and Industrial Areas

CITY	YEAR DATA PUBLISHED OR OBTAINED	COMMERCIAL ALLOWANCES (GPD/ACRE)	INDUSTRIAL ALLOWANCE (GPD/ACRE)
Cincinnati, OH	1980	Case-by-case determination after consultation with the Directors of Sewers.	
Dallas, TX	1960	30,000 added to domestic rate for downtown; 60,000 for tunnel relief sewers.	
Grand Rapids, MI	1980	Offices, 40-50 GPD/cap; hotels, 400-500 GPD/room; hospitals, 200 GPD/bed; schools, 200-300 GPD/room.	
Hagerstown, MD		Hotels, 180-250 GPD/room; hospitals, 150 GPD/bed; schools, 120-150 GPD/room.	
Houston, TX	1960	Peak flows: offices 0.36 GPD/sq. ft; retail 0-20 GPD/sq ft; hotels 0.93 GPD/sq ft.	
Las Vegas, NV		Resort hotels, 310-525 GPD/room; schools, 15 GPD/cap.	
Los Angeles, CA	1980	Commercial, 100 GPD/1,000 sq ft gross floor area; hospitals, 500 GPD/bed (surgical), 85 GPD/bed (convalescent); schools, elementary or junior high schools, 10 GPD/student; high schools, 15 GPD/student; universities, 20 GPD/student. The above values give peak flow rates. Divide by 3.0 to obtain average flow rates.	15,500
Los Angeles Co. San. District, CA	1980	4,000 - 6,000	
Lincoln, NE	1962	7,000	
Milwaukee, WI	1980	240,000 (max); 25,800 (min)	
St. Joseph, MO	1962	64,000 (downtown) 25,800 (neighborhood)	
St. Louis, MO	1960	90,000 average, 165,000 peak	
Santa Monica, CA	1980	Commercial, 9,700; hotels, 7,750	13,600
		Toronto, Ont., 1980 consumption in the CANADA downtown area is acre. GPD is gallons per day cap is capita	Analysis of actual water commercial and industrial approximately 20,000 GPD/

Table 2.2 Average Commercial Flows

Type of Establishment	Avg Flow (gpd/cap)
-----------------------	--------------------

Inflow and Infiltration

Stores, offices, and small businesses	12 to 25
Hotels	50 to 150
Motels	50 to 125
Drive-in theaters (3 persons per car)	8 to 10
Schools (no showers), 8-hr period	8 to 35
Schools (with showers), 8-hr period	17 to 25
Tourist and trailer camps	80 to 120
Recreational and summer camps	20 to 25

Some infiltration of groundwater and inflow of surface water occurs in all wastewater collection systems and capacity must be provided for this additional flow.

Table 2.3 outlines the infiltration design allowance for several cities.

Table 2.3 Infiltration Design Allowance for Several Cities

City	Allowance (GPD/acre)	Remarks
Seattle, WA	1,100	
Bay City, TX	1,000	
Lorain, OH	1,000	
Marion, OH	750	Calculations based on a proposed density, with a 100 GPD/cap average flow and peak of 400 GPD/cap also often used.
Ottumwa, IA	600	Infiltration and exfiltration shall not exceed 200 gal per inch of pipe diameter per mile of pipe per 24 hr period.
West Springfield, MA	2,000	
Alma, MI	140	

The amount of infiltration entering through cracks in pipes, joints and manholes will vary with age and condition of the collection system and the portion of the system that is submerged in groundwater.

The amount of inflow will vary with the number of manholes in a collection system that become submerged in surface water and the number of surface water drainage sources, such as roof drains, that are illegally connected to the collection system.

Tests have shown that a manhole cover that has 1 inch of water over it can allow 20 to 75 gallons per minute (GPM) into the sewer, depending on the number and size of holes in the cover.

Wastewater Collection Systems

A roof connection on a house with 1100 square feet of surface area can drain at a rate of 11 GPM during a rainstorm of 1 inch per hour.

Inflow can be reduced by sealing manhole covers that are subject to flooding during the winter months.

Design allowances for infiltration normally include allowances for inflow. Combined collection systems are designed similar to sanitary collection systems with the addition of storm water flows .

The flow of wastewater in a collection system (exclusive of infiltration and inflow) will vary during a 24-hour period with the minimum flow occurring during the early morning and the maximum occurring around noontime.

Infiltration can also be expressed in construction specifications in terms of pipe diameter, as shown in Table 2.4.

Table 2.4 Infiltration Specification Allowances

Pipe Diam (In.)	Infiltration Permitted	
	(gpd/mile)	(gpd/in. diam/mile)
8	3,500 to 5,000	450 to 625
12	4,500 to 6,000	375 to 500
24	10,000 to 12,000	420 to 500

Peaking Factors

Table 2.5 lists the ratio ranges of maximum and minimum flows to average daily wastewater flow recommended for use in design by various authorities. The ratios in Table 2.5 are often called PEAKING FACTORS.

Table 2.5 Design Ratios of Minimum and Maximum To Average Daily Flow

Population, in thousands	Ratio Ranges	
	Minimum	Maximum
1	0.20	3.9-5.5

Design and Components

5	0.26-0.27	3.3-4.5
10	0.29-0.32	2.9-4.0
50	0.39-0.44	2.3-2.9
100	0.43-0.50	2.0-2.6
200	0.48-0.57	1.8-2.3
500	0.55-0.69	1.5-1.9

The estimated design flow for a typical wastewater collection system can be calculated given the following information on the system's service area and the assumed flow data.

Given Information:

Service area	10,000 acres
Present population	30,000 people
Estimated design period population	50,000 people
Estimated commercial area	500 acres
Estimated industrial area	700 acres

Assumed Flow Data:	
Per capita flow	85 gallons per day per person (GPCD)
Commercial flow allowance	5,000 GPD/acre
Industrial flow allowance	13,000 GPD/acre
Infiltration flow allowance	600 GPD/acre

Design Flow:
Residential flow,

$$\frac{(50,000 \text{ people})(85 \text{ GPD/Capita})}{1,000,000/\text{M}} = 4.25 \text{ MGD}$$

Peak residential flow,

$$4.25 \text{ MGD} \times 2.6 \text{ peaking factor} = 11.05 \text{ MGD}$$

Commercial capacity allowance,

$$\frac{(500 \text{ acres})(5,000 \text{ GPD/acre})}{1,000,000/\text{M}} = 2.50 \text{ MGD}$$

Industrial capacity allowance,

$$\frac{(700 \text{ acres})(13,000 \text{ GPD/acre})}{1,000,000/\text{M}} = 9.10 \text{ MGD}$$

Infiltration and inflow capacity allowance,

$$\frac{(10,000 \text{ acres})(600 \text{ GPD/acre})}{1,000,000/\text{M}} = 6.00 \text{ MGD}$$

$$\text{Total design flow} = \underline{28.65 \text{ MGD}}$$

$$(11.05 + 2.50 + 9.10 + 6.00)$$

While the above example provides a method to estimate design flow for a collection system, it should be noted that the data that was used can vary widely, from geographical area to geographical area

Wastewater Collection Systems

Flow Measurement

for a wide variety of reasons. For example, in the southwest where drought conditions are experienced, very aggressive water conservation programs have been implemented in many areas. The use of mandated low consumption devices such as toilets and showerheads, will reduce estimated flows used in the above example significantly. These variations or considerations need to be taken into account when developing design flow data in your area.

Collection system operators will need to know the fundamentals of wastewater flow measurement in a sewer pipe. There are many devices available for flow measurement.

All of these flow meters are based on the simple principle that the flow rate equals the velocity of flow multiplied by the cross-sectional area of the flow. This principle is expressed by the following formula:

Q , in cubic feet per second = (Area, sq ft)(Velocity, ft/sec).

Calculation of the cross-sectional area of flow in a circular sewer line that is not full is somewhat complex and will not be covered in the basic course.

Velocities in Sewers

Velocities should be measured in the field to be sure ACTUAL velocities are high enough to prevent the deposition of solids. If roots or other obstructions get into a sewer, design velocities can be reduced and problems develop.

Actual velocities in sewers can be measured by using dyes or floats.

Realize that velocities vary during the day depending on the activities of the tributary population.

A scouring velocity should be reached or exceeded

during peak flows, but probably will not be reached during low flow periods.

Actual velocities should be measured in the field, rather than estimating the velocities by the use of hydraulic formulas which give the theoretical velocity.

DYES. Tracer dyes are very effective for estimating velocities.

Put into the upstream manhole the smallest amount of dye that can be seen easily in the downstream manhole.

Fluorescent tracer dyes can be obtained from chemical suppliers.

The supplier of chemicals for a wastewater treatment plant is a good source to recommend the proper type of dye.

The amount of dye used will depend on the type of dye, diameter of sewer and estimated flow in the sewer.

After the dye has been inserted in the flow at the upstream manhole, measure and record two readings:

Total travel time from insertion of dye until the dye is first seen at the downstream manhole T1, and

Total travel time from insertion of dye until the dye is no longer visible at the downstream manhole T2.

The average travel time is $(1/2)(T1 + T2)$.

The average velocity is calculated by dividing the distance (between manholes) by the average time.

Wastewater Collection Systems

$$\text{Velocity, ft/sec} = \text{Distance, ft} / \text{Average Time, sec}$$

Floats are used to estimate velocities in existing sewers flowing partially full.

A float could be a stick, an orange, or any other object that can be easily identified and that travels down the sewer at a velocity similar to the wastewater.

Velocity is determined by recording the time the float takes to travel a known distance, such as the distance between manholes.

Most surface floats such as sticks or oranges travel from 10 to 15 percent faster than the average velocity due to the velocity differences between the surface and bottom sections of the flowing water.

Example- Calculating Velocity

A stick travels the 400 feet between two manholes in three minutes and 20 seconds (200 seconds). Estimate the velocity in the sewer.

KNOWN

$$\begin{aligned} \text{Distance, ft} &= 400 \text{ ft} \\ \text{Time, sec} &= 200 \text{ sec} \\ \text{Velocity, ft/sec} &= \frac{\text{Distance, ft}}{\text{Time, sec}} \\ &= \frac{400 \text{ ft}}{200 \text{ sec}} \\ &= 2 \text{ ft/sec} \end{aligned}$$

Note: The velocity of the stick (2 ft/sec) is 10 to 15 percent faster than the average velocity of the wastewater in the sewer.

Average Velocity, ft/sec

$$= 2 \text{ ft/sec} - 2 \text{ ft/sec}(0.10 \text{ to } 0.15)$$

= 2 ft/sec - 0.2 to 0.3 ft/sec

= 1.7 to 1.8 ft/sec

Flow Variations

Knowledge of the daily and annual variations or fluctuations in a collection system's wastewater flow is useful in planning maintenance programs for the system.

For example, collection system hydraulic cleaning operations using the flow in the system should be scheduled during the hours of sufficient flows.

On the other hand, cleaning with bucket equipment should be scheduled during the hours of minimum flow in the system.

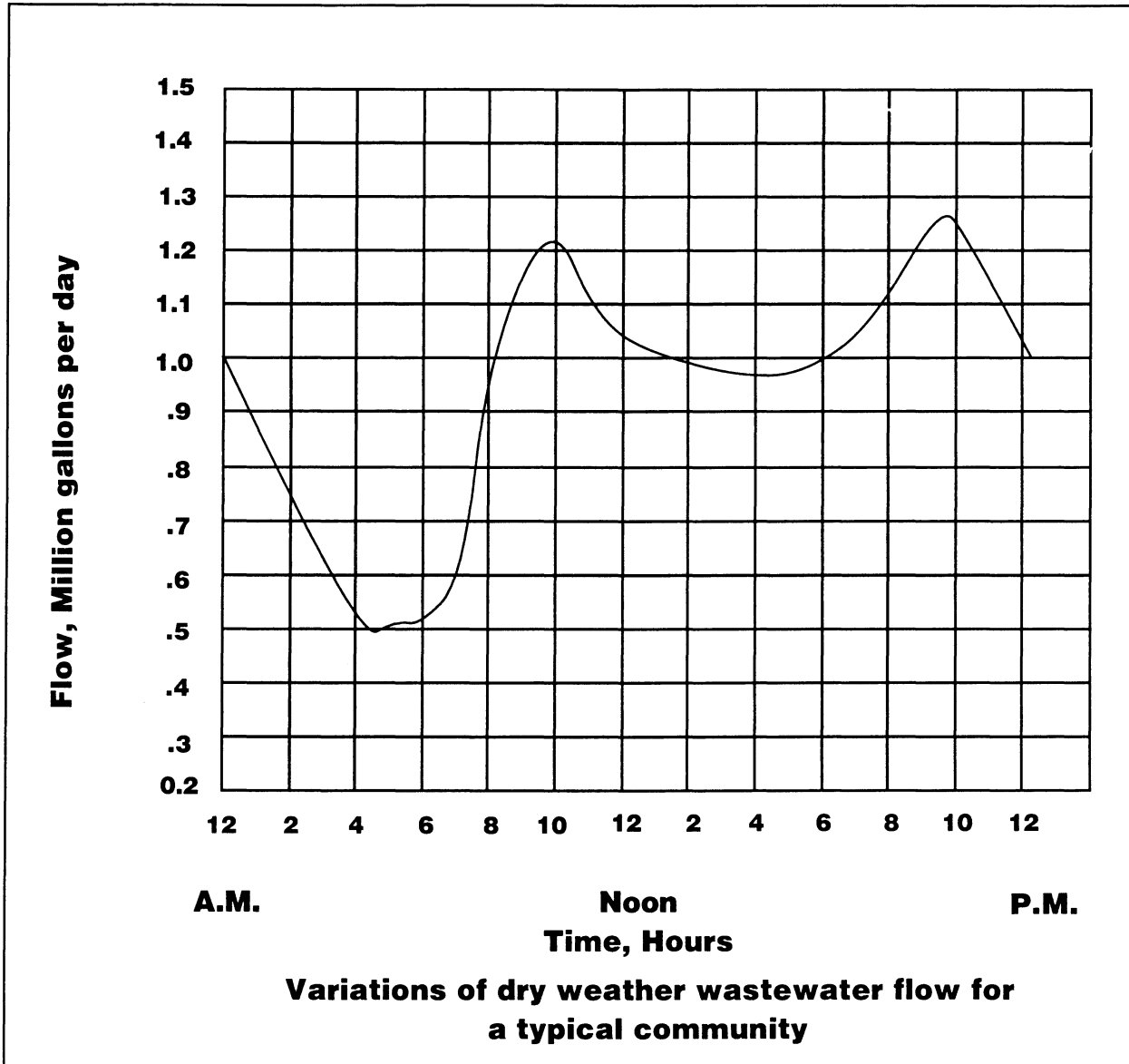
Upstream diversion of flow, if possible, should always be considered as a means of developing an optimum maintenance schedule.

The following figure illustrates daily fluctuations of dry weather wastewater flow from a typical residential community. The chart illustrates the amount of flow which is shown on the vertical axis of the chart against the time of day which is shown on the horizontal axis of the chart. Beginning at 12:00 a.m. we see that flow is at 1 mgd and begins to drop off to a minimum of .5 mgd just after 4:00 a.m. in the morning. This is typical of residential flow when people go to bed at night and are no longer using water for showers, washing clothes, doing dishes, etc.

A local industry that operated 24 hours a day and discharged process wastewater, would have an effect on the minimum flow. The flow increases from the minimum at just after 4 a.m. As domestic and commercial water consumption increases and peaks at 1.3 mgd at 10:00 a.m. Flow then begins to diminish, however a second peak occurs just before 10:00 p.m. at night and then begins to diminish

Wastewater Collection Systems

once again to 1 mgd at 12:00 p.m. The ratio of maximum flow to minimum flow is 1.3 mgd / .5mgd or a dry weather peaking factor of 2.6.



This type of graph which tracks the diurnal or daily flow changes as a function of time is a good diagnostic tool to determine the condition of the collection system and the amount of inflow or infiltration occurring. If plotted on a frequent basis and analyzed, it would also provide indications of potential problems that have occurred such as a broken or collapsed line when significant variations from historical data is noticed.

An industry with a significant wastewater discharge would impose a different flow fluctuation on a collection system depending on its pattern of wastewater discharge.

This can be determined by flow measurement. You could then construct a combined fluctuation chart, similar to the chart, for the flows from your combined residential and industrial sources, or the fluctuation in total flows could be measured in the collection system downstream of the point of combined flows.

To construct a chart showing your system's annual flow fluctuations, calculate the typical monthly residential flows.

Add to these amounts any industrial flows including known or estimated fluctuations.

Next, add in your estimates of infiltration and inflow amounts, on a monthly basis. Infiltration and inflows will vary proportionally to the seasonal variation in groundwater levels and rainfall intensity.

Graph the monthly amounts as you did for daily totals.

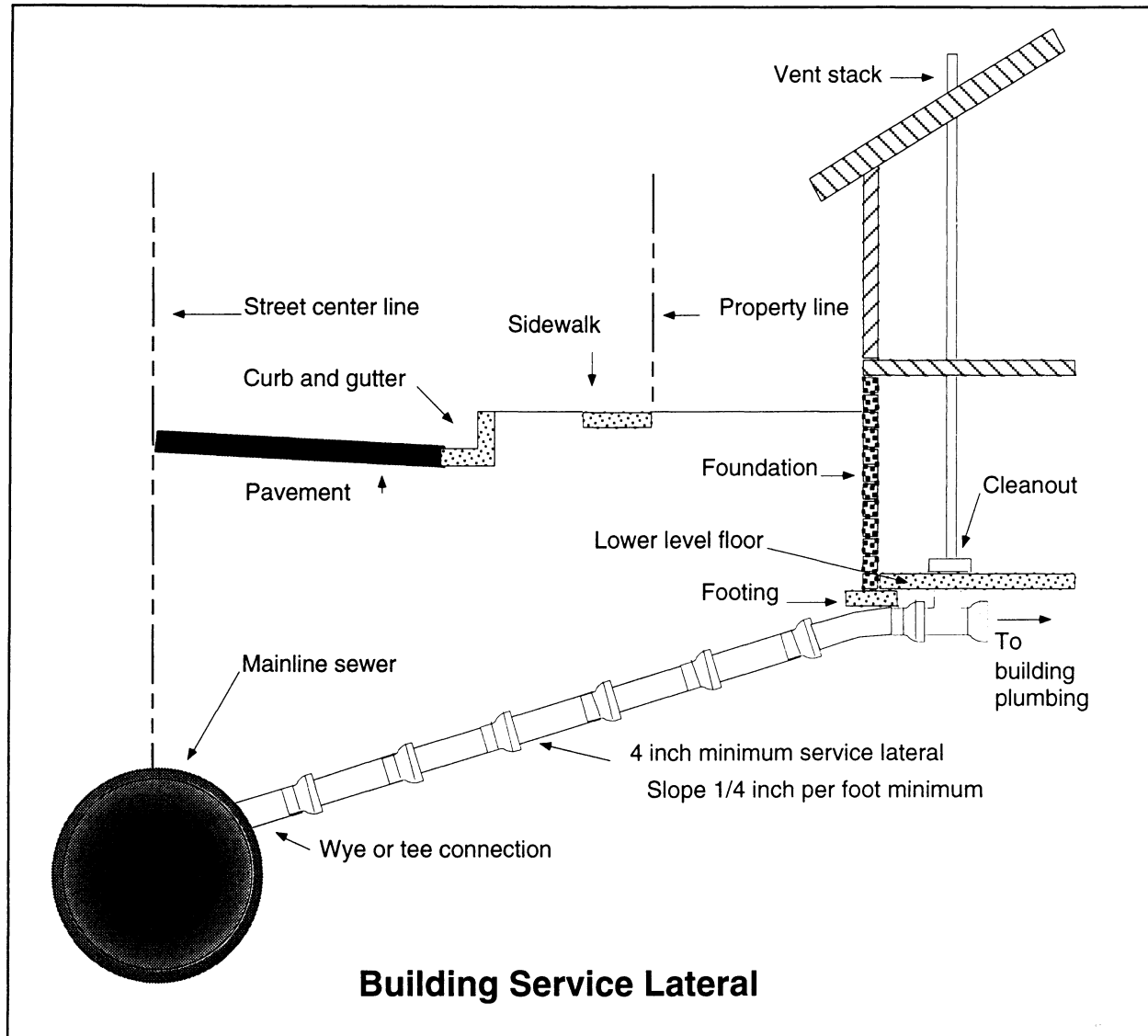
The resulting chart can be used to help you plan long-term periodic maintenance activities.

Gravity Sewer System Components

Lets take a wastewater collection system apart and identify the parts and their purposes. In doing this we will start at the upper end (highest point) and follow the flow path of wastewater through the system.

In a gravity wastewater collection system, wastewater from residences, commercial and industrial developments is collected and conveyed to waste-

Wastewater Collection Systems



water treatment plants through the following parts of the collection system:

Note: When discussing wastewater collection systems, keep in mind that there will be inconsistencies in definitions and terminology.

Building Sewers. A building sewer connects a building's internal wastewater drainage system (plumbing) to the larger street sewer. Most operators refer to these as lateral sewers, house laterals or service laterals.

Design and Components

Technically, a building sewer may connect with a lateral sewer, a main sewer, or a trunk sewer, depending on the layout of the system. (All of these sewers are parts of the sewer in the street.)

The building sewer may begin immediately at the outside of a building or some distance (such as 2 to 10 feet) from the foundation depending on local building codes.

Where the sewer officially begins marks where the building plumber's responsibility ends and the collection system operator's responsibility starts for maintenance and repair of the system. The following figure illustrates a typical building sewer.

Lateral and branch sewers are the upper ends of the street sewer components of a collection system, and in some instances lateral and branch sewers may be located in easements.

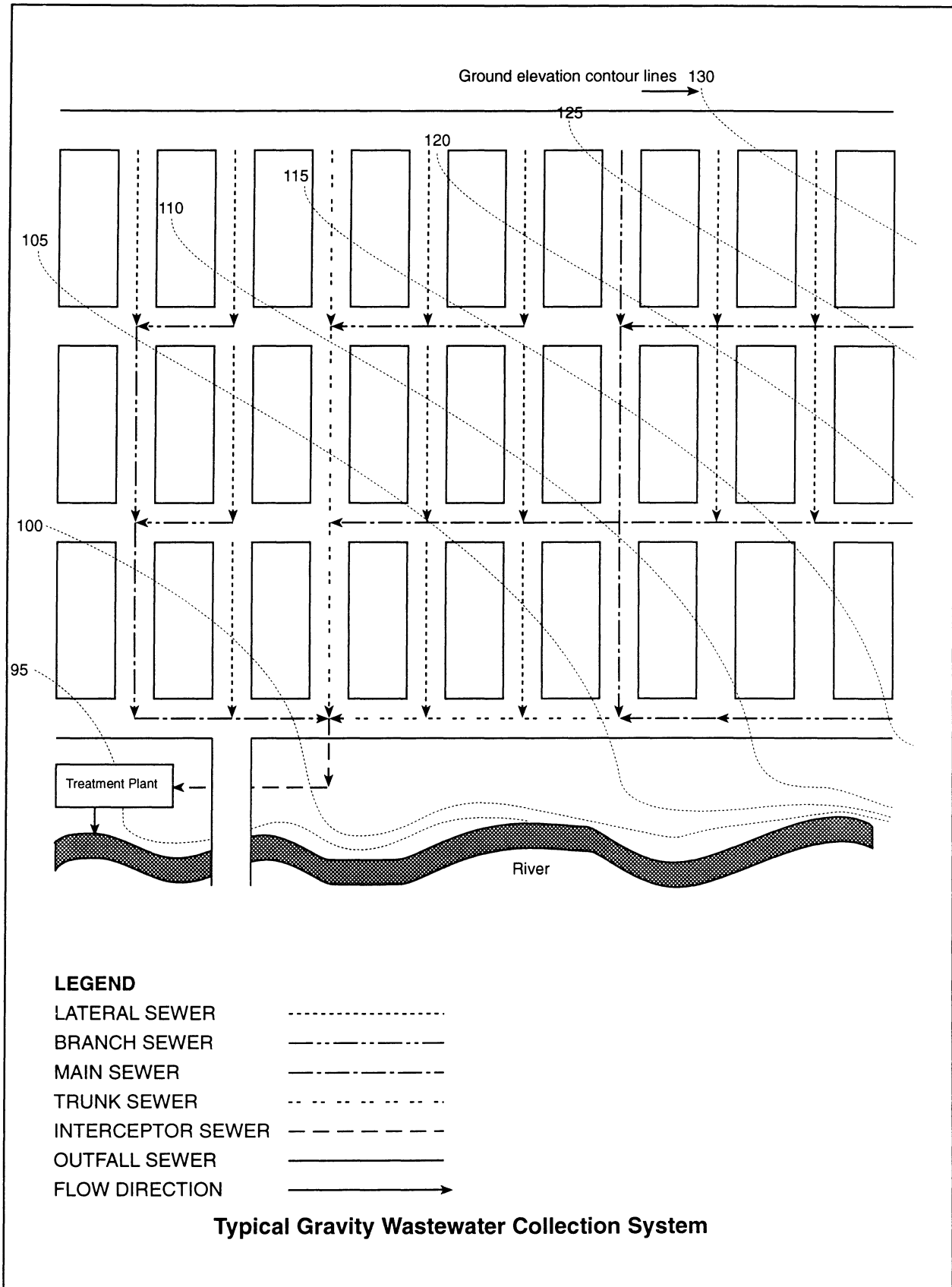
This location should be avoided where possible due to maintenance problems created by locations with difficult access and limited work space. A typical gravity wastewater collection system showing layout is shown in the next figure.

Main Sewers collect the wastewater of several lateral and branch sewers from an area of several hundred acres and convey it (the wastewater) to larger trunk sewers.

Trunk Sewers are the main "arteries" of a wastewater collection system and convey the wastewater from numerous main sewers either to a treatment plant or an interceptor sewer.

Intercepting Sewers receive the wastewater from trunk sewers and convey it to the treatment plant. Some of the trunk sewers may have previously discharged directly into bodies of water or may have routed wastewater to now abandoned treatment plants.

Wastewater Collection Systems



Alternative Sewer System Components

Lift Stations are used in a gravity collection system to lift (pump) wastewater to a higher elevation when the slope of the route followed by a gravity sewer would cause the sewer to be laid at an insufficient slope or at an impractical depth.

Lift stations vary in size and type depending on the quantity and height the wastewater is to be lifted. Sizes and types of lift stations will be covered later in this course.

Low Pressure Sewer Systems may be used when the topography and ground conditions of an area are not suitable for a conventional gravity collection system due to flat terrain, rocky conditions or extremely high groundwater. Pressure sewers may be installed instead of gravity sewers in an area because;

- ◆ a pipe slope is not practical to maintain gravity flow,
- ◆ smaller pipe sizes can be used due to pressurization, and
- ◆ reduced pipe sizes can be installed due to a lack of infiltration and inflow because the pipeline has no leaks and water does not enter the system through access manholes.

Operation and maintenance considerations when comparing pressure sewers with gravity systems include the facts that pressure systems have:

- ◆ higher energy costs for pumping,
- ◆ greater costs for pumping facilities,
- ◆ fewer stoppages,
- ◆ no root intrusion,

Wastewater Collection Systems

- ◆ no extra capacity for infiltration and inflow,
- ◆ no deep trenches or buried pipe, and
- ◆ no inverted siphons for crossing roads or rivers.

The principal components of a low pressure collection system include gravity sewers, holding tanks, grinder pumps and pressure mains.

Gravity sewers connect a building's wastewater drainage system to a buried holding tank located on the lot.

Holding tanks serve as a reservoir for grinder pumps and have a capacity of approximately 50 gallons.

Grinder pumps serve both as a unit to grind the solids in the wastewater (that could plug the downstream small diameter pressure sewers and valves) and to pressurize the wastewater to help move it through the collection system.

Pressure mains are the "arteries" of the low pressure collection system and convey the pressurized wastewater to a treatment plant.

Since the wastewater is "pushed" by pressure, the mains are not dependent on a slope to create a gravity flow and can be laid at a uniform depth following the natural slope of the land along their routes.

Low pressure collection systems must have access for maintenance. This means line access where a PIG can be inserted into a line for cleaning and also removed from the line. Manholes or boxes must have valves and pipe spools (two to three foot long flanged sections of pipe) that can be removed for cleaning the pipe or for pumping into or out of the system with a portable pump.

Vacuum Collection System

Vacuum collection systems are another alternative to a gravity collection system. The vacuum systems are installed for the same reasons that low pressure collection systems are used. Operation and maintenance of vacuum systems are more difficult than low pressure systems because it is harder to maintain a vacuum due to the number of inlets and valves to the system. Principal components of a vacuum collection system include gravity sewers, holding tanks, vacuum valves, vacuum mains and vacuum pumps.

Gravity sewers connect a building's wastewater drainage system to a vacuum interface unit.

A vacuum interface unit seals the vacuum service and connects the vacuum sewer to the gravity flow system from a home. This unit maintains the required vacuum level in the main vacuum sewer system. When approximately three gallons of wastewater has accumulated at the vacuum interface unit, a valve is activated which allows atmospheric air pressure to force the wastewater into the vacuum branch.

Vacuum mains are the “arteries” of a vacuum collection system and convey the wastewater to a treatment plant. Since the wastewater is “sucked” by vacuum, the collection mains do not have to be laid at a slope to produce a gravity pull on the wastewater and the mains may be laid at a uniform depth following the natural slope of their routes.

Vacuum pumps are installed in a central station usually adjacent to a treatment plant and maintain the appropriate vacuum in the main collection system. Access must be provided for maintenance.

Appurtenances

The immediately preceding sections described the principal components of a wastewater collec-

Wastewater Collection Systems

tion system consisting primarily of sewer piping and pumps. This section will describe the appurtenances to a collection system that facilitate and control the flow of wastewater and provide for the access to maintain the collection systems.

Backflow preventers are used to stop the accidental backflow or reverse flow of wastewater into buildings. They function by either allowing wastewater to flow out of a building sewer at a point outside and below the floor elevation of a building or by blocking the backflow of wastewater from the sewer into the building sewer by a one way hinged valve (check valve). Backflow preventers are used when the lowest overflow point in a building's wastewater drainage system is below the rim elevation of the manhole in the lateral or main sewer immediately upstream of the building sewer connection

Building sewer vent traps are used to prevent the passage of gases and odors from the main sewer system into a building's wastewater plumbing (drainage) system.

They are not used extensively today since plumbing codes require adequate trapping and venting of a building's plumbing fixtures and because the traps tend to collect solids, thus causing stoppages in the building sewer.

Also, removal of stoppages in a building sewer is made more difficult since cleaning equipment must negotiate the bends in the trap.

If vent traps are not properly screened, they can allow rodents access to building sewers and the collection system.

Also, if traps are located in a low spot in a yard, this will serve as a source of inflow from surface runoff.

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Vent traps in low spots should be removed and adequate venting installed in the home or building.

Building sewer cleanouts are located as required by local building codes and sewer ordinances.

They are used to allow access to sewers to remove solids which cause stoppages.

As a minimum, a cleanout should be located in the building sewer approximately three feet from the building foundation and another at the building's property line if the part of the sewer in the street is maintained by a sewer agency.

In very cold climates building sewers are usually placed below the frost line and cleanouts are located in the inside wall of basements to provide convenient access in the winter.

Building sewer connections (also called TAPS) to street sewers are either provided during construction of these sewers, if the appropriate location is known, or after their construction.

In either instance they should be constructed with care since these connections can be a source of groundwater infiltration and sewer stoppages if not constructed properly. The taps must not protrude into the street sewer.

Lateral and branch sewer cleanouts are some times placed at the terminals of these sewers, in place of manholes, to provide a means of inserting cleaning equipment and water for flushing the line.

The slant riser provides easier access to the lateral or branch sewer, but the impact of street traffic and cover tend to shear the cleanout pipe below the frame.

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Flusher branches were used in the past for the introduction of large volumes of water in the upper ends of lateral and branch sewers to attempt to move deposited solids downstream to self-cleaning sewers.

Those that still exist are similar to the vertical and slant lateral sewer cleanouts.

However, other sewer cleaning methods are more effective than flushing and flusher branches are not used very often today.

Lamp holes are rarely found today. They are similar to a vertical lateral sewer cleanout.

Lamp holes were placed midway between adjacent manholes for the introduction of a lamp that would be viewed through the sewer line from the manholes to determine if the sewer line was free of solids or breaks that could cause a stoppage of the wastewater flow.

The use of modern sewer line viewing methods, such as closed circuit television, have made lamp holes obsolete.

However, they may still exist in older collection systems where they should be sealed to prevent surface inflow.

Manholes are installed in lateral, main, trunk and intercepting sewers for the purpose of placing persons, equipment and materials into these sewers for inspection, maintenance and the removal of solids from cleaning operations.

Manholes in straight runs of sewer lines should be spaced no farther apart than the distance that can be cleaned by the appropriate type of equipment (usually 300 to 500 feet).

Design and Components

Manholes are also placed at changes in sewer line direction, slope, elevation, pipe sizes and junctions.

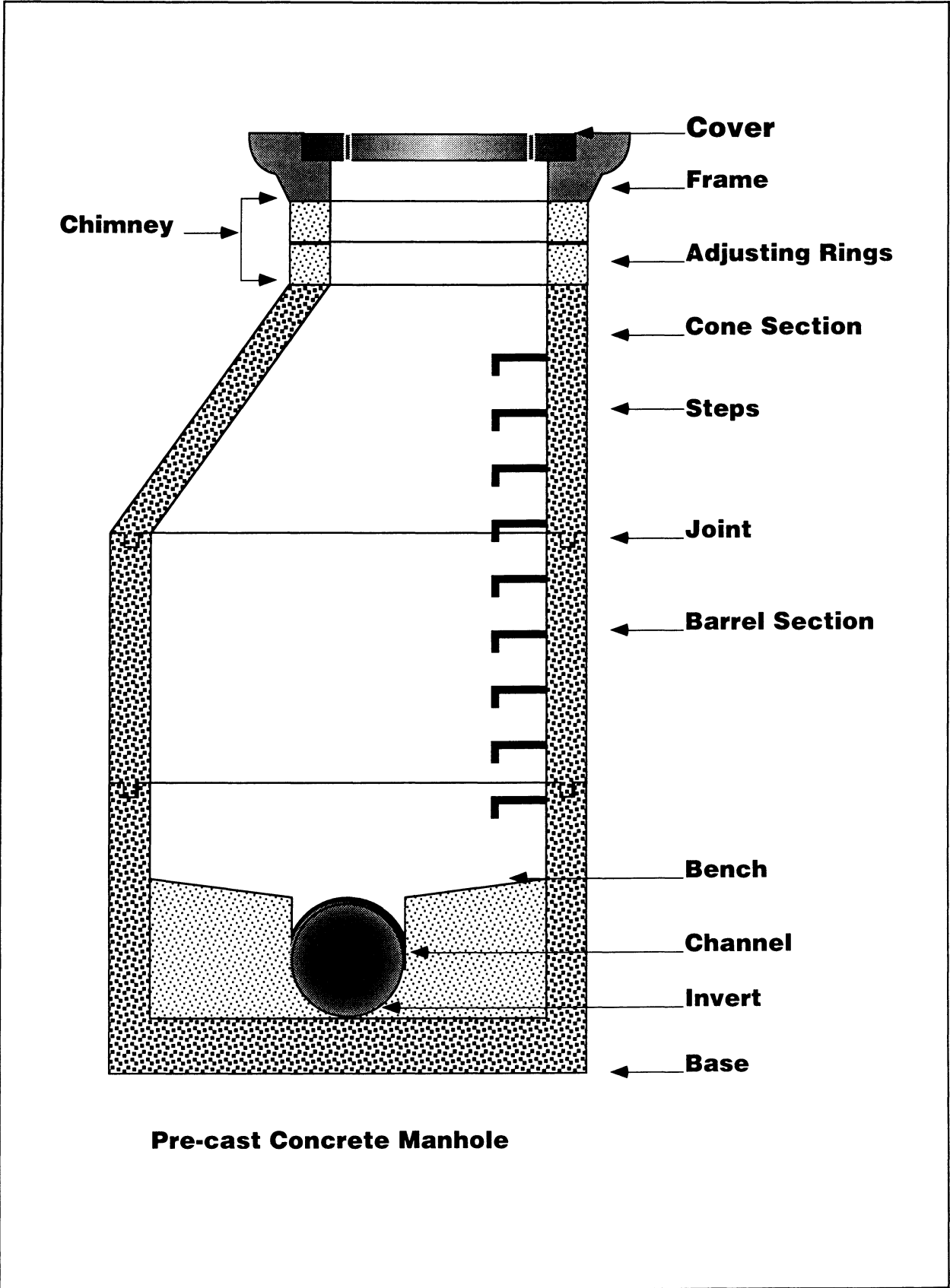
Drop manholes are used when the difference in the elevation of an incoming and outgoing sewer line cannot be accommodated by a drop in the manhole channel without creating excessive turbulence and splashing of wastewater.

Manholes may be furnished with or without steps depending upon the practice of a sewer agency. Some agencies prefer to use ladders for entry and exit of manholes for safety reasons.

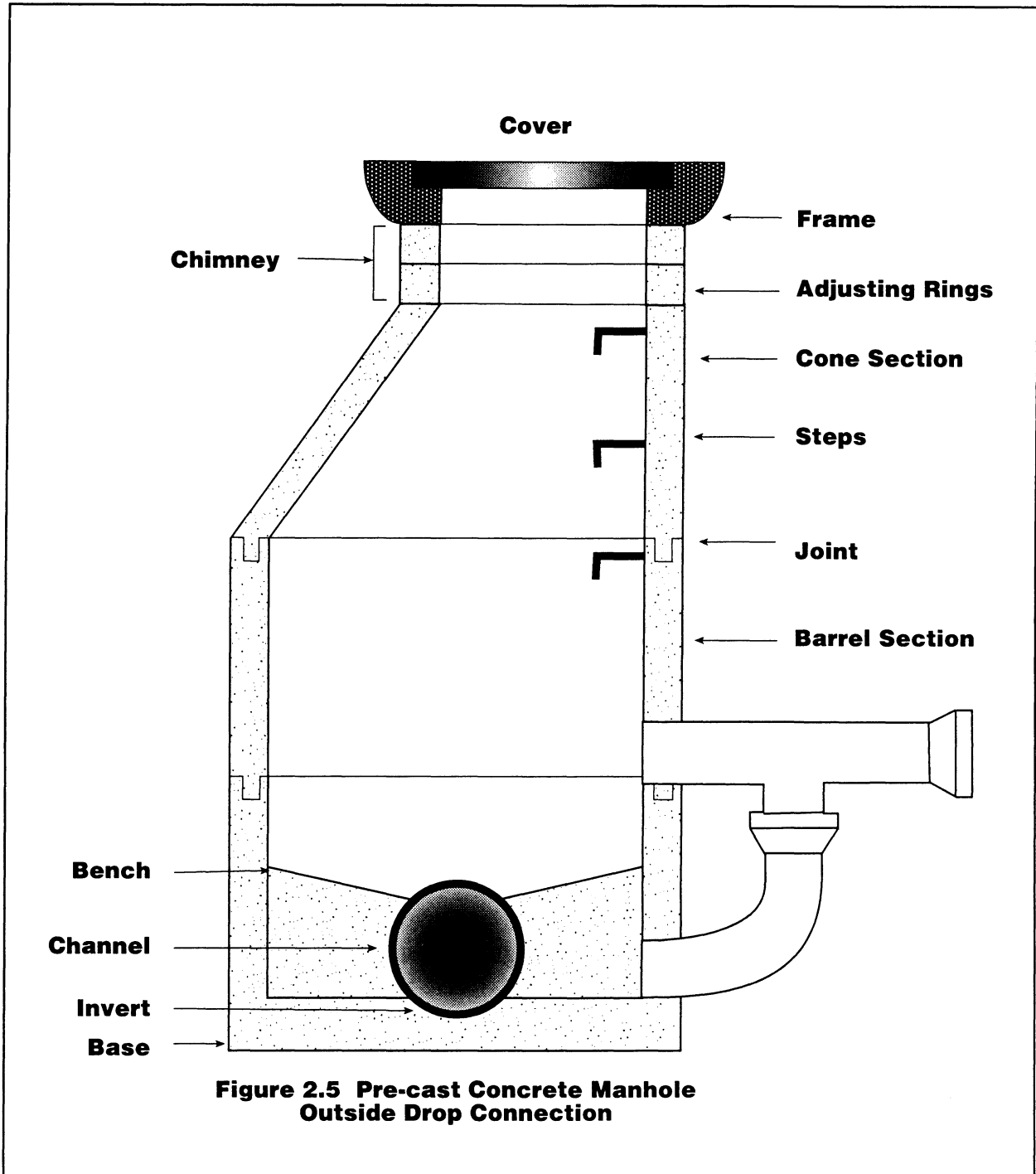
Deterioration caused by corrosion could cause the steps to fail when the operator tries to use them. A typical manhole precast concrete manhole and a manhole with an outside drop connection are shown in the following figures.

The use of outside drop manholes should be considered very carefully. Under normal flow conditions, there is not a problem with them since flow drops down the vertical section and then into the manhole, however when this plugs, the overflow from the pipe then comes out the horizontal section and straight into the manhole. While in some cases it may be possible to get a cleaning tool into the lower elbow and up into the vertical section, it may require personnel to enter the manhole and unplug it from inside the manhole. Obviously this is not a desirable job.

Wastewater Collection Systems

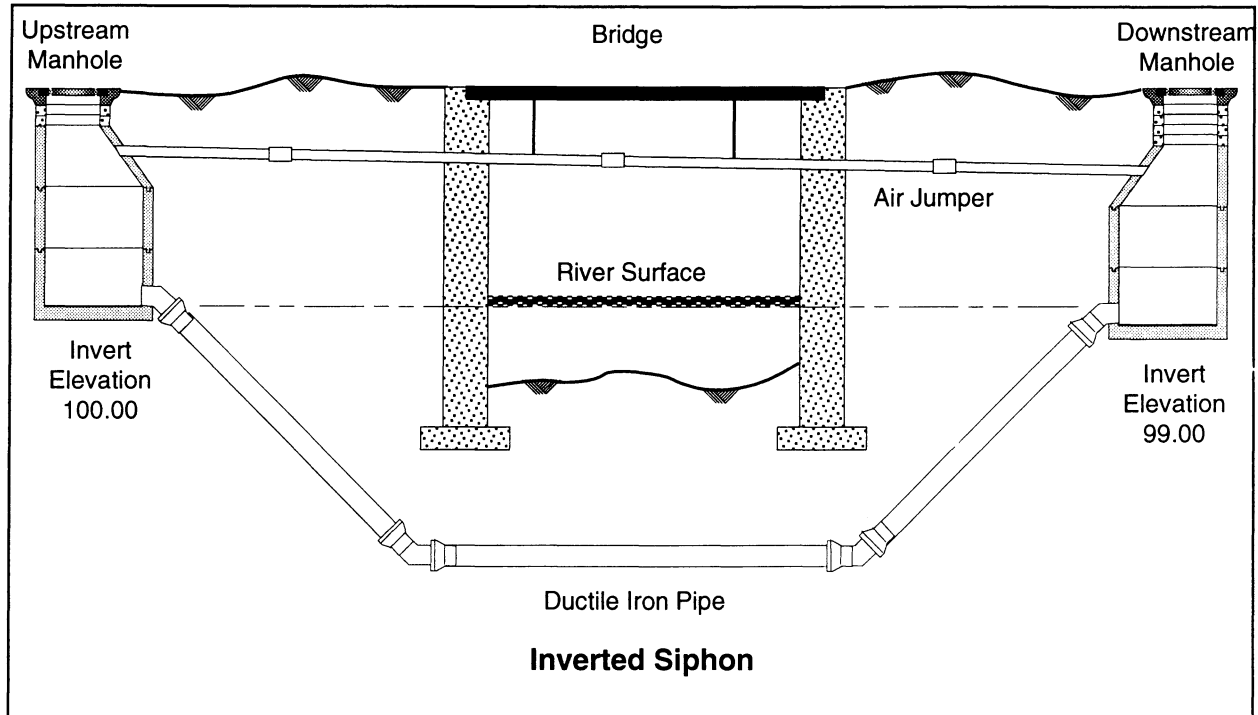


Pre-cast Concrete Manhole



Manhole Material. Manhole bases are generally made of poured-in-place non-reinforced concrete with wastewater channels formed by hand before the concrete hardens.

Wastewater Collection Systems



Manhole barrels are usually made of pre-cast concrete sections with cement mortar or bitumastic joints.

Manholes in older collection systems may have been made with clay bricks and cement mortar joints.

Some manhole barrels are now being made with fiberglass for use in areas with high groundwater and corrosive material in the wastewater conveyed.

Manhole frame and covers are made of cast iron with the mating surface between the frame and cover machined to ensure a firm seating.

Manhole steps should be made of wrought iron or reinforced plastic to resist corrosion. In some jurisdictions steps are prohibited and ladders are used to eliminate the hazard of corroded steps.

Junction structures are used to join large diameter trunk sewers when the junction cannot be made in a

manhole. The structure usually contains facilities for the regulation of wastewater flows in the sewers running out of the junction.. Flow of wastewater through the structure should not produce undesirable turbulence that could release hydrogen sulfide or create a partial blockage of the incoming wastewater. Hydrogen sulfide smells like rotten eggs, is a toxic gas and forms corrosive sulfuric acid when combined with moisture in sewers.

Interconnector sewers are short sewer lines that run between adjacent manholes to allow the regulation of wastewater flows in parallel sewers or the automatic diversion of wastewater to an alternate sewer if the primary sewer becomes blocked. Although the automatic diversion of wastewater from a blocked sewer may protect buildings from wastewater overflow, this type of diversion requires periodic inspection to determine if the primary sewer is blocked. If the wastewater in the primary sewer is blocked, it may become SEPTIC and cause odors.

Inverted siphons are sewer lines installed lower than the normal gradient of the sewer line to pass under obstructions such as water courses and depressed roadways as illustrated in the following figure.

Wastewater is “pushed” through the siphon by the pressure resulting from the upstream sewer (at the junction manhole) being higher than the downstream sewer.

Siphons generally require more maintenance than gravity sewers since solids in the conveyed wastewater must be pushed up the downstream leg of the siphon by the velocity of the wastewater. Low velocities will leave heavy solids at the bottom of the siphon and these must be removed by one of several cleaning methods.

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For this reason, siphons are sometimes constructed with two parallel barrels (pipes) to provide an alternative route for the wastewater if one barrel becomes blocked. Air jumpers are sometimes constructed as part of an inverted siphon since the siphon is completely filled with wastewater, a blockage in the flow of air in the sewer line occurs without an air jumper.

Continuation of the air flow is important if its stoppage would cause a corrosive, odorous or toxic release of hydrogen sulfide at the upstream siphon manhole.

Installation of air jumpers prevents this from happening by providing the downstream flow of air that usually occurs above the wastewater in a partially filled sewer line.

Flow regulators in a wastewater collection system are used to divert the flow of wastewater from one sewer line to another for the efficient use of the system and to prevent overloading one portion of the system.

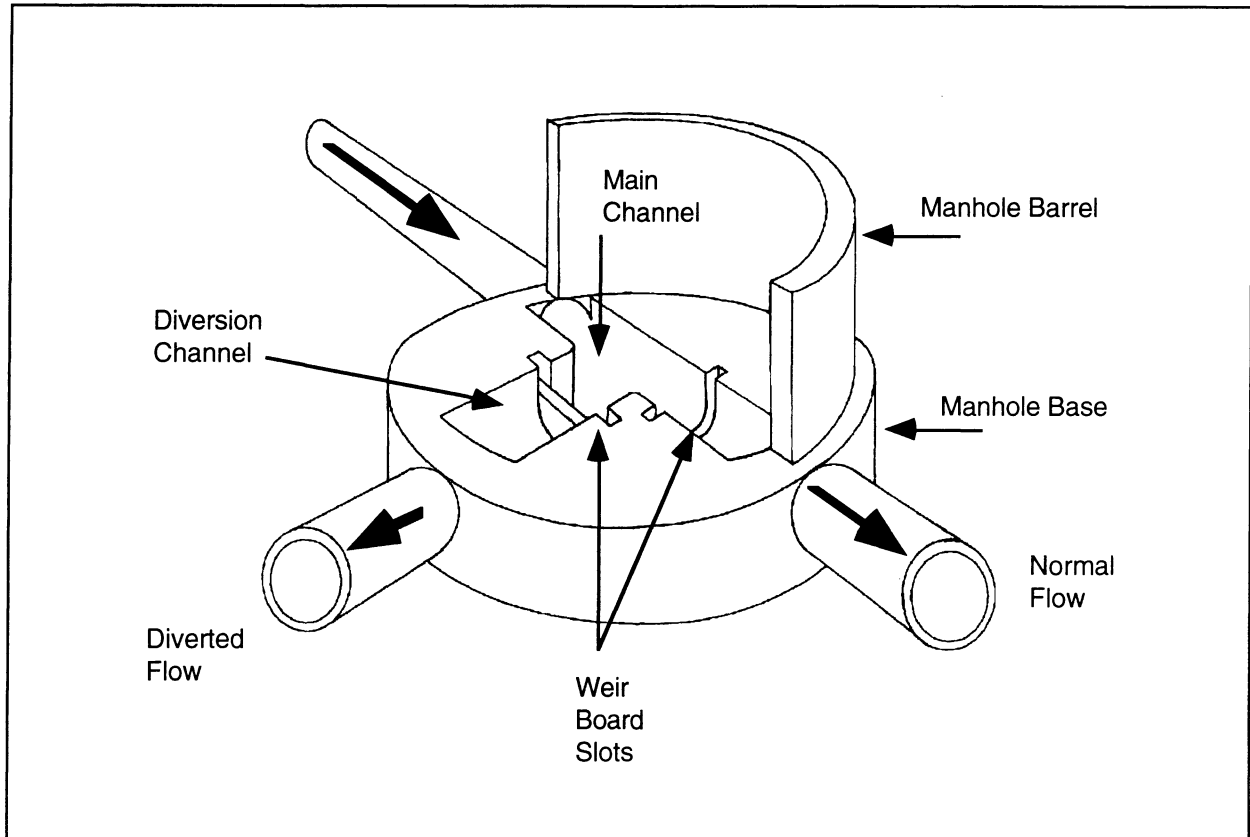
The regulators are usually simple in nature with a minimum of moving parts due to the nature of wastewater.

Weirs are used in manholes and junction structure channels, as shown to regulate the flow of wastewater in the multiple sewers as appropriate for operating conditions.

The weirs are simply boards of an appropriate height that are inserted in preformed slots in the channels.

Design

Collection system operators need to be familiar with the elements of a wastewater collection system design that have an influence on the operation and maintenance (O&M) of the constructed system.



This familiarity will allow an operator to effectively review the plans and specifications for newly designed collection systems to minimize later maintenance and to understand problems in existing collection systems caused by improper or unnecessary design factors.

When operators review designs they should, for example, make sure that manholes are located in accessible locations and that overhead power lines and highway overpasses will not interfere with cranes used to lift pumps or other activities.

Also manholes should not be located in dry creek beds or the middle of major streets or highways.

Layout

A layout of a wastewater collection system shows the general location of laterals, mains and trunk sewers within the service area, is shown in the previous figure of a typical gravity system.

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The layout shows the direction of flow in the sewer system based on the contours of the area, but does not indicate the size or slope of sewer lines which are unknown at the time a layout is prepared.

Field surveys are conducted by engineers to record the location of the physical features and the elevation of the ground surface along the planned route of the sewer lines in the collection system.

Physical information includes location and elevations of buildings to be served, surface improvements (such as sidewalks and street pavement), location of surface and underground utilities (gas, electricity, phone) and other items that will influence the location of a sewer line.

Field surveys include both route surveys and level surveys.

Route surveys pinpoint the location of physical features that will influence the horizontal location of a sewer line.

A surveyor's transit and tape are used to locate these features.

By using measured angles and taped distances, the exact locations of physical features are referenced to the known location of the transit.

Very accurate aerial photographs are sometimes used to determine the location of visible features, with field surveys being limited to the determination of invisible features such as underground utilities.

Level surveys determine elevations of the ground surface along the route of the sewer line, buildings to be served and when possible the elevation of underground obstructions and pipelines.

Slope and Size

The following factors are considered in determining the slope and size of a sewer line.

The slope of the sewer should follow slope of land along the route of the sewer as closely as practical provided the slope is adequate to produce gravity flow and the minimum scouring velocity. The slope of the sewer also known as grade is the ratio in the change of the vertical distance to the horizontal distance of the pipe.

The slope of the sewer will determine the velocity of the flow within the sewer, the steeper the slope the higher the velocity. Gravity sewers are normally designed to maintain minimum velocities to keep the solids suspended. However in some cases, it may be necessary for certain sections of the line to be laid on a flatter slope. This could create problems with insufficient scouring velocities and the resultant build-up of solids in the bottom of the sewer.

Minimum slopes are a function of the diameter of the pipe. For example, the recommended minimum slope for an 8 inch pipe is 0.40 feet for every 100 feet of pipe. Minimum slope for a 16 inch pipe would be 0.14 for every 100 feet of pipe and a 36 inch pipe 0.046, for every 100 feet of pipe.

Deviations from ground slope could cause the sewer to become too shallow for adequate cover on the pipe or too deep for safe and economical construction.

Velocity and Flow

Design flow is the estimated amount of wastewater to be conveyed by the sewer line being designed.

Velocity of the wastewater in a sewer line should be at a speed which will prevent the deposition and buildup of solids in the sewer; this is called a "scouring velocity."

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Experience has shown that wastewater velocities of two feet per second or greater will keep the solids usually contained in wastewater moving in a sewer line.

When the velocity is 1.4 to 2.0 feet per second, the heavier inorganic grit such as gravel and sand begins to accumulate in the invert. At a velocity of 1.0 to 1.4 feet per second inorganic grit and organic solids will accumulate and for a velocity below 1.0 feet per second significant amounts of organic and inorganic solids accumulate in the sewer.

A scouring or self cleaning velocity may not be attainable during periods of minimum daily flows. However, a sewer should be designed to produce a scouring velocity during the average daily flow or, at the very least, during the maximum daily flow.

Collection systems in flat regions with low flow velocities tend to have the solids settle out of the wastewater, thus causing sewer stoppages and the generation of toxic hydrogen sulfide gas.

On the other hand, steep slopes on hilly terrain can produce high wastewater velocities in sewer lines. Velocities higher than ten feet per second can separate solids from the wastewater, cause excessive turbulence at junctions and erode the sewer line.

The size of a sewer line should be large enough for the use of cleaning equipment, as well as flow considerations.

A properly sized sewer line will be approximately one-half full when conveying the peak daily dry weather design flow and just filled when it is conveying the peak wet weather design flow.

Designing for a half-full sewer line allows for a beneficial flow of air above the wastewater and

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allows for some error in determining the design flow.

The flow of air helps prevent the buildup of toxic or explosive gases, an oxygen deficiency, moisture condensing on pipe walls and crown above the water line which can contribute to sulfide corrosion.

Most wastewater agencies require at least a four-inch diameter residential building sewer and a six-inch diameter lateral and branch sewer.

Many agencies require an eight-inch diameter lateral and branch sewer to facilitate maintenance and to convey unexpected wastewater flows.

Commercial buildings require a six-inch or larger sewer line and industrial sewer lines are six-inches or larger and sized on the basis of expected flows.

The Manning Equation is commonly used by engineers to interrelate slope, quantity of wastewater (design flow) and velocity of flow in a sewer line. Although you will probably not be designing a sewer system, this equation will be useful if you need to design an extension of an existing or compare expected design velocities with actual velocities in sewers. The Manning Equation is as follows:

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

where V= velocity, ft/sec

n= Manning's coefficient of pipe roughness

R=hydraulic radius, ft = $\frac{\text{cross-sectional area of flow, sq ft}}{\text{wetted pipe perimeter, ft}}$

S = slope of sewer, ft/ft.

Knowing the available slope and desired depth of flow in a sewer line and assuming a coefficient of pipe roughness, the velocity of flow can be calculated. Then, knowing the velocity and the cross-sectional area of flow, the flow rate can be calculated using the formula:

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$$Q=AV$$

Q= flow, cubic feet per second,

A= Area, square feet, and

V= velocity, ft/sec.

Location and Alignment

Lateral, main and trunk sewers are usually constructed at or near the center of public streets to equalize the length of building sewers and to provide convenient access to the sewer line man-holes.

In extremely wide and heavily traveled streets, lateral sewers are sometimes placed on each side of the street to reduce the length of building sewers and to lessen interference with traffic when the sewer is being maintained.

Sewer lines are usually separated from water mains by a distance prescribed by the appropriate health agency.

Sewers are sometimes placed in easements when the topography of the land or street layout requires their use.

Use of easements should be minimized since sewers in easements are more difficult to gain access to and to maintain than sewers in streets.

With the greater use of curved streets today and the development of sewer cleaning equipment that is more versatile, sewers are sometimes constructed along curved paths.

The radius of a curved sewer will be determined by the radius of the street in which the sewer is being constructed, allowable deflection in the sewer pipe joints and, of major importance, the effect of radius upon cleaning procedures.

Some state and local regulatory agencies prohibit the use of curved sewers because of maintenance

problems.

For the efficient use of modern sewer cleaning equipment, the radius of curvature must be greater than 200 feet.

Also, most pipe manufacturers will specify the maximum allowable deflection (departure from a straight line) in their pipe joints; this amount is usually sufficient for modern sewer cleaning equipment.

Depth

The depth of lateral and main sewers should generally be approximately six-feet deep.

This depth will allow connecting building sewers to cross under most underground utilities and will serve the drainage systems of most buildings without basements.

If most buildings in a collection system's service area include basements, the lateral and main sewers should be deep enough to serve drainage systems in the basements by gravity.

The depth of trunk and interceptor sewers will depend to a great extent upon the depth of connecting main sewers.

The depth and width of a trench, backfill material and method of compaction determine the load placed on the sewer pipe.

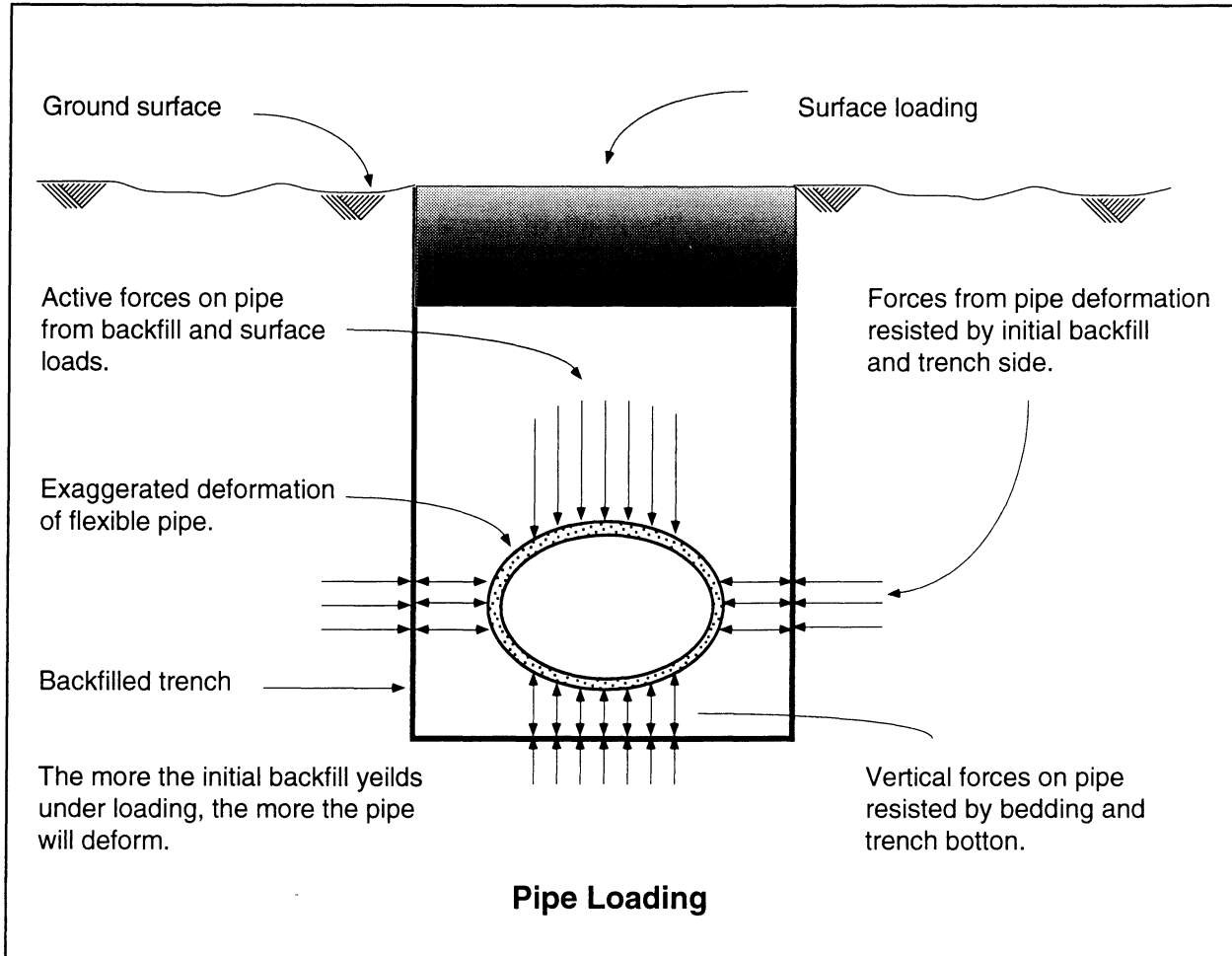
The amount of support provided the sewer pipe by the sides of the trench decreases as the width of the trench increases.

The width of a sewer trench (controlled by the diameter of the pipe, clearance for pipe laying, soil stability for safety during excavation, and the excavation procedures) should be kept to a minimum.

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Most sewer pipe manufacturers will provide information on the allowable loading on their pipe based on depth, trench width and bedding conditions.

Construction materials for sewers are selected for their resistance to deterioration by the wastewater



they convey, strength to withstand earth and surface loads, resistance to root intrusion, their ability to minimize infiltration and exfiltration, and the cost of the materials and their installation.

Pipe Materials

Pipe selection - There are a wide variety of pipe materials used for sanitary sewer construction. Each type is manufactured in accordance with nationally recognized material specifications. The

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type of pipe used depends on various factors and include:

- ◆ Will it be used for gravity or force main (pressure)?
- ◆ Is the wastewater abrasive
- ◆ Are there any special installation requirements such as loading?
- ◆ Is there a potential for internal and/or external corrosion conditions from soil, hydrogen sulfide or industrial material?
- ◆ What are the flow and capacity requirements based on design for pipe size, velocity, slope and friction coefficient?
- ◆ Is Infiltration/exfiltration a potential problem?
- ◆ What physical characteristics such as pipe size, fittings and connection requirements and laying length need to be considered?
- ◆ How cost effective is the pipe, installation, maintenance, and what is the life expectancy?
- ◆ What physical properties such as crush strength for rigid pipe, pipe stiffness or stiffness factor for flexible pipe, soil conditions, pipe loading strength, hoop strength for force main pipe, pipe shear loading strength, pipe flexural strength need to be considered?
- ◆ What about handling requirements including weight, impact resistance, and ease of installation?

New pipe materials and methods are continually being improved and developed for use in sanitary

sewers. Operators need to be aware of these changes in order to take advantage of them.

Classification of Pipe

Pipe for construction of sanitary sewers is manufactured from several types of material producing either flexible or rigid pipe with specific characteristics that will perform satisfactorily in a particular situation.

A flexible pipe will bend or bulge from its usual shape when subjected to a load without being adequately supported. However, it will not crack under most loads and will return nearly to its original shape when a load is removed.

A rigid pipe will require less support; however, it will crack when the combination of a load on the pipe and its support causes a stress that exceeds the strength of the pipe. It will not return to its original shape when the load is removed. Most of the commonly used sanitary sewer materials are described in the following subsections.

Rigid pipe classifications include the following:

- ◆ Asbestos Cement Pipe (ACP)
- ◆ Cast Iron Pipe (CIP)
- ◆ Reinforced Concrete Pipe (RCP)
- ◆ Pre-stressed Concrete Pressure Pipe (PCPP)
- ◆ Vitrified Clay Pipe (VCP)

Flexible pipe classifications include the following:

- ◆ Ductile Iron Pipe (DIP)
- ◆ Steel Pipe

- ◆ Thermoplastic Pipe
- ◆ Acrylonitrile Butadiene Stylene (ABS)
- ◆ ABS Composite
- ◆ Poly Ethylene (PE)
- ◆ Poly Vinyl Chloride (PVC)
- ◆ Thermoset Plastic Pipe

Reinforced Plastic Mortar (RPM)

Reinforced Thermosetting Resin (RTR)

Each of these classifications are discussed in more detail in the following section.

Rigid Pipe

Asbestos Cement Pipe (ACP) - Asbestos-cement pipe is used for both gravity and pressure sanitary sewers. The pipe is produced from asbestos fiber and cement, is available in nominal diameters from 4 inches through 36 inches and in some areas up to 42 inches. A full range of fittings is manufactured that is compatible with the class of pipe being used. Jointing is accomplished by compressing elastomeric rings between pipe ends and sleeves or couplings. ACP, manufactured for gravity sanitary sewer applications, is available in seven strength classifications and is specified by pipe diameter and class or strength. The class designation represents the minimum crushing strength of the pipe expressed in pounds per linear foot of pipe.

Potential advantages of asbestos-cement pipe include; long laying lengths, a wide range of strength classifications, a wide range of fittings available, and resistance to abrasion.

Potential disadvantages of asbestos-cement pipe

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include; subject to corrosion where acids are present, subject to shear and beam breakage when improperly bedded, low beam strength, and restrictions by OSHA due to asbestos content.

Cast Iron Pipe (CIP) - CIP (gray iron) is used for both gravity and pressure sanitary sewers in diameters from 2 inches through 48 inches with a variety of joints. CIP is manufactured in a number of thicknesses, classes, and strengths. CIP is specified by nominal diameter, class, lining, and type of joint. A cement mortar lining with an asphaltic seal coating may be specified on the interior of the pipe. An exterior asphaltic coating is also commonly specified. Pipe is very resistant to crushing and used for creek and river crossings, shallow trench locations, and under heavy traffic load areas.

Potential advantages of cast iron pipe (gray iron) include; long laying lengths (in some situations), and high pressure and load bearing capacity.

Potential disadvantages of cast iron pipe (gray iron) include; subject to corrosion where acids are present, subject to chemical attack in corrosive soils, subject to shear and beam breakage when improperly bedded, high weight and cost.

Concrete Pipe - Reinforced (RCP) and non-reinforced concrete pipe are used for gravity sanitary sewers. Reinforced concrete pressure pipe and prestressed concrete pressure pipes (PCPP) are used for pressure as well as sanitary sewers. Non-reinforced concrete pipe is available in nominal diameters from 4 inch through 36 inch. Reinforced concrete pipe is available in nominal diameters from 12 inches through 200 inches. Pressure pipe is available in diameters from 12 through 120 inches.

Concrete fittings and appurtenances such as wyes, tees, and manhole sections are generally available. A number of jointing methods are available de-

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pending on the tightness required and the operating pressure. Various linings and coatings are also available. Gravity and pressure concrete pipe may be manufactured to any reasonable strength requirement by varying the wall thickness, concrete strength, quantity and configuration of reinforcing steel or prestressing elements. Concrete pipe is normally specified by nominal diameter, class or D-load strength and type of joint.

Potential advantages of concrete pipe include; wide range of structural and pressure strengths, wide range of nominal diameters, wide range of laying lengths (4 to 24 ft).

Potential disadvantages of concrete pipe include; high weight, subject to corrosion where acids are present, subject to shear and beam breakage when improperly bedded and special field repair methods may be required for PCPP including fittings and methods.

Vitrified Clay Pipe (VCP) - VCP is used for gravity sanitary sewers. This pipe is manufactured from clay and shales. Clay pipe is vitrified at a temperature at which the clay mineral particles become fused. It is available in diameters from 3 through 36 inches and in some areas up to 42 in.. Clay fittings are available to meet most requirements, with special fittings manufactured on request. A number of jointing methods are available . VCP is manufactured in standard and extra-strength classifications, although in some areas the manufacture of standard-strength pipe is not common in sizes 12 inches and smaller. The strength of vitrified clay pipe varies with the diameter and strength classification. The pipe is manufactured in lengths up to 10 ft. VCP is specified by nominal pipe diameter, strength, and type of joint.

Potential advantages of vitrified clay pipe include; a high resistance to chemical corrosion, high resis-

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tance to abrasion, and wide range of fittings available.

Potential disadvantages of vitrified clay pipe include; limited range of sizes available, high weight, and subject to shear and beam breakage when improperly bedded.

Flexible Pipe

Ductile Iron Pipe (DIP) - DIP is used for both gravity and pressure sanitary sewers. DIP is manufactured by adding cerium or magnesium to cast (gray) iron just prior to the pipe casting process. The product is available in nominal diameters from 3 through 54 inch and in lengths to 20 ft. Cast iron (gray iron) or ductile iron fittings are used with ductile iron pipe. Various jointing methods for the product are available.

DIP is manufactured in various thicknesses, classes and strengths. Linings for the interior of the pipe (e.g., cement mortar lining with asphaltic coating, coal tar epoxies, epoxies, polyethylene) may be specified. An exterior asphaltic coating and polyethylene exterior wrapping are also commonly specified. DIP is specified by nominal diameter, class, lining, and type of joint.

Potential advantages of DIP include; long laying lengths (in some situations), high pressure and load bearing capacity, high impact strength, high beam strength.

Potential disadvantages of DIP include; subject to corrosion where acids are present, subject to chemical attack in corrosive soils, high weight and cost.

Steel Pipe - Steel pipe is rarely used for gravity sanitary sewers but is common for force mains. When used, it usually is specified with interior protective coatings or linings (polymeric, bituminous, asbestos, etc.). Steel pipe is fabricated in diameters from 8 through 120 in lengths up to 40 ft.

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Pipe fittings include tees, wyes, elbows fabricated from steel. Steel pipe is specified by size, shape, wall profile, gauge or wall thickness and protective coating or lining.

Potential advantages of steel pipe include; light weight, and long laying lengths (in some situations).

Potential disadvantages of steel pipe include; subject to corrosion where acids are present, subject to chemical attack in corrosive soils, subject to excessive deflection when improperly bedded, subject to turbulence abrasion.

Thermoplastic Pipe - Thermoplastic materials include a broad variety of plastics that can be repeatedly softened by heating and hardened by cooling through a temperature range characteristic for each specific plastic. Generally, thermoplastic materials used in sanitary sewers are limited to acrylonitrile-butadiene-styrene (ABS), polyethylene (PE), and polyvinyl chloride (PVC).

Acrylonitrile-Butadiene-Styrene (ABS) Pipe - ABS pipe is used for both gravity and pressure sanitary sewers. Non-pressure rated ABS sewer pipe is available in nominal diameters from 3 through 12 in. and in lengths up to 35 ft. A variety of ABS fittings and several jointing systems are available. ABS pipe is manufactured by extrusion of ABS plastic material. ABS gravity sanitary sewer pipe is available in three Dimension Ratio (DR) classifications 23.5, 35 and 42. (The DR is the ratio of the average outside diameter to the minimum wall thickness of the pipe. When adopted as a standard it is referred to as Standard Dimension Ratio or SDR). ABS pipe is specified by nominal diameter, dimension ratio, pipe stiffness and type of joint.

Potential advantages of ABS pipe include; light weight, long laying lengths, high impact strength, and ease in field cutting and tapping.

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Potential disadvantages of ABS pipe include; limited range of sizes available, subject to environmental stress cracking, subject to excessive deflection when improperly bedded, subject to attack by certain organic chemicals, and subject to surface change from long-term ultraviolet exposure.

Acrylonitrile-Butadiene-Styrene (ABS) Composite Pipe - ABS composite pipe is used for gravity sanitary sewers, available in nominal diameters from 8 through 15 in. and in lengths from 6.25 to 12.5 ft. The jointing systems available include elastomeric gasket joints and solvent cemented joints. ABS composite pipe is manufactured by extrusion of ABS plastic material with a series of truss annuli which are filled with filler material such as lightweight Portland cement concrete. ABS composite pipe is specified by nominal diameter and type of joint.

Potential advantages of ABS composite pipe include; light weight, long laying lengths, ease in field cutting.

Potential disadvantages of ABS composite pipe include; limited range of sizes available, subject to environmental stress cracking, subject to rupture when improperly bedded, subject to attack by certain organic chemicals, and subject to surface change effected by long-term ultraviolet exposure.

Polyethylene (PE) Pipe - PE pipe is used for both gravity and pressure sanitary sewers. Non-pressure PE pipe, primarily used for sewer relining, is available in nominal diameters from 4 through 48 in. Jointing is primarily accomplished by butt-fusion or flanged adapters. PE pipe is manufactured by extrusion of PE plastic material. PE pipe is specified by material designation nominal diameter (inside or outside), standard dimension ratios and type joint.

Design and Components

Potential advantages of PE pipe include; long laying lengths, light weight, high impact strength, ease in field cutting.

Potential disadvantages of PE pipe include; relatively low tensile strength and pipe stiffness, a limited range of sizes available, subject to environmental stress cracking, subject to excessive deflection when improperly bedded, subject to attack by certain organic chemicals, subject to surface change effected by long-term ultraviolet exposure, and special tooling required for fusing joints.

Polyvinyl Chloride (PVC) Pipe - PVC pipe is used for both gravity and pressure sanitary sewers. Non-pressure PVC sewer pipe is available in nominal diameters from 4 through 36 in.. PVC pressure and non-pressure fittings are available. PVC pipe is generally available in lengths up to 20 ft. Jointing is primarily accomplished with elastomeric seal gasket joints, although solvent cement joints for special applications are available. PVC pipe is manufactured by extrusion of the plastic material. Non-pressure PVC sanitary sewer pipe is provided in two standard dimension ratios, SDR 35 and 41. PVC pipe is specified by nominal diameter, dimension ratio, pipe stiffness and type of joint.

Potential advantages of PVC pipe include; light weight, long laying lengths, high impact strength, and ease in field cutting and tapping.

Potential disadvantages of PVC pipe include; subject to attack by certain organic chemicals, subject to excessive deflection when improperly bedded, limited range of sizes available, and subject to surface changes from long-term ultraviolet exposure.

Thermoset Plastic Pipe - Thermoset plastic materials include a broad variety of plastics. These plastics, after having been cured by heat or other means,

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are substantially infusible and insoluble. Thermoset plastic pipe product design should be based on long-term data. Generally, thermoset plastic materials used in sanitary sewers are provided in two categories, reinforced thermosetting resin (RTR) and reinforced plastic mortar (RPM).

Reinforced Thermosetting Resin (RTR) Pipe - RTR pipe is used for both gravity and pressure sanitary sewers. RTR pipe is generally available in nominal diameters from 1 through 12 in. manufactured in accordance with ASTM standard specifications. The product is available in nominal diameters from 12 through 144 in. In small diameters, RTR fittings are available. In larger diameters RTR fittings are manufactured as required. A number of jointing methods are available. Various methods of interior protection (e.g., thermoplastic or thermosetting liners or coatings) are available. RTR pipe is manufactured using a number of methods including centrifugal casting, pressure laminating and filament winding. In general, the product contains fibrous reinforcement materials, such as fiberglass, embedded in or surrounded by cured thermosetting resin. RTR pipe is specified by nominal diameter, pipe stiffness, lining and coating, method of manufacture, thermoset plastic material, and type of joints.

Potential advantages of RTR pipe include; light weight, and long laying lengths.

Potential disadvantages of RTR pipe include; subject to strain corrosion in some environments, subject to excessive deflection when improperly bedded, subject to attack by certain organic chemicals, subject to surface change from long-term ultraviolet exposure.

Reinforced Plastic Mortar (RPM) Pipe - RPM pipe is used for both gravity and pressure sewers. RPM pipe is available in nominal diameters from 8

through 144 in. In smaller diameters, RPM fittings are generally available. In larger diameters, RPM fittings are manufactured as required. A number of jointing methods are available. Various methods of interior protection (e.g., thermoplastic or thermosetting liners or coatings) are available. RPM pipe is manufactured containing fibrous reinforcements such as fiberglass and aggregates such as sand embedded in or surrounded by cured thermosetting resin. RPM pipe is specified by nominal diameter, pipe stiffness, stiffness factor, beam strength, hoop tensile strength, lining or coating, thermoset plastic material, and type of joint.

Potential advantages of RPM pipe include; light weight, and long laying lengths.

Potential disadvantages of RPM pipe include; subject to strain corrosion in some environments, subject to excessive deflection when improperly bedded, subject to attack by certain organic chemicals, and subject to surface change from long-term ultraviolet exposure.

Care must be taken in the selection of materials since sewers are expected to have an economical life of at least 30 years and most are in service for a much longer period.

Pipe Joints

One of the most critical components of the piping system is the joint because of the requirement for the control of ground water infiltration, wastewater exfiltration and root intrusion in sanitary sewer systems. Many types of pipe joints are available for the different pipe materials used in sanitary sewer construction. A common requirement, regardless of the type of sewer pipe used, is the use of reliable, tight pipe joints. A good pipe joint must be watertight, root resistant, flexible and durable. In general, today, various forms of gasket (elastomeric seal) pipe joints are used in sanitary sewer construction. They generally can be assembled by easily in a

Wastewater Collection Systems

broad range of weather conditions and environments with good assurance of a reliable, tight seal that prevents leakage and root intrusion.

Commonly used sanitary sewer pipe joints include:

Gasketed Pipe Joints- Gasket joints effect a seal against leakage through compression of an elastomeric seal or ring. Gasket pipe joint design is generally divided into two types—push-on pipe joint and mechanical compression pipe joint.

Push-on Pipe Joint - This type of pipe joint uses a continuous elastomeric ring gasket which is compressed into an annular space formed by the pipe, fitting or coupler socket and the spigot end of the pipe providing a positive seal when the pipe spigot is pushed into the socket. When using this type of pipe joint in pressure sanitary sewers, thrust restraint may be required to prevent joint separation under pressure. Push-on pipe joints (fittings, couplers, or integral bells) are available on nearly all pipe used in sewer systems today.

Mechanical Compression Pipe Joint - This type of pipe joint uses a continuous elastomeric ring gasket which provides a positive seal when the gasket is compressed by means of mechanical device. When using this type of pipe joint in pressure sanitary sewers, thrust restraint may be required to prevent joint separation under pressure. This type of pipe joint may be provided as an integral part of cast iron or ductile iron pipe. When incorporated into a coupler, this type of pipe joint may be used to join two similarly sized plain spigot ends of any commonly used sewer pipe materials.

Flanged Pipe Joint - Flanged connections are primarily used in pump station piping systems where cast or ductile iron piping is common.

Cement Mortar Pipe Joint - This type of pipe

joint involves use of shrink-compensating cement mortar caulking placed into a bell-and-spigot pipe joint to provide a seal. The use of this joint is discouraged in that reliable, watertight joints are not assured. Cement mortar joints are not flexible and may crack due to any pipe movement.

Solvent Cement Pipe Joints - Solvent cement pipe joints may be used in jointing thermoplastic pipe materials such as ABS, ABS composite, and PVC pipe. This type of pipe joint involves bonding a sewer pipe spigot into a sewer pipe bell or coupler using a solvent cement. Solvent cement joints can provide a positive seal provided the proper cement is applied under proper ambient conditions with proper techniques. Required precautions should be taken to assure adequate trench ventilation and protection for workers installing the pipe. Solvent cement pipe joints may be desired in special situations and with some plastic fittings.

Rubber Coupling With Compression Bands - External sealing bands of rubber are used on plain end pipe. The elastomeric band is slipped over each pipe end and compression bands tightened on each end.

Welded Joints - Welded joints are typically found on steel pipe used for force mains. This type of joint is very strong and leak tight. The most common welded joint is the butt weld or a butt weld with the pipe ends beveled. A sleeve may also be used as shown.

Heat Fusion Pipe Joints - Heat fusion pipe joints are commonly used for PE sanitary sewer pipe. The general method of jointing PE sanitary sewer pipe involves butt fusion of the pipe lengths, end to end. After the ends of two lengths of PE pipe are trimmed and softened to a melted state with heated metal plates, the pipe ends are forced together to the point of butt fusion, providing a positive seal. The

Wastewater Collection Systems

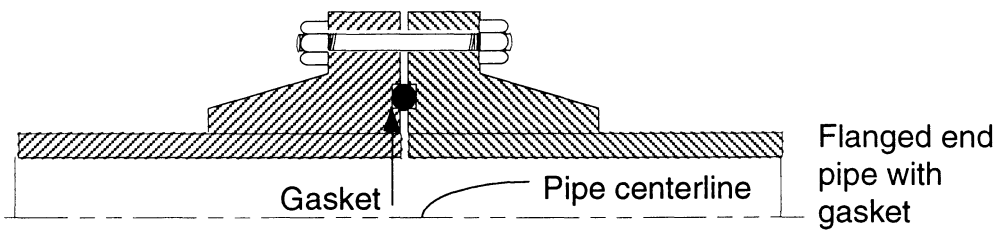
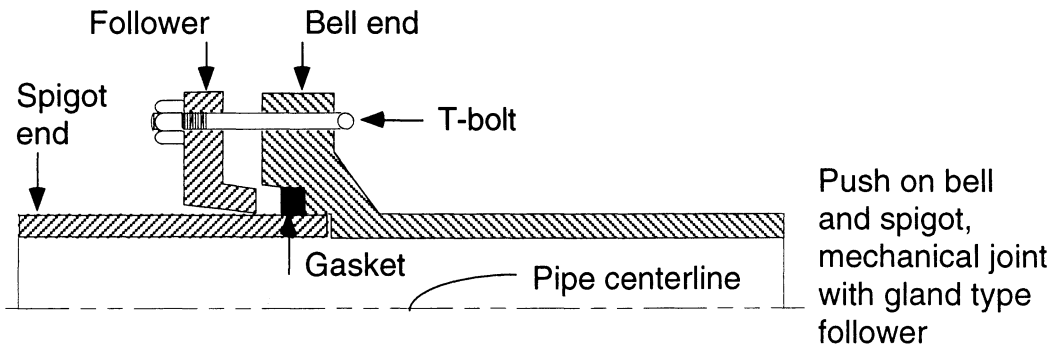
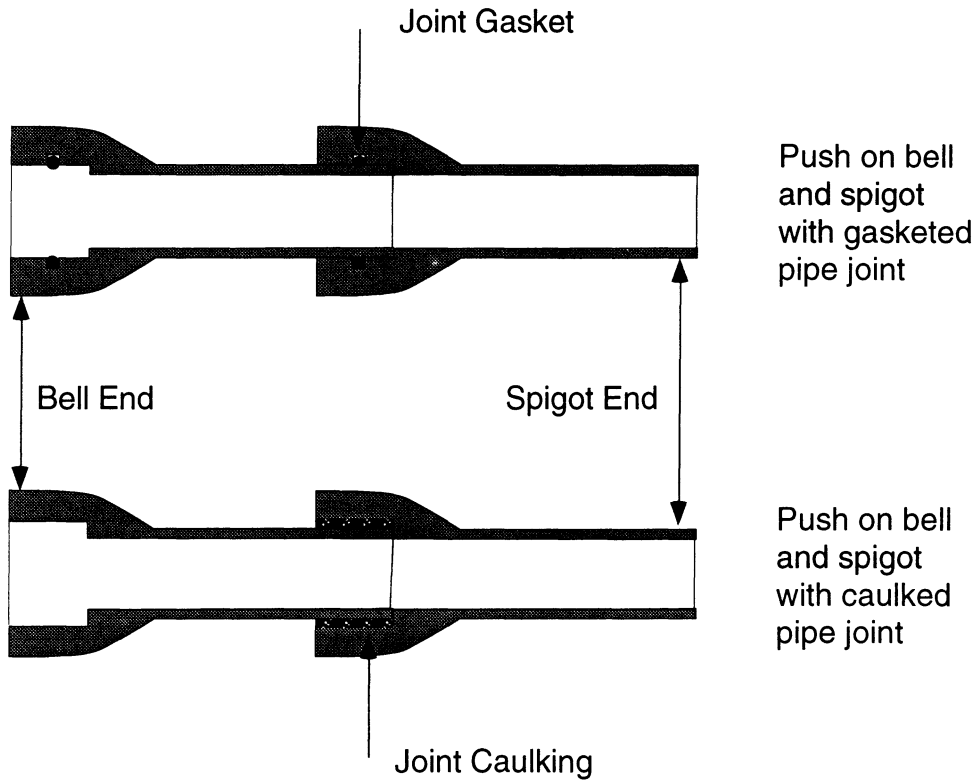
pipe joint does not require thrust restraint in pressure applications. Trained technicians with special apparatus are required to achieve reliable watertight pipe joints.

Bituminous Pipe Joints - This type of pipe joint involves use of hot-poured or cold packed bituminous material forced into a bell-and-spigot pipe joint to provide a seal. While this type of joint can be found in older systems, it is not used in new construction.

Elastomeric Sealing Compound Pipe Joints - Elastomeric sealing compound may be used in jointing properly prepared concrete gravity sanitary sewer pipe. Pipe ends must be sandblasted and primed for elastomeric sealant application. The sealant, a thixotropic, two compound elastomer, is mixed on the job site and applied with a caulking gun and spatula. The pipe joint, when assembled with proper materials and procedures, provides a positive seal against leakage in gravity sewer pipe.

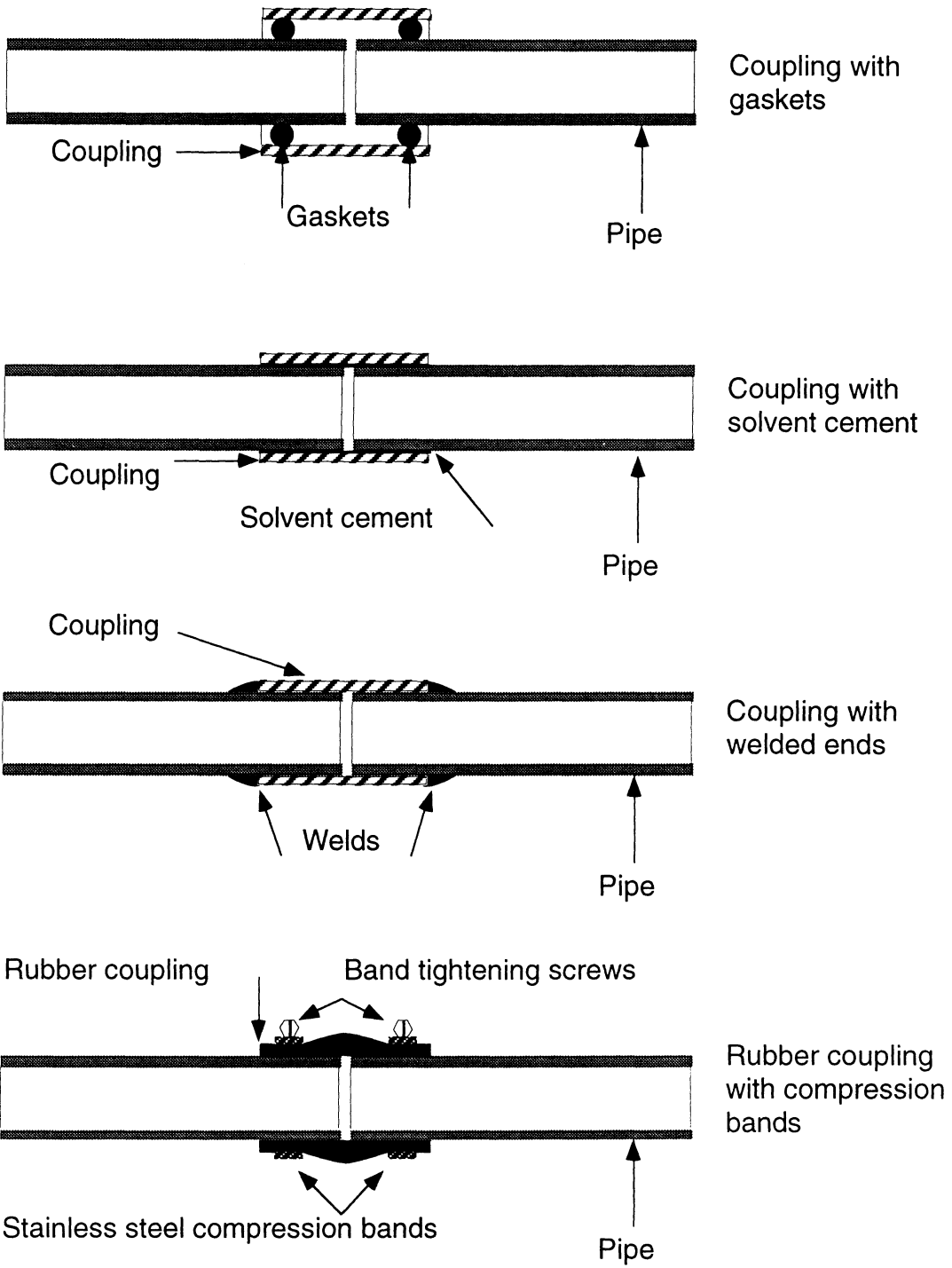
Mastic Pipe Joints - Mastic pipe joints are frequently used for special non-round shapes of concrete gravity sewer pipe which are not adaptable for use with gasket pipe joints. The mastic material is placed into the annular space to provide a positive seal. Application may be by trowelling, caulking, or by the use of preformed segments of mastic material in a manner similar to gaskets. Satisfactory performance of the pipe joints depends upon the proper selection of primer, mastic material, and good workmanship in application.

Pipe Joints



Wastewater Collection Systems

Plain End Pipe Joints



System Design and Review

Plan and Profile - A civil engineer will use the field data and the design criteria to prepare plans and specifications for the construction of a wastewater collection system.

Design Review - Wastewater collection system operators should request the opportunity to review the design of collection systems that they will be responsible for maintaining after construction.

In order to make an effective review an operator must be familiar with the elements of design that can create problems during the life of a collection system.

The following sections give some suggestions for the review of plans and profiles for construction of a collection system.

Office Study - When you receive a set of plans and profiles for review, look them over for an overview of how the system is to work. Then make a detailed review by asking yourself how the design may be improved for the elimination of future maintenance problems. Make a list of items that are not clear to you and ask the designer for a clarification.

Field Investigations - Now that you are familiar with the plans and profiles for a collection system and have developed some ideas and questions concerning the effect of the design on maintenance, you are prepared for a field investigation.

Envision the maintenance of the sewer lines and appurtenances as planned and ask yourself how the actual field conditions will influence maintenance.

During both the office and field review of plans and profiles for a wastewater collection system, ask yourself the following questions concerning the design:

Design Items Influencing Maintenance

Wastewater Collection Systems

- ◆ Is the route or alignment satisfactory?
- ◆ Could there be a better route?
- ◆ Consider the effect of pipe diameters and depth of excavation on future maintenance.
- ◆ Think about maintenance equipment access.
- ◆ Is there sufficient overhead clearance for maintenance and repair equipment?
- ◆ Could repairs be made in case of failures?
- ◆ Availability of large diameter pipe?
- ◆ Depth of excavation?
- ◆ Shoring requirements?
- ◆ Can the system be easily maintained?
- ◆ Will there be any industrial waste dischargers? If so, what will they discharge and will the discharge cause any problems? How can these problems be controlled?
- ◆ Where can vehicles be parked when operators and equipment require access to a manhole?
- ◆ Is traffic a problem around or near a manhole and if so can it be relocated to minimize the problem? Will night work be necessary?
- ◆ Can the atmosphere in the manhole be tested safely for oxygen deficiency, explosive gases and toxic gases? Can large ventilation blowers be used?

Design and Components

- ◆ Can an operator reach the bottom of the manhole with a ladder if steps are not provided?
- ◆ If there are steps in the manhole wall for access, will they be damaged by corrosion and become unsafe?
- ◆ Is the shelf in the bottom of the manhole properly sloped? If the shelf is too flat, it will get dirty; if the shelf is too steep, it can be a hazard to operators.
- ◆ Are the channels properly shaped to provide smooth flow through a manhole to minimize splashing and turbulence that can cause the release of toxic, odorous, and corrosive hydrogen sulfide?
- ◆ Are the channels at least as large as the pipe so maintenance equipment and plugs can be fitted or inserted into the pipes?
- ◆ Can the available sewer maintenance equipment be effective between the manholes or is the distance great?
- ◆ Is the manhole opening large enough to allow access for tools and equipment used to maintain a large sewer line? Is the opening sufficient to handle equipment and personnel during routine maintenance or inspection.
- ◆ Does the area flood? How often? Can flows be diverted? Stored? How? For how long? What tools, equipment and procedures are needed?

In addition to the above questions, use your experience to raise other questions on how the design of a collection system can affect your future operation and maintenance of the system and making repairs in emergency situations.

Wastewater Collection Systems

Communication

Your questions and ideas concerning the improvement of the design of a collection system should be given to the designer in a written and understandable form with an offer to meet to discuss them.

The designer should be capable of explaining and justifying a design in terms of economics and installation.

You should be able to justify your concerns on the basis of operation and maintenance requirements.

Construction, Testing and Inspection

Designers must consider how the wastewater collection facilities they design will be constructed.

Some facilities have been properly designed, but have not functioned as intended due to poor or improper construction materials and techniques.

Good construction, inspection and testing procedures are very important in order to eliminate operation and maintenance problems that could develop from poor construction practices.

Whenever problems (stoppages, failures or odors) develop in your collection system, try to identify the cause so it can be corrected now and in the future design of new systems.

Did the problem start with the design, construction, or inspection of the facility; or was it caused by a waste discharger, by aging of the system, or by your maintenance and repair program? Whatever the cause, identify it and try to correct it.

LIFT STATIONS

Purpose of Lift Stations

Lift stations are used to lift or raise wastewater or storm water from a lower elevation to a higher elevation. Lifting of the wastewater is accomplished by centrifugal pumps or air operated ejectors.

The term **LIFT STATION** usually refers to a wastewater facility with a relatively short discharge line up to the downstream gravity sewer.

A **PUMP STATION** commonly is a similar type of facility that is discharging into a long **FORCE MAIN**.

Throughout this manual when we refer to lift stations, we intend to include pump stations.

In many areas regional agencies are being created to serve more than one community.

As a result, lift stations and force mains tend to be larger and the pumps can range in size up to several hundred horsepower and the force mains can be several miles long.

Lift stations represent a major capital expenditure for an agency or community and they require an adequate budget to operate and maintain them properly.

Failures of lift stations and force mains can have a significant impact on the environment when raw wastewater is discharged over land or into lakes, streams, or rivers.

Backups into private residences caused by a lift station failure can easily cost thousands of dollars to

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clean up, replace, and repair damaged homes or businesses.

Significant lift station failures make headlines in newspapers and tarnish the image of your collection system agency.

Collection system operators, therefore, play a vital role in preventing catastrophic failures affecting the community.

Because pump stations contain complex electrical, mechanical, and hydraulic systems, collection systems operators must have a wide range of training to properly operate and maintain them.

This obviously requires a high level of knowledge, skills, and professionalism by all operators.

In many agencies today, collection system operators begin participation at the design stage of new lift stations because of their knowledge and experience on various types of lift stations.

Operators can help engineers produce designs which result in improved maintenance and operation of lift stations and lower operating costs while minimizing bypasses and backups.

Location

Location and design of lift stations depend on economic factors that are analyzed by the design engineer. Lift stations are installed at low points in the collection system at the end of gravity sewers where the following conditions exist:

- ◆ Excavation costs to maintain gravity flow and sufficient velocity become excessive.
- ◆ Soil stability is unsuitable.
- ◆ Groundwater table is too high for installing

deep sewers, and for trenching.

- ◆ Present wastewater flows are not sufficient to justify extension of large trunk sewers and a lift station offers an economical short-term solution.
- ◆ Other factors that influence the location of lift stations include the location of other utilities and also the surface and overhead structures (buildings and transit systems).

Lift station pumps are designed to move the wastewater with a minimum of energy consumption. The pumps are selected to provide a flow as continuous or constant as possible to minimize surges of wastewater in the downstream sewer and the wastewater treatment plant.

Consideration also must be given to installing pumps that require a minimum of maintenance.

Appearance of lift station buildings and grounds should blend in with the surrounding environment. Odors must be controlled and the noise must be kept to a minimum to prevent the lift station from being a nuisance to nearby neighbors.

Safety of the operators involved in operating and maintaining the lift station must be considered, as well as the safety of the public. If chemicals are added to the wastewater at the lift station, care must be exercised when storing, handling, and applying these chemicals.

Collection system operators should have easy access to the lift station during all types of weather conditions so the station can be properly operated and maintained at all times. Utilities required to operate the station must be readily available.

Wastewater Collection Systems

Reliability is the most important requirement of a lift station. Pumps or ejectors, controls, and the maintenance program must be designed to minimize the chances of failures to prevent the flooding of homes and streets.

Types of Lift Stations

Wastewater lift stations may be constructed in various sizes and shapes depending upon the volume of wastewater or storm water to be handled, the elevation water must be lifted, and the distance water must be pumped before the water returns to flowing in a gravity system.

The lift station may range from a standard manhole equipped with a submersible or other wet well type pump, to a factory prefabricated package station, or to an elaborately designed and constructed station capable of pumping large volumes of wastewater. When larger stations are constructed and require a continuous operational staff, they are often referred to as pumping plants.

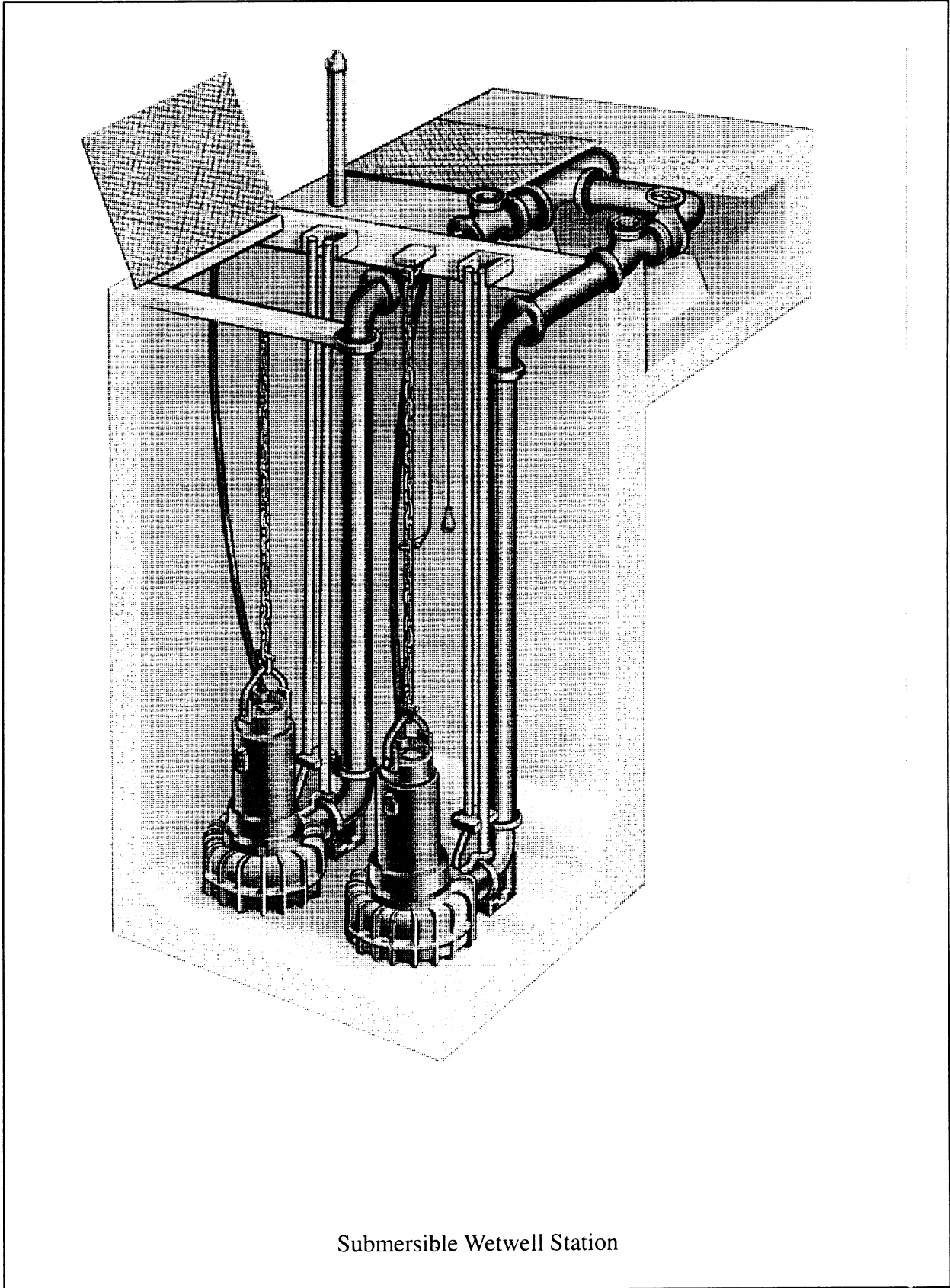
Stations may be classified as wet well or dry well installations, depending on the locations of the pumping units.

Precast concrete manhole sections with submersible pumps have been used as lift stations .

Manhole Used as Wet Well Station

The lift station shown has guide bars made of two-inch pipe which allow the pump to be removed from the top of the manhole by pulling the pump up the guide bars.

When the pump is lowered, a flanged, gasketed connection seals the pump to the discharge.



Submersible Wetwell Station

Wastewater Collection Systems

The weight of the pump keeps it in place and there are no bolts to remove.

Therefore, an operator does not need to enter the wet well to remove or install the pump. Details of a submersible pump and the connection to the discharge pipe or force main are illustrated in the following figures.

Wet Well Station

Large wet well stations today can provide capacities up to 25,000 GPM at discharge heads of 80 to 100 feet or more. These large stations are in wide use and two different types of configurations are frequently constructed:

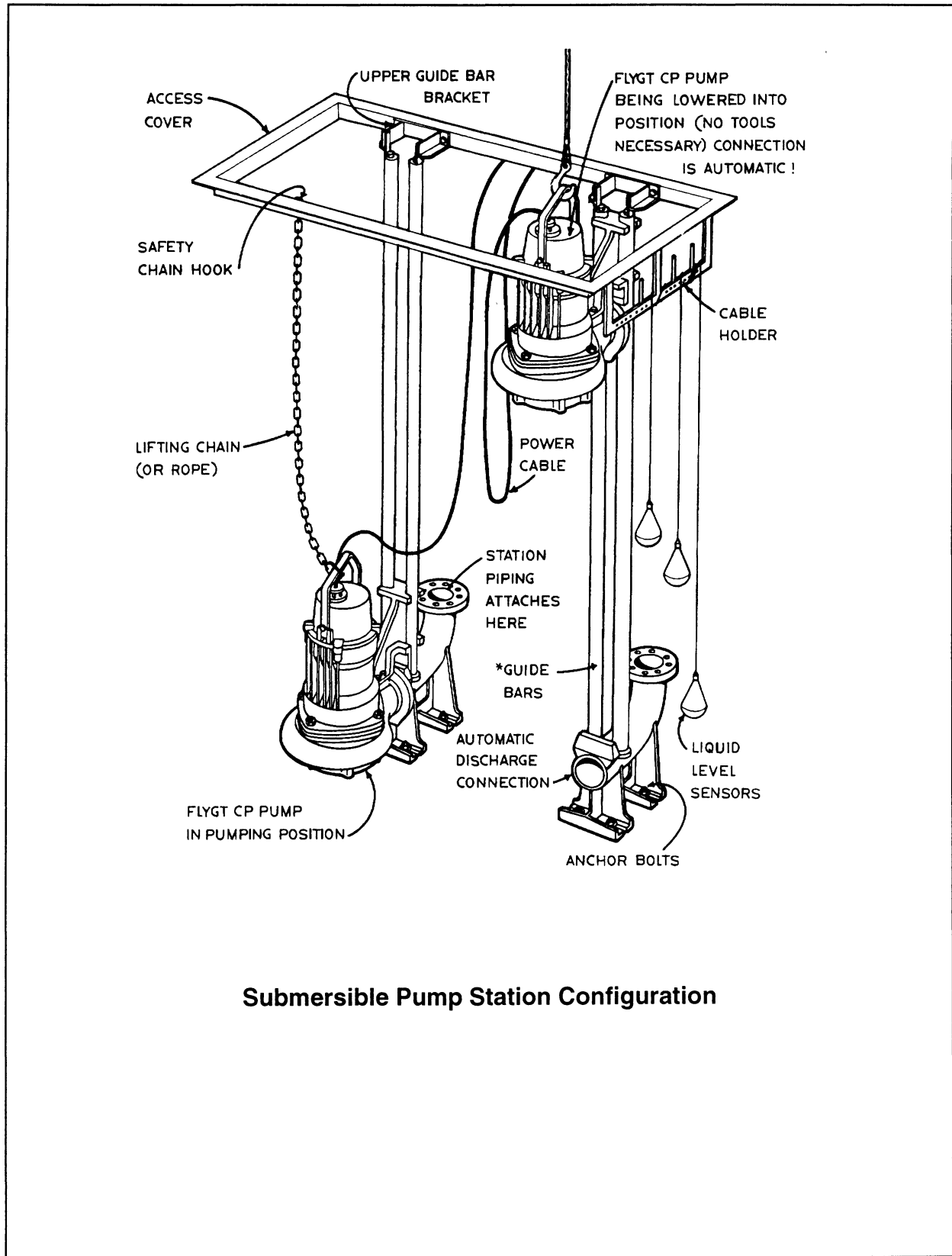
- ◆ Those that use larger submersible pumps, and
- ◆ those that use an above-ground pump station. In this type, a fiberglass enclosure usually sits on top of the wet well with the suction pipe extending down into the wet well (this is known as a pump which pulls a suction lift).

Because the above-ground station must “lift” the water up to the pump suction, the above-ground type stations use self-priming centrifugal pumps.

The maximum pump size is usually six or eight inches, whereas the submersible pump can be as large as twenty-four inches.

Depending on the pump size and number of pumps, the wet well could be constructed of pre-cast concrete manhole sections, rectangular box culvert sections, or poured-in-place concrete structures for the larger pumps.

Wet well installations typically have limited access to the pumping equipment. If anything goes wrong, they can be difficult to repair.



Submersible Pump Station Configuration

Wastewater Collection Systems

Equipment located in the wet well should be minimized, including suction and discharge valves, check valves, or other equipment which requires routine, periodic maintenance. This equipment can be located in small equipment manholes located adjacent to the wet well to make accessibility and maintenance much easier for the operator.

Dry Well Station

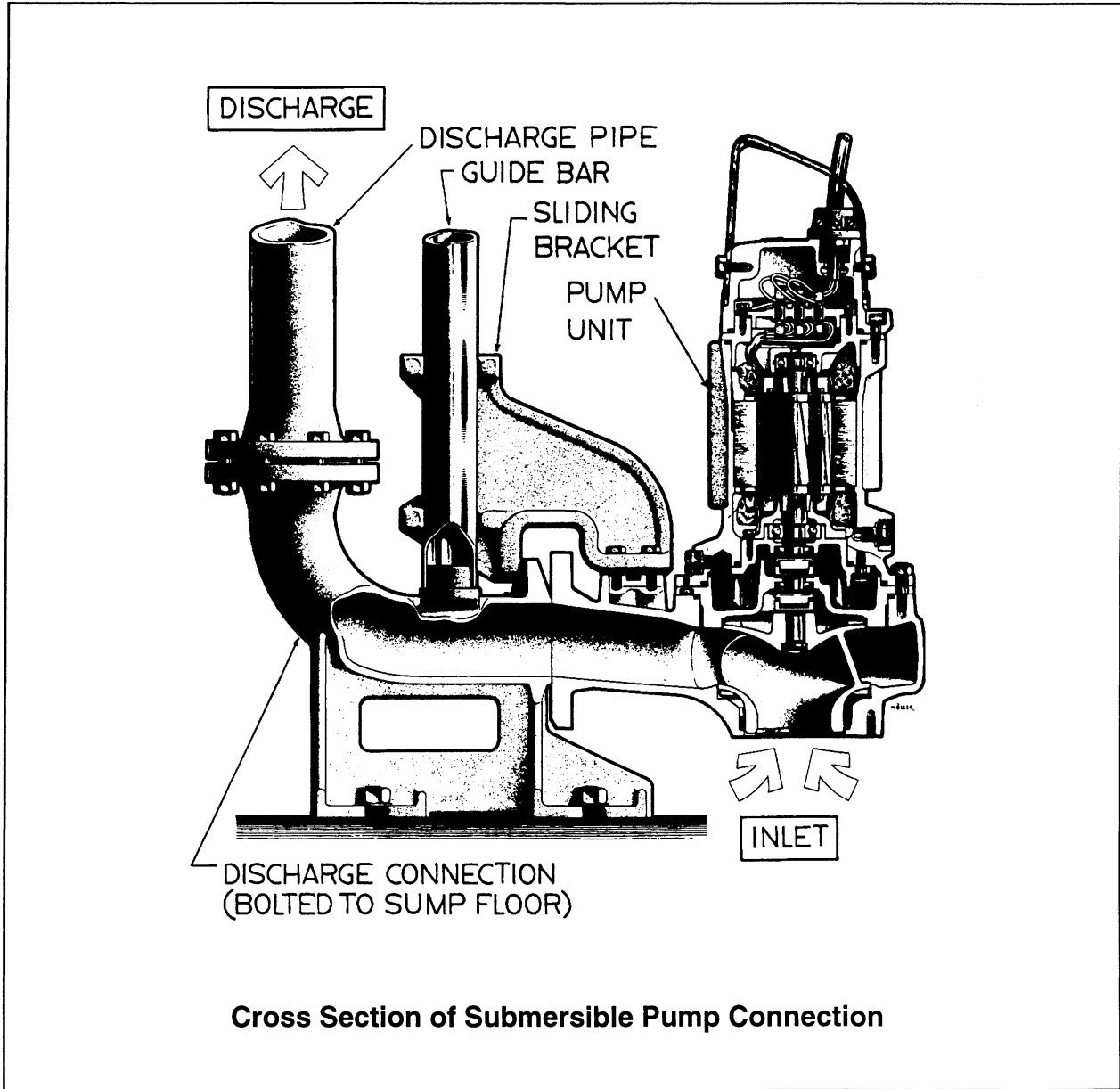
Dry well stations are another common type of lift station found in the collection system. This type of station isolates the pumps, motors, electrical control and auxiliary equipment from the wet well in a separate dry well. This feature provides a cleaner and safer environment for operation and maintenance personnel.

These stations will range in size from smaller prefabricated pump stations constructed of steel or fiberglass that come already assembled from the factory to much larger concrete cast-in-place stations which may or may not include a building to house the equipment, depending on environmental conditions.

The third type of wet well/dry well lift station that has been used in smaller areas is the PNEUMATIC EJECTOR which uses air pressure to eject the wastewater; however, this type of station is limited in capacity and size.

The next figure illustrates a typical duplex (two pumps) submersible pumping station and its major components while the next figure illustrates a prefabricated above-ground duplex pump station with a fiberglass-reinforced plastic enclosure.

These are both prefabricated type stations that are, assembled at the manufacturer's facility and then shipped to the jobsite. The next figure shows a constructed in place type of drywell station.

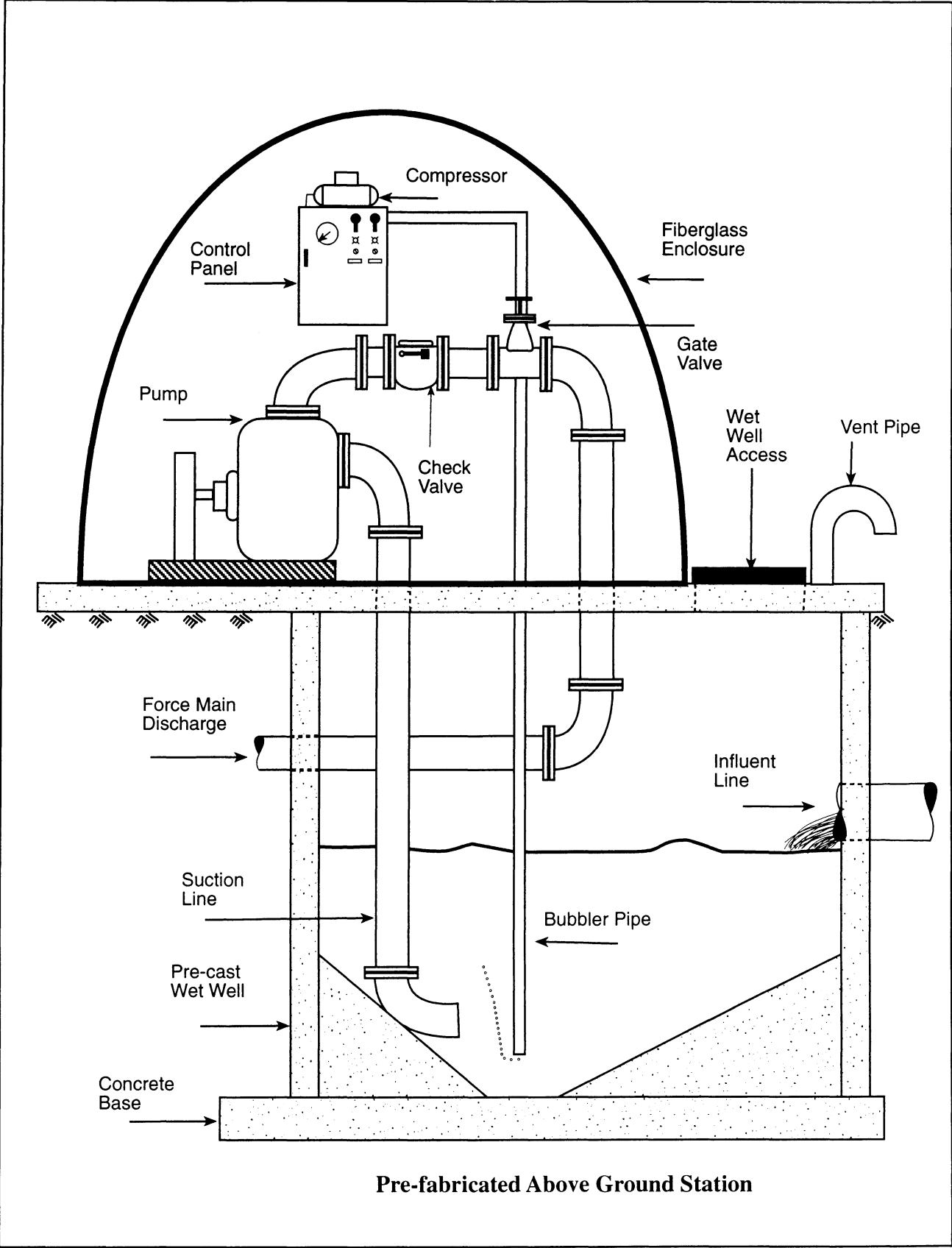


Lift Station Requirements

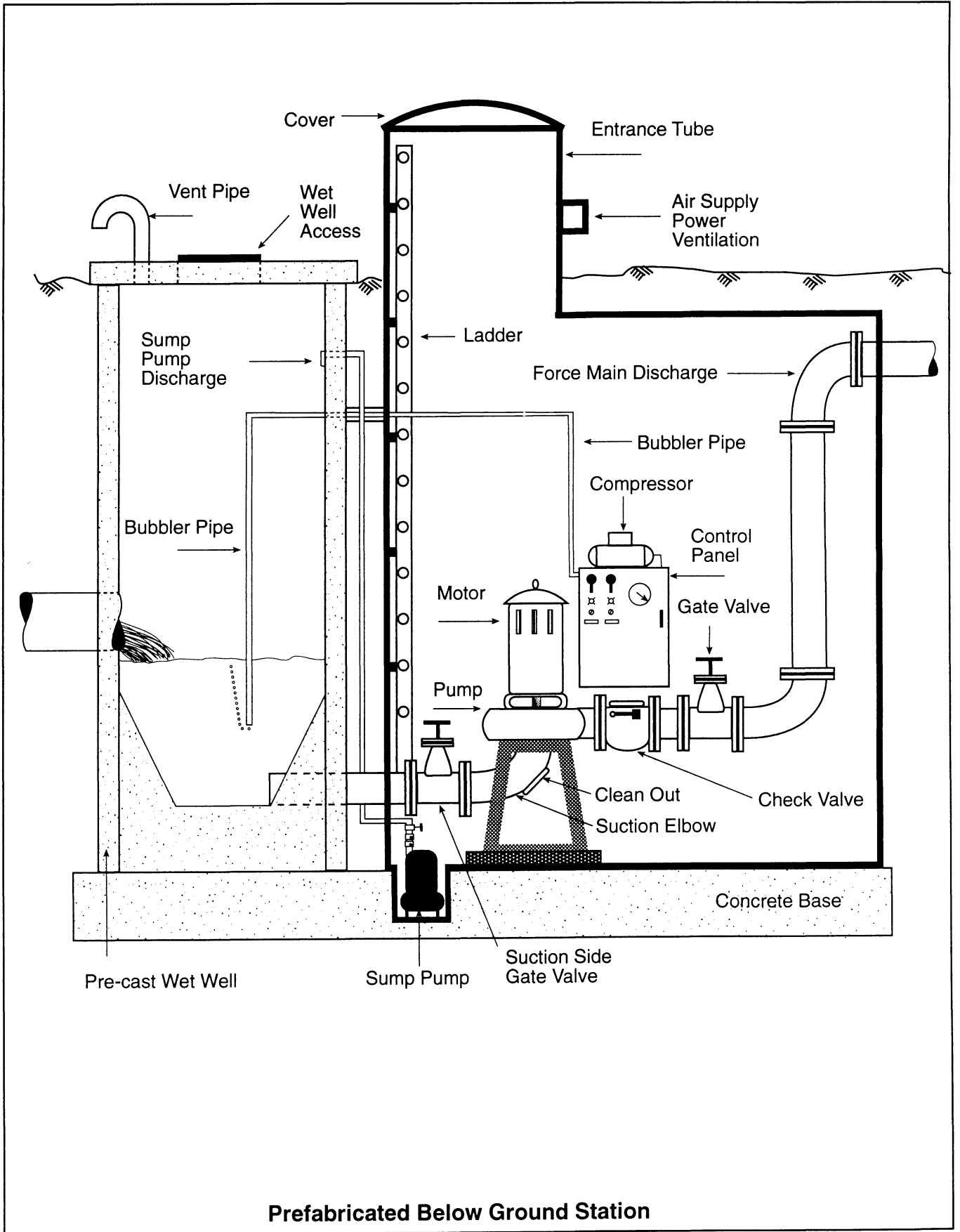
The most desirable operation of a lift station would be the situation where all the flow and solids that discharge into the wet well from the gravity sewer are lifted to the higher elevation and continue to the wastewater treatment plant without delay.

This would occur with the highest use of equipment

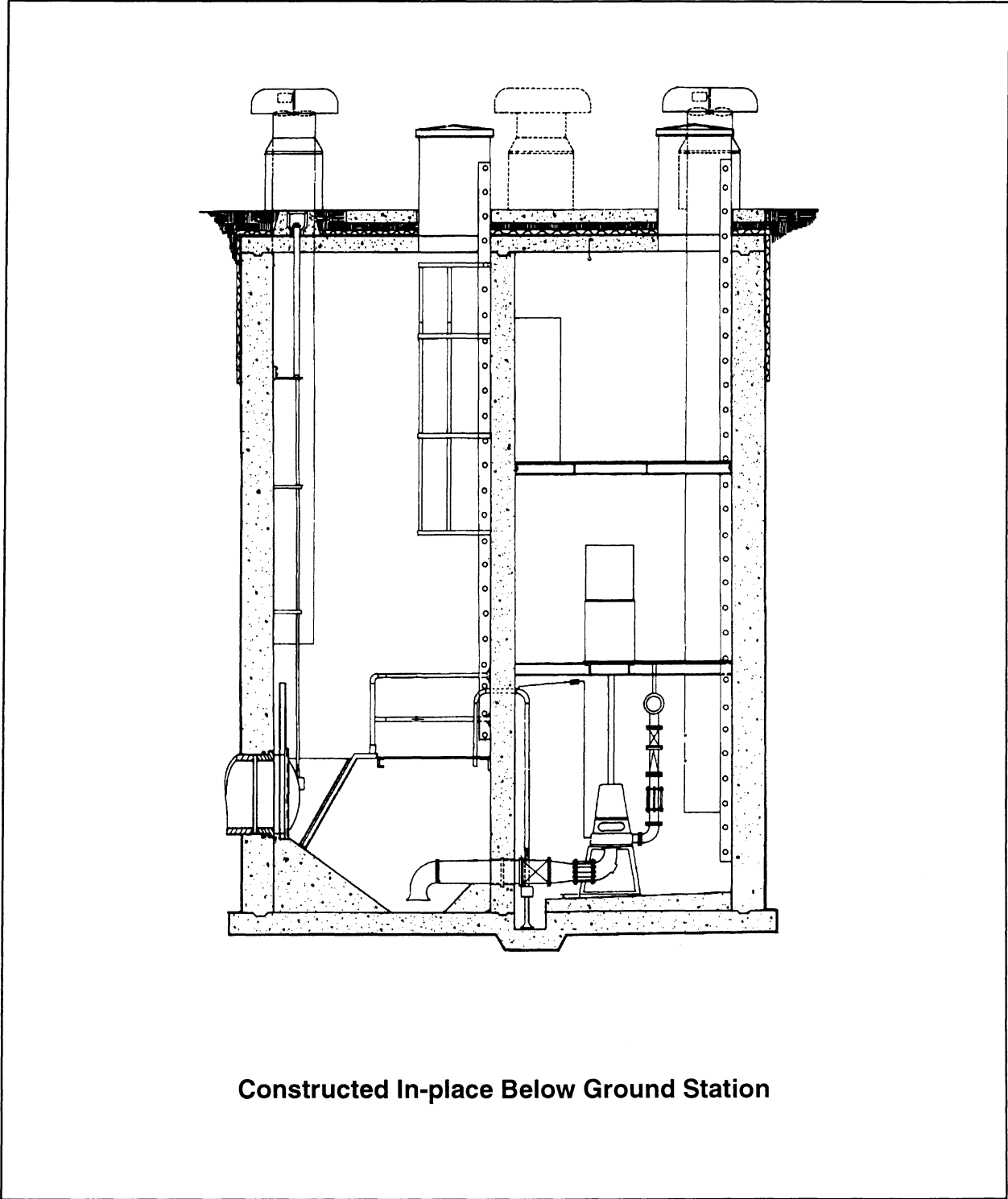
Wastewater Collection Systems



Lift Stations



Wastewater Collection Systems



Constructed In-place Below Ground Station

and energy efficiency possible. Also operational and maintenance problems would be minimized.

Some lift stations almost meet these ideal requirements, but there are many more that are unable to meet these requirements.

Usually a lift station is designed to handle expected peak flows. Often this means that long detention or holding times occur in wet wells during low flow periods.

Provisions for wet well aeration during low flow periods could help keep the detained wastewater fresh.

Do not introduce excessive air into wet wells of pumping stations with long force mains with numerous high points.

Released air can accumulate in the high points in a force main and cause an air bubble to form, which reduces the effective diameter of the pipe.

This will result in higher pumping costs and reduced pipe flow capacity. In addition, accumulated air in the force main can contribute to a phenomenon known as “water hammer” in which extremely high pressure shock waves travel up and down the force main.

Water hammer can cause broken force mains or piping within the pump station.

Trapped air in the force main is usually associated with check valve “slamming” which frequently produces a force strong enough to damage check valves and piping in the station, thus causing a failure flooding.

Air release valves are normally installed at high

Wastewater Collection Systems

points in the force main to automatically blow off accumulated air.

The most critical component of a lift station is the pumping unit; but pipes, valves, controls and power supply also are essential. All of these items must be “go” or the lift station will fail.

Capacity

Flow

Most pump capacities are rated in GPM (gallons per minute). The design engineer must carefully estimate flows under operating conditions to select the proper pump or pumps for the lift station.

Important operating conditions include:

Flow, Q_1 = Average daily dry weather flow

Flow, Q_2 = Seasonal dry weather flow (to handle industrial flows that produce high flows for 1 to 3 month periods such as canneries)

Flow, Q_3 = Peak wet weather flow (based upon a one-in-ten-year occurrence or some other severe storm frequency that produces conditions where inflow/infiltration may enter the collection system, especially important in combined wastewater and storm water collection systems).

Under certain circumstances, Q_2 and Q_3 may range from 1.5 to 10.0 times or more above Q_1 .

These high flows present greater problems in smaller lift stations than in the larger stations with multiple pumping units.

All but the smallest lift stations should have sufficient pump capacity to handle peak flows. During usual or average flow conditions, the pumps that handle peak flows can serve as backup units during periods when the other pumps are shut down for maintenance and repairs.

Head

The term HEAD refers to pressure head (pounds per square inch or psi) or elevation head (feet). Head is a vertical distance and is measured as the difference in elevation between two points. Head may be expressed in feet or psi. Important head terms that should be known when pumps are selected include SUCTION HEAD, DISCHARGE HEAD, TOTAL STATIC HEAD, and TOTAL DYNAMIC HEAD.

Suction heads may be positive or negative (suction lift), depending on whether the water level in the wet well is above (positive) or below (negative) the center line of the pump impeller.

Discharge heads are measured on the discharge side of a pump from the center line of the pump to an elevation on the discharge side. Discharge heads contain 2 components, static and dynamic discharge heads.

Static heads are measured when the pump is not operating and are the differences in elevation (in feet) between the surface of the water on the suction side of the pump and the surface of the water on the discharge side of the pump.

Dynamic heads are measured when the pump is operating and depend on the velocity of water in the pump suction and discharge pipes.

Dynamic heads are greater than static heads because they include the static heads plus the friction losses in the suction and discharge pipes.

The energy required to start a pump is greater than the total dynamic head (TDH) during normal operating conditions because additional energy is required to start the motor and the pump and to start the water flowing through the pipes, the check valves, and the pump.

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Friction losses result from pipe friction and the friction losses due to the water flowing through pipe fittings such as valves, reducers and elbows. The greater the velocity of flow in pipes, the greater the friction losses.

Suction pipes are often larger in diameter than discharge pipes to reduce friction losses in the suction pipe and thus also to reduce CAVITATION problems.

However, cavitation problems are more likely to be caused by excessive tip speed of the impeller, air leaks on the suction side of the pump, and restrictions in the suction line.

Friction losses may be calculated from tables in pump and pipe handbooks by knowing the flow (in GPM) and the diameter, type, and length of pipe and also the size and type of valves and fittings.

Design engineers try to minimize friction losses by careful layout of pipes, selection of pipe size (diameter) and length, and the number of valves and fittings.

Consideration must be given to friction losses at expected flows and suction conditions when determining desired pump characteristics and selecting a pump. If the lift station piping and pumps are not properly designed, problems can develop from vibrations, cavitation, and insufficient pumping capacity, thus requiring excessive maintenance.

Components of a Lift Station

Wet Wells

The wet well size and shape and the equipment located in it must be carefully designed in order to allow proper operation of the pumping equipment and to allow the operator to maintain the wet well area.

Wet Well Dimensions

The wet well size affects many operating conditions of the lift station; however, many of these are fixed at the time of design which limits the improvements an operator can make if problems develop or exist.

The length, width and usable depth will affect the cycle (on-off) time of the pumps since the wet well acts as a storage basin. If the capacity of the wet well is too small, excessive starting and stopping of the pump motors will occur which will ultimately result in a premature failure of the motor winding insulation.

Cycle times should be calculated for minimum, maximum, and peak flow periods. The ability of a motor to withstand frequent starting is generally limited by the motor size and, in the larger horsepower, may be limited to as few as five starts per hour.

If, however, the wet well is too large, solids will tend to accumulate on the bottom since the wet well will be acting as a settling tank, similar to what occurs in a treatment plant sedimentation tank or clarifier.

If solids accumulate in the tank they could partially or totally obstruct the pump suction pipes and, over a period of time, microorganisms decomposing the organic material will generate hydrogen sulfide (toxic) and methane (explosive) gas.

Therefore, the design engineer may have to compromise between motor cycle time, minimum and maximum flows, and the detention time period. This may require annual, semiannual, or even more frequent removal of the solids from the wet well using a vacuum-type cleaning machine.

Another method of cleaning the wet well is the use of high pressure water from the hydraulic cleaning jet) machine. **WARNING:** As the solids are dis-

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turbed they may release hydrogen sulfide and methane gas.

Also, the introduction of large quantities of solids in a short period of time into the pump suction could cause pumps to become partially or fully plugged and actually damage the pumps.

Flow Distribution

Flow distribution from the influent pipe in the wet well can create operating problems if the wastewater flow discharges directly opposite one or more of the pump suction pipes.

Normally, this flow is aerated so that it contains large amounts of air.

As the entrained air rises to the surface, it can accumulate in the suction pipe causing the pump to become air-bound. Then, when the pump is turned on, it will not pump the wastewater.

Entrained air frequently contributes to pump cavitation which can rapidly destroy the impeller or wear rings and other pump components in the liquid end of the pump.

This situation is usually caused by improper design and the operator has limited options available for correction; however, construction of a baffle to divert the flow may be effective.

Operating Levels

The operating levels in a lift station are determined by the high and low water levels in the wet well. The high water level is usually limited to the invert of the incoming gravity pipe, since it is not desirable to allow "backup" into the incoming gravity pipe.

The lowest water level is usually defined by the center line of the pump impeller. When using pumps that are not self-priming, the wet well water

level should not be drawn down below the center line of the pump impeller.

Too small a distance between the gravity pipe invert and the center line of the pump contributes to the short cycling of the pump motors.

Automatic Lead/Lag alternation of the pumps, which selects a different pump each time a complete pump-on/pump-off cycle is completed, is an effective way to minimize short cycling.

The minimum required wet well level (submergence), in some cases, may be higher than the center line of the pump impeller depending on the suction line size and pump capacity.

Even though the minimum water level is above the center line of the impeller, a condition called “vortexing” may occur.

This happens when the water is being drawn into the pump so rapidly that a vortex or whirlpool forms on the surface of the water.

This turbulence draws excessive amounts of air into the pump suction along with the wastewater.

Although the vortex is usually visible to the naked eye and can be observed while the pump is pumping, it can be difficult to detect. The only solution is to raise the minimum operating level for the pumps, however, this will then affect the number of times per hour that the pump motors start.

Aeration systems in the wet well are sometimes necessary to reduce odors in the wet well if detention times are excessive or if the wastewater reaching the wet well is septic due to warm temperatures and long travel times in the sewers. These systems may be another source of entrained air creating pump operating problems and/or air accumulation in the force main.

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Many lift stations built since the 1960's have variable speed pumps that adjust pump speed and pump capacity in an attempt to match the pumping rate with the flow rate into the wet well.

In many cases, however, the wet well in these types of installations may not be of adequate size, since there are a number of factors in the pumping system that determine whether or not the pump's speed will actually be able to match the incoming flow.

If the variable-speed pumping system works as intended, it does provide an almost constant flow to the treatment plant which results in an easier operation of the plant.

On the other hand, if pumps located near a treatment plant come on and off according to levels in a wet well, the treatment plant receives surges of wastewater that are difficult to handle.

Wet Well Access

Larger lift stations which require frequent access by the operator to perform routine maintenance should have stairs constructed in them.

Stairs should be built of a corrosion resistant material such as fiberglass or aluminum, since steel will deteriorate in the corrosive atmosphere of the wet well.

Similarly, doors or access hatches should be made of a noncorrosive material.

Environmental conditions can also create problems for wet well access, particularly below-freezing weather in the northern climates.

Frost and ice buildup tend to accelerate rusting of metal doors. Ice buildup may actually freeze the

door shut.

If the wet well contains a bar screen, a method of material handling must be provided so that screenings can be removed from the wet well. Floats, bubblers, fixtures, metering flumes or other equipment which require maintenance in the wet well should be easily accessible.

Wet Well Inlet Channel

The inlet channel of larger stations must be designed to allow proper flow distribution throughout the wet well and to minimize problems of solids settling and submergence described in previous sections.

A split wet well which allows isolation of one half of the wet well and pump sections is a desirable feature, particularly in larger stations. Frequently, a flume-type flow metering device is also located in the inlet channel to measure the flows being pumped.

Wet Well Safety

Wet wells are defined as confined spaces by most agencies. All the safety procedures and equipment established by your agency should be reviewed carefully and implemented when working in the wet well area.

Hydrogen sulfide and other toxic gases, oxygen deficiency, and explosive atmospheres are all conditions which can exist in the wet well. In addition, slippery ladders or stairs caused by the buildup of slime and the continual presence of moisture can create slipping and falling hazards.

If the wet well has standard manhole steps for access, they should not be depended on to be structurally sound.

After a period of time, corrosion will cause the steps

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to fail and this could be fatal to the operator.

Wet Well Hardware

All hardware in the wet well used for fastening piping, platforms, or stairs should use stainless steel anchor bolts or other noncorroding material.

Aluminum ladders and platforms are popular because of their corrosion resistance features.

However, aluminum must not come in direct physical contact with concrete since this will result in corrosion of the aluminum. Handrail supports, for example, set into concrete without any protective coating will eventually corrode at the interface where the aluminum enters the concrete, resulting in a failure of the handrail when an operator or visitor leans against it.

Wet Well Electrical Systems

The wet well atmosphere can contain explosive or flammable gases and is classified as a Class 1, Division 1 area (National Electrical Code). Any electrical systems must either be explosion-proof or be rated as intrinsically (by its very nature) safe. Equipment installed in the wet well should be kept to a minimum since maintenance can be very difficult. Changing a light bulb in an explosion-proof fixture may be impossible for example, because of corrosion of the machined surfaces and threads in the fixture. Replacement of the entire fixture would then be necessary.

Standard galvanized conduit and fittings will corrode rapidly in the wet well atmosphere, and therefore, aluminum conduit and fittings or PVC-coated conduit should be used.

Fixtures and alarm floats should be easily accessible and not require the operator to increase the possibility of slipping or falling.

If possible, do not install fans, blowers, or motors in the wet well because of the corrosive conditions.

Bar Racks

Installation of bar racks or screening devices in the wet well used to be a common practice, especially on the older combined wastewater and storm water collection systems due to the debris entering the system from the surface runoff drains containing leaves, sticks, cans, and trash.

In collection systems for only domestic and industrial wastewater, bar racks or screens have been eliminated by some agencies at the lift station because most pumping units are equipped with open IMPELLERS or closed two-port impellers sized to pass solids up to the size of a 2.5-inch diameter sphere.

This is the largest size sphere which may pass through most home lavatory and disposal systems.

Bar racks are installed to prevent any large debris from entering and plugging or damaging a pump. In areas where vandals remove manhole covers and throw junk into sewers, bar racks may be helpful. When bar racks are used, they should be cleaned frequently so there is no substantial restriction of wastewater flow to the pumps.

The cleaning of bar racks is accomplished with forks, screen baskets, or any type of tool capable of picking up the debris and removing it from the bar racks.

A limitation of bar racks is the fact that screenings cause odors and attract flies.

Screenings are usually removed from the station in buckets and transported to a disposal site. Agencies that have removed bar screens from lift stations which pump sanitary wastewater have found the

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pump impellers occasionally become plugged with rags (two to three times a year).

However, this problem is preferred to the necessity of visiting a station one or two times a day to clean a screen and struggle with hauling the screenings to a disposal site. Many pumps are designed to “chew” the rags into a size small enough to be pumped.

In larger lift stations, some agencies are installing COMMINUTORS and barminuters to shred rags and debris ahead of wet wells and pumps. A bypass channel with a rack is needed for use when the comminutor is being repaired.

Dry Wells

A dry well is that portion of the lift station which is isolated from the wastewater and used to house the necessary equipment for the lift station to function.

The structure commonly has two or more floor levels

The lower floor usually contains the pumping units, isolation valves, discharge manifold (pipes), and a sump pump to remove excess water such as seal water leakage and clean up water.

Electrical control boards, motors, ventilation equipment, necessary station controllers and auxiliary equipment are housed on the upper floor.

This provides protection to station equipment in case of a broken valve or fitting or a leak that would permit wastewater to flow from the wet well or force main into the dry well side of the station.

Flooding of the lower level could occur, but the electrical systems, motors and expensive control equipment would be protected from water damage and would allow the station to be put back into

service very quickly.

Electrical System

With the exception of very small lift stations such as grinder pump stations that serve one or two residential services, electrical power is three-phase utility power.

Single-phase systems are limited to about five horsepower since beyond that, wire, controller equipment and other components increase dramatically in size to carry the amount of current required for a single-phase system.

Three-phase electrical systems are able to operate higher horsepower loads because the current is distributed over the three phases and three individual sets of conductors.

A block diagram of a typical lift station electrical system is shown in the next figure.

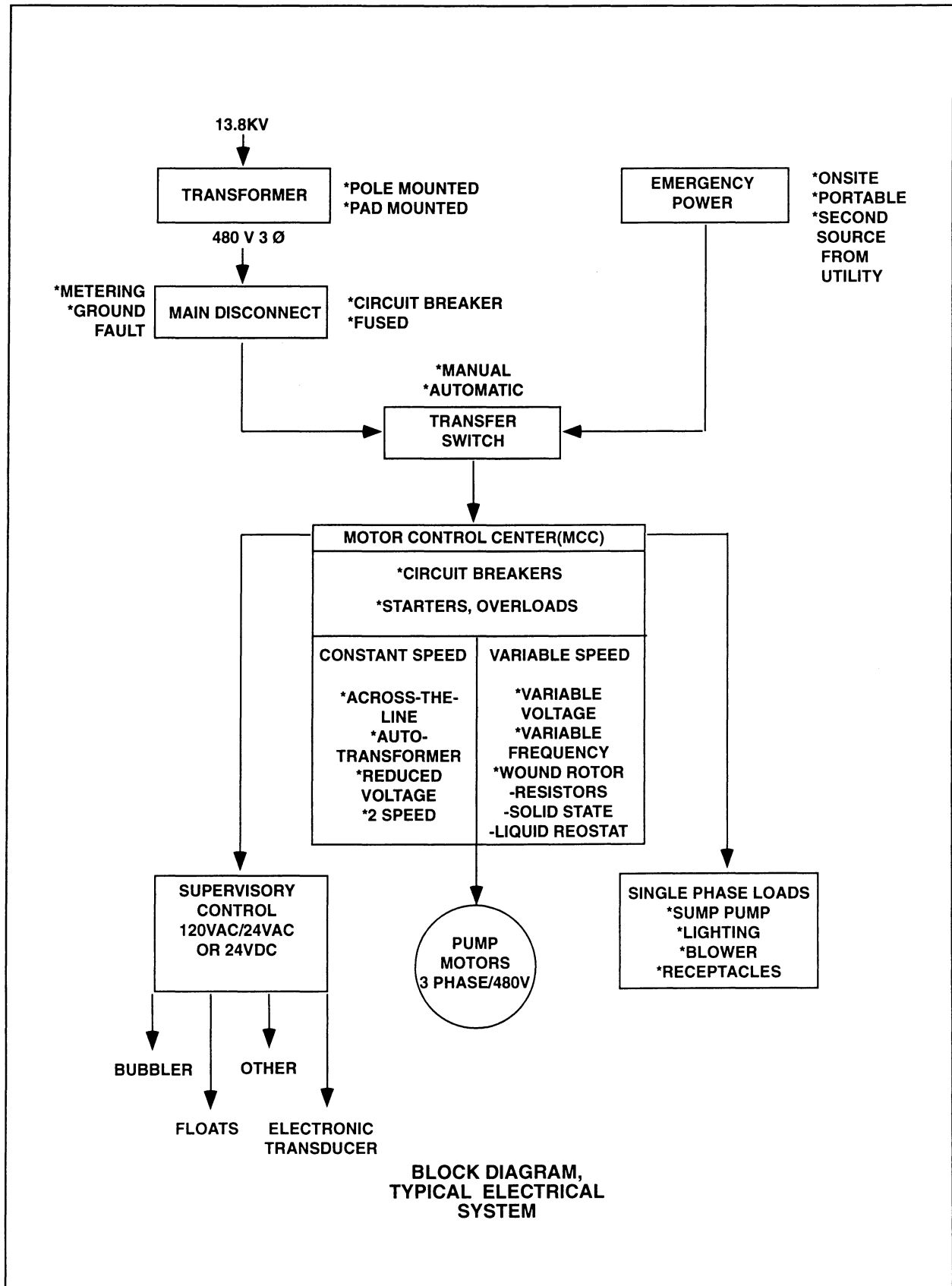
Power Transformers

Power is supplied by the utility company through one or more pole-mounted transformers or a pad-mounted transformer.

The power company usually supplies a high voltage; for example, 13,800 volts (13.8 KV). The transformer(s) steps this voltage down to 3-phase 208, 220, 240, 440, 460, or 480 volt systems at a frequency of 60 cycles per second (60 Hz). In larger pump stations the operating voltage for the motors may be higher than 480 volts; however, this is not common except in extremely large pump stations.

For purposes of discussion, let us assume that in this

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particular pump station the utility company transformer steps the voltage down to 480 volts, 3-phase.

Metering

Power is fed into the power company metering which is usually a watt/hour meter.

A demand meter which measures the peak electrical demand required by the pump station, usually on a monthly basis, may also be installed.

Peak demand in a multiple-pump station usually occurs when all pumps are operating at peak flow conditions.

In some cases, the power company may impose a penalty on the user for high demand conditions.

Coordinating pump operation to reduce maximum electrical demand is one area an agency can examine to reduce electrical operating costs.

Main Disconnect

The main disconnect switch may be fused, a circuit breaker, or simply a disconnect switch to allow isolation of the entire electrical system within the pump station. In newer stations, this section also may contain a Ground Fault Interrupter (GFI) circuit.

Transfer Switch

If the pump station is supplied with either a permanently installed emergency generator or provisions for a portable unit, a transfer switch is used which may either be manually operated or automatically operated when the utility power source is lost. Pump stations with an automatic transfer switch will also have an automatic control system to start up and operate the emergency engine-generator set.

Pump stations may also have provisions for con-

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necting a portable standby power system which, again, is an engine driven generator that can be towed to the site and plugged

Motor Control Center (MCC)

The motor control center, or main panel as it is sometimes called, houses the controls for all motors and electrical equipment operated within the station. These controls include a starter, fuses, heater strips and all the coils and relays necessary for any particular pump or motor to operate.

The motor control center is fed 480V, three-phase power and contains branch circuit breakers, starter devices, three phase overload relays, and a low voltage control circuit for starter coil operation and indicating lights.

Each three-phase motor will have these control components in the circuit.

For small, constant-speed pump motors, power is supplied to the motor via the starter contacts. This is referred to as across-the-line starting (ACL).

In larger motors it is common practice to use an additional control section to reduce starting currents, since across-the-line starting will require motor starting currents of six to eight times the normal running currents.

Frequent starts for a motor are not good because high starting currents generate heat in the windings which cannot be dissipated. If the winding temperature is exceeded, the insulation will break down and cause a short within the motor windings.

Other types of starting methods are also used.

In some motors, different sets of built-in windings are connected during the start phase and the run

phase; this is known as reduced voltage starting. In the autotransformer starting system, different values of transformer-type windings are switched to limit the amount of current during the start phase. Another alternative is to use two-speed motors.

These may be used if the speed is selected to correspond to the incoming flow of the wet well. All of these methods require some sort of additional starter contacts and control arrangements for each motor utilizing them.

Variable-speed motors are often used in an attempt to match the pumping rate to the incoming wet well flow. Types of variable-speed systems typically used are:

- ◆ Variable frequency (VFD), and

- ◆ Wound-rotor motor using variable resistances in the secondary winding of the motor to change the operating speed of the motor. This is accomplished by:
 - ◆ Metal resistors where different values of metal resistors are switched by a controller,

 - ◆ Liquid rheostat which varies the resistance in the secondary by varying the level of a conducting liquid on electrodes, and

 - ◆ Solid state devices which vary the resistance in the secondary using silicon-controlled rectifiers (SCR).

110-Volt/220-Volt Loads

In addition to the 3 ϕ power levels, there are also single-phase, 110-volt/220-volt loads in most stations.

An additional transformer is required to convert the

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480 volt, 3-phase to 110/220 volt, 1-phase. Typically, 120-volt loads would be used for lighting systems, sump pumps, ventilation blowers, and convenience receptacles.

Supervisory Controls

The supervisory control panel, which controls the operation of the pump motors, is usually powered with single phase, 120-volt current.

An additional step-down transformer may be used to reduce control voltage to 24 volt AC or 24 volt DC (24 VAC, 24 VDC).

There are several different methods of measuring the liquid level in the wet well. The supervisory control system uses this signal to turn the pump motors on and off. The two most popular methods are the air-operated bubbler system and the electrically operated float system. Recently, electronic transducers have also been developed which convert wet elevation to an electronic signal.

Motors

Motors can have different voltages, horsepower readings. Also, they will be rated at 60 cycles and single-phase or three-phase. Voltage ratings depend on the local power source and may be 208, 220, 440, 460, 480 volts or higher for very large stations, 60 cycles, and three-phase. Occasionally in a very small lift station a single-phase motor is used.

Submersible pump motors are an integral part of the pump and are encased in the pumping unit.

When a seal fails on a submersible pump, the wastewater penetrates the motor compartment and burns or shorts out the motor.

If a maintenance operator resets the unit and it operates properly for a short period of time with no

overload, the operator can assume that a seal failure was not the reason for the shutoff, but that the pump had overloaded the motor.

Determine the load on the motor and check for proper voltage.

Also look for plugged lines and be sure wet well and pump are clear of rags, mud and debris that could cause a temporary overload.

Motors

By far the most common motor used in lift stations is the squirrel cage induction motor (SCIM). **The next figure** illustrates a typical horizontal squirrel cage induction motor and the various motor components. The term squirrel cage originated from earlier induction motors in which the rotor (rotating part) looked like a squirrel cage.

Three-phase power from the Motor Control Center (MCC) is applied to the stator winding which generates a rotating magnetic field.

The rotor assembly, because of the way it is constructed, behaves like a transformer.

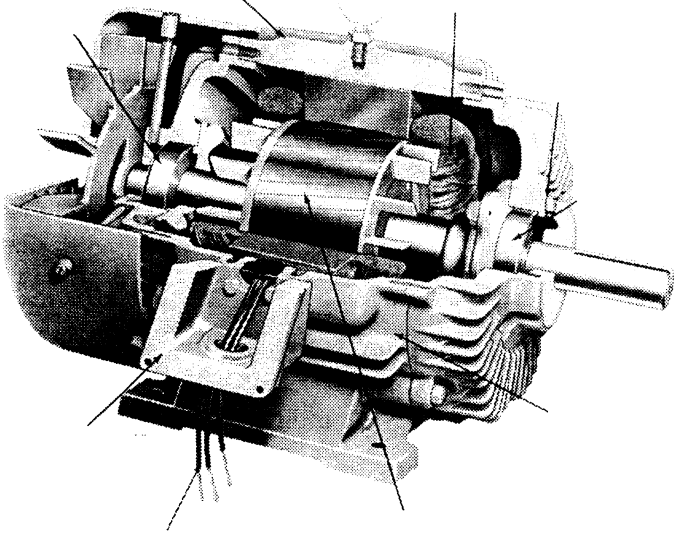
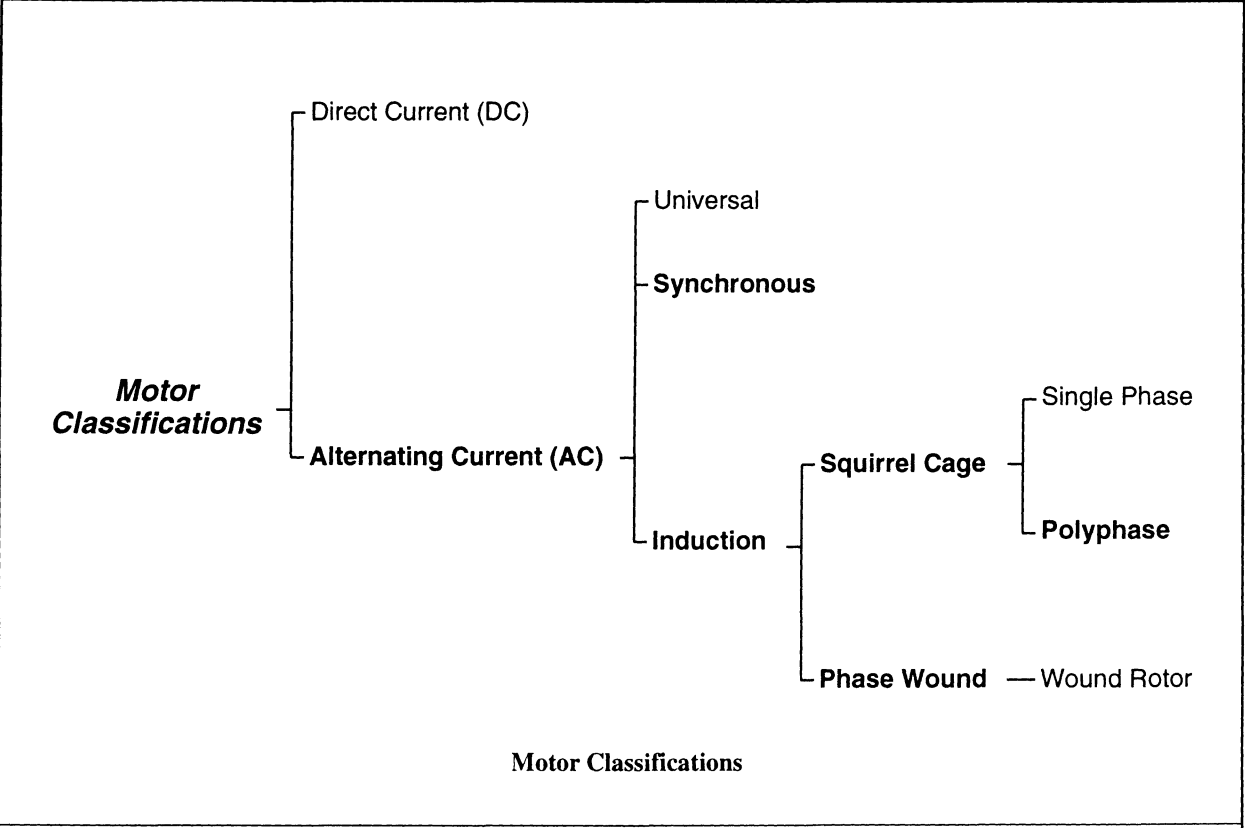
Voltage is induced into the rotor which causes current flow and generates a second magnetic field in the rotor circuit. There are NO electrical connections between the stator windings and the rotor.

It is the interaction of the two magnetic fields that causes the rotor to turn and to develop torque.

Some variable-speed systems in lift stations use a variation of the squirrel cage induction motor called the wound rotor induction motor (WRIM).

In this case, the rotor circuit is connected externally through the use of slip rings and brushes which

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allows the external connection of various values of resistance. This causes the rotor to change speed ranging from zero RPM when the rotor circuit is “open circuited” to full RPM when the rotor circuit is “short circuited.”

Depending on space requirements in the station, motors and pumps may be mounted horizontally or vertically. The mounting configuration is unique for each design.

Motors are selected based on a number of factors as listed below:

- ◆ Design - NEMA A, B, C, OR D
- ◆ Horsepower
- ◆ Synchronous Speed-3600, 1800, 1200, RPM
- ◆ Frame Size
- ◆ Voltage
- ◆ Frequency
- ◆ Phases
- ◆ Enclosure
- ◆ Service Factor
- ◆ Ambient Temperature
- ◆ Environmental Condition
- ◆ Special Electrical Features
- ◆ Special Mechanical Features

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- ◆ Mounting
- ◆ Type Bearings Required
- ◆ Duty-Continuous, 1 Hour, Etc.

These features are discussed in more detail below. Because the use of induction motors dates back to the early 1900's, and because they are in such widespread use, they are very well standardized. Electrical equipment standards including motors are specified by organizations such as the National Electrical Equipment Manufacturers Association (NEMA) and the Edison Electric Institute. Therefore, many of the things which apply to a motor of one manufacturer, such as dimensional information, will be identical to that of any other manufacturer. If, for example, you were to replace a motor that was constructed with a 445 T frame, this machine would be dimensionally the same as a 445 T frame from a different manufacturer.

Power Supply Voltage

Motor nameplate voltages will be less than the utility power system voltage because of the following established recommended standard for 60 Hz power systems:

Nominal Power System Volts	Motor Nameplate Volts
208	200
240	230
480	460
600	575

Motors rated 200 horsepower and below will operate at rated load with a voltage variation of + or -10 percent of nameplate value. If frequency varies as well, the sum of the voltage and frequency

variation should not exceed +10 percent. In any case, frequency should not vary more than +5 percent.

Motor Type

Although there are four designs specified (A, B, C, D), the NEMA design B is most common in wastewater lift stations and is characterized by normal starting torque, low starting current, and low slip.

In the case of variable-voltage and variable-speed drives, high-slip NEMA design D motors are generally used and their full load speed is 8 to 15 percent lower than the synchronous speed.

Enclosure

The motor enclosure used depends on the ambient or environmental conditions where the motor is installed and are of 2 general classifications:

- ◆ Open and Totally Enclosed

An open machine has ventilating openings to permit passage of external air over and around the windings of the motor. A totally enclosed machine is constructed to prevent the free exchange of air between the inside and outside of the motor frame, but is not airtight.

The two general categories of enclosures are broken down further as described in the following paragraphs.

- ◆ Open Drip Proof (ODP) - The ventilating openings are constructed so that drops of liquid or solid material falling on the motor at an angle of not greater than 15 degrees from the vertical cannot enter the motor directly or by striking and running along the motor frame surfaces.
- ◆ Open Drip Proof-Fully Guarded - An open

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motor having all air openings that allow direct access to electrically live or rotating parts, has either limited size openings or has screens to prevent the accidental contact of parts.

◆ Totally Enclosed Ventilated - An enclosed motor which is not equipped for cooling by external means.

◆ Totally Enclosed Fan Cooled (TEFC) - An enclosed motor equipped with an integral fan.

◆ Explosion Proof - An enclosed motor whose enclosure is designed and constructed to withstand an explosion of a gas or vapor if it occurs within the motor and prevent the ignition of the gas or vapor surrounding the motor (hazardous atmospheres are classified by the National Electrical Code).

Motor Windings and Insulation

In certain environments such as very damp or warm weather climates, additional insulation treatment is desirable to improve the ability of the motor insulation to resist moisture.

Standard motor insulation will have one or more coats of varnish applied during construction.

Additional coats will improve the resistance to moisture. In certain cases, a special insulation system called non-hygroscopic insulation is available; it is made of materials that will not absorb or retain moisture.

Motors can also be selected for hot, humid environments by specifying tropical insulation treatment, including:

Use of a higher class of insulation for higher ambient operating temperatures,

Special insulating materials such as varnish to prevent fungus growth, and

Screens over all air openings on open, drip-proof motors to prevent the entrance of rodents and snakes.

Altitude

Motors depend on the ambient air to remove heat and this heat transfer is a function of air density. Altitude can decrease the effectiveness of this process.

Accepted guidelines state that air density has little effect on cooling between sea level and 3300 feet. As a rule of thumb, motor operating temperature will increase one percent for each 330 feet increase in altitude over 3300 feet.

Motor Mounting

There are three types of standardized machine mounting configurations for motors. These allow you to attach pumps or other equipment to the motor.

- ◆ Type C face end shield. Provides a male rabbet and tapped holes for mounting bolts (sump pumps).
- ◆ Type D flange. Has a male rabbet, but with hole through bolts in the flange.
- ◆ The Type P base. Has a female rabbet and through bolts for mounting in the flange and is used to mount motors in a vertical position.

NEMA Code Letters for Locked Rotor Kilovolt-Ampere

Motor Codes are particularly important when considering the sizing of pump station standby power since it directly relates to the generator's ability to start the motor.

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The motor code represents the locked rotor kilo-volt-ampere (KVA) per horsepower of the motor and is calculated by: $KVA/HP = 1.73 \times I \times E/1000 \times HP$

The table lists the letter designation and the KVA per horsepower required:

Letter Designation	KVA Per Horsepower
A	0.00-3.15
B	3.15-3.55
C	3.55-4.00
D	4.00-4.50
E	4.50-5.00
F	5.00-5.60
G	5.60-6.30
H	6.30-7.10
J	7.10-8.00
K	8.00-9.00

Typically, lift station motors are Code G or Code H motors.

Internally Thermally Protected Motors

Many agencies require motors to be supplied with internal thermal protection which constantly monitors the winding temperature of the motor.

If the temperature is exceeded, a switch, which is connected to the control circuit in the motor control center, opens and stops the motor. (These standard connections are labeled P1 and P2 in the motor conduit box.)

The circuit can be wired so that when the motor winding cools down and the thermostatic switch resets, the motor restarts; however, it is preferable to lock the motor out through the control circuit to prevent the motor from restarting until the problem is investigated.

Unless the motor is specially designed, the motor ambient operating temperature should not exceed 40°C (104°F).

Service Factor

Service factors greater than 1.0 allow an added margin of safety to account for higher voltage or frequency variations. A 1.0 or 1.15 service factor is usually found on lift station motors.

The service factor should not be used for continuous motor overloading which exceeds the nameplate horsepower.

INDUCTION MOTOR					
4	5	6	DUAL SPEED	1	2 3
OPEN	• • •			↔ ↔	
LINES	↑ ↑ ↑			↑ ↑ ↑	
LOW SPEED				HIGH SPEED	
SER NO		TYPE		MOD	
HP		FRAME		SF	
AMPS		VOLTS		INS	
RPM		HERTZ		EFF	
DUTY		°C		DES	
SE BRG		EO BRG		OP IN	
Ø 3		KVA CODE			
ROTATION FACING DRIVE END WITH PHASE SEQUENCE A-B-C					
CCW A-T B-T2 C-T • CW A-T B-T2 C-T					

Shown above is a typical motor name plate for a dual speed AC induction motor. The name plate indicates the motor has 6 leads and in the low speed connection, 3-phase power is connected to lines 1, 2, and 3. Lines 4, 5, and 6 are not connected. The high speed connection requires the lines to be connected to 4, 5, and 6, and leads 1, 2, and 3 are connected together. In addition, the name plate indicates serial number, type and model, the horsepower rating, full load amps, operating RPM, duty shaft and bearing number, motor frame size, operating voltage and frequency, ambient operating temperature, opposite end bearing number, KVA code, service factor, insulation rating, efficiency in percent, name and design, and operating instruction numbers. The last piece of information this name plate provides is the phase sequence which determines rotation in conjunction with the phase sequence of the utility supplied power.

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Controls

Controls to start, stop or change pumping rates in a lift station are used to tell the pumps when to operate based on the level of the wastewater to be pumped from the wet well.

Primary controls such as floats, bubblers or pressure sensitive devices measure the level of water in a wet well.

Secondary controls convert the measurement from the primary controls into a signal for a pump to start, stop, or change speed.

These secondary controls convert a sensing signal into a mechanical or electrical signal which, in turn, actuates low voltage motor relays to start or stop motors or milliamp signals to change ranges on variable-speed equipment.

Float Controllers

Float controllers are one of the oldest methods used to start and to stop pumps or to indicate the level of water surface in the wet well. The float may be a four- to eight-inch diameter ball manufactured from copper or stainless steel, or it may be a flat plate of six to twelve inches in diameter and several inches thick manufactured from copper, stainless steel, or a ceramic material, or it may be a cylinder of six to ten inches in diameter and six to ten inches in depth and made of glass, stainless steel, or a ceramic material. In some instances old brown jugs were used for floats. The jugs were partially filled with sand or lead shot to provide stability and to counteract the float buoyancy.

All of these devices float on the water surface. When the wet well fills and the water surface rises, the float rises; and as the wet well is pumped down, the float drops with the water surface.

The float must be physically attached by steel rods, steel tapes, cables, or ropes to transmit the rise and

fall of the float to a recording or signaling device.

Rod-attached floats

Ball floats are usually attached to 1/4 or 3/8-inch steel rods. The rod is attached to the top of the ball float and extends up to or through the cover of the wet well and passes through the eye of an actuator arm that is connected to a micro switch. The float rod is equipped with brass stops on both sides of the micro switch arm. When the wet well fills, the bottom stop on the float rod pushes the micro switch arm up and starts the pump. When the wet well is pumped down, the float drops and the rod travels downward. When the top stop on the float rod pushes the micro switch arm down, it turns the pump off. The wet well rise and fall levels are selected or changed by moving the rod's stops to new positions on the float rod.

Lowering the bottom stop on the float rod permits a higher wet well water level by starting the pump later. Raising the bottom stop will lower the wet well level at which pumping is started. Once the top stop on the float rod is positioned, it should not be changed because it is set to turn the pump off before it loses suction. If a pump loses its suction and is allowed to operate, the pump could be seriously damaged.

The most common application of ball-type float controllers is on sump pump.

Steel tape, cable, or rope-attached to floats

This type of float is a little more complicated than the attached float. Generally this type of float requires a stilling well for the float to prevent excessive movement of the float. Too much movement of the float will produce incorrect readings. A stilling well is usually a section of pipe ten to twelve inches in diameter which extends several feet above and below the normal wet well operating water level. Usually the stilling well stands verti-

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cally in a corner or against a wall of the wet well. The stilling well is open at the bottom or is provided with a smaller inlet pipe of 2.5 to 4 inches in diameter near the bottom to permit water in the stilling well to follow the rise or fall of the water in the wet well.

The float is housed inside the stilling well and is provided one to two inches of free clearance to permit the float to travel up and down the stilling well.

At the top of the float is attached the steel tape, cable, or rope that goes up the stilling well, through the cover of the wet well, and is wound onto a small drum which is counter balanced to maintain tension on the float.

When the water in the wet well rises, the float rises and the drum rotates, thus winding in the float tape, cable or rope.

This rotation takes in slack in the line attached to the float and keeps the line taut.

When the wet well is pumped down, the float lowers and the drum reverses direction, thus unwinding the line attached to the float. When the wet well water level rises, the float rises and the float line is wound onto the drum or sheave.

This permits the counter balance to drop and rotate the drum holding the cams and mercury switch.

When the drum rotates sufficiently to drop the mercury switch from contact with the cam, this allows the mercury to run down to the contact end.

When this occurs, the switch closes, the pump motor starter is energized, and the pump starts.

When the wet well water level drops, the float drops, reverses drum rotation and unwinds the line attached to the float.

If the float drops far enough, the cam on the drum will raise the mercury switch, tilt the switch so the mercury leaves the contact end, opens the circuit and shuts off the pump.

These types of float controllers, described above, are no longer installed in new pump stations. In many cases, they have been replaced with other types of controllers due to the maintenance required for the electromechanical components.

The more current system of float control utilizes metal or plastic floats that are sealed with a mercury switch inside. Mercury is a conducting metal that is liquid in its normal state. It has very good conducting characteristics and is used to close contacts, depending on position in the float switch.

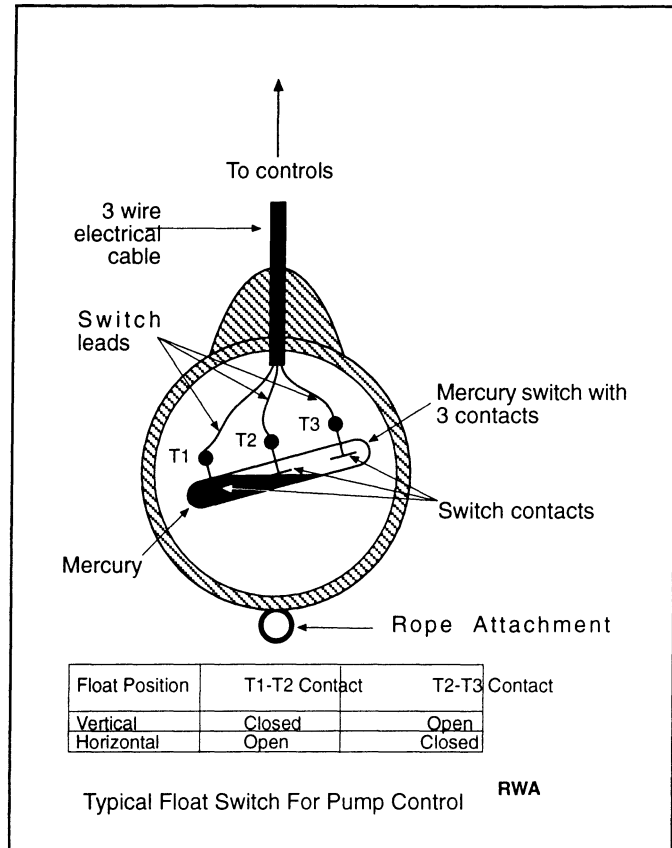
The float switch itself is permanently mounted inside the float at a slight offset angle so that in the vertical position, mercury makes contact between two of the switch contacts.

As the float tips, however, mercury flows to the other side of the bulb and makes electrical contact between the other switch contacts.

The following figure illustrates this type of float. The float enclosure is constructed of polypropylene or stainless steel.

Enclosed inside the float is a mercury switch with three contacts. Depending on the position of the float, will determine which contacts the mercury touches.

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For example, in the illustration shown, with the float in the normal vertical position, the mercury is making contact between the switches connected to T1 and T2. Mercury, which is a conductor of electricity, provides the closure between the two contacts connected to T1 and T2. Each of the contacts are connected by switch leads which in turn are encased in a three wire electrical cable leading up to the pump station control system. As the water level rises, the float will tip causing the mercury to flow to the other side of the switch and making contact between T2 and T3.

Generally, each pump in the pump station will have a start float and stop float. In addition, there is usually a third float used to signal a high wetwell condition and in some cases, there may a float to indicate low level cutoff or low level condition in the wetwell. When used for alarms, it is convenient

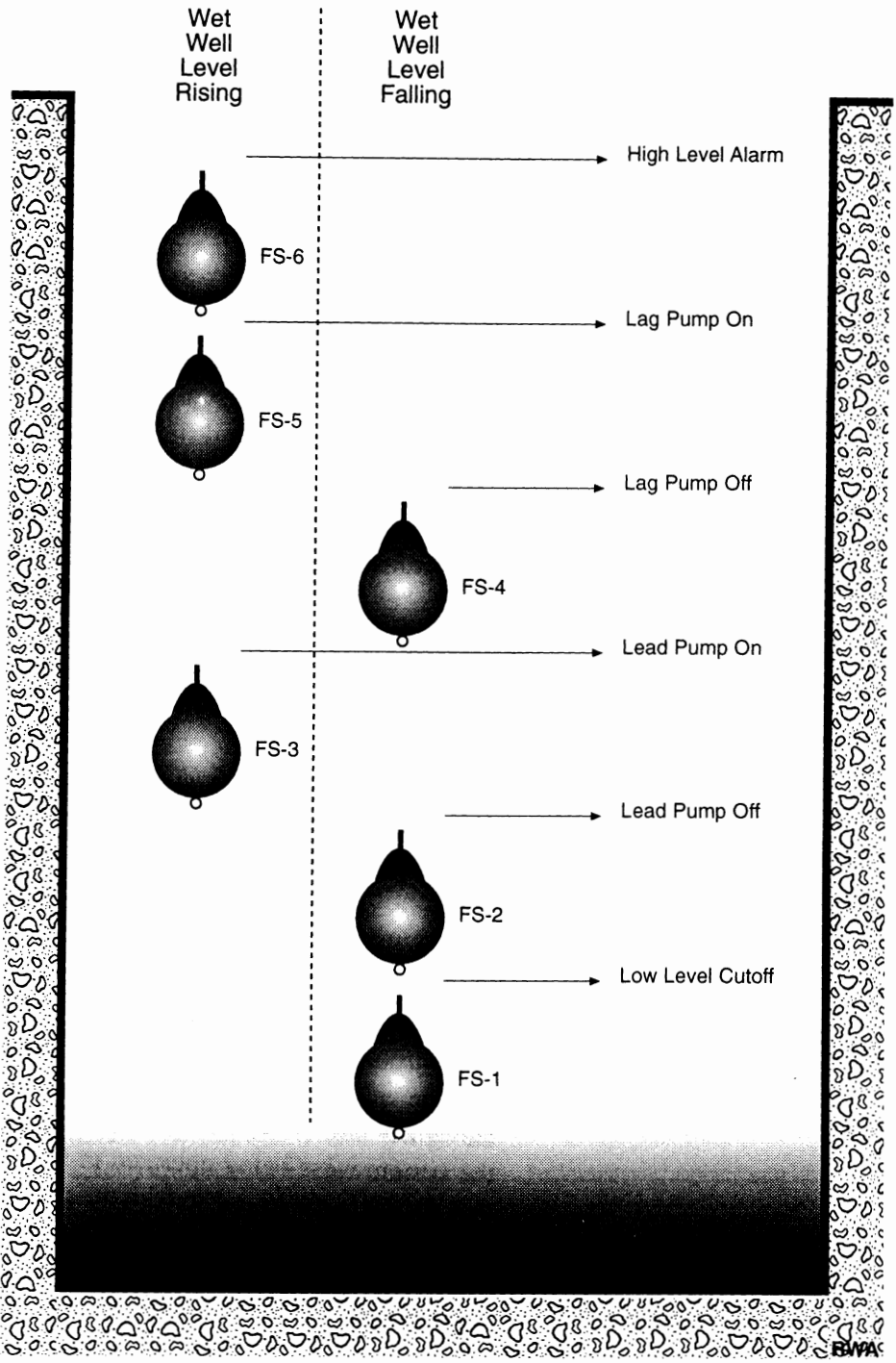
for operators to attach a rope and eye bolt to the bottom of the float and run that to the top of the wetwell, as shown in the figure . This allows testing of the float from the top of the wetwell without physically removing the float and tipping it above ground. Normally these floats are weighted internally to provide some sort of stabilization. Floats can be easily adjusted for different elevations in the wetwell simply by raising or lowering the float via the cable, tying off the cable at the top. However, this type float is susceptible to grease and rags as well as becoming entangled with other floats and cables. They can also be purchased with pipe mounted attachments which reduces the possibility of cable fouling, however, adjustment of the float elevation becomes more difficult.

The next figure is a typical float arrangement for a duplex pump station with high level alarm float and low level cutoff float. As the wetwell rises, float switch FS-1, the low level cutoff float, tips and enables the control circuit. As the level continues to rise, float switch FS-2, the lead pump off float, also tips, however, no control action takes place. As the level continues to rise, float switch FS-3, lead pump on float, turns on the lead pump. Under normal circumstances, the wetwell level is then pumped down until float switch FS-2, the lead pump off float, returns to the vertical position. At this point, the lead pump turns off.

The purpose of the low level cutoff float is to ensure that the waster level in the wetwell remains above the center line of the pump volute. If, for example, the system were being operated in manual control and the operator forgot to turn the pump off, the low level cutoff float switch would do so prior to pumping the wetwell down below the center line on the pump volute.

The low level cutoff float also provides additional protection in the event that the lead or lag pump off float switches fail.

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Typical Float Arrangement For Duplex Pump Station With High Level Alarm and Low Level Cutoff

In the event that this lead pump was unable to pump down the wetwell and the level continued to rise, float switch FS-4 would move to the horizontal position, this float switch is the lag pump off float switch and would not cause any control action. However, as the wetwell continued to rise, float switch FS-5, the lag pump on float switch, would move to the horizontal and energize the lag pump on. Now as the wetwell is pumped down and the wetwell is falling, float switch FS-4 would turn the lag pump off when the wetwell allowed it return it to the vertical position. In the event that two pumps were unable to pump down the wetwell, float switch FS-6, the high level alarm float switch, would activate when the level in the wetwell moved the float switch to the horizontal position.

Limitations of float control systems can include the following:

- ◆ Grease and debris enter the stilling well and hinder or stop the up-and-down movement of the float.
- ◆ Debris can be removed from the top of the stilling well.
- ◆ Grease can be controlled by running clear water (hot water is better than cold water) into the stilling well at a rate of 1 to 2 gallons per minute to keep the float and stilling well clear of grease and solids.
- ◆ Be sure that this flow of water does not produce false readings of the wet well level unless the openings to the wet well become plugged.
- ◆ Float attachment line or counterbalance line breaks and unwinds from drum sheave, thus allowing counterbalance to fall and all or none of the pumps could be called on to operate

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- ◆ Floats develop leaks which change or stop pump operation.
- ◆ Cables or ribbons attached to float can become twisted.

Electrode Controllers

Use of this method of control requires that electrodes be installed and maintained in compliance with safety regulations.

Be sure that power to the electrodes is turned off and properly tagged before performing any maintenance on the equipment.

Operators should be cautioned not to touch electrodes with bar screen rakes and other tools. Electrodes hanging in the wet well are at staggered elevations, usually six to eight inches apart.

As the wet well water level rises and submerges an electrode, the water surrounding the electrode completes the control circuit and starts the pump.

When the wet well level is pumped down and the electrode exposed to air, it opens the electrical circuit and shuts off the pump.

One electrode controls a single pump, and each pump usually has its own electrode.

A high wet well elevation electrode is used to indicate flooding of the wet well and activates an alarm to signal a high water level or flooding.

Limitations of electrode controllers include the following:

- ◆ Rags and debris can wrap around electrodes and alter desired start and stop water levels and sequences of pumps.

- ◆ Grease and/or slime can cover an electrode, thus preventing good conductivity and causing intermittent or unreliable operation.

Enclosed-Electrode Controllers (Seal trode units)

These controllers are a refinement of the old free floating electrodes. They work in the same manner except they are enclosed in a two to three-inch diameter pipe with a bulb type container on the bottom end containing an electrolyte solution.

Electrodes (one for each pump and a high level alarm) are set at different elevations in the pipe housing.

The bulb at the end of the pipe holds from three to eight quarts of electrolyte solution.

This volume is sufficient so that water pressure on the outside of the bulb will force the electrolyte solution up the tube to an electrode that completes the circuit and turns on the pump.

As the water level in the wet well rises, it compresses the bulb and forces the electrolyte up the pipe to the electrode.

When the wet well level is high enough to develop the pressure required to force the electrolyte solution up the tube to the electrode, the circuit is completed and the pump is started.

When the water level in the wet well drops, the electrolyte solution also falls and opens the circuit.

The electrodes in this system are spaced much closer in elevation (1.5 to 2.0 inches) because the change in water pressure on the bulb is small compared to changes in the water depth wet well.

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Limitations of enclosed electrodes include the following:

- ◆ When bulb breaks, electrolyte solution is lost
- ◆ Shorts occur in electrode wiring
- ◆ Bulb life is three to five years

Pressure-Sensing Controllers (Air Bubblers)

Air sensing (pneumatic) controllers are being used in many new lift stations being constructed today.

They are adaptable to several different control systems and may be used in either simple diaphragm and mercury switches for control inputs, in complex fluidics (air) systems using orifices and chambers to control outputs, or in analog equipment with differential transmitter square root extraction (a method of measuring pressure) and averaging relays that convert signals from pneumatic to electronic (4 to 20 milliamp) outputs for use by controllers and integrators.

Bubblers provide constant, low-volume, low-pressure air through a vertically mounted pipe in the wet well. The bubbler system is aptly named since, when working properly, bubbles can be observed at the surface of the wet well.

The principle of the bubbler system is actually fairly simple. If you have ever blown air through a straw into a glass of water, you know that it requires a certain amount of air pressure to displace the water in the straw and to force air out the bottom of the straw. The amount of force required is determined by the depth of the liquid over the end of the straw.

For example, if the depth of the water is 2.3 feet, it will require a pressure of 1 PSI (pounds per square inch) to push the air through the straw and out the bottom. (We know this since 1 PSI is equal to a column of water 2.3 feet high.)

Since the air pressure in the straw is directly related to the level of water over the end of the straw, it stands to reason that by measuring the air pressure we can determine the actual water level or depth.

The next figure illustrates a pneumatic bubbler system which because of its redundancy is extremely reliable. Described below are the individual components of this system.

Two-1/6 or 1/12 horsepower air compressors are mounted on a small-ten gallon air receiver tank which acts as an air reservoir. The tank is desirable since it allows the compressors to shut off instead of running continuously. Additionally, in the event of a failure of both compressors, the system would continue to operate because of the reservoir for some period of time (depending on the pressure in the tank) Note: Tank condensate must be bled off from the tank drain periodically.

Pressure in the discharge side of the tank is sensed by two pressure switches which turn the compressor on and off in a lead/lag sequence.

If the lead compressor fails, the lag compressor comes on when pressure in the system drops to a lower preset value at the lag pressure switch.

A two-inch 0-to-100 PSI gage is mounted in the line so that high pressure air can be monitored.

A desiccant-type air dryer (one that uses silica gel as the dehumidifying agent and that can be regenerated) is located in the line to remove moisture and prevent condensation farther downstream in the

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instrumentation or in the bubbler line.

A shutoff valve permits isolation of the high pressure air side from the low pressure air side for maintenance purposes and is in the normally open position during operation.

A pressure-reducing valve and a two-inch gage reduce the high pressure from 40 to 80 pounds (PSI) to generally less than 5 PSI (remember that the pressure will be determined by the depth of water in the wet well). Usually this is established by the highest level that can be reached under high wet well conditions. The two-inch gage monitors the downstream or low pressure side of the pressure-reducing valve.

An air flow regulator maintains a constant low volume flow of air into the system; typically, one-half to one cubic foot per hour.

A zero-to-five PSI pressure transducer senses the pressure in the line and converts the pressure to an electrical signal which is then sent to the motor control center and sequences pumps, alarms, and other supervisory control functions.

A low pressure switch is also installed at this point so that a loss of pressure can be sensed and alarmed.

A six-inch 0 to 160-inch gage, which is mounted on the supervisory control panel door, reflects actual level in inches in the wet well.

The last bleed-off valve shown in the system is in the normally closed position and is used for bleeding off condensation .

This particular system incorporates a manual purging panel which allows high pressure blow

down of the bubbler pipe in the wet well to clear grease or other accumulated debris from the system.

The advantage of a manual system versus an automatic purging system (which uses solenoid valves) is positive isolation of the low pressure instruments, specifically the pressure transducer, low pressure switch, and gages. Permanent damage to these instruments will occur if they become over-pressurized as might happen with automatic solenoid valves if high pressure air leaks past the seat.

The manual purging panel has quick disconnect pneumatic fittings on the front of the supervisory control. The operator physically removes the bubbler system low pressure side and connects it to the high pressure side.

Bubbler System Maintenance

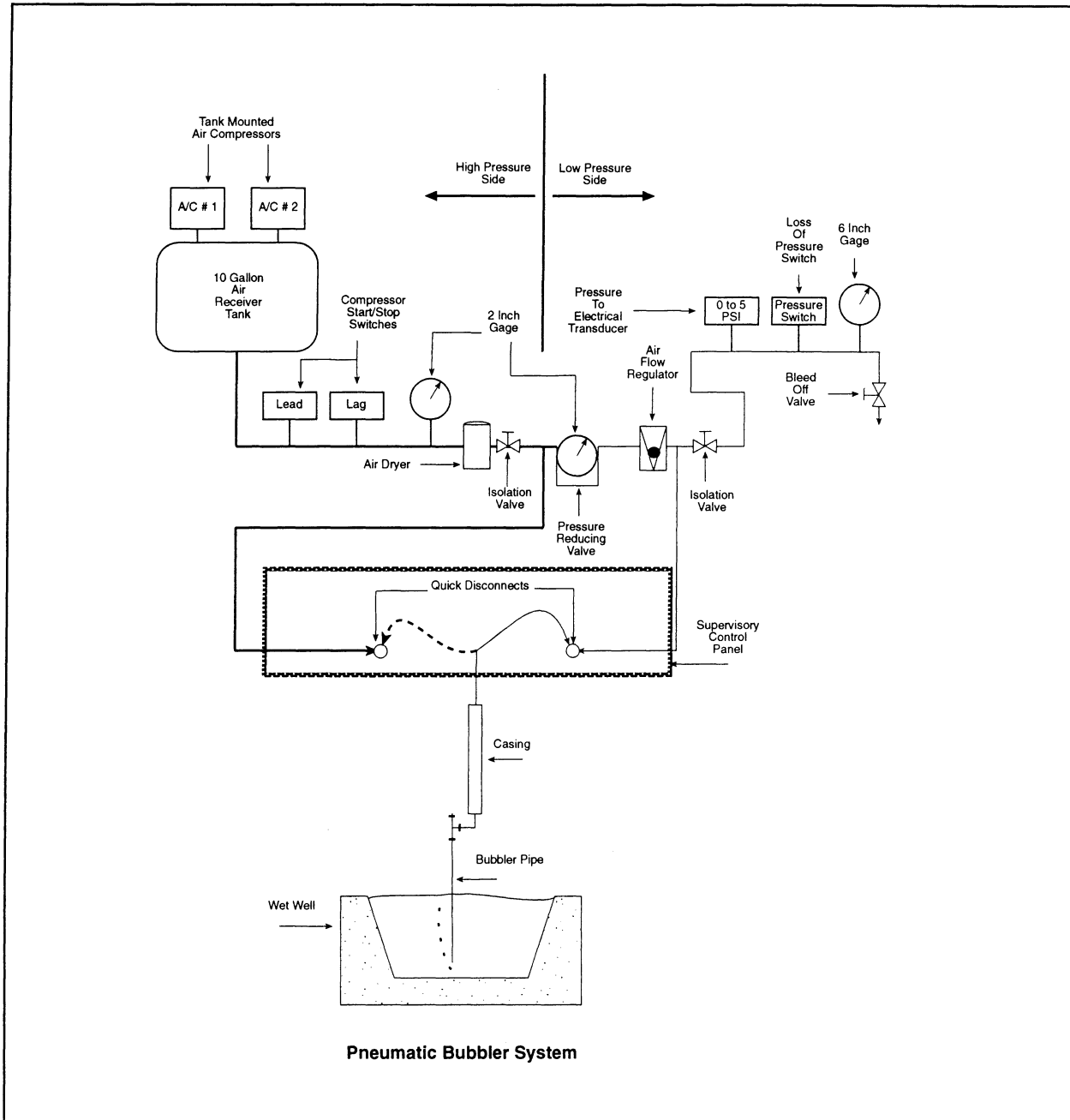
System maintenance consists of the following tasks:

- ◆ Draining condensation from air receiver weekly or monthly,
- ◆ Changing dryer desiccant,
- ◆ Weekly purging,
- ◆ Weekly checks of pump/alarm sequencing, and
- ◆ Semiannual checks of bubbler pipe in wet well for corrosion or looseness.

Many pump stations have been flooded when high wet well levels caused flow through the bubbler pipe wall hole and back into the dry well. The hole should be well sealed. If wastewater enters the system, it will damage the instruments. A loop in the bubbler pipe in the dry well ABOVE the highest wet well level possible will eliminate back-siphon-

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ing/draining into the system under high wet well conditions. In northern climates during cold weather, if moisture accumulates in the loop it can freeze and cause a plugged bubbler. Do not allow condensate to accumulate.



Symptoms of Plugged or Broken Bubbler

Plugged	Wet Well Level Minimum	Air Pressure Maximum Indicate high wetwell	Pumps Full on All pumps called for
Broken	Maximum	Minimum Indicate low wetwell	Off No pumps called for

Limitations of pressure differential controllers include the following:

- ◆ Air compressor failure,
- ◆ Bubbler blockage (line must be purged regularly) tube breakage, or outlet elevation shifts, and

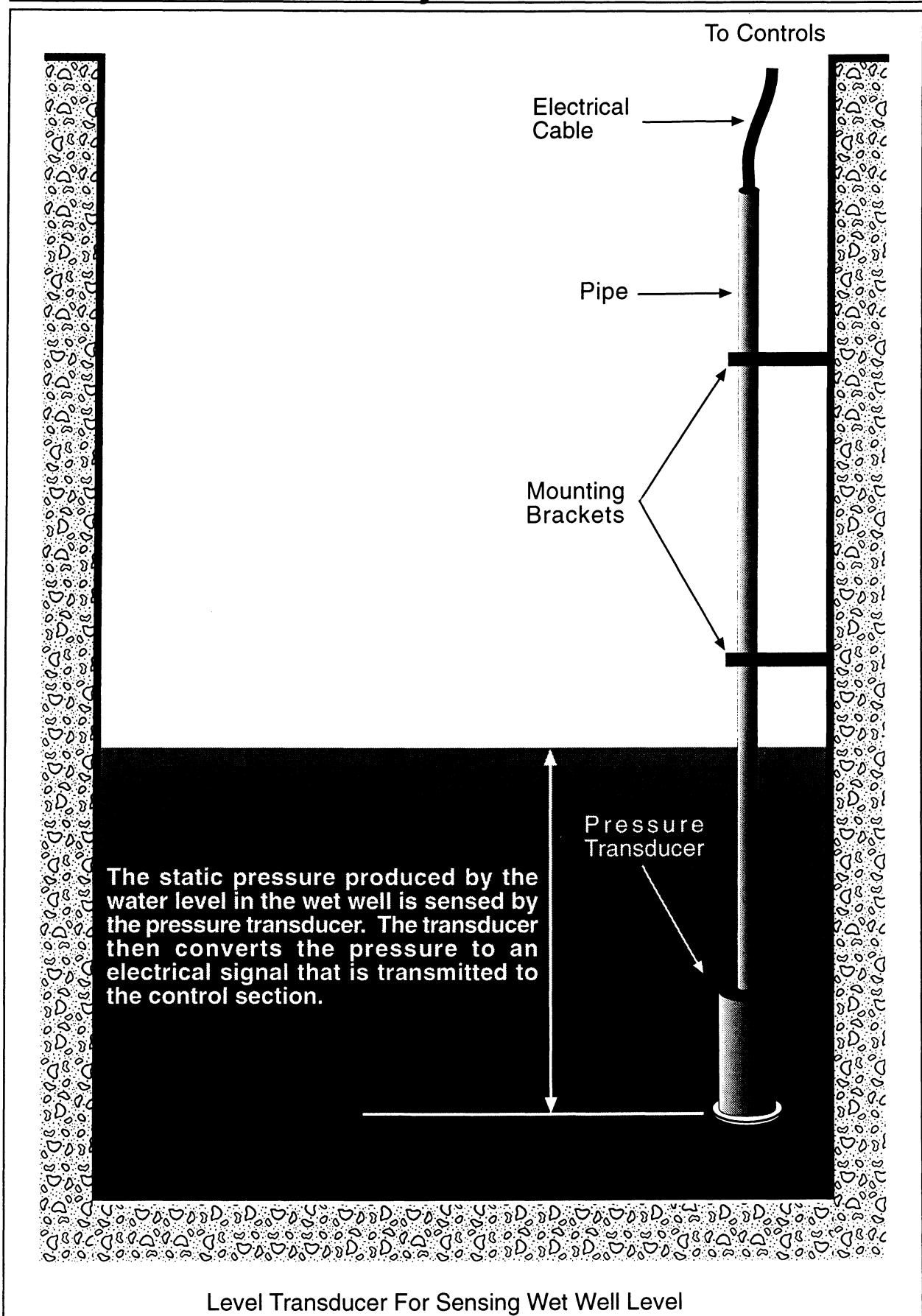
Complex equipment provides more opportunity for failures and requires a higher level of training for operators to troubleshoot, repair and keep instruments calibrated. Often the more reliable an alarm system is, the more complex it becomes.

Microprocessor-Based Supervisory Controllers

The development of microelectronics has also impacted lift station control systems. Many manufacturers today produce microprocessor-based supervisory controllers, which offer the following features:

- ◆ Easily adjustable pump on and off levels
- ◆ Alternating sequence,
- ◆ Auto/manual functions,
- ◆ Alarms at both high level and low level set points, and
- ◆ Digital readouts of wet well level.

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The microprocessor-based systems incorporate small computers into the supervisory control system. They can receive input from a bubbler-type wet well sensing system that translates air pressure into an electrical signal, from an electronic transducer mounted in the wet well or an ultrasonic level sensor.

Electronic Level Transducer

Electronic level transducers supply a continuous signal that represents the level in the wet well.

The transducer section which is continually submerged is actually a pressure transducer. Pressure created by the static head of water level in the wetwell is sensed by a flexible membrane at the bottom of the transducer. This pressure is then converted into an electrical signal which is transmitted through the electrical cable to the control system.

The electrical signal is, therefore, proportional to the level in the wetwell. The transducer can be permanently mounted as illustrated or can be suspended. The controls for this type of transducer offer a wide range of flexibility allowing the operator to change operating levels in the wetwell at the control panel.

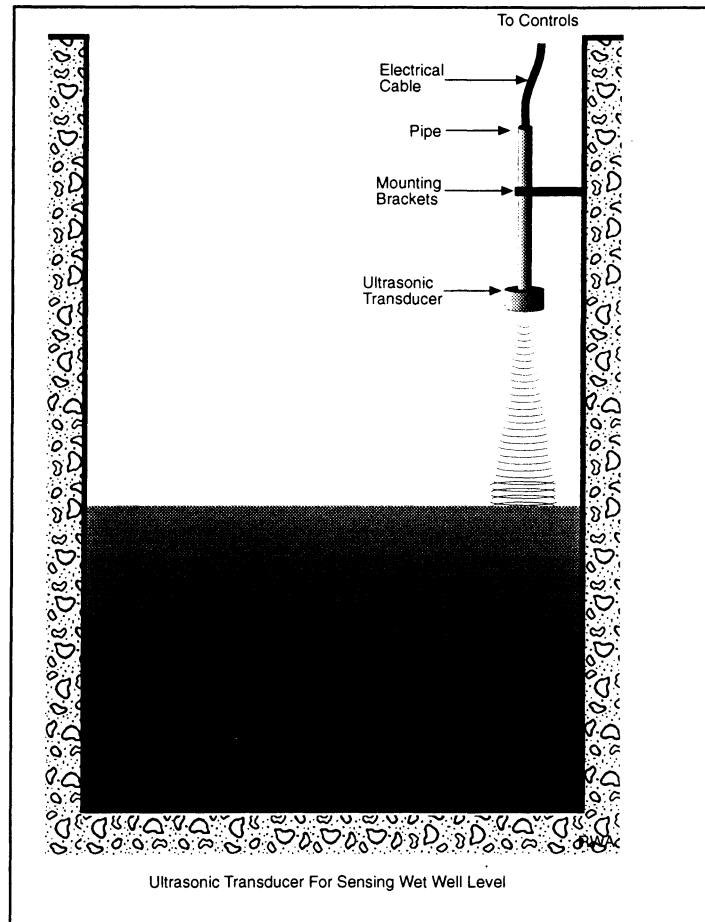
This type of control console will be interfaced with programmable logic controls other forms of microprocessor based supervisory control systems.

Ultrasonic Level Detector

This type of level device uses a permanently mounted transducer in the wetwell that is installed above the highest water level in the wetwell. The transducer generates ultrasonic pulses which hit the surface of the water in the wetwell and are reflected back to the transducer. The system measures the time required for a pulse of energy to leave the transducer and return. This is the same principle

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that radar and sonar operate on. The time information is then converted into an electrical signal in the control system. As with the level transducer, the controls provide a wide range of flexibility in pump station operation and interfacing with other pump station controls.



These systems are very flexible, easy to adjust and are consistent. Care must be taken, however, in their selection, installation and maintenance since microprocessors are susceptible to voltage surges on the line from lightning strikes, utility company switching and power failures.

Centrifugal Pumps

Pumps constitute major pieces of equipment in a station, and obviously, one of the most important components. Yet, they remain one of the least understood pieces of equipment in the station. Reliable and efficient pump operation depends heavily on the collection system operator's knowledge and understanding of the principles of operation.

By far the most common type of pump found in raw wastewater lift stations is centrifugal; therefore, this section will focus on centrifugal pumps.

It is preferable to design pump stations with multiple pumps so that, at any given time, one pump can be taken out of operation for routine, periodic maintenance.

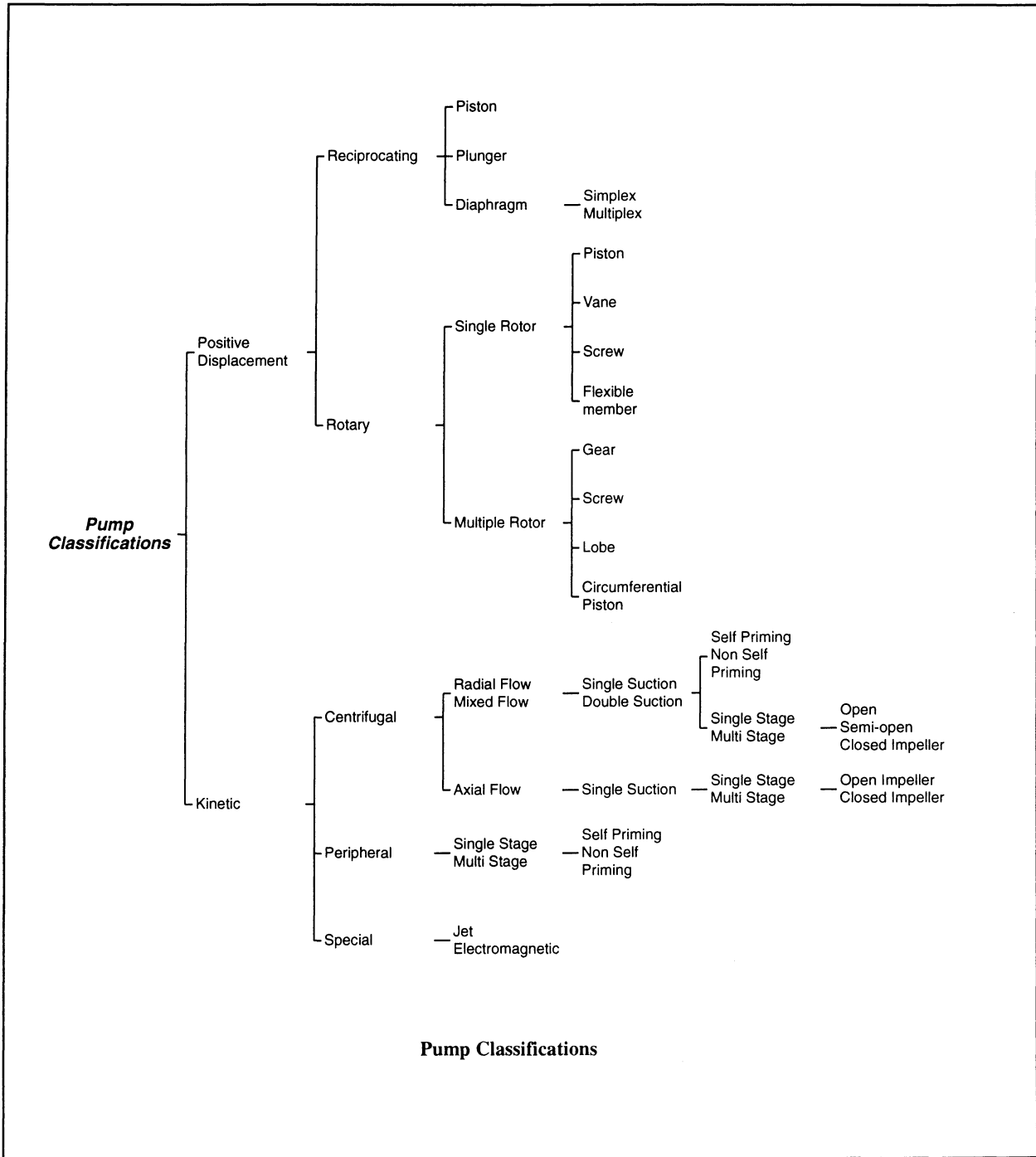
Stations must be capable of operating even during peak flow periods with the possibility of one pump being out of service for maintenance; therefore, a station designed for capacity at peak flows will normally have one additional pump sized to handle peak flow pumping requirements.

If two pumps are required under peak flow circumstances, the station should have three pumps and so on.

Pumps are installed with a piping layout that allows isolation of any pump from the rest of the hydraulic system through suction and discharge isolation valves (discussed later in this chapter).

Check valves in the discharge piping for each pump prevent backflow through the pump back into the wet well.

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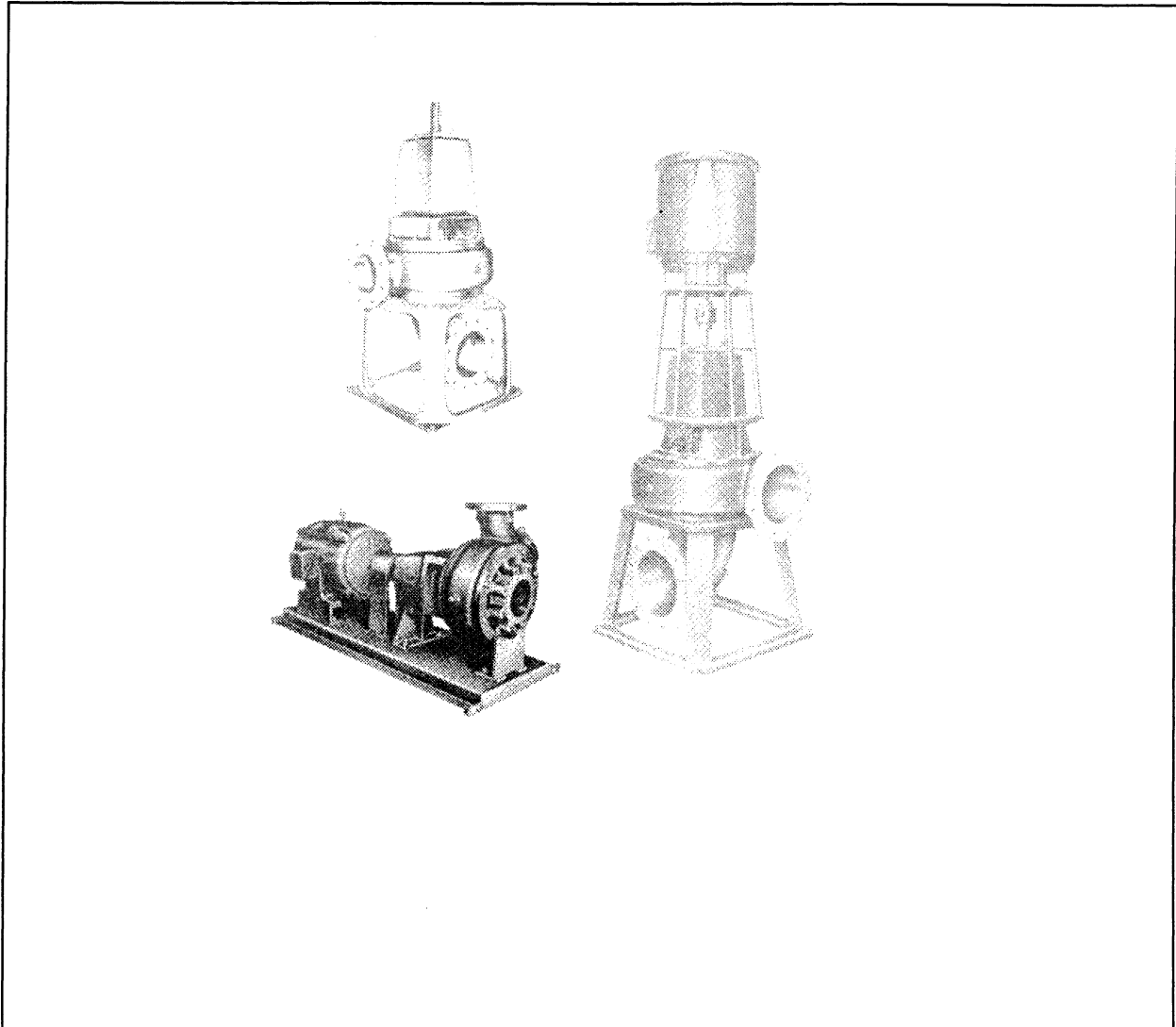


Pump Mounting Configurations

In dry well/wet well types of lift stations, raw wastewater pumps are found in one of the following types of layouts:

Flexibly Coupled - In this layout the pump and the motor shafts are connected by a flexible-type

coupling, as illustrated in the next figure., which shows a horizontal mounted centrifugal pump.



The figure also shows a vertically mounted centrifugal pump. (Note the adapter between the motor and pump required on the vertical installation) and a flexibly shafted pump- In this layout the pump normally sits on the bottom floor of the pump station and the motor is separately mounted on an intermediate floor.

The pump shaft and the motor shaft are connected by a drive shaft similar to that found in vehicles.

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The drive shaft would connect to the pump shaft.

Close-Coupled - Close-coupled pumps use a standard squirrel cage induction motor with an extended shaft that extends beyond the motor and is used to mount the pump impeller on. Submersible pumps use this type of motor/pump arrangement, as well as many of the prefabricated stations of smaller size.

The motor, in this case, is mounted directly to the pump through the use of an adapter bracket.

Close-coupled pumps are generally used in smaller pump stations, particularly the prefabricated type of “canned” lift stations.

The submersible pump is a special configuration of the close-coupled pump in that it also uses an extended motor shaft for the pump shaft in addition to having a waterproof motor capable of submer-sion.

In addition to these three types of configurations, pumps may either be horizontally or vertically mounted.

Generally, pump stations use the vertical pumps since they reduce the size, and therefore, initial construction cost of the station.

The vertical pump configuration requires sufficient room to remove the pump and rotating element from the volute, as well as room for the lifting device such as a winch or come along on the ceiling. During the design review stage of lift stations, be sure there is a lifting device for the pumps and enough space to remove the pump and rotating element from the volute.

The principle of operation of all three layouts remains the same. The only significant differences are the method in which the torque is transmitted from the motor to the pump rotating element.

Pump Components

The next figure illustrates a non-clog, centrifugal, vertical raw wastewater pump which could be found in a lift station. The particular pump illustrated could be used as a flexibly coupled pump with the addition of an adapter bracket to support the motor or a shafted pump which would use a drive shaft between the pump and the motor. Components pump are described in the paragraphs below.

Keyway Coupling

The outboard end of the shaft has a machined keyway used to key a flexible coupling to the shaft. There is also a drilled, tapped hole which allows the insertion of an eye bolt to facilitate removal of the pump power frame and rotating element from the permanently mounted volute. This allows removal of the entire pump power frame and rotating assembly, including the impeller, without disturbing the suction and discharge piping or the pump base.

External shaft adjustment

Raw wastewater pumps, in particular, are subject to wear between the bottom of the impeller and the bottom of the volute. Clearance must be maintained to a few thousandths of an inch (generally 0.0015 inch or less), depending on the manufacturer. If this clearance is allowed to open up, rags and other debris may be caught between the rotating impeller and the stationary volute. When this happens, pump efficiency is lost since recirculation takes place. Not all of the flow being discharged from the rotating impeller goes into the discharge pipe, but rather, some of it recirculates back around to the suction and the impeller eye.

Wear Rings

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Most pump manufacturers offer replaceable wear rings for both the impeller and the casings which can be replaced as wear takes place. In addition, some method of adjustment of the clearances is generally provided on the outside of the pump. In this pump, jack screws are provided so the adjustment can be accomplished externally. In some pump designs it is necessary to remove the upper bearing cap and shim underneath the bearing cap to vary the clearances.

Double Row Thrust Bearings

Normally, in this type of design, the upper pump bearing in the power frame is a thrust bearing (can accommodate vertical thrust along the axis of the shaft), which can accommodate both upward and downward thrusts created by the weight of the shaft and the impeller and thrust developed by hydraulic forces when the pump is operating.

Radial Bearing

The lower bearing in the power frame is a radial-type bearing which is designed to accommodate radial thrust loads that occur perpendicular to the shaft (sideways thrust). If a pump is operating normally, radial thrust loads are usually small; however, the bearings are generally designed to accommodate unusual circumstances which would increase radial thrust such as occasional plugging or unbalance in the impeller. The majority of bearings in pumps are re-greaseable and fitted with zerk fittings.

In some cases, a shield is provided at this point to provide isolation of the bearing from water spraying out of the stuffing box and is referred to as a slinger.

Leakage Accumulator Gland

This may or may not be a standard feature depending on manufacturer.

Packing Box

The stuffing box area of centrifugal pump provides isolation between the liquid end of the pump and the atmosphere, and may use one of two different methods of sealing; packing or mechanical seals. Both types of sealing methods have advantages and disadvantages.

A stuffing box that uses conventional packing is characterized primarily by the slow, continuous leakage at the top of the stuffing box which is necessary to provide lubrication between the stationary packing and the rotating shaft element. Packing material can be graphite asbestos, teflon, or some other braided material.

Some manufacturers have discontinued the manufacture of graphite asbestos packing because of current health concerns over asbestos; however, the asbestos in that type of packing is “bound” into the material as opposed to free asbestos. There is little danger to the health of operators in the use of graphite asbestos packing.

Lantern Ring

A lantern ring is usually installed in the stuffing box. This is a perforated metal or plastic perforated ring, completely surrounding the shaft that provides distribution of water into the stuffing box when an external water source is used as a method of lubrication.

In the case where pumps are pulling a suction lift (where the normal water level of the wet well is below the center line of the impeller), the water distributed throughout the lantern ring serves the important function of providing a seal between the atmosphere and the liquid end of the pump.

If this were not the case, air would be sucked into the volute and the pump would be unable to maintain a prime.

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Stuffing boxes that use packing require frequent adjustments so that the amount of leakage through the top of the stuffing box is minimized, yet, will provide adequate lubrication. Packing can also harden during long use and require replacement. When it loses its flexibility, it loses therefore, its ability to seal the stuffing box area. When packing replacement is required, it is necessary to remove the old packing and install new rings of packing.

The alignment of the lantern ring must be maintained if an external water supply is used so that water continues to be distributed evenly throughout the stuffing box and the shaft.

The top of the stuffing box is called a gland and is normally held in place by adjustable cap screws. These screws allow the operator to increase the amount of pressure the gland exerts on the packing as well as remove the gland to install new packing.

A desirable feature of stuffing boxes is that they be manufactured in two parts or split . This simplifies the job of packing replacement and permits shaft inspection at the point where the packing makes contact with the shaft or shaft sleeve.

Collection system operators must understand that the use of conventional braided packing requires that the stuffing box area clearances be maintained in terms of wear, surface roughness, or other factors which will affect the lift of the packing and its ability to seal.

For example, if the lower pump bearing allows radial movement, or if the shaft deflection occurs at the stuffing box, the packing will be “pounded” each time the shaft rotates and will lose its ability to seal effectively.

Surface roughness on the stuffing box also affects the ability to seal. If the clearance between the liquid end and the bottom of the stuffing box is excessive, as pressure is applied to the gland,

packing can be extruded.

Packing Advantages

- ◆ Over the short term, packing may be less expensive than a mechanical seal; however, over the long run, when labor and material costs are considered, this may not be the case.
- ◆ Pumps can generally accommodate some mechanical looseness from bad bearings, tolerances, or clearances in the stuffing box area. Under these circumstances, however, more frequent replacement/adjustment of the packing will be required.

Packing Limitations

- ◆ Increased wear on the shaft or the shaft sleeve.
- ◆ Continuous leakage of raw wastewater used as the lubricating method or clean water to the atmosphere which requires increased house-keeping. If the seal water comes from a domestic water supply, there must be an “air gap” between the domestic supply and the seal water piping to prevent contamination of the public water supply from backflows.
- ◆ Increased labor required for adjustment and replacement of packing.

Mechanical Seals

A second method of sealing the stuffing box area is a mechanical seal, the most common being the double mechanical seal with two sealing areas. Double mechanical seals consist of the following components:

A stationary ring inserted into the lower part of the stuffing box and held in place by o-rings. Typically,

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this is a carbon graphite material.

A rotating element installed on the shaft using o-rings to secure the element to the shaft which then rotates with the shaft. This element is normally ceramic and may have some type of hardened metal material on the face.

Both the stationary element and the rotating element have very highly polished faces, which contact each other through a very thin film of lubricating liquid, usually clean water.

As the shaft rotates, it is the interface between the rotating and the stationary elements which provides the method of sealing.

In a double mechanical seal the rotating and stationary elements are duplicated at the top of the stuffing box, but reversed.

The next element is a compressed stainless steel spring which exerts a continuous pressure against the upper and lower rotating elements and maintains a positive pressure of the rotating faces against the stationary faces.

Most mechanical seals are not designed to run dry since they use water for lubrication and to dissipate heat generated at the faces of the seal.

The fluid must be clean since any abrasive material introduced into the stuffing box would cause rapid wear and premature seal failure. Water may be supplied from an external clean water source such as a utility's drinking water system or a well.

An appropriate backflow-prevention device or air gap must be installed to prevent contamination of the clean water source with raw wastewater in the event of a seal failure.

Filtered raw wastewater piped from the pump discharge through a filtering mechanism into the stuffing box area is common.

Most seals must be lubricated at all times when the pump is operating.

Advantages of Mechanical Seals

- ◆ Mechanical seals are virtually maintenance free, no adjustment required or normally available,
- ◆ Leakage of raw wastewater into the pump station from the top of the stuffing box is eliminated,
- ◆ Less wear on the pump shaft or shaft sleeve,
- ◆ Less power consumption, and
- ◆ When installed and operated properly, will last for several years before replacement is required.

Disadvantages of Mechanical Seals

- ◆ Initial cost is significantly higher than packing and can range from several hundred to several thousand dollars, depending on the size.
- ◆ Require more skill and care by the operator when replacing.

Shaft Sleeve

A desirable feature of wastewater pump is a replaceable shaft sleeve which is keyed to the shaft in the stuffing box area.

This allows for replacement of the sleeve rather than the entire pump shaft when wear occurs in the

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stuffing box area because of packing.

Under certain circumstances wear will occur when using mechanical seals, particularly if the lower seal face fails, thus allowing raw wastewater to fill the stuffing box.

Different types of corrosion and pitting of the shaft sleeve can also occur even when the seal is operating normally, so that when seal replacement is required, it may be necessary to replace the shaft sleeve or resurface it in order to provide a positive sealing surface for the rotating element o-rings.

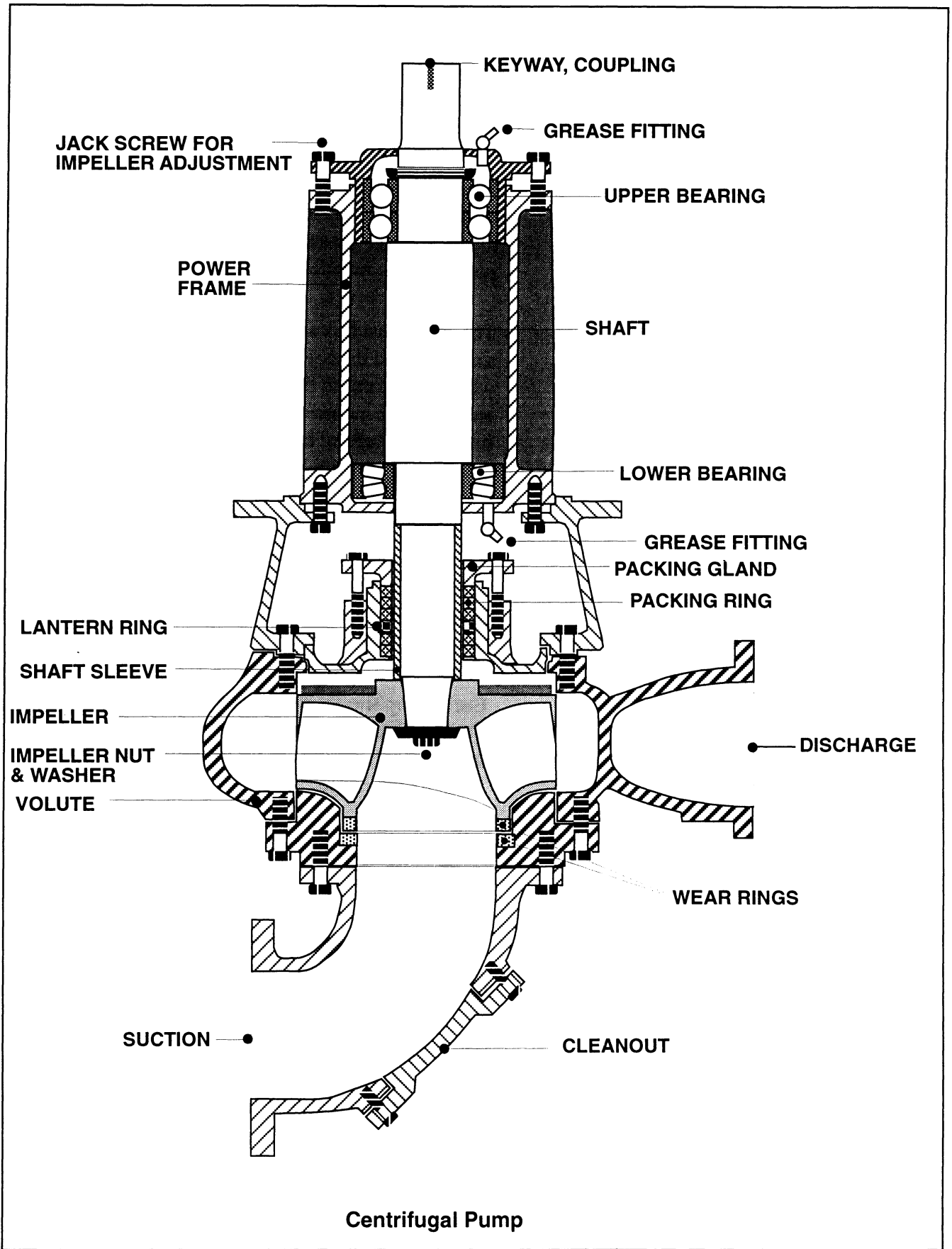
Shaft sleeves may be manufactured from brass, hardened stainless steel (440 series), or conventional stainless steel (316 series).

It is also possible in some cases to have local machine shops manufacture shaft sleeves with customized coating such as ceramic or other hardened metal materials through flame spray technology.

This method of manufacture uses a base material such as brass for the sleeve. The shaft sleeve is slightly undercut and then either molten ceramic or hardened alloy is sprayed on to the surface.

The sleeve is then machined and polished. Ceramic material is frequently used in pumps with conventional packing since it significantly increases the life of the shaft sleeve.

Polished hardened alloys are used with mechanical seals since the polished surface provides a positive sealing method between the o-rings used for the installation of the rotating element portion of the mechanical seal.



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Shaft

Two key elements of the pump shaft are adequate size to prevent breaking, and a tapered end (which most manufacturers use) where the impeller attaches to the shaft.

Shaft dimensional tolerances must be maintained because of critical clearances at the upper and lower bearing, the stuffing box area and the tapered portion at the impeller end.

The shaft must be carefully handled during pump assembly and disassembly to prevent damage which would cause the shaft to deflect; for example, 0.002 inches of deflection is the maximum limit at the stuffing box for long packing and mechanical seal life.

Impeller

Raw wastewater pump impellers are designed with very large openings at the eye of the impeller passages and discharge areas in order to pump solids in the wastewater.

Each pump should be equipped with a bottom VOLUTE drain valve and line to the sump and a top or middle volute access inspection port for cleaning the pump.

Large horizontal pumps should have a vent valve on top of the volute for priming purposes.

Operating and maintenance problems in pump stations are frequently the result of the operator's inability to understand centrifugal pumps.

They are basically simple machines that do not require extensive technical knowledge to understand and interpret their operation.

How to Read and Understand a Centrifugal Pump Selection Curve

The first step in understanding centrifugal pumps is to understand a pump selection curve and, at first glance, this appears to contain a lot of confusing information. **(The next 3 figures will be used for this discussion.)**

Explanation of Pump Curve on a Step-by-Step Basis

Pump Size - Centrifugal pumps normally are defined by three dimensions; pump suction size, pump discharge size, and the pump volute size, all measured in inches. In this case, this pump is an 12 x 14 x 22 where the 12 indicates a discharge size in inches, the second 14 indicates suction size in inches, and the 22 indicates volute size which is frequently related to the maximum impeller diameter that can be installed in this pump. (A letter, for example A indicates a design modification from the original 12 x 14 x 22).

Operating Speed - Operating speed is a function of the motor RPM. The same pump can be operated at different RPM's to give different operating characteristics depending on motor or engine RPM.

Solids Handling Capability - This indicates the approximate solid size which will pass through the impeller without plugging the impeller. In this case, it is a 4-inch diameter sphere.

Impeller Pattern Number and Case Pattern Numbers - These are numbers used by the manufacturer to indicate the pattern numbers used when casting the different parts.

Operating Area - All centrifugal pumps have a recommended operating envelope (or range) as indicated by the solid bold line on the pump curve.

Operation outside of this envelope could cause mechanical damage to the pump components, such as bearings, or cause the pump to operate at exces-

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sive levels of vibration.

Minimum Impeller Diameter - This indicates the minimum size impeller which can be installed in the pump.

Normally this is a function of operating efficiencies and other design features in the pump.

Total Dynamic Head (TDH) - The vertical scale on a pump curve indicates the total dynamic head, usually in feet, although, as shown on this curve, it can also be converted to meters.

The total dynamic head is really a pressure measurement and can be converted to pressure in PSI by using the following conversion factor: 1 pound per square inch (PSI) equals 2.31 feet of head.

Capacity - The horizontal scale on the curve indicates the flow capacity in gallons per minute (GPM). If using the metric system, this could also be expressed in liters per second (L/S) or cubic meters per hour (cu M/hr).

Efficiency - As with an electric motor or the engine in your car, the efficiency of the pump is a function of several items and can vary.

In this case, the efficiency ranges from 50 to 82 percent, depending on where the pump is operating.

Brake Horsepower (BHP) - Brake horsepower is the horsepower required at a given point in order to pump the flow at a given head.

Net Positive Suction Head (NPSH) - Net positive suction head is an indication of the pump's ability to draw water into the volute and the eye of the impeller. On a pump curve this is indicated as a

number expressed in feet and reflects the amount of NPSH required ($NPSH_R$). During the design stage of the pump station, the engineer must calculate the NPSH available ($NPSH_A$). The NPSH available in the pump station must be greater than the NPSH required by the pump at the selected operating point or cavitation is likely to occur.

Operators can use the pump curves to determine the proper operating ranges for their pumps and to compare actual efficiency with expected efficiency.

If you know the actual pumping capacity in gallons per minute (GPM) and total dynamic head (feet) of your pump, you can determine if you are operating within the envelope and the expected efficiency.

If the pump in the figure is pumping 4000 GPM against a total dynamic head (TDH) of 50 feet, then the pump efficiency should be about 82 percent.

Find 4000 GPM across the bottom of the drawing and then move upwards until this vertical line intersects with the horizontal 50-foot TDH line from the left side of the drawing. At the point where these two lines intersect is where the pump efficiency is read from the pump efficiency curves (about 82%). The brake horsepower (BHP) is between the 60 HP and 75 HP lines at about 68 BHP. The water horsepower (WHP) can be calculated from the following formula:

$$WHP = \frac{(\text{Flow, GPM})(\text{TDH, ft})}{3960}$$

The pump efficiency can be calculated by the following formula:

$$\text{Pump Efficiency, \%} = \frac{(\text{WHP})(100\%)}{\text{BHP}}$$

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If the calculated pump efficiency does not agree with the value from the curve, then there could be some problems with the pump operation.

The wire-to-water efficiency is the efficiency of the electrical input in terms of pumping water.

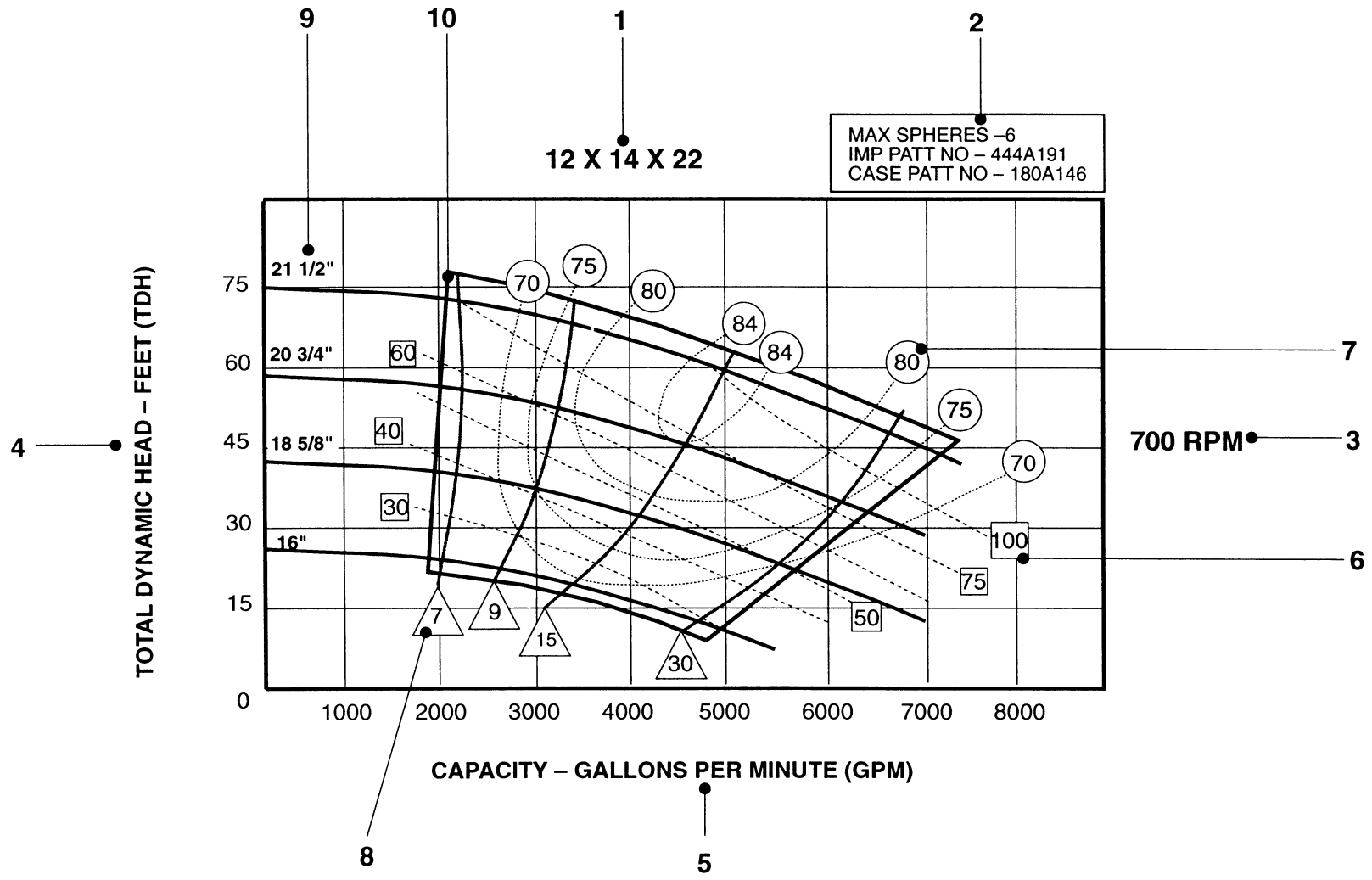
Wire-to-Water Efficiency, % = $\frac{WHP(0.746 \text{ Kilowatts/Hp})(100\%)}{\text{(Electrical Power, Kilowatts)}}$

Sump Pump - The lower floor of the dry well should be provided with a sump and submersible pump to collect seal water and water used to hose down and clean up the area. This drainage water should be pumped out of the dry well sump and discharged at a high elevation into the wet well.

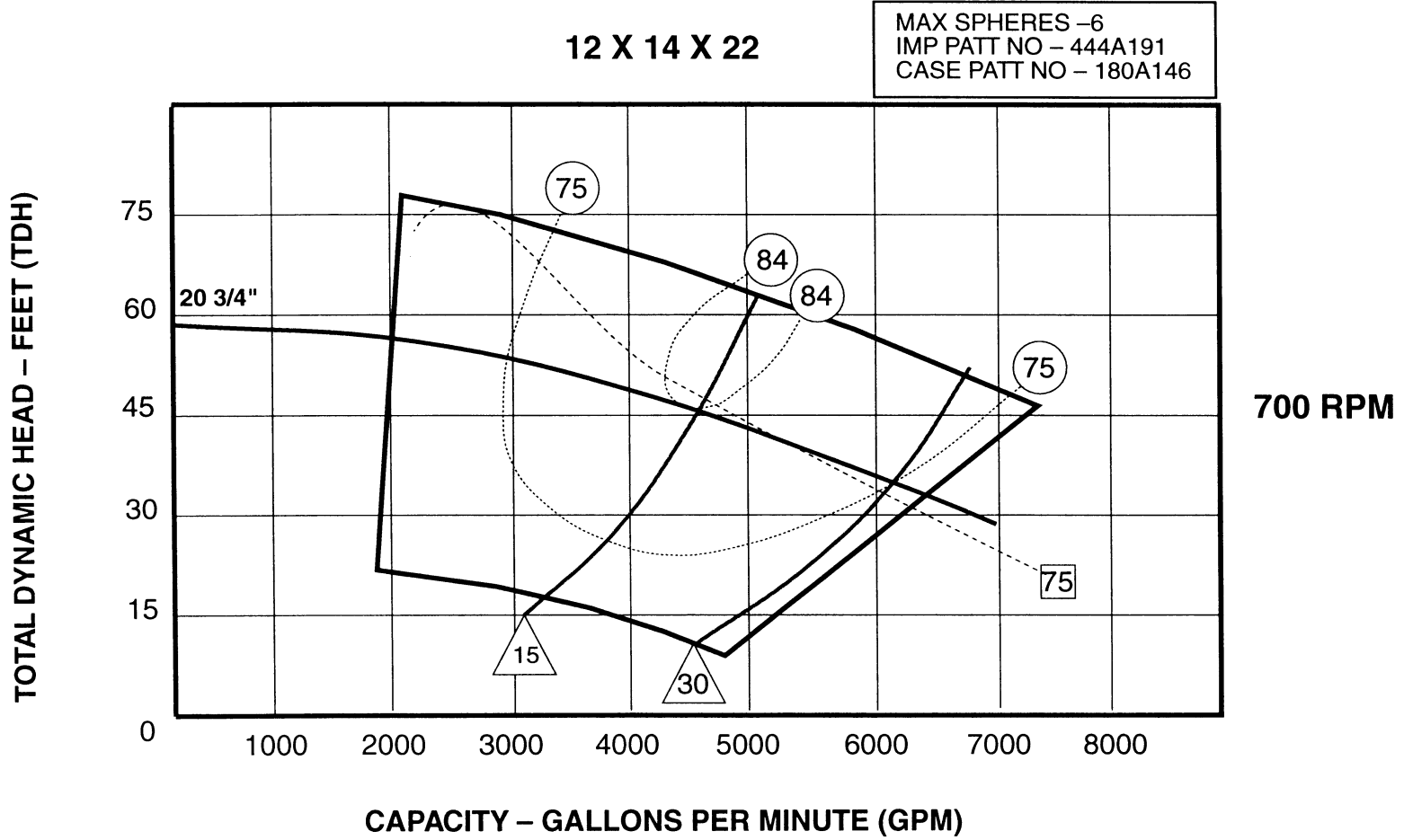
The discharge pipe of the sump pump must include at least one check valve or, for added safety, two check valves. In addition, if the check valve is located in the vertical piping run, it should be a valve designed specifically for a vertical installation. Generally it is desirable to have the sump pump discharge into the wet well above the highest possible elevation that water could reach under flooded conditions in the wet well.

This minimizes siphoning back through the piping into the dry well. Normally this is not possible but the double check valve installation provides added protection. The dry wells of many pump stations have been flooded because of check valve failure which did not prevent backflow from the wet well.

It is a good idea to install a wire mesh screen around the sump area to screen out large pieces of material which could and will clog the sump pump. In addition, installing a union on the discharge piping will facilitate easy removal of the pump for maintenance and cleaning of the sump.



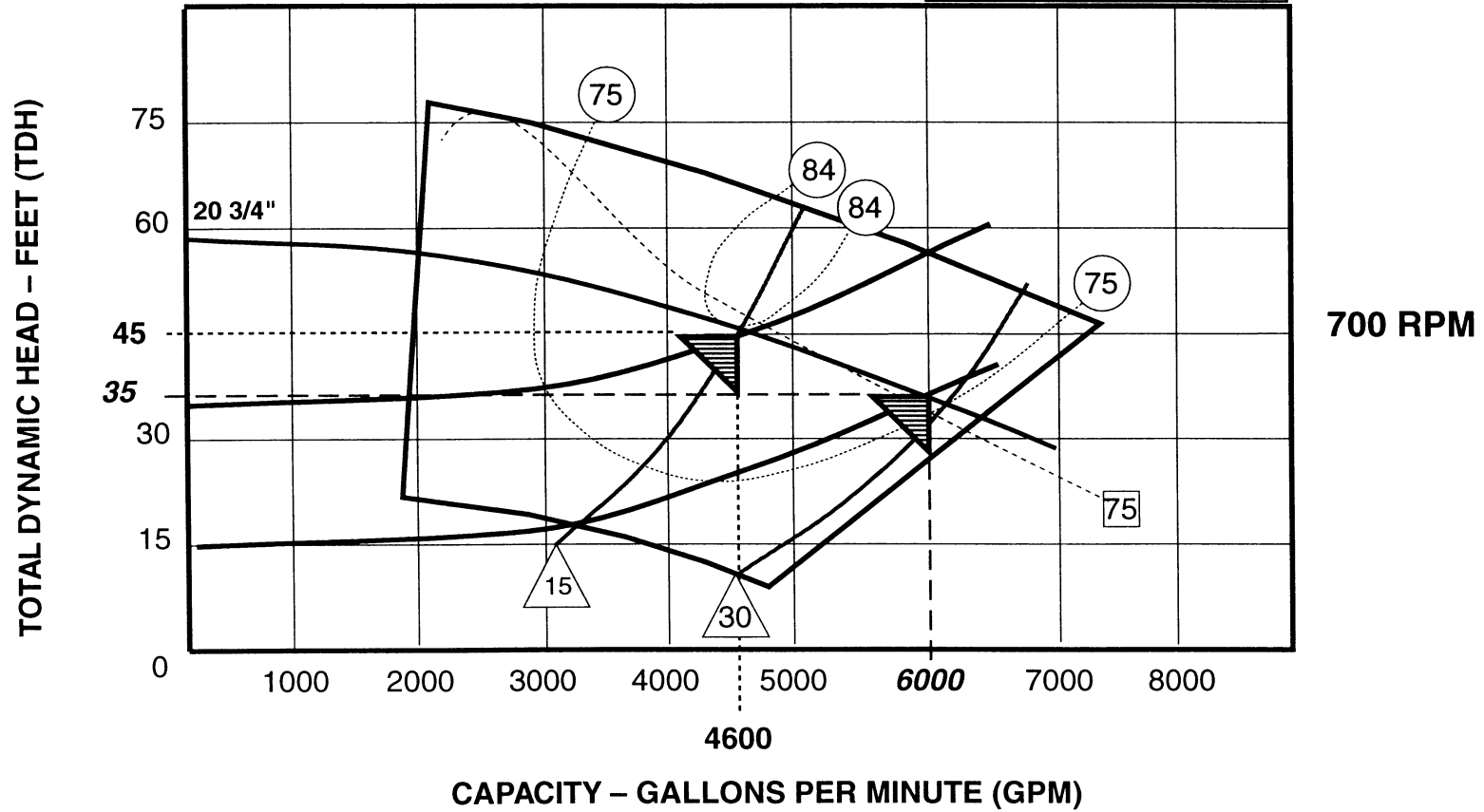
TYPICAL MANUFACTURERS PUMP CURVE



Simplified Pump Curve

12 X 14 X 22

MAX SPHERES -6
IMP PATT NO - 444A191
CASE PATT NO - 180A146



Pump Curve Based On 4600 GPM @ 45 Feet of Head

Lift Stations

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Lift Station Valves

Valves are of critical importance to lift station operation and maintenance but are frequently neglected during preventive maintenance. The major valves found in wastewater lift stations are:

- ◆ Discharge check valves (swing or ball check, wafer)

- ◆ Cross connect or pump suction and discharge pipe isolation valves (gate, plug).

There are different types of valves used for each of the above applications and they are discussed individually in detail below.

Gate Valves

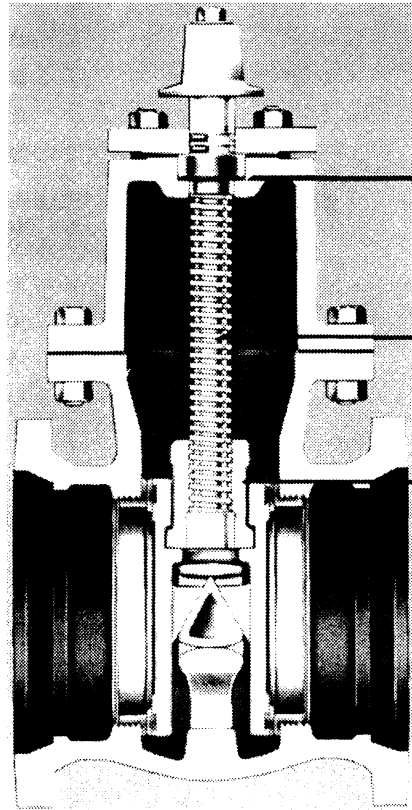
Pump suction and discharge isolation gate valves are found immediately before and after the pump to allow isolation of the pump from the wet well and the force main during pump or check valve maintenance.

The most common type of valve used for this application is a gate valve in which discs or gates are used to provide a shutoff. The next figure illustrates a non-rising stem gate valve (NRS). An outside screw and yoke valve (OSY) is a variation of this where the stem rises as the handle is operated.

Normally, the non-rising stem valve is used in lift stations because, as the name applies, additional headroom is not required to accommodate a non-rising stem as the valve operates.

The principle of operation for non-rising stem valves requires that sliding wedges, which are attached to a threaded shaft, are also attached to the discs or gates. The stationary portion of the valve has machined faces upon which the discs seat.

As the wedge and disc assembly is lowered on the



Non-rising Stem Gate Valve

shaft into the flow area, the wedges slide against each other and provide wedging pressure on the back of the discs, which then seat against machined faces in the valve body.

In the open position, the wedge and disc assembly is raised into the upper bonnet portion of the valve where it is out of the flow and does not interfere with the flow through the valve. The threaded shaft normally is sealed, either through o-ring type seals or with conventional packing.

The valve should be frequently exercised, at least

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semiannually, in order to keep the threads on the shaft stem and the collar operational.

As can be seen, the threaded shaft, gate, and wedge and disc assembly, although it is out of the flow, can still accumulate solids in the bonnet area since the bonnet cavity is not isolated from the flow.

Solids and grease often accumulate on the shaft, thus making it difficult to operate the valve. In the event this occurs to the suction valve, disassemble the valve bonnet after isolating the valve from the wet well and the force main.

This normally requires placing a pneumatic plug or bag in the suction line in the wet well. Drain the suction pipe and the pump volute of water, and then disassemble the valve. In some cases it may be feasible to attach high pressure water or an air source to the bonnet via a threaded hole with a pipe plug installed in the bonnet; however, this is not always successful.

CAUTION! Before disassembling the bonnet, you must ensure that the pump discharge valve is shut and holding (don't depend on the check valve alone) and that the pneumatic plug or bag in the suction pipe is secure. Use an auxiliary pump to install the pneumatic bag or plug in the suction line. It may be necessary to schedule this work during the low flow periods and depending on the upstream storage and other conditions, including the availability of a tanker to pump into when using the auxiliary pump. Normally, a thorough cleaning of the valve threaded stem and the gate assembly is all that is required unless you observe severe deterioration of the faces on the discs and on the seat of the valve body. To disassemble the discharge valve, it will be necessary to drain the force main in addition to isolating it from the wet well.

The outside screw and yoke valve is similar in

operation with the exception that the threaded stem actually rises and is not exposed to the accumulation of solids from the wastewater. Since the threaded portion is located outside of the valve, additional headroom is required to accommodate the rising stem when the valve is in the open position.

Under no circumstances should gate valves be buried as is common practice in drinking water distribution systems. At some point in time a gate valve will require disassembly and maintenance. Submersible station valves should also be located out of the wet well area, since corrosion occurs and access is difficult when maintenance is required. A valve manhole adjacent to the station is a better design.

Gate valves are also commonly used in the discharge manifold and cross-connect valves in the pump station.

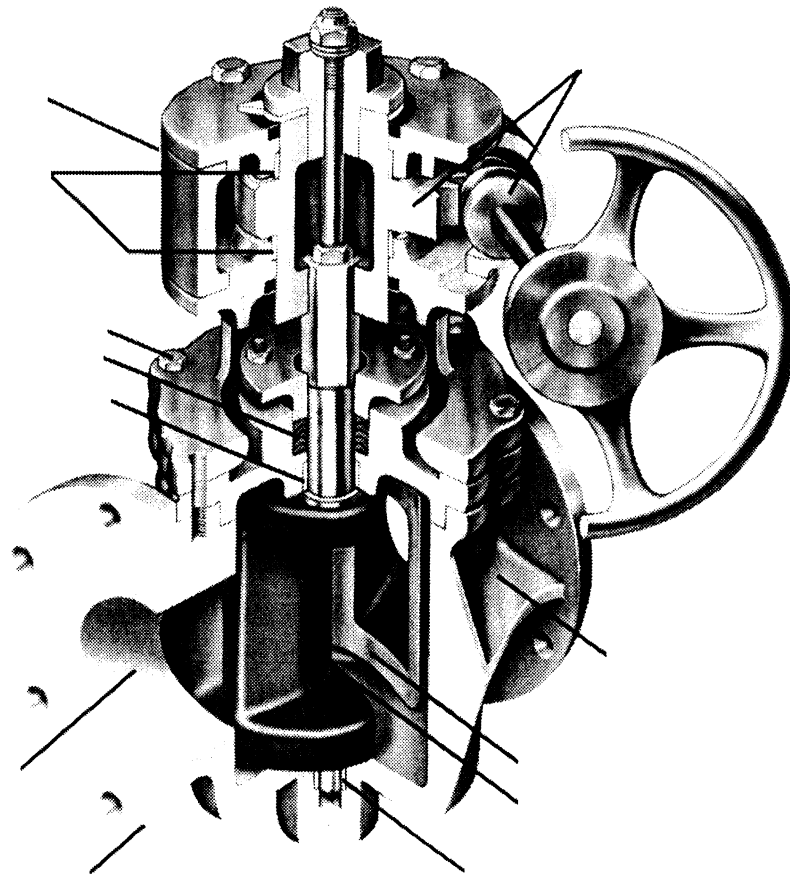
Plug Valves

Plug valves are another type of valve that are successfully used as suction and discharge isolation valves in lift stations and are frequently used in wastewater plants where high solids content such as sludge pumping systems are encountered .

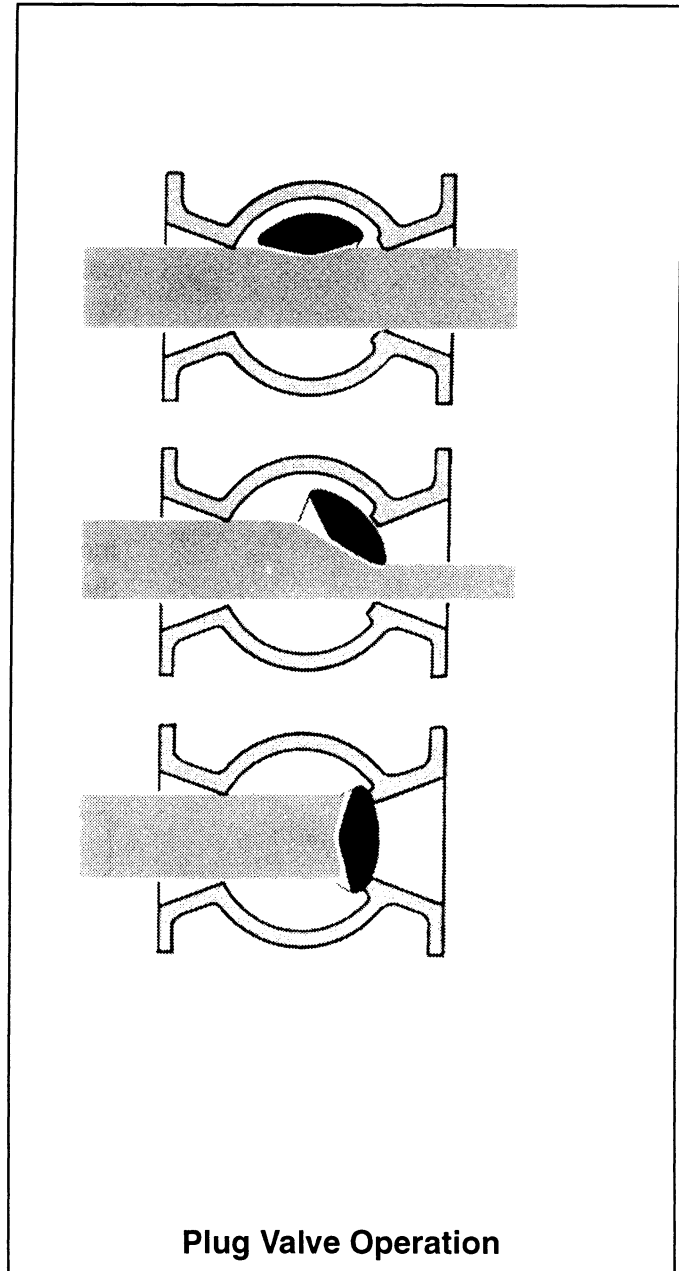
As the next figure illustrates, a plug valve consists of the valve body and a rotating plug that operates through 90 degrees. The next figure shows the open, closing and closed positions of a plug valve. In the open position, the plug normally resides in the side of the valve out of the flow; in the closed position the plug seats up against the valve body, providing a positive shutoff.

Many agencies specify plug valves as opposed to gate valves since they are less susceptible to plugging.

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Plug Valve



Check Valves

Normally a check valve is installed in the discharge of each pump to provide a positive shutoff from force main pressure when the pump is shut off and to prevent the force main from draining back into the wet well.

The most common type of check valve is the swing check valve. This valve consists of a valve body

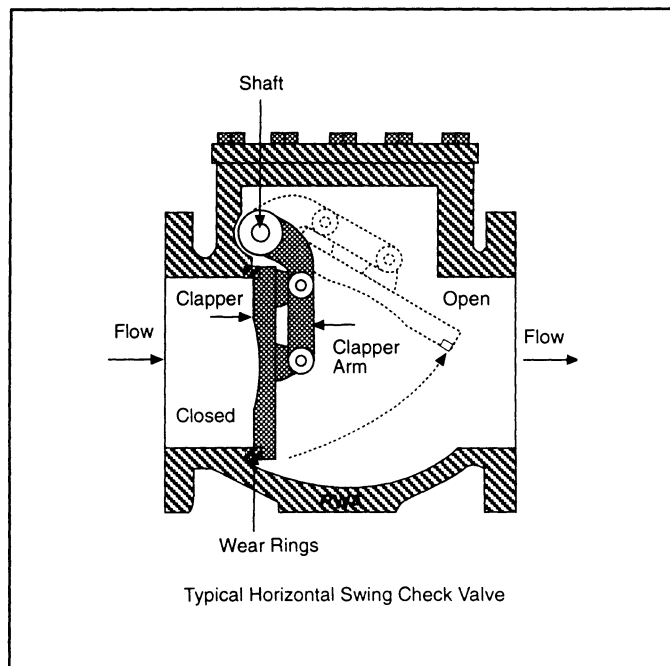
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with a clapper arm attached to a hinge that opens when the pump comes on and closes to seat when the pump is shut off.

Check valves must close before the water column in the pipe reverses flow; otherwise, severe water hammer can occur when the clapper arm slams against the valve body seat. If this occurs, an adjustment of the outside weight or spring is usually required.

A traditional clapper type of check valve has a lever on the extended shaft which allows adjustment of the weight on the arm and/or spring to vary the closing time.

Wear occurs within the valve primarily on the clapper hinge and shaft assemblies and should be checked annually for looseness.



Other types of valves can also be used as check valves in larger lift stations. These valves may be air-operated or electrically operated. Plug valves are frequently used.

Ventilation and Auxiliary Equipment

Ball check valves are also used and rubber flapper-type check valves are used in some facilities.

The dry well must be equipped with ventilation equipment to maintain the dry well portion of the station atmosphere in a dry and safe environment. Ventilation equipment should operate continuously to assure a safe working access for operation and maintenance operators.

A lift station dry well may be considered a confined space by state industrial safety agencies and requires frequent air changes. Monitor for oxygen deficiency and explosive and toxic gases during visits to the station. Wet wells also require provisions for ventilation.

In regions with high humidity, dehumidifiers may be necessary to keep condensation under control. This problem is most serious in the smaller, package-type lift stations which are of prefabricated steel.

Usually the dehumidifier runs constantly, and outside air is used for ventilation only when the access cover is open.

A ventilation fan can be turned on or off by a switch at the access cover. This procedure keeps moist, outside air from entering a lift station when it is unoccupied and provides the driest possible conditions.

Depending upon agency requirements or preference, lift stations also may include telemetering systems for monitoring or controlling the station operation.

A flow measuring device may consist of either a Parshall flume, a weir, a magnetic meter, or a venturi meter.

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The station may have emergency generator units for continued operation during electrical power failures.

Large lift stations may use gas or diesel engines to operate pumping equipment due to the ease and reliability of regulating pump speed.

Some stations are equipped with individual water wells to supply seal water, water for the application of chemicals such as chlorine, or cooling systems for heat exchangers on equipment.

A lift station may vary from a simple and efficient telemetered design requiring a visit once a month to a highly complex installation demanding continuous staffing.

Construction of New Station

Many large municipal agencies do their own design work for lift stations. Smaller agencies usually rely upon a consulting engineering firm for station design.

In either case, operation and maintenance operators should be given the opportunity to review the prints and specifications of a new lift station before the award of a contract for construction.

This review is very important to be sure adequate provisions have been made for the station to be easily and properly operated and maintained.

When it comes to operation and maintenance of a lift station, the knowledgeable, experienced operator is an expert and can contribute to new lift station construction projects during the planning and design phase.

The operator's input can have a long-term effect on the operating requirements, and therefore, the operation and maintenance budget of the station. Participation by the operator during planning and

design will result in the following positive, contributions:

- ◆ Identify problems in existing stations to ensure those problems are eliminated in new stations,
- ◆ Make the station more reliable, reducing the numb emergency call outs,
- ◆ Increase operator safety,
- ◆ Provide for sufficient space to safely operate and maintain the facility, and
- ◆ Reduce maintenance required, including emergency maintenance (EM), corrective maintenance (CM), and preventive maintenance (PM).

Keep in mind that it is not the operator's job to tell the engineer how to design a facility, but rather to provide positive input on improving the operation and maintenance of the station.

If possible, be very specific and make recommendations. A carefully kept log of existing station operation maintenance requirements will assist the engineer. The operator should have an opportunity to participate in the project design in the following stages:

- ◆ Planning stage,
- ◆ 20% design review,
- ◆ 40% design review, and
- ◆ 90% design review.

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Examination of Prints:

When examining the prints, operation and maintenance operators should look for accessibility not only for equipment, but for operators to get to the station.

- ◆ Is there sufficient space for vehicles to park and not restrict vehicles passing on streets or pedestrians on sidewalks?
- ◆ Is there room to use hydro-lifts, cranes and high velocity cleaners as needed at the lift station?
- ◆ Are overhead clearances of power lines, trees and roofs adequate for a crane to remove the largest piece of equipment?
- ◆ Are lifting hooks or overhead rails available where needed in the structure?
- ◆ Has sufficient overhead and work room been provided around equipment and control panels to work safely?
- ◆ Is lighting inside and outside the station provided and is it adequate?
- ◆ Does the alarm system signal high water levels in the wet well and water on the floor of the dry well?
- ◆ Is there sufficient fresh water at a high enough pressure to adequately wash down the wet well?
- ◆ Are there any operator traps or head knockers such as low-hanging projections or pipes, unprotected holes, or unsafe stairs or platforms?
- ◆ What happens when the power goes off and

backup or standby systems fail?

- ◆ Is there access to the wet well? If you have to clean out incoming lines, it may be necessary to put a temporary pump in the wet well.

All of these questions must be answered satisfactorily if the lift station is to be easily operated and maintained.

Equipment should be laid out orderly with sufficient work room and access to valves and other station equipment, controls, wiring, pipes and valves.

If there is any possibility of future growth and the station may be enlarged, be sure provisions are made to allow for pumping units to be changed or for the installation of additional pumping units.

If additional pumping units will be necessary, be sure spools and valves are built now for ease of expansion.

Be sure there is sufficient room to add electrical switchgear for future units. If stationary standby power units are not provided, make certain there are external connections and transfer switches for a portable generator.

Reading Specifications

Review the specifications for the acceptability of the equipment, piping, electrical system, instrumentation, and auxiliary equipment. Determine if the equipment is familiar to your agency and if its reliability has been proven.

Find out what warranties, guarantees, and operation and maintenance aids will be provided with the equipment and the lift station.

Require a list of names, addresses and phone num-

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bers of persons to contact in case help is needed regarding supplies or equipment during start-up and shakedown runs.

Services of factory representatives should be available during the initial startup of all major pieces of equipment.

Require factory representatives to demonstrate the operation of equipment under all possible operating conditions.

Be sure that the equipment brochures and other information apply to the equipment supplied. Sometimes new models are installed and you are provided with old brochures.

Be sure the painting, color coding on pipes and electrical circuits meet with your agency's practice.

Try to standardize electrical equipment and components as much as possible so one manufacturer can't blame the other when problems develop.

Standardization also can help to reduce the inventory of spare parts necessary for replacement.

A few hours spent reviewing plans and specifications will save many days of hard and discouraging labor in the field in the future when it is a major job to make a change. Very often changes on paper are relatively simple.

Preliminary Inspection of a New Lift Station

After a lift station has been constructed it is inspected by the contractor, the engineer, and the operating agency before final acceptance.

This inspection should be planned and conducted by the people responsible for the operation and maintenance of the lift station in cooperation with the contractor and the engineer.

One way to accomplish this is to include in the specifications a specific schedule that identifies the section of specification, the item to be checked and who is responsible; for example, electrical contractor, mechanical contractor, or other specific contractor.

Then check off each item by noting who accepted each item and the date.

All equipment checkout and adjustments should be performed PRIOR to any equipment training. This will maximize the amount of time spent on training as opposed to adjustment and trouble shooting.

Documentation is particularly important for proper operation and maintenance of the lift station equipment. The equipment manufacturers' O & M manuals should include the following:

A suitable binder that allows for quick and easy reference to all mechanical/electrical and hydraulic equipment provided in the pump station. Generally, photo copies should not be accepted, since they may be illegible, and therefore, of limited value to the operator.

Information about each piece of electrical and mechanical equipment should include nameplate data, operation and maintenance instructions, spare parts list, recommended spare parts stock list, part numbers, troubleshooting information, assembly/disassembly instructions, tolerances, tools required, and safety precautions. In other words, a sufficient amount of information to allow adequate maintenance of the equipment.

The manual should be available when you accept the station from the contractor, not three months later. Now, during the preliminary inspection, is the appropriate time to develop and record both routine and emergency information and procedures. Use

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the following outline as a guide in assembling your documentation.

As-built specification of the facility including:

- ◆ Size, length and details of force main (discharge point)
- ◆ Available power and fuse size
- ◆ Pump and motor sizes and rated capacities
- ◆ Actual capacities of pumps and rates of flow throughout the day
- ◆ Normal pump levels-start/stop/high and low, levels
- ◆ Elevation of each manhole invert and depth of the manhole
- ◆ Lowest homes on the system (most probable ‘ points)
- ◆ Alternate route of temporary pumping:
- ◆ Elevation and length of temporary pumping
- ◆ Type of equipment needed
- ◆ Number of services, plus commercial hookups
- ◆ Available equipment and methods of operating when a power outage occurs
- ◆ Equipment needed for pump and motor removal
- ◆ List of private companies providing emer-

gency pumping equipment and personnel

Station data

- ◆ Wet well size
- ◆ Storage time
- ◆ Average flow, GPM
- ◆ Peak flow, GPM
- ◆ Average flow, GPD
- ◆ Wet well depth
- ◆ Distance of bubbler tube off wet well bottom
- ◆ Type of wet well suction

Pump Station Calibration: As part of the startup and acceptance procedure, a pump station calibration should be performed to:

- ◆ Verify operating conditions of the pumps in accordance with the nameplate,
- ◆ Establish a base line that can be used for comparison when future pump station calibrations are performed

The calibration of pump station is a fairly quick and easy method to verify the operating efficiency of the pumps including capacities and discharge heads.

Operation under test conditions will reveal only the immediate equipment and construction problems.

These problems should be recorded on a punch list

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during the preliminary inspections and a copy given to the contractor.

This punch list of problems should be quickly corrected so the station can be ready for service.

Do not accept any portion of a new lift station, because official acceptance of completed work is the engineer's job.

Lift Station Maintenance Program

To obtain maximum life and use from a new lift station, begin the station preventive maintenance program now when it is new.

Start the program by filing data in a station record book. Record station identification code number, location by map and street numbers, date of construction, size of station by flow capacity and other important information required by your agency. Also file a set of plans and specifications for reference purposes.

Start the preventive maintenance program by making a complete list of all equipment at the station. Information recorded should include equipment name plate data.

Mark each piece of equipment with an identification code number and record the number. There should be a minimum of two copies of this information. Keep one copy at the lift station and the other in the station record book at the agency office.

Once this has been done, permanent identification of all equipment involved in the station will be available when needed. Prepare a spare parts list and order any extra parts now.

Record keeping must begin when the station is first

started so that any peculiarities of the equipment are known from the beginning. These records should include any of the contractor's data collected during construction and also data required according to the specifications. These specifications include:

- ◆ Equipment manufacturers' O & M manuals,
- ◆ Engineers O & M instructions, including detailed emergency procedures,
- ◆ Pump and motor operational characteristics,
- ◆ Pump and motor coupling alignment readings,
- ◆ Wet well control levels, and
- ◆ Auxiliary equipment data.

Inspection of Lift Station:

Hopefully you had the opportunity to review the plans and specifications for the new lift station. Now is the time to determine if the station was built as you wished.

Look at those items you previously reviewed. Ask yourself what problems will be faced when maintenance and repairs are to be carried out under adverse conditions. Think of the worst situations so that your preparations will be adequate when needed

Inspect the building for access so equipment can be removed. To insure that equipment can be worked on, the following items must be considered.

Is there an emergency lighting system and is it adequate? Is there enough head room to pull pumps, motors, gear heads or other pieces of equipment?

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If head room is not needed, are the passageways wide enough to allow for the removal of gear boxes, engines, control panels, and standby generators?

If pumps have to be removed through the roof of a building, do we have clearance for a crane or other lifting device to get within reaching distance?

Where are the electrical lines located that supply the building? Will they restrict use of the lifting equipment? The time to consider all of the above is now, not when conditions are adverse.

If there are potential problems related to equipment removal, the time to correct these problems is now.

Plan to conduct corrective work before a crisis occurs. Don't wait for an emergency to arise to discover that a critical piece of equipment can't be moved when a unit needs repair. Dismantling equipment in place under restrictive conditions is slow and difficult work.

The next unit to inspect is the wet well. What kind of conditions will be encountered when you attempt to clean the sump or possibly to enter it and remove grit? In a sanitary wet well, are there enough openings for washing the sump walls and floor?

Can it be ventilated easily? What type and size of ladder will you need for access?

If there is a bar rack, or comminuting device, consider the conditions you will encounter to clean the rack and how you will dispose of the debris.

Also consider the tools needed and whether or not the necessary tools will be stored at the site. If tools must be transported, make notes of what will be needed and how transportation will be accom-

plished. Inspect the equipment that measures the water level in the wet well.

Before entering any lift station or other wastewater facility, safety procedures must be followed to insure that the hazards encountered will be eliminated or brought to a minimum. The hazards are as follows:

- ◆ Insufficient oxygen,
- ◆ Explosive and toxic gases,
- ◆ Poor footing caused by grease or slimes,
- ◆ Unsafe stairs and walkways,
- ◆ Dangerous electrical gear, and
- ◆ Inadequate drainage.

If the wet well is to be entered, all confined space entry procedures must be followed. Begin by setting up a blower that will give a minimum of two air changes a minute within the wet well. The wet well must be washed thoroughly using a hose with a nozzle. After washing has been completed, the wet well can be monitored for toxic or poisonous gases, explosive gases, and lack of oxygen. **IF ALL CONDITIONS ARE SATISFACTORY, THEN AND ONLY THEN IS IT PERMISSIBLE TO ENTER THE WET WELL.**

All of the safety equipment and clothing listed under safety for confined spaces should be available for use at this time. Monitor the wet well gases and oxygen continuously until the job is completed and everyone is out of the sump.

The next item to inspect is the electrical equipment. Begin by recording all name plate data. Put code

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numbers on each panel beginning at the main breaker. Branch panels that supply power to major circuits carry the code number of the piece of equipment that it serves.

A lighting branch panel has its own listing or numbers and the lights or plugs it serves also carry this number. With a system like this, the problem of locating controls, plugs, and lights is quite simple.

Individual inspection of the major circuits is necessary. Record the parts that most likely will need attention during an emergency.

All fuses must be listed and spares kept at the station. Data on switches, relays and heater strips must be recorded. Be sure that all overload heaters are size. Control circuit equipment must be listed.

Make this inspection with the main breaker to the equipment being inspected locked in the OFF position.

No attempt should be made to inspect or repair electrical equipment unless a basic knowledge of electricity and the safety precautions needed are fully understood and applied.

Request an electrician to help if you are not qualified or not authorized to inspect electrical equipment, circuits and controls.

After listing all necessary data and putting code numbers in place, read the operating instructions and examine the controls for their proper operation. Move all switches with the power off to see how they operate.

Check reset buttons and know what they are supposed to do. Before the station becomes opera-

tional, it is essential to learn how things are supposed to work.

The approach to solving any problem must be made with logic and caution.

- ◆ Be deliberate and think each step out before making any changes.
- ◆ Mark all settings, if possible, so that you can return to the starting point.
- ◆ Wait a short period when changing settings to obtain and observe the results.
- ◆ Do not make a change if you think it is not safe.
- ◆ Before leaving the electrical equipment, tag any dangerous area with “not to be tampered with or touched by inexperienced hands” and lock out.

The next point of inspection is the pumps. All name plate data must be recorded. Lock out pump and determine direction of rotation.

If local electrical utility company has worked on their lines near the station, be sure the power leads (legs) are hooked up correctly and the rotation of the pumps is in the proper direction.

Inspect the backspin preventer if the pumps are so equipped by trying to turn the pump shaft in the direction against the indicated rotation. Backspin equipment operation also may be detected by listening to the pump motor when the unit is shut down after a run. When the unit comes to a stop, the backspin unit begins to engage and it can be heard as a ratcheting sound. If a right-angle gear head is used, the backspin equipment may be

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located on this unit.

Equipment specifications will have to be checked to determine if there is anti-rotation equipment provided in the gear head.

Examine all gages for location and determine at this time what they are to indicate.

Any valves located on the suction or discharge should be examined for correct and easy operation so that you are familiar with them.

Place equipment numbers on these valves so that a preventive maintenance card can be made to service them.

Maintenance record cards should be prepared for each piece of equipment inspected.

Inspect the drive and pump for proper alignment.

If belt-driven, record the sizes of the belts and numbers so that spares will be available when needed. Inspect all rotating parts for missing guards and secureness. The guards must be built for easy access to the equipment being shielded, but still meet all safety requirements.

Inspect the lubrication equipment used and note all pertinent information needed to keep it operating. Solenoids used to operate the oilers should be standardized when reviewing the specifications in order to reduce the inventory of spares necessary for replacement.

Inspect suction and discharge lines. The suction line must be kept clear of debris. If a check valve is supplied on the pump discharge pipe, this valve can become a problem when stringy material gets caught on the flapper and it stays in the open

position.

If the lift station uses gasoline or diesel engines, they may be in the form of standby generators or as a pump drive. When used as a pump drive, the operation may go through a right-angle gear unit .

These units are used to keep a large engine from being located on a lower deck where the pump must be located for efficient operation. The engine is kept on the top for easy access, cooling, ventilation, exhaust, and above the level of flooding.

The engine must be inspected for sufficient oil, water and fuel to operate properly. Without any of these, the unit will not function properly.

Examine the battery for water, tight cables and clean terminals.

If the engine is large and requires compressed air for starting, inspect the auxiliary air system.

Inspect and adjust alarm system for proper operation at the predetermined points of alarm or shutdown.

Failure of the alarm system to shutdown devices could cause an engine to burn up.

Make sure that all hoses are secure and clamped tight.

Loose nuts and bolts must be tightened. Be aware of the ones that continually become loose. A different type of fastener may solve this problem.

Leakage of any sort should not be tolerated. Keep cleaning equipment at the station to keep leaks wiped up so that you know when a new leak starts.

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Vibration will continually cause problems of leakage and loose parts, so you must never let up on your preventive maintenance program.

Determine what type of fuel is to be used and the storage capacity, the engine's consumption rate, and when the fuel will be delivered. The fuel tank should be kept full so condensation won't collect on top of the tank.

Inspect all controls for free and easy operation. Make a record of their settings before and after operation. This becomes the standard and a starting point for troubleshooting when problems occur in the future. When operating, set marks can be made with fingernail polish at the set point.

Inspecting and obtaining a standard for the engine will help tremendously when problems do occur. The jobs of troubleshooting and repairing become easy when there are good data for reference. This data can be obtained only when the engine is new or rebuilt and is being operated for the first time.

The final point of inspection is the housekeeping needed to maintain an acceptable station which will satisfy the public or surrounding area. Inspect all fences to see that they are complete and have a neat appearance.

If made of wood, be sure the paint has good color and is protecting the wood. Chain link fences usually require little maintenance, but should still be inspected for damage or poor installation. Metal chain link fences must be grounded in case a power line drops across them and an unsuspecting operator goes to open the gate.

Examine all paved areas for proper drainage and good workmanship when an area is paved. Inspect unpaved areas for weed control.

Examine all exterior parts of buildings. Look for poor installation or possible future problem areas. At this time, get a ladder and inspect the building's roof. Be sure that all openings are adequately covered or louvered.

Operational Inspection:

We are now ready to operate the lift station. Open any valves on the influent line to fill the wet well. Make certain that the pump volute drain lines and vent lines are closed.

If there is no wet well, open the valve to the suction side of the pump. Inspect the sump and bar rack at this point for debris and free flow into the station.

Remove the floating debris left by the contractor in the sump or off the bar rack that you should have removed BEFORE the station was placed in service.

Problem materials include small pieces of wood, like grade stakes or pieces of plastic of any size, cans, and bottles. Some objects can plug off the eye of the impeller.

With the sump filling, inspect your sump level indicator to see that it is working properly. If there is no indicator, visually check the sump level or watch the rise in the pump control stilling well.

If a bubbler system is used, watch the pressure gage indicator and verify wet well level readings with actual readings.

Once the station is in operation, the determination of the sump level will become a part of the normal inspection for system maintenance.

Inspect the discharge side of the pump for clear passage of the liquid to be pumped. All valves must be open.

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Bleed air from volute of pump. Sumps usually fill slowly unless a means of causing rapid filling can be found, such as using water from a fire hydrant.

When the sump is filling, recheck for power to pump and proper rotation of the pump. If an engine is the power source, it must be checked out before operating.

Put the pump on manual operation and momentarily start pump. Watch rotation of pump shaft to see that rotation is correct. There is usually an arrow attached to the side of the pump to indicate the proper direction. If there is not, you will have to refer to the manufacturer's manual to find out how to determine correct rotation.

If the pump is a centrifugal pump, the rotation is in the direction of the volute. Another means of determining rotation is to take a load check of the amperage drawn by the pump motor and compare this value with motor name plate data. If the rotation is in the wrong direction, the amp reading will be lower than the motor rating due to less work being done by the pump by rotating backwards.

If the discharge flow is low or the wet well is being drawn down slowly, the rotation could be in the wrong direction. Higher amp readings can result from head conditions lower than design head conditions. Low head conditions can be corrected temporarily by throttling a discharge valve or permanently by installing an orifice plate in the discharge.

Now that the rotation is in the proper direction, the next job is to see that all operating controls are put into the automatic position for the test operation. Start by examining all automatic switches to see that they have been put into the automatic position.

Circuit breakers must be checked to see that they

are in the on position.

Oilers or solenoids operating the oilers should have been inspected during previous inspections.

The electrical alarm systems must be examined to see that they are in the activated position. The electrical components of an engine must be inspected to be sure that there are no drains on the battery. The mechanical inspections should include inspecting all valves to see that they are open or closed according to the operation desired. You must be sure that all oilers have been filled and are not dripping.

If a bubbler system is used, an inspection should be made to determine that it is functioning properly and that there is enough air pressure provided to make the control system operate.

Other mechanical checks should be made on the engine. Determine that the linkage is ready to operate. Inspect the clutch to be sure that it is engaged. Examine all cooling water valves to see that they are in the proper position.

Check to see that pre-heaters (if provided) on the engine are operating. The heaters inside the building should be examined to see that they are functioning to maintain the proper humidity and temperature within the station. Up to this point we have been recording all the data that have been observed. This information becomes your base for future operation reference.

Notify operators of downstream lift stations and wastewater treatment plants that the lift station is being tested and tell them the volumes of water that can be expected. Allow the sump to fill and activate the station. Watch the level of water in the sump to be sure that the pump starts at the desired level. If not, adjust this operating point by whatever means

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available.

The pump must be stopped after being started, so as not to pull the sump level down too far. When the starting point has been set by a visual or simulated means, we can continue to the next point of operation and that is to allow the sump to continue to rise. If more than one pump is involved, each start position for each pump must be determined and recorded as the level rises until all start points have been activated. Allow the level to rise and activate the high level alarm.

At this point you may now start the pumps in their reverse order. Each pump when started must be inspected for its operation and all data recorded. The first item to inspect is the electrical load on motors. Record any electrical malfunctions and have them corrected. The pump should be inspected for proper operation and any unusual noises or vibrations noted along with excessive heating.

Inspect the packing gland or mechanical seal. If the unit has a mechanical seal, there should be no leakage. If it is a packing gland, get the data on size of packing needed. Set packing so that there will be leakage of approximately one drop per second. If the packing is Teflon, you must adjust the gland tight with your fingers and run the pump 15 to 30 minutes while you watch the packing gland. Teflon will expand. Do not tighten gland during this period of operation. You are watching to see that it does not get hot. If Teflon gets hot it will glaze and stop working properly.

After this period of operation, adjust the packing gland nut one FLAT tight by turning bolt one flat on nut. Maintain one to three drops of water per second on the packed glands. No more adjustments are necessary. If leakage continues excessively, something wrong was done when the unit was packed and it must be repacked.

Most packed seals have flushing water supplied to the seal. The pressure needed here is 3 to 5 psi above the pump discharge pressure. There should be a filter in the flushing line if the water being pumped is used for this flushing water. Obtain all the information needed to service the unit and to have spare parts available.

Do not operate any unit if you think it is not functioning properly. Shut it down and have the contractor examine the problem. When the problem is corrected to your satisfaction, you may proceed with the test operation. All gages should be inspected and their set points recorded.

Continue with the individual operation of all pumps until they have been checked out to your satisfaction. They must comply with the specifications and operate on the performance curves as intended by the design engineer.

When all data have been recorded, shut the pumps off and allow the wet well to refill. When full again, operate the pumps to adjust the shutdown points. You may have to operate more than one pump to pull the sump level down. While pumping the level down, observe the pumps in operation and record any unusual conditions. With all set points adjusted, operate the station on automatic a number of times through the full range, observing what happens and recording the results. Too much information is better than not enough.

When you are satisfied that the automatic system is operating in a consistent manner, notify the engineer that the lift station is acceptable to you and you wish to put it on line.

During the first few weeks of operation, frequently inspect the equipment. Bearing failures and other problems may develop after a few days of operation.

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Operation of Lift Stations

After a lift station has been constructed and put into operation, it is the responsibility of the operating agency to insure the continuous and efficient operation and maintenance of the lift station, including the structures and the grounds.

This responsibility includes preventing failures in operation that would result in flooding upstream homes, businesses or streets. Responsible design includes no facilities for bypassing wastewater to rivers, streams, lakes or drainage courses. When emergencies occur, portable emergency equipment must be used to pump the wastewater to a functioning section of the downstream collection system and not to the environment. When untreated wastewater is discharged to the environment, public health hazards and pollution of adjacent receiving waters result.

Lift stations may be located throughout a community and must be neat in appearance, blend with the architecture and landscaping of the neighborhood, and not create a nuisance to neighbors through odors or noise. Complaints from the public will be few if the operators responsible for the lift station maintain the facility in top operating condition and respond to questions or complaints from the public in a positive and concerned manner. When responding to a complaint, be sure to tell the public what has been done or will be done to correct the complaint.

Lift Station Visits By Operators:

ONE RULE THAT SHOULD APPLY TO ALL LIFT STATION VISITS IS THAT FOR SAFETY PRECAUTIONS, THERE MUST ALWAYS BE TWO OPERATORS MAKING THE STATION VISIT. Many state OSHA agencies consider a wastewater lift station a confined space. Safety precautions regarding the potential presence of hazardous gases apply not only in the wet well, but in the dry well area of the station too. This rule

must be obeyed during off-duty hours such as nights, weekends and holidays when operators are responding to lift station telemetry alarms. Always take the few extra minutes to pick up the required additional crew member. The additional effort is critical and worthwhile when compared to the sorrow and costs that result from an injury or a lost life.

Frequency of Visits to Lift Stations:

A rule cannot be developed for determining the frequency of visits to lift stations for operational inspections. The frequency of lift station visits varies by community and may range from continuously staffed pumping plants, twice daily visits, once a day, two to four times a week, once a week, to once a month visits. Frequency of lift station visits depends on the following:

- ◆ Number of stations in the community,
- ◆ Type of wastewater being conveyed,
- ◆ Potential damage resulting from storms flooding station,
- ◆ Condition of equipment, such as equipment temporarily repaired and waiting for replacement parts,
- ◆ Design of facility and equipment installed in the lift station,
- ◆ Adequacy of preventive maintenance and overhaul program,
- ◆ Type, adequacy, and reliability of telemetry system, and
- ◆ Attitude of operating agency towards operation and maintenance

Typical Lift Station Problems

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The attitude of the operating agency is probably the most significant factor today in determining the frequency of lift station visits. Many operating agencies make daily visits to their stations because they have always visited lift stations daily and also because they know that a great number of other communities make daily visits.

However, have the people responsible for station operation and maintenance analyzed their collection system and their operation and maintenance programs and proved that daily station visits are required?

To conduct this type of analysis, records must be kept and studied in order to answer the following questions:

- ◆ How many station failures are found each day?
- ◆ Electrical power failures.
- ◆ Failure of level-sensing or other control equipment.
- ◆ Flooded wet wells.
- ◆ Plugged pump impellers or lines.
- ◆ Overheated and tripped-out motor thermal overloads.
- ◆ Sump pump off and sumps or dry wells flooded.
- ◆ Air- or gas-bound pump.
- ◆ Stuck or blocked check valve.

- ◆ Pump control systems not functioning.
- ◆ Failure of lift station telemetry system.
- ◆ Ventilation fans burned out.

- ◆ What functions were performed at each lift station that kept the station operating, and what would have occurred if the function had not been performed during the daily station visit? For example, assume a pump impeller was plugged with rags and not pumping. The station crew during their visit and inspection discover the problem, de-rag the pump and restore the pump to service. However, if the pump had plugged immediately following their visit, the telemetry system would have indicated a failure. This crew or another crew would be dispatched to return to the station. If the pump was not telemetered, the back up or alternate pump would have pumped the wastewater until a high wet well level was reached. At this point a high water level alarm would have been activated or the other pump would have handled the flow until the next day when the crew again routinely visited the station. Therefore, with an adequate telemetry system, a routine visit is not essential under these conditions.

- ◆ How many actual hours of work are performed at each station during the visit? Do not include crew travel time to the station.

- ◆ What is the critical period of time if the station does fail? This time period is the length of time from when the failure occurs at high water level in the wet well to when backup flooding or overflow will occur. When this critical time is determined (it should be reevaluated annually because flow conditions change), it provides the time available for a station crew to respond to an alarm condition. Any critical

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time under one hour creates a serious problem for the operating agency and corrections should be made by installation of larger pumps. If power failures are a problem, an emergency generator should be installed to operate the station during power failures. Another possibility is to staff the station on a continuous basis and to operate with manual controls or overrides during power failures.

Lift stations operate automatically and, if properly designed and maintained, do not require daily visits under most circumstances. Typically the daily visit is usually a quick inspection of the power panel for tripped breakers, indicating lights of operating equipment, flow data and recording elapsed time meter readings. Motors in the station are usually examined to see if they are noisy or running hot. Items typically checked during a visit include the pump packing or seal system, check valves, and suction and discharge pressures, routine lubrication and clean up. The sump pump switch is flipped to see if it is operating. The visiting crew may bleed condensate from the air bubbler system for wet well and pump control and glance at the wet well indicator to see if it is reading properly. The crew may look into the wet well for sticks and even observe that there is water in it.

Unfortunately this description of a lift station inspection is not uncommon even when performed by competent and well qualified operators.

Daily visits tend to cause operators to give the station a quick glance in a noncritical manner because the crew was here yesterday and will be back tomorrow. For this reason, important maintenance items are often delayed until tomorrow which sometimes doesn't come for a month.

Stations that are visited daily may be dirtier and more in need of maintenance than stations visited

less frequently. If a lift station requires a daily inspection, the station book should have a daily task check off sheet indicating the tasks to be performed and a space for the initials of the operator who performed the task to indicate who did the job.

A very important aspect regardless of the frequency of visits is the fact that operating and maintenance operators must be provided the time and training to adequately perform each task. Also supervisors must occasionally inspect stations after a crew visit to see that the tasks were performed and not merely signed off.

Once procedures and objectives have established that specified tasks must be done on a routine frequency (whether daily, weekly, monthly, quarterly or annually), the operators responsible for the lift station must accept the responsibility and be sure the task is completed when scheduled so the operation of the lift station will be as reliable as possible.

Analysis of records can indicate if adjustments in the frequency of tasks are necessary.

Small communities with one or two lift stations may find it more economical to visit stations twice daily rather than to install and to maintain a telemetry system. When the operating agency has 15 to 50 lift stations to operate and maintain, then the time consumed for the single daily visit becomes very large and quite expensive. If it is possible to reduce station visits from once a day to once a week. The savings are substantial. Monthly station visits are practical, but visits at greater time intervals are not cost effective.

This section is not attempting convince every operating agency to extend lift station frequencies visit to because this is not applicable to every station. It is attempting to indicate that many

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people have little confidence or no faith in their lift station's equipment and programs and do not believe that a station can operate a week, let alone 30 days by itself.

The following is a list of requirements that must be met to permit limited visits to lift stations of once a week to once a month.

- ◆ Equipment lubrication reservoirs must be large enough to hold lubricant supplies to meet needs between visits to the station.

- ◆ Telemetry of the station is required. Most lift stations constructed today are telemetered at least for the high water alarm. Usually other items may be sensed and alarmed on the same high water alarm signal, for example:
 - ◆ Water level in sump pump pit or dry well,
 - ◆ Power failure,
 - ◆ Air compressor failure,

 - ◆ Lift pump check valves, (When pump motor starts and check valve does not open, an alarm sounds indicating a pump failure).

In stations using other auxiliary equipment necessary for station operation, the following additional items also may be sensed and telemetered:

- ◆ Water supply pressure,
- ◆ Chlorine leaks,
- ◆ Low chlorine pressure,

- ◆ High temperatures of motors and engines,

◆ Worker inside stuck elevator

With the recent advances in solid state equipment, telemetered monitoring and supervisory control systems have become much more commonplace in collection systems. They range in complexity from very basic monitoring systems to more sophisticated computer-based alarm, telemetry, supervisory control, and flow-monitoring systems.

These systems consist of an electronic interface device located in the lift station which transmits alarm or monitored information via radio or over leased telephone lines. In some cases, an agency may run its own transmission lines; however, this currently is not common practice.

Information is received at a central location. This could be a 24-hour, seven-days-a-week dispatch center in the community such as the public safety office, or in the case of a utility that has their own 24-hour, seven-day-a week dispatcher, to that office.

A simple system may be nothing more than an annunciator board that indicates the lift station and type of alarm. However, microcomputers are now frequently used in this application and perform logging functions to record various information such as date, time and nature of alarm.

In some systems the computer automatically polls various lift stations at a predetermined sequence and inquires the status of the station. If an alarm occurs, the computer can be programmed to automatically dial a pre-programmed number to a collection system operator and relay a message over the phone.

These monitoring and telemetry systems are frequently referred to as SCADA, which stands for Supervisory Control and Data Acquisition system.

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Analog or digital inputs (AI, DI) are fed into a remote terminal unit (RTU) which is in fact a microprocessor located in the lift station. Information is transmitted over a leased telephone line, into a communication interface and ultimately into a mini-computer. Other auxiliary equipment include printers, XY plotters, video copier, fixed disc for memory and tape backup unit.

Although this is a fairly sophisticated system, its complexity is dictated by the numbers of field inputs and the needs of this particular agency. However, the basic concept would apply to small systems without the optional auxiliary equipment.

Virtually any type of alarm telemetry system improves the options available to the collection system operator when delegating personnel and equipment resources, particularly during emergency situations such as tornadoes, extremely high intensity rainfall, thunderstorms or other conditions which may leave the community and the collection system without utility power, or flooding or other emergency conditions.

If the collection system operator has a thorough knowledge of the system, a telemetered supervisory system which indicates station status will be invaluable in preventing backups and/or bypasses, station flooding or other severe problems in a collection system.

Lift station problems may be listed in the following four categories:

Power

- ◆ Power failures.
- ◆ Electrical circuit failures.
- ◆ Thermal overloads tripped.

- ◆ Fuses blown.
- ◆ Relays burned out
- ◆ Motors burned out.

Control systems

- ◆ Telemetry system failure.
- ◆ Wet well controller.
- ◆ Float type
 - Float stuck in stilling well,
 - Float line broken.
 - Power off and cam override stops.
 - Mercury switches failed.
- ◆ Bubbler type
 - Air compressor failed.
 - Bubbler line plugged or restricted.
 - Leak in air piping system.
 - Diaphragm ruptured
 - Mercury switches failed.
 - Condensed water in air lines.
 - Bubbler line broken off in wet well.
- ◆ Electrode systems

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Short in electrode leads.

Electrodes coated with grease or rags.

Electrodes tangled when wet well changes levels.

Seal trode units

Bulb ruptured

Electrolyte leaked out.

Pumping systems

- ◆ Pump impeller plugged with rags or sticks.
- ◆ Pump suction blocked.
- ◆ Check valve stuck open or flap broken from shaft.
- ◆ Pump drive shaft from motor broken.
- ◆ Failure of packing gland or seal water supply.
- ◆ Pump air- or gas-bound.

Structures

- ◆ Grit deposits in wet well.
- ◆ Grease and floating debris in wet well.
- ◆ Force main restricted or plugged.

Most of these problems can be prevented through a good preventive maintenance program.

PIPELINE CLEANING AND MAINTENANCE

In Chapter 5 we will discuss the need for a physical inspection program for collection systems in order to develop a system inventory including the size, type, age and condition of the system. Inspection also helps to locate gravity sewers and their alignment so accurate maps of the system can be maintained and to identify defects in the collection system so short term maintenance requirements can be identified as well as long term repair and rehabilitation programs planned. Once we know what we have in the ground, where it is located and what the condition of the system is, we can now develop a maintenance and cleaning program for the system that will include planning and scheduling preventive maintenance.

The most effective maintenance program is one that relies primarily on proactive maintenance activities, that is, planning and scheduling maintenance to prevent problems from occurring. Sewer cleaning using hydraulic or mechanical cleaning methods needs to be done on a scheduled basis to remove accumulated debris in the pipe such as sand, silt, grease, roots and rocks. If left to accumulate the capacity of the pipe is reduced and a blockage can eventually occur resulting in over flows of the system. Physical damage can also result from roots and corrosion. Sewer cleaning should be scheduled on a regular basis, some agencies for example, clean 100% of their system on a three or five year schedule. This can result in over maintenance of the system since some sections will not require cleaning that often, and conversely some sections may require cleaning on a more frequent basis such as monthly if they are susceptible to blockages. As part of the maintenance program, of course, the problem areas need to be diagnosed and, if necessary, rehabilitated as part of the long term planning process in order to reduce the level of effort required to maintain the problem area.

While we can never eliminate reactive maintenance

activity, such as corrective and emergency maintenance, we can reduce the frequency and consequences of reactive maintenance by developing a maintenance program that relies on preventive maintenance activities of the collection system.

To operate and maintain a wastewater collection system so it will function as intended, we need to minimize stoppages that result in bypasses and overflows. This section discusses how to identify the causes of stoppages and odors, how to select solutions to these problems, and how to actually solve these problems.

Identifying Problems and Their Solutions

Identification of Problem

Potential problems are often found during routine cleaning and maintenance. Our job is to try to prevent stoppages that will result in wastewater backing up and overflowing onto the street or into homes or businesses. We can consider a sewer stoppage to occur when a sewer system becomes plugged and the flow backs up.

Types of Stoppages:

For the sake of recording stoppages for follow-up maintenance work, stoppages must be identified according to the cause or type of problem. Stoppages are caused by obstructions such as:

- ◆ roots
- ◆ grease
- ◆ debris
- ◆ broken pipe
- ◆ joint failure

These obstructions may require removal, repair, or replacement immediately to correct the problem.

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Many stoppages are caused by people not realizing the consequences of their activities. Vandals have placed debris into lines and structure openings which were designed to vent the collection system. Also, they have placed materials or debris into structures designed for the purpose of performing maintenance work in the sewers. Manhole covers have been removed in isolated sewer easements by vandals. These openings offer an ideal place for vandals to cause a serious back up of wastewater in a very critical area.

Some stoppage problems created in sewer easement areas also may be caused unintentionally. This is especially true when a large piece of construction equipment begins rough grading work and this equipment knocks off the top of a manhole, spilling dirt, rocks, and other material debris into the opening and causing a stoppage in the sewer. In most cases, the equipment operator is not aware of the location of the manholes because they are buried or covered with overgrowth.

Other physical type stoppages are caused by obstructions found in the sewer. These obstructions are sometimes found to be created by plumbers, equipment, or by some force of nature.

A plumber-made obstruction can be caused by:

- ◆ the placement of a building sewer tap connection that protrudes into the main sewer
- ◆ a poorly repaired pipe section
- ◆ backfill damage to pipe
- ◆ the misuse of trench compaction equipment
- ◆ pipe damage due to the improper use of sewer cleaning equipment

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The forces-of-nature type of obstructions include:

- ◆ the penetration of roots into the pipe connection or openings which cause pipe to break and/or restrict water flow
- ◆ ground movement shifting the pipe (such as caused by earthquakes), weather changes, soil conditions underground
- ◆ the deterioration of other utility pipes

Some of the most common types of debris found when removing a stoppage are:

- ◆ a build up of solidified grease
- ◆ detergents
- ◆ sticks, rags, plastic bags
- ◆ broken pipe, brick, rocks, sand,
- ◆ silt

Larger items removed from lines and manhole openings which have caused a major problem for removal are:

- ◆ broken manhole and flushing inlet castings
- ◆ concrete and asphalt rubble
- ◆ steel rebar
- ◆ large metal and plastic buckets
- ◆ broken and lost plumber rods, snakes and plugs

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- ◆ wooden posts and timber materials
- ◆ barb wire; tree limbs, and stumps

In some instances where the invert of a small diameter sewer is connected to the invert of a large diameter sewer which is flowing at maximum flows, hydraulic conditions can cause serious stoppages to develop. Not only do stoppages develop in the sewer, but solids can build up in a manhole and produce harmful and obnoxious gases. Most instances of a hydraulic-caused stoppage condition are found to be in sewers that have been extended to new developments from existing mains which were not designed for the future potential growth of a community.

Hydraulic-caused stoppages can be minimized by proper design. Wherever flows from one sewer meet and join the flow in another sewer, the flows should always be going downstream in the same direction as much as possible. A more frequent cleaning schedule is the best possible solution to hydraulic-caused stoppages in many cases.

Identifying Causes of Stoppages and Problems

First, try to correct the problem as quickly as possible. If the cause of the stoppage can be identified, the best method of correcting it comes next.

A mental checklist to identify the problem would include:

- ◆ Does this line have a history of previous stoppages? (A root problem line or a grease problem line.)
- ◆ Are trees growing near the line?
- ◆ Have new building sewers or new lateral or

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branch sewers been installed recently?

- ◆ Have repairs been made recently to the sewer, to other utilities or to the street?

- ◆ Are there any ground or surface indications, such as a settlement or a sink hole?

Once the cause of the problem has been identified, the methods for solving the problem can be analyzed.

Overview of Methods for Cleaning and Maintaining Sewers

Sewer cleaning and maintenance methods depend on the characteristics of the wastewater being conveyed to the treatment plant, fluctuations in wastewater flows, alignment or grade of the sewer, pipe material and condition of the sewer.

Stoppages can be cleared or prevented and sewers cleaned by either hydraulic or mechanical methods. Hydraulic cleaning methods consist of cleaning a sewer with water under pressure that produces high water velocities. These velocities are usually high enough to wash most grit, grease and debris found in sewers down the sewer and leave the pipe clean. Mechanical methods of clearing stoppages in sewers consist of using equipment that scrapes, cuts, pulls or pushes the material out of the pipe.

Hydraulic cleaning equipment used today includes high velocity cleaners, balls, kites, bags, parachutes, tires and scooters. High velocity cleaners rely on jets of high velocity water squirting from a nozzle at the end of a hose in a sewer. The high velocity water cleaners also are called “jet cleaner,” “jet rodder,” “hydraulic cleaner,” or “high pressure cleaner.” Balls, kites, bags, parachutes, tires and scooters all rely on the same principle.

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These devices fit into a sewer and partially block the flow. Water builds up behind the device and creates a pressure. This pressure forces water at a high velocity around the outside edge of the cleaning device. This high water velocity cleans the walls of the sewer and pushes the material and debris downstream where it can be removed at a manhole. Flushing is a hydraulic cleaning method that relies on additional water being discharged into a sewer in sufficient quantities to create high velocities and clean the sewer.

Mechanical cleaning equipment consists of bucket machines, power rodders, hand rods and winches for pulling scrapers, porcupines, swabs and various cutting tools through the pipe to remove hardened grease, invert debris, roots or physical obstructions such as bricks, rocks or other large objects that find their way into the sewer system. Bucket machine operation consists of a set of specialized winches that pull a device through a pipe to collect debris. Materials are captured using a special bucket and are removed from the pipe. Rodding (either using a power rodder or a hand rodder) consists of pushing or pulling a steel rod or snake through a sewer with a special tool attached to the end. These tools are designed to cut or scrape materials from the pipe walls and are most effective on hardened grease and roots.

Both hydraulic and mechanical cleaning methods are used to maintain sewers in working condition. Chemicals and bacteria cultures also are used in sewer maintenance programs to keep lines clear.

Odor control (especially hydrogen sulfide control) requires that sewers be maintained as clean as possible. Hydraulic and mechanical cleaning methods as well as chemicals are used in odor control programs to maintain wastewater collection systems.

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What type of equipment is best suited for removing stoppages and cleaning sewers? The answer to this question can only be determined after an analysis of the cause of the problems and the solution selected. Following is a list of the basic types of equipment used to identify and remove stoppages and clean sewers.

Rodding

- ◆ **Equipment:** Truck or trailer mounted rodding machine or hand rods with an assortment of specific cutting tools and operational accessories.

- ◆ **Advantages:** May be used to cut roots, scrape, and dislodge and remove certain types of material found in sewers. This equipment is very effective in removing collection line emergency stoppages.

- ◆ **Limitations:** Ineffective for removing sand and grit accumulations in sewers, but can loosen materials so they can be flushed out with hydraulic cleaners. Rods have a tendency to bend or coil in large diameter pipes and are most effective in 15 inch diameter and smaller pipes. When using hand rods in a sewer with a high head condition, behind an obstruction caution must be exercised when the obstruction is broken because the rods may be forced back out of the man hole.

Sewer Ball or Tire

- ◆ **Equipment:** Assortment of various sizes of sewer balls or tires to fit different diameters of sewers, tag line winch, cable, reels, water tank truck and dump pickup. Provide water from a hydrant through a hose with an AIR GAP

- ◆ **Advantages:** Hydraulic action of spinning ball and high velocity of water flowing around ball dislodge debris from pipe walls and move

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debris downstream. Very effective in removing heavy concentrations of sand, grit, rock and grease from sewers.

◆ **Limitations:** Dangerous to use in locations with basement fixtures and steep-grade hill areas. Strong possibility of flooding dwellings. Cannot be used effectively when sewers have bad offset joints or protruding service connections because ball can become distorted, get past these obstructions and not do an effective cleaning job. In sewers where the ball has a tendency to get stuck, a bag full of ice can be used. When the bag becomes stuck, wait for the ice to melt sufficiently for the bag to continue downstream.

High Velocity Cleaner

◆ **Equipment:** Truck or trailer mounted high velocity cleaner with an assortment of nozzles, easement rollers and operational accessories.

◆ **Advantages:** Very effective in cleaning flat, slow flowing sewers. Efficient in removing grease, sand, gravel, and debris in smaller diameter sewers. Effective in breaking up solids in manholes and washing structures. May be used to remove emergency stoppages.

◆ **Limitations:** Efficiency and effectiveness in removing debris from larger diameter lines decrease as the cross-sectional area of the pipe is increased. This method, when used by an inexperienced operator, may cause a backup into residences. Extra time by an experienced operator may be necessary to remove grease and roots from some locations.

Bucket Machine

◆ **Equipment:** Power bucket machine and power bucket machine truck loader, dump truck and assorted operating rollers and tools.

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- ◆ **Advantages:** Best suited to remove large amounts of sand and debris from larger diameter sewers effectively. Provides the ability to work in pipe sizes other cleaners cannot work in efficiently.

- ◆ **Limitations:** Set up can be time consuming and bucket operations require some advance planning. Can damage small pipes if not properly used. May not clean all debris out of large lines and other hydraulic cleaning devices should be used after bucketing a line.

Kite or Bag

- ◆ **Equipment:** Water tank truck, dump pickup truck, and power drum winch machine.

- ◆ **Advantages:** Very effective in moving accumulations of decayed debris and grease downstream. Capable of washing ahead of it a full pipe of deposits, including roots.

- ◆ **Limitations:** Must use caution in locations with basement fixtures and steep-grade hill areas.

Scooter

- ◆ **Equipment:** Water tank truck, dump pickup truck, tag line, and power winch. Provide water from a hydrant through hose with an air gap.

- ◆ **Advantages:** Hydraulic water action scours inside of line. Very effective in removing heavy debris and cleaning grease from line.

- ◆ **Limitations:** When cleaning larger lines, the manholes must be designed to a larger size to receive and retrieve this equipment or the scooter must be assembled in the manhole. Must use caution in locations with basement fixtures and steep-grade hill areas.

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Flushing

- ◆ Equipment: Water tank truck and fire hose if fire hydrant is not convenient.
- ◆ Advantages: Supplies a surge of water to move light, decaying organic matter downstream in slowly flowing sewers.
- ◆ Limitations: Causes a temporary movement of debris from one point to another in the collection system. Flushing does not remedy the cause of the problem and does not move heavy debris and grit. Must use caution in locations with basement fixtures and steep-grade hill areas.

Scraper

- ◆ Equipment: Wing scraper, "C" drag bucket, power bucket machine, basin machine and dump truck or bin.
- ◆ Advantages: Removes large amounts of sand, stone, rocks and debris from larger (usually 36 inch diameter or larger) sewers.
- ◆ Limitations: Sewers can be damaged. Setting up of equipment is time consuming; therefore, the operation is usually run in two or three shifts during a 24-hour period.

Work Assignment

When a crew is assigned a regularly scheduled sewer cleaning job, the crew should be notified and dispatched by a written order.

Crews assigned to clear emergency stoppages are notified by radio and immediately attempt to clear the stoppage. A written report is prepared after the stoppage is cleared. Work performed also must be recorded. This information provides vital documentation of the ability of the wastewater collection system to perform its intended job and also the

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effectiveness of equipment and crews.

Work assignments should include the following information for each location:

- ◆ Location of job, including map book number, map page and manhole number.
- ◆ Street or easement.
- ◆ Location of upstream and downstream manholes.
- ◆ Line-of-sight or sound-powered telephone communications.
- ◆ If in street, traffic conditions, or
- ◆ If in easement,

Notification of property owners.

- ◆ Are dogs locked up?
- ◆ Keep children out of work area.

Sewer conditions.

- ◆ Depth.
- ◆ Water supply needed.
- ◆ Upon arrival at the work site, the sewers to be cleaned are located using a map.

Records

A record of all cleaning operations should be made and filed for future reference. These records should include the date, street name or number, line size, distance, and manhole numbers or identification.

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Also note the kind and amount of materials removed, wastewater flow, and amount of auxiliary water used. If particular problems were encountered, these too should be noted, especially the exact location of obstructions.

If pieces of broken sewer are removed, this may indicate a TV inspection is needed and that a repair may need to be made on the broken sections of pipe.

Recording traffic patterns at a site can be very helpful next time equipment must be set up at the location. Indicate where cars park (such as over manholes), traffic volume during rush hours, and whether police traffic control should be called for help before going to the site.

Computers are being used in many aspects of collection system operation, maintenance and recordkeeping. Computer software packages are available for scheduling preventive maintenance activities, issuing work orders for repairs, keeping track of where work is done, who did the work, when, and the labor and materials required. With the proper software any information in the computer's records can be recalled for future use.

Computers are also used to keep spare parts inventories and to order spare parts when the supply runs low and before they are needed for scheduled maintenance and repairs.

When making out records, remember that you or someone else will be referring to them. The more complete the record the easier the next operation becomes since you have a history of this sewer.

Hydraulic Cleaning

Sewer cleaning methods described in this section rely on the cleansing action caused by high velocities of water in the line.

Wastewater Collection Systems

High water velocities can effectively remove grease, sand, and other debris. Cleansing velocities can be obtained by allowing water pressures or head to build up in the line or by using a pump to produce the water pressure.

Hydraulic cleaning methods include:

- ◆ balling,
- ◆ high velocity cleaners,
- ◆ flushing, sewer scooters,
- ◆ kites, tires and
- ◆ poly pigs.

Balling

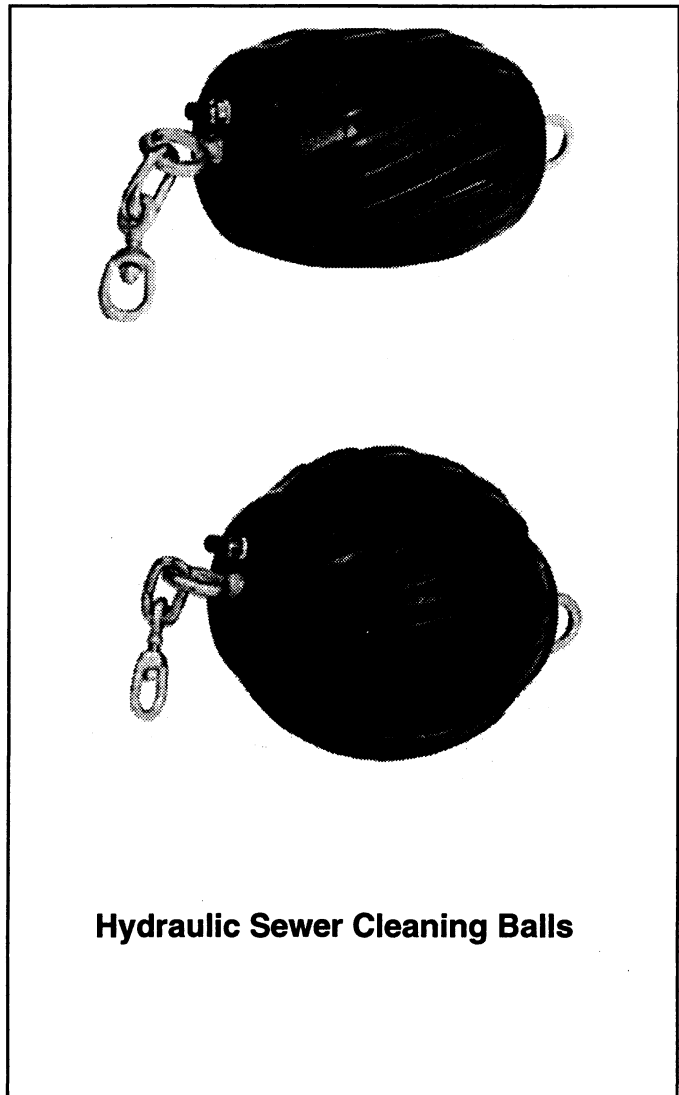
Balling is one method of removing debris from sewers. The tool is literally a “ball” of special design shown in the next figure.

This cleaning procedure is one of the less expensive methods and is quite popular in some cities. Usually balling is not the only cleaning method used by an agency since the ball primarily removes deposits of inorganic (grit) material lying on the bottom of the line and grease buildup inside the line.

Balling can be used only in areas where the necessary water pressure behind and around the ball can be obtained without flooding basements or homes at low elevations.

Flooding can occur when the elevation of the head of water on the upstream side of the ball is higher than a plumbing fixture in a home or basement.

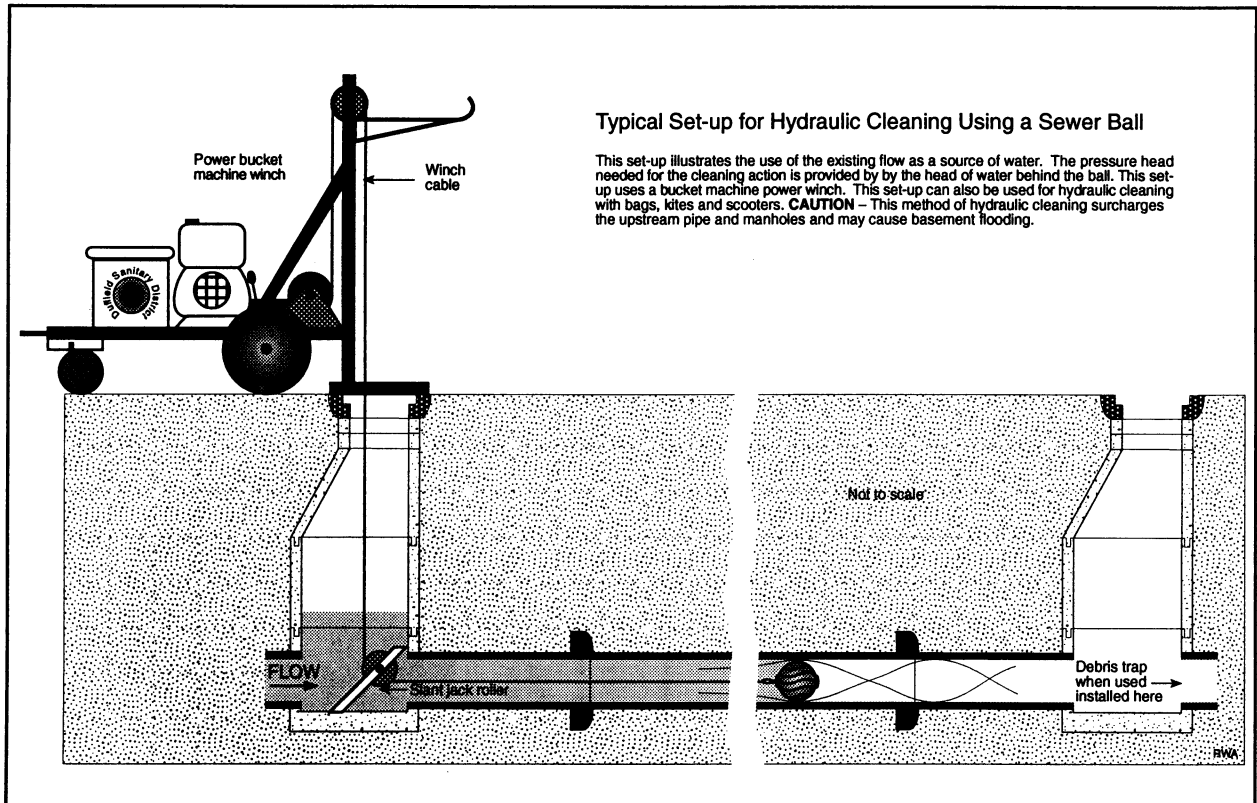
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If many roots are involved, a power rodding machine probably will be needed. Power rodding and other cleaning methods and procedures will be discussed fully in other sections of this section.

Balls are available in sizes 6, 8, 10, and 12 inches for small lines and sizes up to 48 inches for large trunk lines. Larger sizes may be obtained by special ordering.

Wastewater Collection Systems



Balling is most commonly used in preventive maintenance programs. Under these conditions balling is very effective in reducing the possibility of stoppages developing.

An effective balling program can reduce the production of hydrogen sulfide in collection systems, thus reducing damage from hydrogen sulfide caused corrosion and the release of odors smelling like rotten eggs.

Some sewers require cleaning by balling more frequently than others. Required frequency of cleaning may vary from six months in some sluggish lines, to three years in other lines.

Realize that these are typical frequencies and that some sewers may require monthly cleaning while other sewer may never need cleaning. Many communities try to ball their entire collection system

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every year.

To determine the frequency of balling for your collection system, study your agency's records. Base the frequency of cleaning the various sections of the collection system upon:

- ◆ Reducing the number and types of stoppages and complaints by analyzing records and inspecting manholes for the presence and amount of deposits.
- ◆ Size of area the collection system serves.
- ◆ Types of waste carried by collection system:
 - ◆ Residential
 - ◆ Commercial
 - ◆ Industrial
 - ◆ Storm water

The main purposes of balling or the use of tires are to keep the sewer clear of debris and to maintain flow velocities two feet per second or more in the sewers to the wastewater treatment plant.

Crews and Equipment

At least three operators are needed for cleaning lines up to 18 inches. When cleaning those lines located in easements or off the street, additional help may be required depending on the difficulty of the job.

Although some of the equipment listed below is used for balling, the majority of collection system maintenance departments will have most of the regular tools needed. Basic essentials include:

Wastewater Collection Systems

- ◆ Water truck holding 1,000 or 2,000 gallons with hoses and air gap for hydrant use,
- ◆ Tag line and a suitable reel to store it on or power winch and cable ,
- ◆ Manhole jack or roller,
- ◆ Plugs,
- ◆ Balls ,
- ◆ Equipment truck,
- ◆ Debris and grit trailer,
- ◆ Ladder,
- ◆ Manhole hook
- ◆ Buckets, rope and manhole shovel,
- ◆ Hip boots and gloves ,
- ◆ Method of communications,
- ◆ Collection system map,
- ◆ Safety equipment.

Some communities use domestic water from fire hydrants instead of a water truck to obtain water to provide the necessary head for a balling operation. If fire hydrants are used, the following additional equipment will be needed.

- ◆ Five to eight 50-foot lengths of 2.5-inch fire hose

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- ◆ Hydrant wrench
- ◆ Water meter
- ◆ Control valve for regulating flow at manhole
- ◆ Traffic ramp to protect hose
- ◆ Hydrant gate valve
- ◆ Air gap device

Air gap devices are required to prevent any back-flow of wastewater from a manhole into a drinking water supply. The purpose of an air gap device is to provide adequate space above the top of a manhole and the end of the hose from the fire hydrant.

This gap insures that no wastewater will flow out the top of a manhole, reach the end of the hose from a fire hydrant, and be sucked back up the hose to the water supply. Suction conditions could develop if the water supply pipe near the fire hydrant should rupture and cause a washout or if any other rare condition should develop that could cause a back-flow in the hose.

Power driven reels are either truck mounted or trailer mounted with stabilizer legs to hold the machines firmly in place over the manhole while in operation.

Because of the terrific strain and pressure generated as water builds up behind the ball, a strong steel cable is needed. Truck mounted winches are preferred by some agencies because this method allows the truck to tow other trailer mounted equipment, such as exhaust blowers.

The smaller balls are designed with diagonal ridges and grooves on the outer surface. As water builds up

Wastewater Collection Systems

in the sewer in back of the ball, water will flow through these grooves and the ball will rotate.

The outside design of the large balls differs somewhat, usually having a heavy tread surface to encourage a scouring action to the interior of the sewer.

The ball is resistant to punctures and is inflatable by means of a valve core. Into each side of the ball a strong metal eye lug is molded to which a clevis and swivel can be attached. The tag line is then attached to control the ball and allow it to spin. This clevis and ball bearing swivel are very essential items since they keep the line from twisting. The clevis is quickly and easily fastened to the tag line and ball.

The reel, although primarily to hold the rope, also is used to apply a brake or drag to control the travel of the ball down the sewer.

The manhole guide jack or roller is essential to guide the tag line into the sewer without causing unnecessary wear and to give proper rolling action as the tag line is pulled back and forth or in restraining the ball.

Plugs, either mechanical or inflatable, are needed to control water coming into the working manhole from upstream. If there is insufficient flow in a sewer for balling, this method of “plugging off” the upstream water provides a method of getting an adequate supply of water to begin the balling procedure. Use a two-foot head of water on the ball to clean a line.

If the material removed from the line is to be hauled away by the balling crew, a truck is needed.

Equipment Set Up

Before setting up the balling operation, certain

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safety measures need to be taken, both for handling street traffic and personal safety at and in the man-holes.

Position the reel or power equipment so the tag line is centered in the upstream or working manhole . Attach the line to the ball using the clevis and swivel. Place the ball in the manhole by hand, unless the water is too high. If the water is high, push the ball into place with a forked rod. Insert the ball into the sewer just far enough to determine if it is inflated properly. The ball needs to be snug enough to cause good cleaning action, but not so tight the water cannot flow around the ball and carry it downstream. On the other hand, if it is too loose the ball will only float downstream with little cleaning action. When inflating the ball be careful that it does not become too hard. The ball must be soft enough so it can squeeze around obstructions in the sewer.

Most sewer balls have two nipples on opposite sides that are used to attach the line to the ball. If one nipple breaks, use the other nipple. **DO NOT ATTACH A LINE TO ONE NIPPLE FROM THE UPSTREAM MANHOLE AND A LINE TO THE OTHER NIPPLE FROM THE DOWNSTREAM MANHOLE, BECAUSE THIS WILL CAUSE A REDUCTION IN THE SWIRLING ACTION OF THE BALL AND THUS REDUCE THE CLEANING ACTION.**

The manhole guide jack or roller is now installed in the bottom of the manhole and secured to allow the tag line to run freely and away from areas of the manhole that will cause abrasion. This roller or jack must be secure enough to allow strain on the tag line without lifting the jack out of position.

An operator is stationed at the downstream manhole with adequate communication with the operator running the ball and tag line at the upper manhole.

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The downstream operator's job is to keep the operator guiding the ball informed of conditions in the downstream manhole during the balling operation.

Cleaning Operation

The balling operation is now ready to begin. If the water supply coming into the working manhole is not enough to give proper head pressure, the plugs can be used. Insert plugs into lines coming into the manhole so the section of pipe being cleaned is isolated.

Discharge water into upstream manhole with the water truck or from a fire hydrant with an air gap over the manhole. Usually a balling operation will function very well with 2.0 feet of head in the upstream manhole to create a scouring velocity around the ball. There should be a maximum elevation set by the crew leader that the water head may reach.

If plugs are used to store water in the upstream line for release to operate the ball, be sure to attach a safety line securely to them. When the plug is released, the water pressure behind it will have a tendency to "blow" it out and there is the danger of losing it into the downstream line and causing a major problem. Either method will create enough pressure to operate the ball properly.

As the ball begins to travel downstream, it will also be turning with water traveling around it and flushing debris ahead of it. Hold the tag line tight and allow the ball to travel slowly downstream at a steady rate. This procedure produces the best cleaning action.

Ineffective cleaning results if the ball travels too fast. If you are short of head pressure, holding or stopping the ball travel and then releasing it at intervals will increase the head pressure and spinning action.

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This also causes the jet stream around and in front of the ball to break up debris deposits. The ridges of the grooves in the ball's surface also will give a scouring action to the interior of the sewer.

If the ball suddenly stops, this is an indication of a large deposit, that sufficient material has built up to stop the ball travel, the ball has hit a bad tap, or a crushed or offset pipe.

By pulling back on the tag line a short distance, the ball will 'egg shape' causing first, a vacuum in front of it and then a sudden flushing action. This "bouncing" of the ball sometimes has to be repeated several times to remove large or stubborn deposits. If a deposit can't be removed or reoccurs frequently, complete a form requesting that the line be tele-vised.

As the operation continues, the debris to be removed will start appearing when the ball gets within 20 to 25 feet of the downstream manhole. When the debris does begin to appear, an operator should be in the downstream manhole with a short handled shovel, shaped to fit the channel, so that the operator can remove the debris as it appears.

The accumulation of the debris may be slowed down by holding the tag line and stopping the forward progress of the ball. By releasing the ball a little at a time, the operator in the downstream manhole is able to remove all of the debris as it appears. **DO NOT USE A SAND TRAP OR OTHERWISE RETARD THE FLOW IN THE DOWNSTREAM MANHOLE** because a trap can hinder the effectiveness of the balling operation.

When balling a sewer that contains considerable debris and slimes that are producing hydrogen sulfide (rotten egg smell), it may be desirable to use a sand trap. This is better than having an operator in the manhole shoveling debris and being exposed to

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the hydrogen sulfide which is being pushed down the sewer ahead of the balling operation. If a sand trap must be used, the pressure head behind the bail will have to be raised to maintain the cleansing velocity around the ball.

The information and procedures given for balling also can be used for cleaning with tires. When a flushing action is needed in a sewer, give slack to the tag line and the tire will tip forward from the top, thus releasing water. Pull back on the tag line and the tire will return to an upright cleaning or flushing position. Tires are not as flexible as balls and cannot be inflated or deflated like a ball for proper fitting in a pipe. Tires used for cleaning sewers can be made up in an agency's shop.

Constant communication between the reel operator and the operator removing material from the bottom of the downstream manhole relayed through the operator above the downstream manhole is essential for the safety of the operator in the downstream manhole. If auxiliary water is being used, shut this water off at the control valve once debris starts arriving in the downstream manhole. The downstream operators should shovel this material into a bucket and lift the bucket from the manhole with a rope as quickly as possible so the operator can continue.

Continue balling and watch and listen for the ball at the downstream manhole. Keep it from entering the manhole until all remaining material has been removed. A strong shovel or bar can be placed over or across the incoming line to hold the ball back. When the manhole is clean, the ball can enter the manhole. If the tag line is of sufficient length to reach the next downstream manhole, insert the ball in the downstream line, and the operation can continue without another complete set up. The one crew needs only to move to the next lower manhole and get ready to remove debris when it starts arriving.

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Precautions and Safety

Certain precautions have to be taken or at least considered before and during all cleaning operations.

Using water pressure in the cleaning of gravity flow sewers always requires care and judgement with respect to basement fixtures and low elevation homes.

If there is any possibility of the water level behind the ball getting higher than basement fixtures , inspect these residences or business establishments for potential problems or use another method of cleaning, such as a high velocity cleaner.

If a stoppage occurs below the ball, it must be cleared as soon as possible to avoid flooding homes or streets. First try to break the stoppage by using the ball. If this doesn't work, use a hand rod, power rodder, or high velocity cleaner at the downstream manhole to clear the stoppage.

As previously outlined, all street work requires safety measures sufficient for the particular conditions involved. Emphasis should be made in getting barricades or warning measures a good distance away from the working areas. Always use flagmen where there is a need to control traffic.

If a sewer ball becomes stuck, try to work it loose without breaking the cable. A high velocity cleaner inserted in the downstream manhole hole may be able to go up the line and knock the ball loose. Another approach is to use a power rodder and try to puncture the ball. When a ball becomes stuck, be sure upstream homes don't flood while you are working the ball loose.

Because sewer balls use the principle of hydraulic head to develop high velocity flow around the ball, precautions must be taken when determining the

Wastewater Collection Systems

size of the winch and tag line to use to connect to the ball. Manufacturers, for example, recommend a maximum allowable back pressure of 5 feet of water when using balls from 6 inch diameter up through 18 inch diameter. This hydraulic head of water on the sewer ball exerts a force on the winch and cabling. For example on a 6 inch ball:

The force in pounds is equal to the cross sectional area times the hydraulic head in pounds per square inch. A five foot head of water is equal to 2.16 pounds per square inch (remember the formula: feet of water divided by 2.31 feet per PSI). For a 6 inch diameter ball, the cross sectional area is equal to πr^2 where r is the radius. For a 6 inch diameter ball the radius is equal to 3 inches and π is equal to 3.14.

$3.14 \times 3^2 = 28.26$ square inches.
 28.26 square inches \times 2.16 pounds per square inch is equal to approximately 61 pounds of force on the winch and the tag line.

Now lets look at an 18 inch ball with a 9 inch radius using the same formulas:

$3.14 \times 9^2 = 226$ square inches \times 2.16 pounds per square inch = 488 pounds of force exerted on the winch and tag line.

The above calculations are based on a full diameter pipe and in fact, the force would be something less than that calculated, however this illustration shows the approximate amount of force that can be generated when using sewer balls for cleaning with a 5 foot of hydraulic head behind the ball.

Summary

The balling method of cleaning is a relatively easy procedure, is very effective, and uses a minimum amount of equipment. Common sense measures of operations are involved and techniques can be developed and used to overcome problems common to this method of cleaning.

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High Velocity Cleaning Machines

The use of water pressure to clean sewers dates back to the early 1900's; however, this method has been improved upon with the present day high velocity cleaning machines.

High velocity cleaners were developed primarily as a preventive maintenance tool. They are most effective at removing silt, sand, sludge, light grease, and other loose debris found in sewer pipes. They are not as effective as power rodding machines removing heavy roots, hardened grease, and other hardened deposits, and are not as effective in large diameter pipes as power bucket machines to remove packed debris that can be found in them. These high velocity cleaners are used in daily maintenance, and with the use of various tools and operator experience, areas where mechanical cleaners may also need to be used can be pin pointed.

High velocity cleaners come in a variety of specialized sizes for different work requirements and can be either trailer mounted or truck mounted. In the early years of these hydraulic cleaners there were only a few standard configurations, however, today there are a wide range of machines that are available to help with specific system requirements. Trailer mounted systems usually use a 3/4" diameter sewer cleaning hose, and develop water flow from 25 gpm through 40 gpm, at pressure ratings from 1500 psi to 2000 psi. Truck mounted systems usually use a 1" diameter sewer hose that increases the water flow to the nozzle, and can develop water flow from 55 gpm to 80 gpm, at pressure ratings from 1500 psi to 2500 psi.

Additional specialized equipment is also used in some system maintenance for specific duties. This equipment can be higher volume of 100 gpm at 2000 psi, and used to move large amounts of debris from the pipe with the use of the higher water flow. Higher pressure systems with low volume such as 18 gpm at 4000 psi can be used to work in small

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diameter lines and for stoppages, however, water flow is limited, and may not clean larger lines well with pressure alone.

Some high velocity cleaners have an air conveyance system that use large fans or positive displacement vacuum pumps for material removal capabilities. With this type of system, material can be vacuumed from the manhole into a debris tank as it is brought back with the jet and taken to a disposal area. These systems can be either trailer or truck mounted and are generally known as combination machines.

The high velocity water cleaners consist of a water supply tank, a high pressure water pump, pump power source, and a hose reel with 500 or more feet. Specialized equipment, either trailer or truck mounted, have a variety of water capacities from 300 gallon to large truck mounted units with 3000 gallon capacity. Pump power sources can include auxiliary engines, power take off systems, or hydrostatic drives. Hose capacities can vary from 500 feet to 1000 feet.

To help in easement and remote cleaning operations, specially designed easement machines have been developed for use in these difficult terrain areas. These machines have a hose reel with hundreds of feet of operating sewer hose on them, and are self powered to access areas common vehicles have difficulty getting into. Remote operating controls allow operators to clean lines in these areas without damage to property, vehicles, or injury to personnel.

At the end of the sewer hose, various cleaning nozzles are attached for different conditions found in the sewer. These nozzles force the water in the hose to exit the nozzle orifices in a specific pattern for the work needed to be done. Other operating accessories are used along with the various nozzles

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which include; a lower manhole roller or slipper guide to protect the hose at the mouth of the pipe in the manhole, a finned nozzle extension to keep the nozzle off the pipe invert and prevent the nozzle from turning up laterals, and easement rollers for use off road or manholes with difficult access.

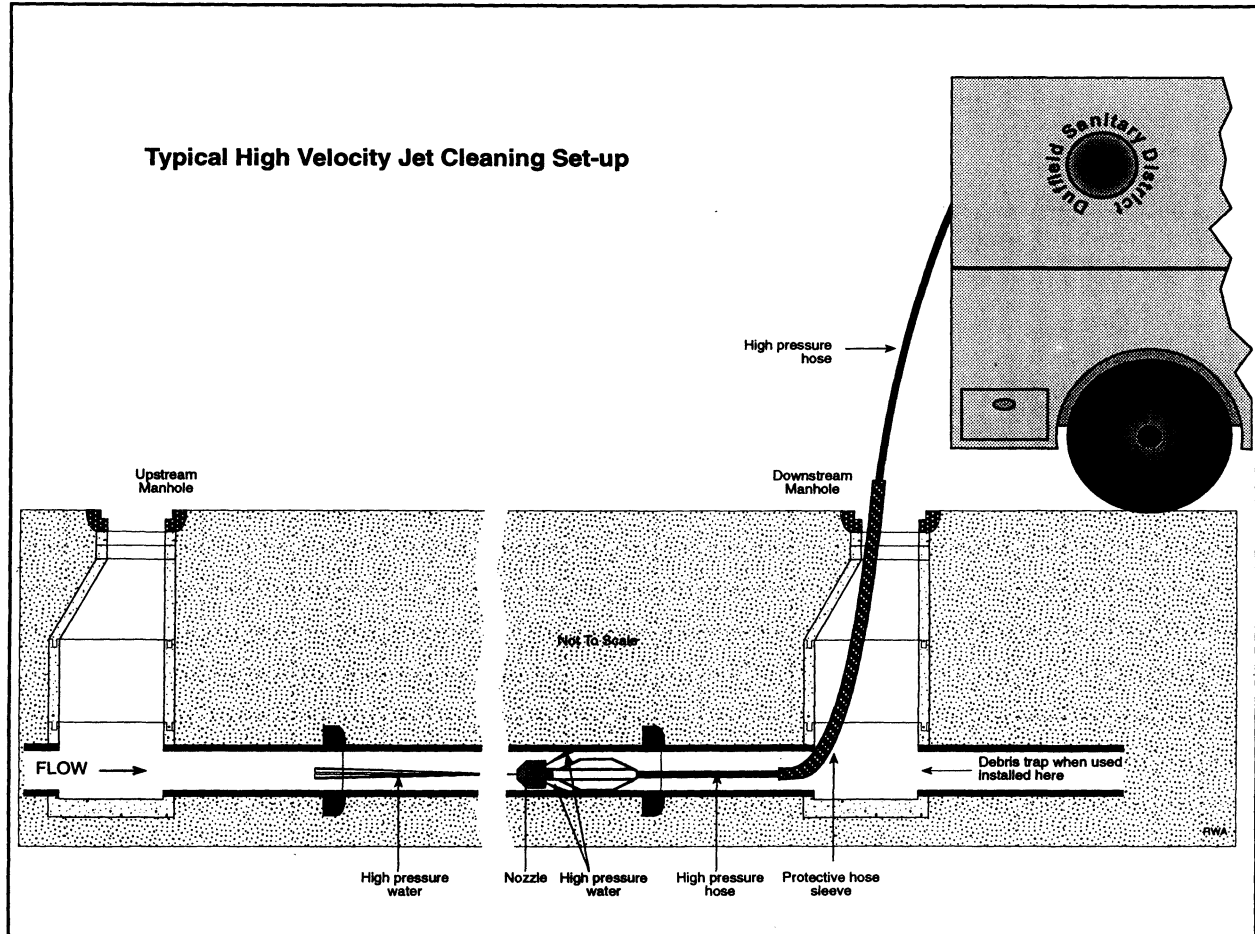
Also used are sand traps that help contain materials collected in the pipe. To prevent a large amount of debris from forming in the larger diameter sewer pipes downstream, sand traps are used to block off the down stream pipe in the manhole so that water that enters the manhole must build up and drain out through the top of the trap. Solids will settle out at the trap and will be easier to move. Debris shovels and grabbers are used to remove this material, as well as air conveyance vacuums that pull materials from the manhole.

High velocity cleaners have an effective range of cleaning ability, from 4" in diameter, to 20" in diameter, depending on the machines size and capabilities. These cleaners have increasing difficulty cleaning large diameter pipes as the cross section of the pipe gets larger. These cleaners are most commonly used as a preventive maintenance machine, that when used properly, will keep sewer pipes clear, and pin point the need for mechanical cleaners in specific areas. Primarily used to clear and flush debris, static deposits of materials, grease, and detergents, they do not work well in removing roots, hardened grease, and hardened deposits on the pipe invert unless special tools are used.

Additionally, these machines can be used for a variety of tasks that are not specifically sewer operations. They can be used for street washing, back up fire control, chemical spraying, and watering landscape. While this equipment does have a range of uses outside of sewer maintenance, it is important to recognize that the primary usage is for sewer cleaning, and this equipment should be constructed for this task.

Wastewater Collection Systems

Although the design of the high velocity cleaning machine will vary with different manufacturers, they are essentially all the same.



Crews and Equipment

These machines consist of a water supply tank usually with a capacity of 1,000 gallons or more, a high pressure water pump and an auxiliary engine for its operation. The unit will have a powered drum reel capable of holding at least 500 feet of hose, usually one inch ID. To the end of this hose, a nozzle will be attached which will create water velocities that do the cleaning.

Accessories are varied and new tools continue to be developed as well as techniques in their use. Among these accessories for this cleaning method

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will be a nozzle with rear jets only, a nozzle with rear jets and one forward jet, a dual nozzle, a hose roller or hose guide, and a wash-down gun or nozzle. In addition, sand or debris traps, manhole shovel, debris bucket and hand line, and a manhole lifter are essential tools too. Machines with 1-1/4 inch ID hose and special nozzles can be used to clean debris from larger lines and storm sewers.

For purposes of discussion, we will consider the use of a truck mounted, high velocity cleaning machine. These units are available as trailer mounted types as well, but they usually have less water tank capacity.

We will concentrate on the cleaning of sewers with 6 to 15 inch diameters; however, because of the design of this equipment, it is also effectively used for street cleaning, backup fire control equipment, chemical spraying, and watering landscape along streets and in parks .

The machine is operated by one operator. This operator will need help in order to be notified when the cleaning nozzle has reached the upstream manhole, and when the grit and debris are removed from the working manhole.

Equipment Set Up

Because this piece of equipment is a self-contained mobile unit and this method of cleaning smaller sewers is relatively fast, several set ups will usually be made in the course of a day's work.

Basic safety measures still apply, since for the most part this equipment will be set up in the street and traffic conditions must be considered.

Fill the water tank from a fire hydrant close to the area where you will do the cleaning. A 1,000 gallon tank full of water weighs 8,340 pounds plus the weight of the tank and truck. Even with baffles in the tank, sharp turns or quick stops can create

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driving hazards.

When using a fire hydrant, attach a gate valve on the discharge line to regulate flows. NEVER throttle or control flow from a fire hydrant with the hydrant valve because this could damage the hydrant valve. When filling a water truck, you must have an air gap between the discharge line and the top of the water tank.

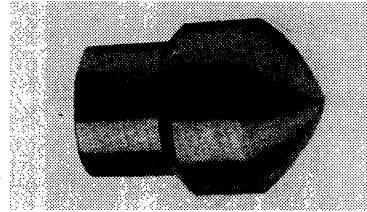
The machine will be equipped with a length of fire hose and an approved hydrant wrench. If the amount of water used is to be recorded, an approved meter also will be part of the equipment.

If a given area or subdivision is to be done completely, start at the top or highest point in the collection system. Whether routine cleaning or spot cleaning, position the high velocity cleaner hose reel over the center of the downstream manhole.

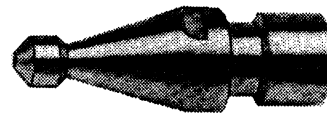
Select the nozzle to be used for this size. The angle of the rear jets vary from 15 to 30 degrees. Usually, the smaller the pipe, the less angle needed. Experience will teach the operator the right tool and technique. Install the proper size sand or debris trap in the downstream manhole. Start the auxiliary engine; turn the reel directional control to "out"; and using the reel speed control, lower the hose and cleaning nozzle into the manhole.

Direct the nozzle upstream in the line leaving a sag in the hose. The hose guide or roller is usually put into place after the hose has started up the line. The hose needs freedom at this point since the water pressure that forces water at a high velocity out of the rear orifices gives the jet propulsion action that moves the nozzle up the line. The hose guide should not obstruct this first start of the operation. The cleaning operation should be ready to begin.

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Typical Jet Nozzle



Penetrator Nozzle

Cleaning Operation

Because the high velocity cleaner is a mobile, self contained unit and this method of cleaning smaller sewer is relatively fast, several set ups will usually be made in the course of a day's work. Basic safety measures still apply, since for the most part this equipment will be set up in the street and traffic conditions must be considered.

Operation of the high velocity cleaner requires some expertise. The diagnosis of system problems, nozzle selection, proper set up, and field maintenance procedures for the cleaner are some of the areas that operators need to be aware of in order to use this equipment safely and effectively.

Proper field maintenance procedures of the equipment can be found in the instruction books and O&M manual that were originally provided with the equipment, or from servicing vendors. Daily fluid

Wastewater Collection Systems

checks such as engine and pump oil levels, greasing of bearings on the hose reel and swivel, strainer checking, and inspection of all gauges and controls are common to all equipment and should be performed in the field on a regular basis. In addition, operators need to be knowledgeable about safety, startup and operation procedures that are specific for the machine they are using.

The cleaners water tank is filled usually from a fire hydrant close to the area where you will do the cleaning. When using a hydrant, a special hydrant wrench should be used to operate the main hydrant valve. NEVER use a pipe wrench on the hydrant valve, as the valve nut is brass and can be easily damaged. A gate valve that fits on the hydrant should be used to regulate water flow and eliminate the need to open and close the hydrant main valve repeatedly. The hydrant main valve should be opened fully, and the gate valve then opened to allow the water to run for a few minutes, this clears the rust from the hydrant water. If rust is present in the water, it will have a brownish red tinge to it. There should be a screen filter in the pump suction line to filter out large particles that can damage the pump and water system. This filter should be checked daily for any materials trapped in it.

When the water runs clear, the gate valve should be closed slowly to prevent water hammer in the water main, the fill hose to the cleaner is attached, and the gate valve slowly opened to prevent a sudden rush of water that may bring rust into the water tank. Flow of water from the hydrant is regulated with the gate valve, NEVER throttle or control water flow from a fire hydrant with the hydrant valve as this could damage the valve. A partially opened hydrant valve may also result in water discharging through the hydrants weep hole, undermining the hydrant. You must have an air gap for the water going into the tank from the fill line to prevent a cross connection of the water in the cleaner with

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the fresh water coming into the tank. If the amount of water used is to be recorded, an approved meter will also be part of the equipment.

Remember, a 1000 gallon water tank when full will weigh 8,340 pounds, plus the weight of the vehicle and cleaner. Even with baffles in the water tank, sharp turns or quick stops and starts can create driving hazards. Large trucks over 26,001 lbs now require a Commercial Drivers License (CDL), and proper licensing is mandatory.

If a given area is to be done completely, start at the top or highest point in the collection system. Whether routine cleaning or spot cleaning, position the high velocity cleaner hose reel over the center of the manhole. In areas where manholes are offset from the road, or in easements, easement rollers will need to be used to allow the hose to change direction smoothly.

Once the cleaner has been positioned, a cleaning nozzle must be selected. Nozzles will come in an assortment of shapes, sizes, and angle of discharge. The angle of discharge is given in degrees and the most common nozzles are those with discharge angles of 15°, 35°, and 45°. This is the degree of spray angle that the nozzle uses to clean effectively. A 15° nozzle will have a lower spray pattern in the pipe than a 45° nozzle, but will provide better thrust to pull the nozzle up the line. A 35° nozzle will better clean a 10" diameter sewer pipe than will a 15° nozzle due to the steeper angle of the spray, but will have less thrust.

There are many different kinds of nozzles that can be used, however, they all are designed to provide a specific task that falls into 5 categories; Preventive maintenance, stoppage relief, crown obstruction, invert obstruction, and specialty usage. As a guideline, the following parameters are used to determine what nozzle to use.

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Preventive maintenance nozzles are used when there are no known problems in the pipe, and a quick cleaning is scheduled. The standard radial nozzle is used for preventive maintenance work, with a 35° spray angle preferred by most operators. This nozzle will clean most diameter pipes effectively and provide a good thrust to allow the nozzle to reach the next manhole.

Stoppage nozzles are used for emergency work to remove a blockage in the sewer. Generally, these nozzles are 15°, or 35° to provide high thrust needed to pull the sewer hose into a dry pipe as the blockage is approached from the downstream or dry end of the pipe. The head of the nozzle has a large front orifice that is designed to pilot a hole for the nozzle head to enter the material and blow back materials as the head moves through the debris until the stoppage is relieved.

Crown obstruction nozzles are designed to remove grease, waste oils, and detergents from the top and sides of pipe walls. These nozzles are generally set at 35° or 45° to provide a sharp cutting spray to dislodge built up materials.

Invert obstruction nozzles are designed to remove static debris from the floor of the pipe such as sand, gravel, and sediments. These nozzles are usually designed to use a low spray angle directed at the bottom of the pipe to move materials on the bottom of the pipe, and water needs to be directed there. Water volume plays a large roll in moving materials once the nozzle dislodges them, and these nozzles will use water faster than most other nozzles. This allows the materials to be flushed from the pipe and brought to a manhole or sump for removal.

Specialty nozzles are nozzles made for specific tasks. These would be tandem type nozzles for silt or sludge, teardrop nozzles at 11° to climb steep

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grades, cable towing nozzles for camera or bucket machine cable towing, or nozzles designed to make an attaching tool operate such as a hydraulic root cutter. These nozzles come in a variety of different angles and configurations, however, they are seldom useful outside of their respective designed task.

Experience will be the best teacher as to which nozzle is best used in a given situation. Regardless of which nozzle is used, a finned nozzle extension should be used. The extension attaches to the sewer hose, and the nozzle to the opposite end of the extension. This finned extension does two things; helps to keep the nozzle from running on the rough surface of the pipe and wearing, and also helps prevent the nozzle from turning up a lateral or service connection.

Test the manhole atmosphere for sewer gas and install the proper size sand or debris trap in the downstream manhole. Materials will settle out when the flow slows and ponds as it drains out through the top of the trap.

Once the nozzle and extension have been attached to the sewer hose, start the auxiliary engine, or engage the system power take off, and lower the hose into the pipe. Be sure the footage meter is either attached, or the hose passed through it before you do this. To protect the sewer hose, either a lower manhole roller or a slipper guide should be used to shield the hose from the rough edges of the pipe opening in the manhole. This will not only protect the hose, but will allow smoother operation of the hose in and out of the pipe.

As a greater measure of protection for the sewer hose, a steel braided reinforced leader hose should be used on the nozzle end. The first 10 feet of sewer hose just behind the nozzle will be the first to wear with the impact of materials that are being moved, especially in lines where sand and gravel

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are being removed.

The cleaning nozzle should always be pointed upstream of the operating manhole, and laid on the invert of the manhole with a little sag in the hose. The roller or slipper guide is usually positioned after the nozzle starts up the pipe. The hose now needs to be unrestricted as the nozzle climbs the pipe using pressurized water to provide the jet propulsion action that moves it. The cleaning operation is now ready to begin.

Turn the water valve on and start the high pressure pump. Water now is being pumped through the hose and cleaning nozzle. With an increase in pump speed, sufficient water velocity will build up to propel the nozzle up the sewer.

An experienced operator is the best person to teach you how far to go into the sewer. Often it is possible to go several hundred feet, but it is not always safe to do so unless a history of this part of the collection system is known. First try 50 feet to check the situation in the sewer. In any case, if the hose suddenly slows or stops, don't try to go farther. By increasing pressure you may be able to go farther, but don't do it before determining how much material is in the line.

At this point, with the hose roller in place, turn the reel directional control to "in" to return the nozzle. Increase engine speed to obtain approximately 1,000 PSI or the proper rating of the particular unit.

With the reel speed control, slowly start the hose reeling in until the nozzle is just ready to come back into the manhole. The amount of material you have brought back will determine how far and how fast subsequent runs can be made. Repeat this operation until the upper manhole has been reached and no more material is brought back.

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During this operation several items may have to be considered and done. If this is a normal operation of routine cleaning, perhaps the entire line from manhole to manhole can be cleaned without enough material building up in the working manhole to make removal necessary until the job is finished.

On the other hand, it may be necessary to clean out the channel after each “pull” if there is a lot of debris in the line. When loosened materials build up to the point of overflowing the debris trap, pull the hose and nozzle out of the manhole. Stop the pump until after the debris is cleared.

During the cleaning operation, care has to be taken to keep the nozzle moving and pump operating at all times. This is especially true in small lines since you do not want to cause a stoppage. A stoppage can occur if you try to go into the line too far at a time and bring back so much material that the nozzle cannot move it downstream fast enough. The smaller lines then quickly fill with water and this in turn goes up the building service lines. If this happens on shallow lines, home damage may result from flooding.

Always watch the flow coming into the working manhole. If this flow should stop, a stoppage has developed in the sewer. Pull the hose and nozzle out at once and start over. If the nozzle hits an obstruction and stops, pull the nozzle back to clear the line and then run the nozzle into the obstruction again.

The exact distance the cleaning nozzle has moved up in the sewer must be known at all times. Most machines are equipped with a footage meter; but if not, have some identification a hose coupling or so many wraps of hose, so as to give an estimate of where you are in the sewer. If you know the distance between manholes, the footage counter will allow you to make the final run without someone being at the upper manhole.

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The high velocity cleaning machine also may be used for stoppages in sewers. Set up is the same as routine cleaning. A nozzle with a forward jet as well as rear jets may be used. This forward jet provides a cutting action ahead of the nozzle. Also the debris trap would be replaced perhaps with a special fork or pole to allow the free flow of wastewater when the stoppage is broken. Large pieces of solids are caught without causing the working manhole to back up.

Upon contact with the stoppage, if the nozzle will not penetrate the stoppage, pull the hose back a few feet by hand and let go. The nozzle will shoot forward quickly and give a pounding effect on the stoppage. When it breaks loose, retrieve the hose and nozzle quickly. After the line returns to normal, reclean the line completely.

The high velocity cleaning machine is quite effective in cleaning inverted siphons and easement areas. Special rollers are available where the truck cannot be positioned over the manhole. Remote control equipment is available if practical.

Precautions and Safety

Although some of the precautions of operation have been given, there are others which soon become obvious. One of these is cleaning from a manhole to a cleanout. Most often the cleaning nozzle will stop at the bottom of the cleanout. On short runs, however, it is possible to have enough speed and thrust that the nozzle will go up to the street surface and even knock small cleanout covers out of place. When cleaning up to a cleanout, there is also the chance of getting the nozzle stuck. If this should occur, shut the machine off, pull the cleanout cover and dislodge the nozzle with a long rod or pole.

If fresh soil or parts of the sewer pipe are washed down into the lower manhole when pulling the nozzle back, stop the operation. Continued attempts

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to clean the sewer could result in a large hole developing under the street and the eventual collapse of the street into the sewer.

While cleaning, so much material can build up below the nozzle that you cannot pull the nozzle through under pressure. Stop the pressure and pull the nozzle back through the stoppage “dead” (without water flowing out the nozzle). If this fails, try to get the nozzle to the upstream manhole and take it off, thus allowing only the hose to be pulled back through the stoppage to the downstream manhole. Replace the nozzle and go back up the line after the stoppage.

Often a bend in the line will prevent you from pulling the nozzle back under full pressure. The more pressure at the nozzle, the stiffer the hose becomes. Reduce the pressure even turn it off for a short distance until you are past the bend.

In cold weather, particular precaution has to be taken to keep the equipment from freezing. Special attention should be given to the high-pressure pump to make sure that it is properly drained. If the machine is equipped with a canopy over the engine and pump area, the areas can be separated by a curtain and a small electric heater can be left inside the pump area overnight or when not in use during freezing weather. Another approach to prevent freezing during cold weather is to install a piping system which allows water to circulate through the pump and hose. Be sure to include the hose because some water always remains in the hose, no matter how much time and care are taken to drain the hose.

Do not allow an inexperienced operator to operate the machine alone. Personal safety is not so much a problem because of the design of the machine; however, costly problems can develop if care is not given to existing conditions in the collection system and those that the cleaning operation can create.

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Caution and experience are required to prevent "blowing toilets" with a high velocity cleaner.

Purged plumbing, or "blown toilets", are the result of a combination of pressure, nozzle angle, and system conditions. A nozzle moving up a pipe will pull air from upstream. If the pipe is clogged with roots or grease, sufficient air cannot be pulled easily through the pipe, and the air will be pulled from house vents, which can pull down water in all of the P traps of the house, as well as the toilets. When the nozzle returns downstream, the air is now pushed, and can exit through these same vents with sometimes dramatic results.

To best avoid purged plumbing situations, use a steeper angled nozzle, at a minimum pressure when climbing the pipe. The longer the cone of spray from the nozzle is in the pipe, the more air it will pull. A 15° nozzle will pull more air from upstream than will a 35° nozzle. In areas there are known purged plumbing problems, use a low operating pressure of around 1000 to 1200 psi to help reduce the air movement in the pipe. Cleaning will not be affected much by the reduced pressure, and will help relieve some of the problem. If a problem continues with a higher degree nozzle and lower pressure, a closed circuit inspection camera should be called in to see if there is any root or grease build up that can be removed to help increase the diameter of the pipe, and allow increased air flow.

Also, do not sacrifice clean lines for footage. This equipment is capable of doing a thorough job of cleaning. There is a tendency to consider the line to be clean when perhaps you are running low on water. Take the time to get another load and make sure the line is properly cleaned.

Proofing tools are used to be sure the line does not have grease or root deposits remaining in the pipe

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after cleaning. A proofing tool is used on the end of the cleaning hose much like a finned nozzle extension. When the tool is placed on the hose, and the nozzle then connected on the end, the nozzle pulls the tool up the line. The tool is designed to pass easily through a given diameter, and if obstructions such as roots are present it will stop, allowing the operator to note the footage and line section for later work with a rodder, or hydraulic root cutter.

Hydraulic root cutters can be used on high velocity flushing machines and can be effective on minor root and grease problems. These tools attach to the sewer hose, using water pressure and volume they are designed to propel themselves up the pipe while turning a cutting blade or saw. These cutting tools do not do the same work as a Rodding machine in heavy root and grease masses, and use of them should be for light preventive maintenance duty. Caution in operation of hydraulic root cutters should be used, and they should never be used with inexperienced operators. Dropped or misaligned joints, turns or dips in the pipe, and heavy debris can cause the tool to become stuck, possibly resulting in having to dig up the pipe to get the tool out.

There are occasions when the high velocity flushing machines are used to perform other tasks such as stringing cable through pipes for closed circuit TV inspection cameras or power Bucket Machines. When towing a cable with a sewer hose, care must be taken to be sure that the hose is not wound empty on the reel. If the hose is flattened out as it is wrapped, the next time the cleaner is used, the hose will expand and could damage the hose reel of the cleaner. Always keep about 500 pounds of pressure in the hose when pulling a load to insure the hose does not flatten.

Jet and Vacuum Machine (Combination Machine)

The machine is a dual engine design to be used for removing sand, stones, bottles, cans, grease, sludge

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and other debris from sanitary sewer and/or storm drain lines by the flushing action of high pressure water.

The high pressure water pump is hydraulically driven with the chassis engine as the power source. The machine includes an air conveying vacuum system, powered by an auxiliary diesel engine, to provide for the simultaneous removal of debris flushed to the manhole by the high pressure water (Jet Rodder) system, or for the removal of debris from sumps, catch basins, digesters, wet wells, bar screens, etc. The machine is also include an enclosed and sealed body for storage of the collected debris.

Debris Body

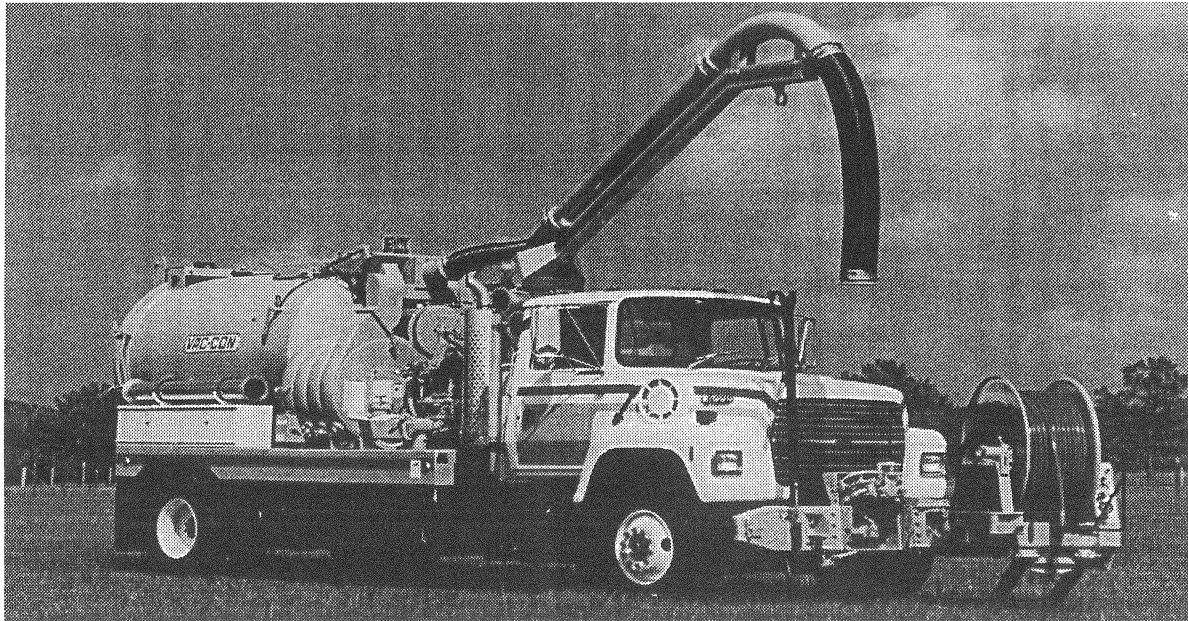
The debris storage body is constructed of a minimum 3/16" corrosion and abrasion resistant steel. The body is round for maximum strength and has a usable liquid capacity of 14 cubic yards or 2,800 gallons. The body has a full size rear door that is hinged at the top and is equipped with a replaceable neoprene type seal to prevent leakage. The door is pneumatically opened and closed. Debris body is dumped by raising to a 50 degree angle, utilizing a forward mounted, double acting hydraulic cylinder. Dump controls are provided at a central curb side location, directly behind the cab of the truck.

Water Tanks

Water tanks have a capacity of 1,300 gallons and are manufactured from noncorrosive aluminum to prevent rust. The water tanks are easily removed from the unit to provide complete access to the truck chassis for maintenance purposes. The water tanks are adequately vented and connected to provide complete filling. A minimum 4" connection between tanks is provided. The water tanks are

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totally separate from the debris tanks and provide no structural support. The water tanks come equipped with an anti-siphon device and 25' of hydrant fill hose and fittings. A water level sight gauge is also provided. The water tank is supplied with "Y" pattern stainless steel strainer to filter the water before it enters the tank. The water tanks carry a 10 year warranty against corrosion or cracking.



Combination Jet and Vacuum Machine

Vacuum System

Vacuum is created by a 38" diameter tapered aluminum centrifugal compressor. The centrifugal compressor is capable of air flows from 0 to 8000 CFM and pressures from 0 to 114" negative water pressure. The outer housing is manufactured out of a 1/4" spun steel. Unit has the ability to vacuum and jet rod to depths of 75 feet without use of any special attachments. Compressor is able to vacuum wet or dry material without damaging vacuum system.

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The centrifugal compressor is driven direct through a helical gear step-up transmission drive.

Vacuum System Engine

The shrouded auxiliary engine used to drive the vacuum system is liquid cooled, diesel powered, turbo charged, 4 cylinder minimum, heavy duty industrial, 4 cycle engine, and comes equipped with high temperature, low oil pressure shutdown system as well as an exhaust silencer. The auxiliary engine control panel is curb side and located directly behind the cab. The control panel consists of the following: engine ignition, tachometer, water temperature gauge, oil pressure gauge, voltmeter, hourmeter. The entire auxiliary vacuum engine is insulated in a noise deadening shroud to further decrease the operating noise level. The noise deadening shroud is on roller tracks, allowing the shroud to be easily pulled away from the engine, providing complete engine access.

Vacuum System Pickup

Is designed for front end operation with hose mounted and stored at the front work station. The boom is operated by an electric over hydraulic system which draws its power from the auxiliary engine's hydraulic power source. The boom is hydraulically driven, up, down, left and right. Boom is controlled by a remote, push button control station by cable to the hydraulic power swing and lift cylinders. The control station comes equipped with control switches for all directions, as well as safety emergency shutdown button which automatically eliminates power to the boom. A cab protection device, independent of cab, that will protect cab from boom will be provided. The vacuum hose will be mounted on a boom which will rotate a minimum 180 degrees and provide 179" of reach off the center line of the unit.

Water Pump Drive

The high pressure water pump is a double acting, single piston pump, hydraulically operated from a

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direct hydraulic pump. The hydraulic flow to drive the water pump will be from a hydraulic oil pump driven by the truck engine, via a heavy duty, air shift, power take off. The water pump operates with an oil to water ratio of 1 to 1. The power take off engages the hydraulic pump, but not the water pump, to eliminate unnecessary high pressure ball valve bypass and water pump water. The water pump is capable of maximum water pressure and flow while achieving maximum vacuum pressure. The water pump operates independent of the vacuum system. Water pump has capability of being disengaged from driving mechanism from front control panel for increased life.

High Pressure Water Pump

The high pressure water pump is a double acting, single piston type with a rated design capacity of 100 GPM and 2,500 PSI. The hydraulic pump and water pump is sized to allow the water system to operate with 60 GPM at 2,000 PSI continuous duty operation. The water pump cycles approximately every 4 1/2 seconds. The pump cycle provides an automatic "Jack Hammer" action in the hose to assist the nozzle in breaking through obstructions. The water pump location provides a flooded suction inlet to eliminate potential cavitation damage. The high pressure water pump is designed so no damage will occur if run at normal operating pressure without water for 10 minutes. An oil to water heat exchanger is provided in the water system to cool hydraulic fluids. A monitor light is provided to indicate when designed flow or pressure is exceeded.

Front Mounted Hose Reel

A hose reel assembly is mounted on an independent frame, which can be removed from brackets permanently attached to main truck frame members. Hose reel will be constructed to tip forward hydraulically, providing full access to the chassis engine. The hydraulic tilt power is provided via a hydraulic pump. Hose reel will have a minimum

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capacity of 600' of 1" ID rodder hose. Hose reel will be driven via a hydraulic motor. The motor controls the reel speed and forward and reverse rotation. Hose reel has a 1" rotating swivel joint that is adjustable, and has replaceable seals on the inlet line to provide free rotation of hose reel. All operating controls are located on the hose reel.

Handgun Cleaning System

The high pressure water will be utilized to supply 20 GPM at 600 PSI (relieved to protect operator) to a handgun system. A handgun will be supplied that comes equipped with 25' of 1/2" wire reinforced hose. The handgun should come equipped with quick connect coupler. Handgun system will include front and rear couplers that allow the operator to deliver water to area served by pickup hose and to the inside of the debris body for cleanout. The handgun should allow for changing of flow pattern from a fine mist to a steady stream.

Electrical System

The entire electrical system is done to NEMA 4 levels, vapor sealed to eliminate moisture damage. All electrical connections is require no exposed wires or terminals. All light bulbs are shock mounted to eliminate bulb failure. All wiring is color coded and run in sealed terminal boxes.

High Pressure Jet Hose

Jet hose will be supplied that is 1" ID and has operating pressure of 2500 PSI and a burst pressure of 6250 PSI, 400' will be supplied with unit. A 15 degree sand nozzle and a 30 degree sanitary nozzle is furnished. These nozzles should both be equipped with tungsten carbide orifices for added life.

Front Operating Station Operating Controls

Operator station is located at the front of the truck at the right curb side of the hose reel.

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Controls and Gages

Truck engine throttle, high pressure water pump - on/off, hose reel forward-reverse valve, adjustable hose reel speed control, overspeed warning light for water pump, oil dampened water pressure gauge, boom controls, handgun control valve, hose reel tilt control.

Mounting

Unit will be mounted on approved truck chassis at the factory of body manufacturer.

System Operation

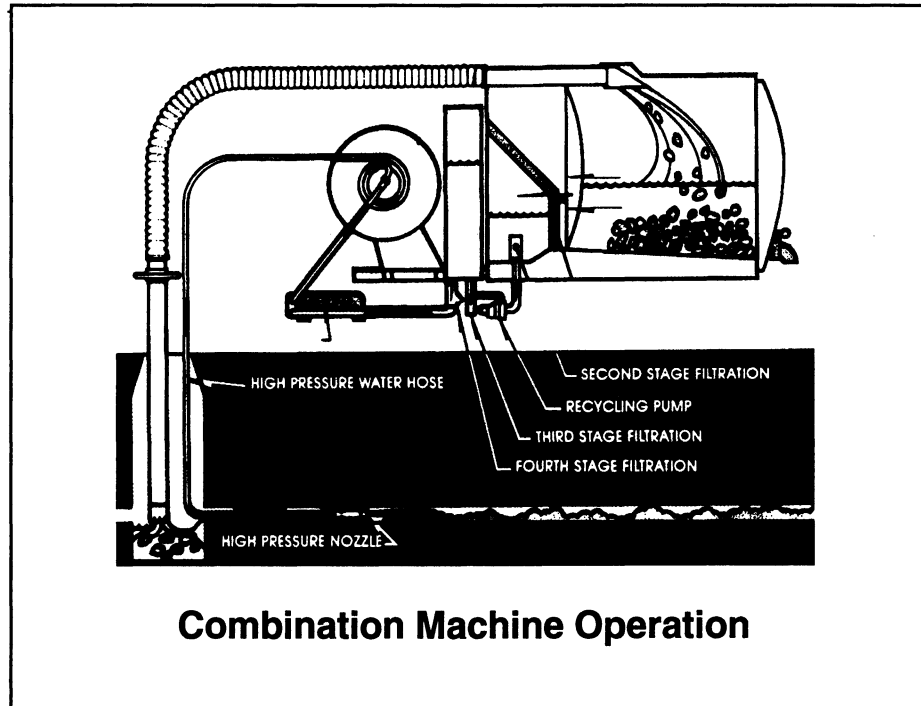
As backflushed debris is vacuumed from the manhole, water and solids are retained by the collector body. The air passes through a filter screen before entering the positive displacement vacuum pump and clean air is exhausted to the atmosphere. An automatic ball float shut-off system with primary and backup floats, prevents water from entering the vacuum pump.

The two figure-eight impellers rotate in opposite directions to move entrapped air around the case to the outlet port. The positive displacement vacuum pump combines high vacuum with high CFM providing material conveyance in three different modes.

In the AIR FLOW mode, materials can be conveyed up to 500' horizontally or 150' vertically. With PURE VACUUM, liquid can be lifted in a solid column up to 217" vertically. By using an optional FLUIDIZING NOZZLE, material can be removed from beneath the liquid surface at depths of up to 75'.

The recycling system separates solids from the water after they enter the collector body. The filtered water is then returned to the storage tank for later use for hydraulic sewer cleaning.

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The recycling rate is faster than the water usage, assuring continuous sewer cleaning and eliminating trips to refill the water tank. The recycling system functions simultaneously or independently of the vacuum and water systems. Optional controls prevent the recycling pump from running dry and the water tank from overflowing.

Recovered water flows through a series of filters (cleaned by a patented reverse-air back flushing system) to a centrifugal pump. Solids are returned to the collector body through a centrifugal separator. Filtered water is returned to the storage tank and then used for additional high-pressure sewer cleaning.

Flushing is another method of hydraulic cleaning and is occasionally used at the beginning of the collection system where low or sluggish flows permit the deposition of solids. This procedure may be effective in removing floatables, but not grit and other heavy solids. Flushing also is used with mechanical clearing operations such as power

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rodders and bucket machines. High velocity cleaners and balling do a much better job of cleaning sewers than flushing.

During the flushing operation, observe the flow characteristics in the sewer is the flow through the manhole slow or sluggish? A partial stoppage may restrict the flow of the flushing water being discharged into the sewer. OBSERVATIONS OF LOWER THAN EXPECTED FLOWS AT A DOWNSTREAM MANHOLE THUS INDICATE THAT THE UPSTREAM SEGMENT OF THE LINE REQUIRES ADDITIONAL CLEANING. As the water flows, a physical and visual check can be made of the material in the line such as sand, grease, and debris. THIS OBSERVATION ALSO MAY DICTATE THAT MORE EXTENSIVE CLEANING IS NEEDED.

Stoppages are commonly located during the flushing operation. Material often will have built up to the point of causing a stoppage when just a sudden charge of water will break it loose, thus clearing the line. Having this large amount of water passing through all at once has a definite control on rodents and insects.

Also cleaning the manholes with water pressure eliminates manhole shelf build up of street dirt and debris. Cleaning the manhole with water pressure, combined with the flushing action within the sewer, will minimize the build up of sulfide and slime in the line. This is one of the primary problems of line decay and replacement. Flushing may be used in steep hills where the use of balling or high velocity cleaners creates a high risk of flooding homes when not properly operated.

Flushing

This method of cleaning in smaller collection systems usually must be repeated frequently to prevent many routine problems, but requires large

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volumes of water. Before starting a flushing operation, notify the water department whose hydrants will be used as a source of water. The opening and closing of hydrants must be done with great care because improper procedures could create water quality problems in the water distribution system. Also notify the operator of the downstream wastewater treatment plant whenever larger than normal flows can be expected at the plant.

Crews and Equipment

Because of the small amount of equipment and number of operators involved in flushing, the actual cost appears attractive. However, the procedure may not be cost effective because of the limited cleansing action from flushing.

A tank truck with a capacity of 1,500 to 2,000 gallons is needed. The truck should be equipped with a reel for holding approximately 100 feet of 1 -inch ID hose and a pump to give sufficient pressure to do an effective job of manhole cleaning. The nozzle type may vary from an adjustable model to a plain piece of pipe reduced to give a good cutting action. A 1/4 inch pipe nipple brazed onto a 1 -inch female hose fitting provides a good stream (if the pump provides 25 to 30 psi in the line) for hosing down the manhole barrels and a shelf prior to flushing the line.

A 2 1/2 inch or larger gravity discharge line from the bottom of the tank on the truck should be provided to permit a large flow of water. Location of the line must be convenient for the truck driver to position it over the manhole. If possible, the ideal location is just ahead of the left front wheel. This line should be equipped with a quick opening, full flowing valve. A short piece of old inner tube fastened just above street level will help direct the flow of water into the manhole if positioning is difficult.

The tank truck equipment should include a good

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filler hose, usually a short length of fire hose to reach from a fire hydrant to the top of the tank's filling hatch, hydrant wrench, water meter, air gap device, and manhole lifter. Some communities require a 2 1/2 inch water meter so that they can pay for the water used for flushing.

A debris bucket, rope and manhole shovel are other pieces of essential equipment, plus the usual safety equipment. The equipment and tools for this operation should be arranged on the tank truck in such a manner as to be handy and within the limits of space available.

Two operators are needed and they should be clothed with hard hats, red vests, and gloves. Typical street traffic should be expected but keep in mind, too, you probably will not be long at one manhole.

Flushing crews usually have to enter every third or fourth manhole to remove debris.

Equipment Set Up and Flushing

Determine whether to use a tanker or fire hydrants or both as a source of water for the flushing operation. Start the flushing operation at the extreme upstream end of the collection system.

Place the water line over the manhole and protect the equipment and working area with sufficient safety cones, flags, and warning signs.

A good visual inspection should be made of the manhole condition. If the water has been backed up, there will be evidence of debris in the shelf area and high water marks indicated by a grease ring. The general condition of the manhole, by number, should be part of the report and recorded at this time.

The manhole should be cleaned with the pressure

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hose. Since you will want to get more water and move on as quickly as possible, clean the manhole first. Use a pressure hose to clean the manhole and wash the manhole cover casting, cone, barrel, and shelf of the manhole

The amount of water you will dump into the line will be related to the amount of flow at the time of flushing. The entire water load may not have to be dumped in one manhole. After you have dumped some of the water, observe if there is any evidence of the water backing up.

If the flushing water backs up into the manhole, stop the addition of flushing water or reduce the application rate to prevent flooding of connected residential and commercial services. Observe the water flowing in the downstream manholes and look for signs of grease, roots, or other debris that are creating the restriction. If the restriction is caused by a heavy deposit of wastewater solids, flushing **MAY** move the cause of the restriction down the line to a manhole where it can be removed or broken up by spraying with the tank washdown hose and flushed on downstream. If the deposit is caused by roots or grease, prepare and submit a note or work order to have that segment of the line cleaned by using the proper equipment to remove the restriction.

Close the manhole and go to the next downstream manhole. Inspect this manhole as outlined above and clean it completely with the washdown hose.

This operation will be repeated from manhole to manhole. As long as heavy flows are observed in the manholes, the operation is progressing satisfactorily. If the flows decrease, look for a stoppage by looking for flows backing up in the upstream manhole. If there is no evidence of a stoppage and flows are declining, more water will have to be introduced to maintain cleansing flows for the

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flushing operation.

The cleaning at each manhole with a hose takes only a few minutes, but this is the time and place where you should be alert for those items referred to in the beginning of this section foreign material, grease, sand, and roots that can cause problems or indicate problems are occurring.

How many feet of sewers can be flushed by a crew in one day is difficult to estimate because of the many problems of manhole location, traffic conditions, and other obstacles. As much as 20,000 feet or more of sewer and many manholes can be flushed in a day if you do not encounter too many problems. Daily production depends upon the number of manholes that have to be entered and cleaned, plus their condition and location. Whether manholes are located in rear easements and whether flushing can be accomplished by laying a fire hose from a hydrant or from the tank truck to the manhole in a backyard have considerable influence on the time required to flush a line.

Precautions and Safety

Safety measures need to be followed carefully at all times, from properly protecting the equipment and working area with safety cones to checking manholes for gases found in sewers (toxic and explosive gases and oxygen level).

When flushing, the turbulence many force accumulated gases from dislodged debris or slimes downstream, so care must be taken at all times.

This method of cleaning presents problems very similar to those of balling. Consideration has to be given not to put more water into the collection system than it can handle. Care must be given that a stoppage is not caused which in turn may flood a residence or business. The amount of material and debris being flushed through should not be allowed

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to accumulate. Care is needed in this respect, especially when first starting a flushing program.

Records

Since many manholes are going to be opened and cleaned during the flushing operation, there is no better time to make records of defects, leaks, roots, and other problems. In addition, the amount of grease or other material visible also can be recorded.

Scooters

The scooter is another cleaning tool found to be very effective for cleaning wastewater collection systems by using water pressure. The scooter is designed to be self-propelled in gravity collection systems and operated similar to a balling operation. The operation is quite simple and again the cost is considerably less than the cost of some other cleaning methods.

Basically the scooter is a framework on small wheels with a circular metal shield at one end which is rimmed with a rubber flange. The top half of the shield is hinged and is controlled by a chain-spring system. The lower half of the shield is fastened with bolts to the front of the undercarriage.

The flow of water behind and around the scooter is controlled by hinging the upper half of the shield to the scooter. This allows for hydraulic cleaning action and control of the flow of water in the line at the same time. Smaller scooters may be hinged only where the shield is attached to the scooter.

The scooter is capable of removing large objects and such other material as brick, sand, gravel, and rocks. Scooters are considered more effective in larger lines (over 18 inches) and have been used to remove grease in these lines. Even inverted siphons with angles of less than 22½ degrees can be cleaned with the scooter.

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Since the scooter is dependent upon water pressure behind it, caution has to be used where sewers are shallow or there is a danger of flooding homes or business property because of the build up of water in the sewer.

Scooters are available in sizes from 6 to 96 inches. The same undercarriage is used for some of these sizes. For instance, one carriage frame will adapt to shield sizes to clean 8 to 15 inch diameter pipes, and another frame will be used for 15 to 36 inch diameter pipes.

On larger sizes, stabilizing weights are used on the tail section of the carriage frame to counteract the head pressure during the cleaning operation.

The head shield on the larger sizes is designed to hinge into two or three parts. This compensates for the high head pressures when folding the head shield to allow water to pass. A spring-loaded mechanism allows the upper section to fold first, thus releasing the initial pressure. As the head pressure decreases, the middle section can be folded by a continued pull on the shield control cable.

Large units are not only heavy to handle, but difficult to get through small manhole openings. By being able to fold the head shield, the scooter can be installed in most instances without dismantling. In some situations the unit may have to be assembled in the manhole.

Precautions and Safety

As with all cleaning methods, certain precautions need to be taken before and during the operation.

One of the most important precautions for this method of cleaning is to determine if a build up of water (head of water in the working manhole and in the sewer being cleaned) will flood a residence or business. The scooter requires a good head pressure

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to function effectively.

Examine the manhole structures on large lines to be sure the sewer scooter can be installed.

More time is needed to set up and remove the larger units. Allow for this time when preparing work schedules.

Always examine cables at start and finish of each section to avoid having a cable break when the scooter is in the middle of a sewer.

Kites, Bags and Poly Pigs

Kites, bags and poly pigs describe equipment commonly used to clean larger diameter sewers. For example, instead of using a sewer ball to clean a large diameter sewer, use a kite or bag slightly smaller in diameter (2 inches smaller) than the sewer. With a small head (2 feet) on the sewer, the velocity of water flowing around the outside of the bag or through the outlet of the kite will create a cleansing velocity like the velocity around a sewer ball. Kites are called parachutes too.

The procedure and precautions for using either kites or bags are similar to those for balling, but a cable is usually not attached to the poly pig. Poly pigs may be equipped with a small radio transmitter for tracking the pig's travel through the sewer line and fittings.

Wastewater collection line cleaning techniques described in this section rely on a mechanical action to clear the sewer. This clearing action results from the material in the sewer being removed by a scraping, cutting, pulling, or pushing action caused by a mechanical device or machine. Clearing techniques outlined in this section include bucket machines, power rodders and hand rods.

Mechanical Cleaning

Mechanical cleaning equipment consists of bucket machines, power rodders, hand rods and winches for pulling scrapers, porcupines, swabs and various cutting tools through the pipe to remove hardened grease, invert debris, roots or physical obstructions such as bricks, rocks or other large objects that find their way into the sewer system. Bucket machine operation consists of a set of specialized winches that pull a device through a pipe to collect debris. Materials are captured using a special bucket and are removed from the pipe. Rodding (either using a power rodder or a hand rodder) consists of pushing or pulling a steel rod or snake through a sewer with a special tool attached to the end. These tools are designed to cut or scrape materials from the pipe walls and are most effective on hardened grease and roots.

Power Bucket Machines

Sewers are purposely designed to develop sufficient velocity to provide a self-cleaning action and to convey solids through the system to the wastewater treatment plant. When deposition of solids occurs in a sewer, first consideration should be given to hydraulic cleaning techniques to remove the solids from the sewer.

There are instances when the hydraulic techniques are not the best method of removing roots or deposits of solids because of the volume, size, weight, or type of material that may be found in the sewer.

This material may be lumped together or spread separately along the line. Types of deposits include silt, sand, gravel, or some type of industrial solid waste. The entry of silt, sand, gravel, and rocks into the collection system is often traced to some damage either to the sewer line or manholes, or a section where repairs were made to the system.

Pipes or manholes may be broken by various construction projects, grade changes of streets, earth-

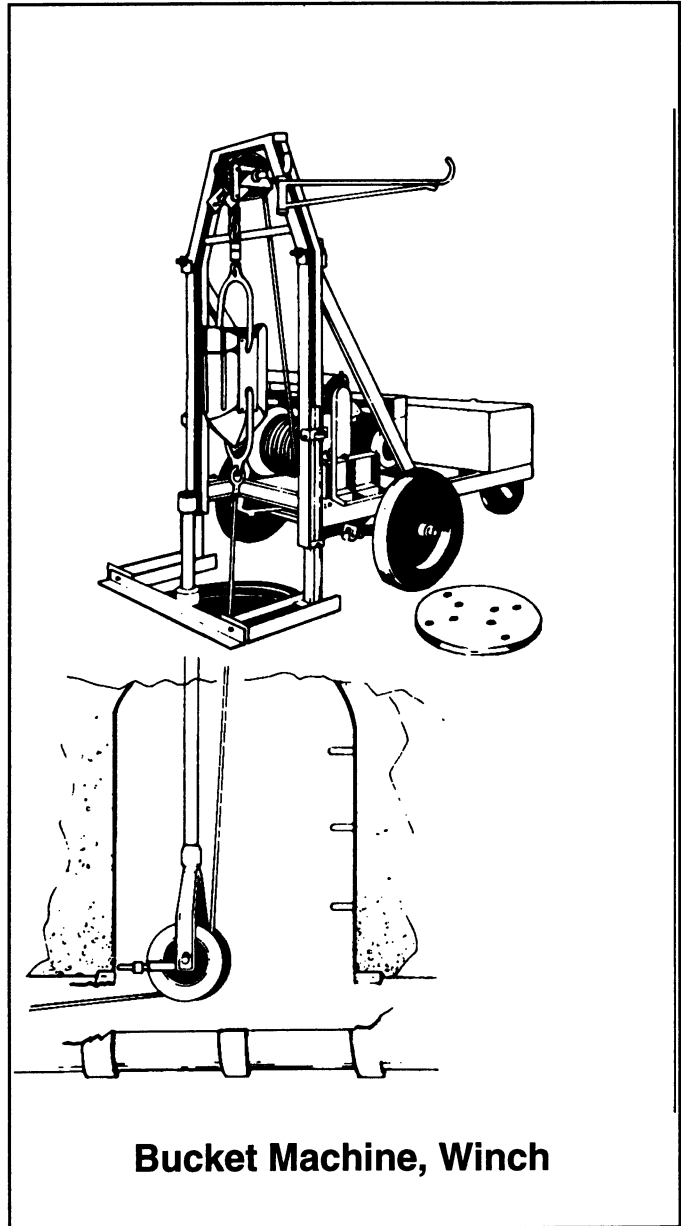
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quakes, or excessive loads from vehicles and heavy equipment. When a pipe breaks, large quantities of debris can enter the collection system.

When there is an indication that a sewer is failing, and that sand or mud is entering the sewer, do not use a high velocity cleaner. Nozzle action develops a negative pressure that can hasten the collapse of a bad section of pipe. A bucket machine can be used to remove the sand or mud when proper care is exercised. If possible, televise the sewer as soon as possible to determine the cause of the problem and the condition of the pipe.

Solid debris is constantly entering the collection system through various means such as loose or misaligned joints and connections, manhole lids, service connections and end users. Suspension of the material depends on the velocity of the flow and the size and weight of the material. A velocity of 2 feet per second may not be sufficient to keep heavier solids in suspension and solids deposition will take place along the invert of the pipe. The larger the line size, the less effective hydraulic cleaning methods become. Large trunk and interceptor lines can reach 60" in diameter or more, negating the use of hydraulic methods as an effective means of removal. In lines of this size, high velocity cleaners can put more material into suspension than can be removed, creating a larger problem downstream.

Power Bucket machines are a necessary maintenance tool for removing large amounts of debris from the sewer and their efficiency increases over other methods as the pipe sizes grow larger. These machines should not be used in small lines of 6" - 12" on a routine basis unless a porcupine or squeegee is being used, or materials are being carefully removed from a pipe collapse. Bucket machines provide a mechanical method to remove a large amount of material without allowing much of the material to escape downstream.



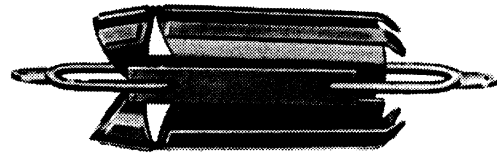
Crews and Equipment

Buckets range in size from six inches to thirty-six inches in diameter. Volumetric capacity of the buckets range from 0.13 cubic feet to 8.5 cubic feet. An 18 inch diameter bucket will pass through a standard 24 inch diameter manhole opening and has a volume of approximately 1.6 cubic feet.

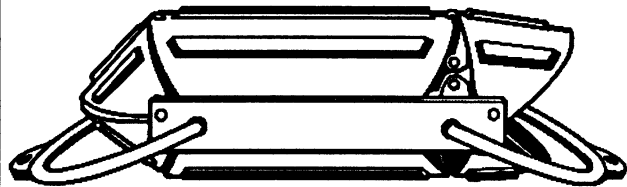
The bucket machine is usually trailer-mounted , but

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can be truck-mounted. Trailer-mounted bucket machine units must have a pintle safety hook attached to the truck that tows the trailer to the job site. Also a wire cable and shackles should be placed around the truck frame and to the frame on the bucket machine for added safety in case the pintle hook fails.



Clamshell Bucket



Double Clamshell Bucket

The bucket machine units have a steel framework on which is mounted a gas engine and a drum winch. The drum is coupled to the engine through a controllable drive train, usually a chain and belt drive combination. The drum is capable of holding 1,000 feet of 1/2 inch steel cable and is mounted on the framework in such a position that it can be centered over a manhole. The framework includes a vertical "A" frame of sufficient height to allow the cleaning bucket to be lifted above ground level.

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Two machines are needed for this operation and both are basically the same in design. At least one machine also will be equipped with an additional smaller drum capable of holding 1,000 feet of 1/4 inch steel cable. This drum can be operated separately from the 1/2 inch cable drum. The purpose of the small cable and drum is twofold. One is for the purpose of threading the sewer line from manhole to manhole, and the other is to have a suitable cable which can be left in the line overnight. The drum is, therefore, often referred to as an overnight drum.

An optional addition to one machine may be a chute with rollers and shaker bar which allow the material removed to be dumped directly into a dump truck. Machines without this attachment have the "A" frame as previously mentioned. The machine which does the pulling of the bucket out of the manhole will be referred to as the working machine. It will have a small swinging boom or arm attached to the "A" frame which is used for dumping the full buckets.

With each bucket machine, equipment will be needed in the manhole to guide the cable into the sewer line without rubbing or cutting into the pipe. At the working machine, use a V-shaped roller of sufficient size to accommodate the size bucket being used. This roller will be held in place by means of a steel pad which in turn is firmly secured flush with the street surface by two adjustable stabilizer legs on the machine. The companion machine may use the same method or perhaps use a slant jack in the bottom of the manhole for the cable to travel over. This would dispense with the use of the pad and roller.

A variety of tools are available for use with these machines and more are being developed, making these machines usable for purposes other than bucketing of debris. Root cutters and insertion pullers can be used with bucket machine power winches.

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For this discussion, we will consider the use of the clamshell bucket and porcupine tool. These are available in sizes from 6 to 36 inches in diameter, but sizes under 12 inches are rarely used.

The bucket is of such design that when being pulled into the sewer line the jaws are in an open position. The jaws dig into the deposits of material.

When the working machine pulls the bucket out, the jaws are forced closed by means of a slide action. Any material in or in front of the bucket is scooped up.

The porcupine tool is a steel cylinder having solid ends with eyes cast in them to which a cable can be attached. Many short pieces of cable protrude from this cylinder like a round brush. This tool is quite effective for final cleanup since the bristles have a scrubbing action.

Equipment needed other than that furnished with the bucket machines includes sandtraps, manhole shovel, debris bucket and hand line, manhole litter, pipe wrenches, and hand tools such as crescent wrenches and pliers.

Safety equipment includes flags, cones, barricades, traffic signs, sewer gas detection equipment, safety harness and rope, and such other safety devices the job setup may require .

Experience has shown that many unexpected repairs occur during the clearing operation. Extra cable swivels, clevises, cable clamps, and other essential accessories should be readily available if not with the machines.

The number of operators needed to effectively conduct the clearing operation will vary, but at least three operators are needed and four operators are recommended. If traffic control dictates, flagmen

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will also be needed.

Equipment Set Up

Whether the working machine is set up at the upstream or downstream manhole depends on field conditions. In smaller sewers with lower flows the working machine is usually located at the downstream manhole. Under these circumstances there is little tendency for the material being removed to be washed out of the bucket. Also working from the downstream manhole reduces the possibility of a stoppage developing in the sewer below the working area.

Often the working machine is located at the upstream manhole when clearing debris from larger sewers. Under these conditions the debris in the full bucket tends to remain in the bucket because the bucket is being pulled against the flowing water when the full bucket is returned to the working manhole. If flows are low, the possibility exists of a stoppage developing downstream from the working area.

Once this equipment is set up, it usually remains in one position for several hours. Special emphasis is placed on safety measures taken for control of traffic and insuring a safe environment in a manhole.

Bucket machine clearing requires a certain amount of skill in operation of the equipment and this can be obtained only by actually working with the equipment. This method is one of the more expensive operations due to several factors, but mainly the hours involved in setting up the equipment. In the process of bucket machine clearing, it is not unusual to find you cannot complete the job before the end of the day. Because of the time and effort needed to thread the line, the overnight line is left in the sewer.

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During the set up operation, communication has to be established with both the operators at the upstream and downstream manholes. Communication may be either by sound powered telephones, radio, or signals. A foolproof system must be devised and used between winch operators because someone can easily be injured if the proper signal is not sent, received, or is misunderstood.

The two machines are positioned over the respective manholes ; the working machine at the downstream manhole and the backpull machine at the upstream manhole. The pads are placed under the stabilizer feet of the machine and these feet jacked down so sufficient weight of the machine holds the pad in place. The legs also function as a method of leveling the bucket machine. Insert a sand trap or debris trap in the downstream line to stop material pushed ahead of the bucket when clearing.

The lower manhole roller is lowered into the manhole by attaching various lengths of threaded pipe, usually 2-inch pipe in 4-foot sections. With this roller properly situated, the cable and bucket must clear the top of the sewer, the pipe is then secured to the pad by means of a chain clamp device. With this firmly in place, the roller will not lift up when strain is applied to the cable while pulling. Give consideration to this NOW since there is the same pressure exerted to lift up on the roller in relation to the power exerted in pulling with the cable. If there is a set up problem, roller security is one of THE FIRST problems encountered when the clearing operation starts.

To thread the sewer, a synthetic rope can be used. The upstream machine can be equipped with a small drum exactly the same as the ‘overnight’ drum on the downstream working machine. One thousand feet of the synthetic rope can be carried on this drum. Some synthetic rope has been known to deteriorate without warning due to chemicals in wastewater.

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To this rope attach a nylon parachute designed and available for such use and allow this parachute to float downstream to the working manhole. A high velocity cleaner may be used to string the line also. Attach the parachute rope to the 1/4-inch steel cable of that machine. A swivel must be used to keep the rope and cable from twisting. The upstream operator engages the small rope drum and pulls the 1/4-inch cable upstream to the machine. Remove the rope drum from the machine so it will not interfere with the operation. Connect the 1/4-inch cable and swivel to the 1/2-inch cable. When ready, signal the downstream operator to engage the small drum of the machine and pull in the 1/4-inch cable, thus threading the sewer line with the 1/2-inch cable. The operator of the working machine will likewise remove the 1/4-inch cable drum.

Operation

The clearing bucket is now ready to be attached to the cable. Experience and history of the sewer line dictates how much smaller a bucket must be than the actual diameter of the sewer. A cable swivel of sufficient size is attached to each BAIL OF THE BUCKET by means of a clevis. The 1/2-inch cables are then attached to the swivels using a clevis. Position the bucket so the jaws will be opening upstream.

Take up the slack in the cable of the working machine until the bucket is hanging free over the manhole. Signal the upstream operator to take in the cable. Hold the brake securely on the working machine to keep the bucket from dropping into the manhole. Experience is gained quickly at this point because special care has to be taken in getting the bucket around the lower roller and into the sewer.

At the start, always make a few short pulls to check out not only the amount of material in the sewers, but also the equipment and the set up. One approach is to try an undersized bucket first to determine if it can be pulled through the sewer. If this works, a

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larger bucket can be tried because it will remove more material before it is full. As the bucket is pulled upstream into the material deposited in the sewer, a definite resistance can be noticed when the bucket is full.

When the bucket is full, pull the loaded bucket back out of the sewer. To start pulling the bucket back, signal the working machine operator after disengaging the machine. Hold a slight amount of brake to keep the cable from spooling too freely as the bucket is pulled downstream. If the working machine is equipped with a footage counter, watch closely as the full bucket nears the manhole. Reduce the speed of pull when the bucket enters the manhole and makes the sudden turn around the lower roller and up to the street surface. If a footage counter is not used, the operator can quickly note the cable wraps and their position on the drum. This technique also can apply when the bucket is being pulled upstream. The operators, by knowing the approximate diameter of the drum, and the number of wraps or layers pulled off, can judge fairly closely the distance the bucket is in the sewer. Bucket location is important to this operation.

When the bucket is pulled back out of the manhole and a sufficient distance above street level, the helper will swing the small boom out and attach a hook and short chain to a special eye on one side of the open end of the bucket. With a long hook, this helper will quickly pull the bucket to one side and away from the manhole by engaging the hook on the lower bale of the bucket.

At the same time, the machine operator releases the brake thus allowing the bucket to drop. When the bucket is suddenly stopped in midair by the short chain on the boom, the jaws slide open and allow the debris to spill on the street or into a container or truck. Practice and coordination of this operation between the operator and the helper will result in keeping the pile of debris in one area where it can

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be loaded and hauled away.

The operator will engage the cable drum, again lifting the bucket enough so the short chain can be unhooked from the bucket. The operation is now ready to be repeated. After several pulls, check the buildup of material against the sand trap in the bottom of the manhole. This material should be removed before it is lost downstream.

When the bucket of the correct size has been pulled freely from the upstream manhole to the lower manhole, it may be advisable to finish cleaning the sewer with the porcupine cleaning tool. Remove the bucket, fasten the two cables together and pull the cable upstream until the swivels are above street level. Attach the porcupine with a swivel at each end and insert it carefully into the sewer. If a slant jack is used, the porcupine may have to be put on in the manhole due to the design of most slant jacks. If a pad and roller are being used, allow the working operator to slowly pull the porcupine into the sewer and then on downstream where it can be removed.

This in turn may cause problems of flooding if there are building laterals connected into the sewer being cleaned.

Since each machine is capable of handling 1,000 feet of cable, often it is possible to pull through or skip a manhole, thus saving another time-consuming set up. Two sections can be cleared at once, provided the sections are in a straight line. A disadvantage of this procedure is that you may greatly increase pipe damage by more trips through the same section of sewer. A short damaged section may become a long damaged section.

If the working machine is equipped with a truck loading chute, the operation of dumping the bucket is done by the machine operator. Loading chutes eliminate loading the material from the street to the

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truck and considerable clean up. An extra operator is important at this end of the operation even with the chute method of dumping. Often the operator needs help when the controls of the machine cannot be left. When extra help is not available, the danger of accidents is greatly increased. This method of clearing is time consuming; and when the operation is hurried, quality of clearing, equipment care, and safety are often unintentionally sacrificed.

If the job is not complete at the end of the day, the bucket is removed at the downstream working manhole, and the 1/4-inch overnight drum is installed and connected with a swivel to the 1/2-inch cable of the upstream machine. When the 1/4-inch cable is pulled through, it is secured in the upstream manhole in such manner that it cannot come loose. The manhole cover can be replaced.

The 1/4-inch cable and drum are then removed from the downstream working machine and lowered into the manhole and secured.

The pull line will be ready for the next day's set up and considerable time saved.

When work is complete, the reverse procedure of set up is used to remove the equipment from the sewer and the manholes. Hose off buckets and cables. Load the equipment into the trucks and prepare for the next set up or the next day's use.

Final clean up is performed with special care given to washing down and completely cleaning the entire area where debris or wastewater has been deposited on the street surface during the operation..

In these instructions, the set up of this equipment has been to have the working machine at the downstream manhole and to do the actual clearing by going upstream into the material to be removed.

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This does not mean the reverse procedure cannot be used and it often is. However, conditions in the sewer must be kept in mind and particularly the results of whichever procedure selected. If large amounts of debris and especially roots are encountered when pulling the clearing tool downstream, a stoppage can be caused below the working area. By working upstream as outlined, this danger is practically eliminated. However, use of improper tools and techniques also can allow debris to cause a stoppage downstream. Again, the continuous use of this equipment and the experience gained will govern the choice of the set up procedure.

Precautions and Safety

Because a rather large tool is being used in the sewer, any problem encountered which would keep the bucket, porcupine, or other such clearing device from moving can cause water to build up behind it. Prevention of stoppages during clearing should be foremost in the mind of the operator. If there is any question of the clearing tool getting through, try a smaller size and determine if the sewer would allow a larger tool to pass through the sewer. As mentioned previously, it is important to know the location of the clearing tool at all times. Footage counters are recommended; but if they are not available, keep track of the wrap of cable. In the event the clearing tool has to be dug up, it helps to know where it is stuck.

Regularly inspect cable clamps, clevis and swivels, bucket condition, cable condition, and condition of accessories. If a cable should come loose from the bucket on the wrong end for any reason, you may not be able to pull the bucket through the debris to the manhole at the other end.

If a bucket becomes lodged, don't try to force your way through. If pulling the bucket upstream, have the downstream machine pull it back a few feet and try again. Pulling back will open the jaws and likely let the bucket come into the problem area at a

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different angle. If repeated attempts fail, have the bucket pulled back a few feet, enough to open the jaws, and then hold the brake tightly on the upstream machine while the working machine again pulls. This tends to hold the jaws open and also gives a lifting effect to the bucket.

Be careful when lowering the bucket into the working manhole. Do not allow the cable to tangle or come off the lower roller by keeping the slack out of the cable. Prevent the bucket bail from folding back on the bucket when it is pulled into the sewer because there is no way of its flipping back over when you start to pull the bucket.

Personal safety must be stressed when using cable operated equipment. Be especially careful when guiding cable onto in .. the drums. Keep your hands clear of the drum. Use a manhole hook to guide the cable.

In an instant, your hand or fingers can become entangled and the operator cannot stop the machine fast enough to avoid injury.

New or inexperienced operators should not operate this equipment without proper training and supervision. Some of the safe practices used are techniques acquired through repeated operations and observations of problems encountered during rewinding.

Records

Since bucket machine clearing is not repeated in the same line any more often than necessary, good records must be kept. Often at a given spot in the sewer line the bucket may 'hang up.' This could be caused by several possible factors, but if it is a severe problem, a repair at that point may be indicated. Cocked joints can turn into broken joints if the bucket is banged against them continuously and even cause the bucket to become lodged tight. Let this event become part of the permanent record.

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If repairs subsequently are made, this too can be noted and the next time this sewer is cleaned, the operators will have this information.

Power Rodders

The power rodding machine can perform tasks that hydraulic cleaning methods have difficulty in doing, such as heavy root removal, grease and deposit removal, and stoppage relief. While they are effective in these areas, power rodding machines do not move silt, sand, and sludge as efficiently as hydraulic cleaning methods. Many agencies use both power rodders and high velocity cleaners in collection system maintenance due to the respective limitations and advantages of each method of cleaning.

Power rodding machines use a steel rod to push or pull various clearing tools through sewers. These machines are of various designs, but are equipped to store either continuous or sectional rod in a reel-type cage in lengths up to approximately 1,000 feet. This reel can be rotated to give turning action at the same time the rod is pushed out or in.

Power rodders can be used for the following purposes:

Scheduled clearing of:

- ◆ Roots
- ◆ Debris accumulations

Threading cable for:

- ◆ Balling equipment
- ◆ TV inspection
- ◆ Bucket machines

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Emergency use for clearing stoppages.

Power rodders are one of the most widely used method for clearing a wastewater collection system. Since the machines were introduced for commercial use in the early 1950's, many improvements have been made in design, operation, and clearing tools.

Although other clearing methods play an important role in maintaining the collection system, the power rodder can handle stubborn stoppages of roots, grease, and debris. The power rodder is a handy tool as support equipment to thread cables in lines for other cleaning and maintenance methods. After a sewer has been cleared with a power rodder, it should be cleaned hydraulically to restore the line to full capacity.

Rodding machines use either a sectional steel rod, or a continuous rod to attach a cleaning tool to. While the work that is accomplished is relatively the same, these are two different types of machines.

- ◆ The sectional power rodder is designed to use sections of rods that are mechanically attached to each other. Rod size can be either 5/16", or 3/8" diameter, and are available in 36", 39", and 48" lengths. They are assembled by means of a threaded nut into a coupling after the special hooked end of the rod is set into the coupling. Sectional rodding machines will be equipped with a chain drive head that will be set up for one of these lengths, and one length ONLY can be used. The diameter of the rod can be changed, however, if desired. The rods are connected and stored in a reel inside the machine. Between 800' to 1000' can be stored on most of these machines.

- ◆ The continuous power rodder is designed to use a single, continuous rod. The rod size can

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be one of the following; 5/16" (.375), 3/8" (.393), or 1/2" (.461). Continuous rodders are equipped with a multi-roller drive head that moves the rod in and out of the machine. The drive head will be set up for one of these diameters, and ONLY that diameter can be used, regardless of length. Rod storage in these machines is usually between 1000' and 1500', with some special application machines holding 2000' of rod.

◆ Both types of rodder use a gas or diesel engine between 16 and 25 horsepower, and a hydraulic system for power. (Older machines may use a smaller engine with a mechanical, belt driven power system). Both machines are available in a trailer or truck mounted configuration, with power take off (PTO) availability on the truck mounted unit for power supply. Both types of machines can be effective in lines up to 15" in diameter depending on the diameter of the rod that is used, and can operate at distances of 750' to 1000' effectively.

Comparisons Between Continuous and Sectional Rodders

While each machine performs roughly the same work, and operation set up is similar between them, it is important to understand why these machines are different.

Continuous rodding machines are quickly and easily loaded, however, when loading continuous rod, a special transfer rack is necessary to do it safely. When continuous rod needs to be changed, the entire reel must be loaded. Sectional rodding machines may require hours to assemble and load a full reel, however, the entire reel very seldom needs to be replaced at the same time.

Sectional rods are pushed through the drive head by a positive drive. Continuous rods are pushed by

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rollers which can slip and cause wear. Continuous rod drive heads require daily tightening on the rollers to insure a proper grip on the rod, and to reduce roller and rod wear. Couplings on sectional rods cause more wear on the guide hose liner.

Continuous rodders can rod greater distances than sectional rodder, and are less apt to break at great distances due to the torque transfer through the continuous length of the rod. Sectional rod couplings can work loose or increase drag friction of the rod in the pipe.

Continuous rod must be clean as it passes through the drive rollers to prevent damage and wear. Sectional rod drive heads are more forgiving, however, sectional rod couplings can attract debris. Continuous rod is easier to clean than sectional.

When a sectional rod is broken, repairs can be made in the field by either installing a replacement rod, or rejoining the string together and adding a new rod later when increased footage is needed. When a continuous rod breaks, repair is difficult and the broken rod must be discarded. The continuous rodder is reduced in operating length to the length remaining in the reel. In some cases only a few breaks in the rod will require a new reel to be installed.

A broken continuous rod in a sewer is more difficult to retrieve since the pick up tool does not have couplings to grab with a retrieval tool.

Crews and Equipment

Two operators are needed to properly operate the power rodder and three are recommended. One operator performs the actual operation and an assistant is needed for close observation of the action of the rod and guide hose at the working manhole. The third operator is needed to notify the operator when the clearing tool has reached its

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destination, or the location where it is removed, or where it is changed to a different tool.

The equipment operator should be well trained in the use and operation of the power rodder and will be responsible as well for supervision of the proper set up, safety measures and selection of the clearing tool to be used. The effective use of the selected tool will depend to a great extent upon the operator - how well the operator determines the problem at hand and how conscientious the operator may be in getting the sewer as clear as possible.

Tools and accessories are varied, but basic in design. Many have been developed on the basis of field reports and the industry continues to produce more effective new tools and techniques.

The same basic tools are used for either the continuous or sectional power rodder. These tools include root saws, square bar augers, spring blade cutters, round or square bar corkscrews, porcupines, swabs, pickup tools, and assembly wrenches.

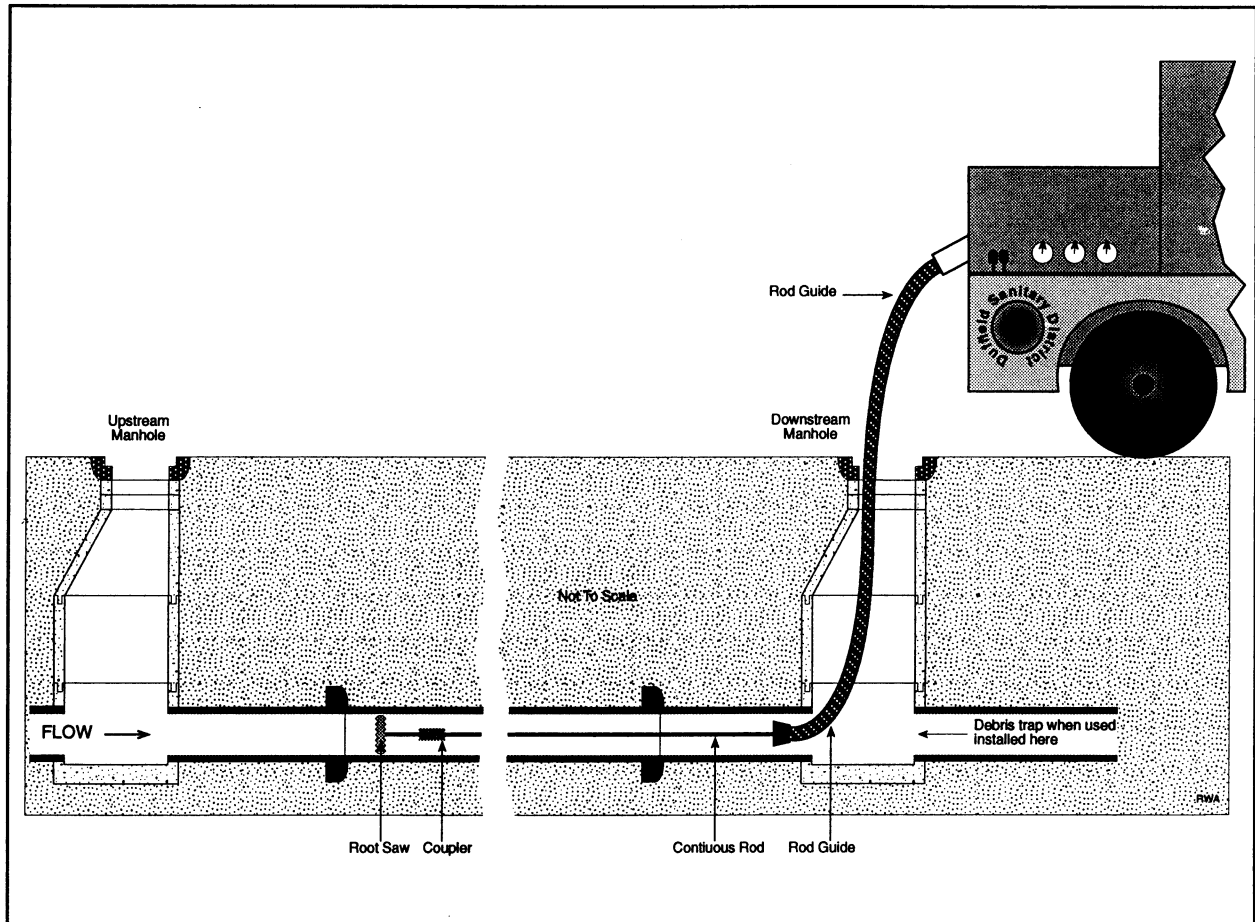
Equipment Set Up

If a particular area or subdivision is to have roots or grease cleared with a power rodder, start at the top of the system. In so doing, any debris you may lose downstream from your work will be going into an area that you will be going to next and not into a cleared line. Be careful that any debris lost downstream does not cause a stoppage in a downstream sewer already in poor condition.

Whether rodding upstream or downstream, the set up of the power rodder will be the same, except when rodding from inlets, siphons, and other similar structures. First position the machine at the manhole so the rod guide hose is pointed in the direction you will be rodding. Most collection system operators rod only from the upstream manhole when there is no stoppage. When rodding from the downstream

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manhole and using small tools (spearhead blade or bullet nose), these tools will occasionally turn up house service connections instead of going up the sewer.



Since most manholes are in street areas, certain safety measures must be taken for handling traffic and insuring safe conditions in manholes. Install a leader tool or smooth coupling on the end of the rod before installing the rod guide hose. This leader tool will prevent the sharp end of the rod from damaging the interior of the rod guide hose. After installing the rod guide hose, run the rod out far enough from the end of the rod guide hose to remove the guide tool and install the selected clearing tool.

Pull the clearing tool back near the end of the rod

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guide hose. A rope will be fastened to the end of the rod guide hose and with this, insert the clearing tool into the sewer. Most power rodders are equipped with a rod guide hose brace to keep the hose from pushing back out of the sewer into the in contact with roots or other material in the system. Proper positioning of this brace is important since slack rod in the manhole can cause breakage and is extremely dangerous.

Pull the power rodder away from the manhole just enough to take the slack out of the guide hose. Often a hose-jack or brace is used to support the hose, especially when working in shallow manholes where several feet of guide hose could be left unsupported between the manhole and the power rodder. Install a sand trap or other suitable debris trap. If rodding upstream, install this trap in the downstream side of the working manhole. If rodding downstream, put it in the downstream side of the lower manhole. This will keep loosened roots, grease chunks or other material from going farther and possibly causing a stoppage.

Different models of power rodders may add to, or change this set up procedure will slightly, but generally this procedure cover the basic set up.

Tool Selection and Operation

A history of the sewer you are clearing will be of great help; but lacking this information, other indications of which clearing tool to use may be grease in the manhole or trees growing close to the sewer.

A wide variety of tools are used with the rodding machine to solve different cleaning problems. Tools used with the rodding machine are designed to be rotated clockwise in the pipe. Only corkscrew, or boring tools can be rotated counter clockwise to disengage from material or to get past misaligned joints. Rates of turning speed for each tool varies on

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line size, conditions in the pipe, and operator experience levels. As a general guideline, cork-screw and boring tools should be rotated slowly, about 25 rpm, to avoid the potential to exit the pipe either through a service connection, or off set joint. Root saws need to turn faster to effectively cut materials, and need to turn at about 35 - 50 rpm depending on line conditions. Finishing, or pull back tools need to rotate quickly, at about 55 - 60 rpm, as they are slowly pulled back.

Most tools are designed to fit well within the pipe for which they are made, for example, an 6" root saw will usually measure 5 - 5/8" in diameter. This will leave room of the tool to make any turns or dips in the pipe without getting stuck. Finishing tools are the only tools designed to fit tight into the pipe, however, these are only used after the bulk of the material has been removed to clean the pipe to the side wall. Examples of different tools, equipment and applications are listed below.

ROUND WIRE CORKSCREW: Generally used with hand rodding applications in small diameter pipes to relieve stoppages, or to thread into and break up solid deposits.

SQUARE BAR CORKSCREW: Primarily used to relieve stoppages in pipes over 6" in diameter. An effective stoppage tool due to the open structure of the blade that allows materials to pass through the tool.

DOUBLE POINT CORKSCREW: Used to engage and retrieve root masses, cans, plastic bottles, and fabrics from a pipe. Double point allows the tool to bite into material and retrieve it.

SAND CORKSCREW: Used in pipes where sand has impacted the line. The forward screw portion pilots the tool into the sediments, and the following screw portion further enlarges the access point and

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allows water to enter the material to loosen it.

AUGER: Used to pilot a hole through roots, grease, and other solids in the pipe. Primarily used in conjunction with other tools to open a path in the line so that another tool, such as root saw, can be used easier. Effective in cleaning misaligned pipes, as the turning direction can be reversed to climb over bad joints.

SAND LEADER: Used to rotate and remain above sand and other built up deposits to thread a line with cable or attach a different tool from the next manhole or access point.

ROOT SAW: Used exclusively to cut through root masses in the pipe after the Auger has piloted a hole in the line. Available in many different configurations for different kinds of root cutting from small curtain or "veil" roots, to complete root intruded pipes.

SPRING BLADE CUTTER: Used as a finishing, or pull back tool after a root saw or auger has removed the bulk of roots or grease from the line. The tool is installed at the manhole away from the rodding machine, and is slowly pulled backward through the pipe at a high rotation speed. The blades are designed to scour the pipe walls to remove the balance of materials left behind. This tool should be used **ONLY** while being pulled.

PORCUPINE: Also used as a finishing tool to scour the pipe after cleaning operations. This tool, as with the spring blade cutter should be used **ONLY** while being pulled.

SPEARHEADS: Spearheads, or boring tools are used to break up stubborn stoppages, break glass, pierce cans, and break up packed silt, sand, or industrial debris.

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PILOT BULLET: Used primarily on the end of the string of rod to allow the rod to guide easily through the rod guide hose. Installed after the line has been cleaned, and the rod is pulled back into the machine. This tool can also be used for stop-pages, and treading a cable in a pipe.

PICK UP TOOL: Used to retrieve sectional rods that have broken in a sewer line. Tool slowly turns and locks on the rod coupling, allowing the string of rod to be removed.

ASSEMBLY WRENCH: Used on the coupling nut to install and change tools, or change sectional rods.

ASSEMBLY TURNING HANDLE: Used to provide a firm, safe hold on the rod coupling so that the assembly wrench can turn the coupling nut.

RATCHET TURNING HANDLE: Used in hand rodding applications, it allows one way turning of the rod by a ratchet device. Ratchet can be set up for clockwise or counter clockwise turning.

PULL OUT TOOL: Used in hand rodding applications, it allows the rod to be pushed or pulled in a pipe while the rod is being turned either by hand or with a Rod Turning Machine.

BAR TURNING HANDLE: Used in hand rodding applications, the bar will lock onto a rod coupling allowing the operator to turn the rod safely by hand.

SWIVEL: Used when towing a cable through a pipe. Swivel allows the cable or rod to twist independently and does not allow knotting of the cable.

ROD GUIDE HOSE: Used on all power rodders to

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protect and support the rod from the machine to the bottom of the manhole.

LOWER MANHOLE BRACE: Used with the rod guide hose to prevent the bell end of the hose to push back out of the pipe when an obstruction is encountered. This brace attaches to the guide hose bell and when placed against the opposite wall of the manhole prevents the guide hose from pushing out of the pipe invert.

The clearing operation is now ready to begin. One operator can be either stationed and protected at the opposite manhole or sent there before the clearing tool gets there. The reason is twofold: first, to make sure you have completely rodded this section of line, and second, to remove any excess roots, or change to another tool before pulling back into the line. **NEVER** take hold of the clearing tool until it has stopped rotating and the power rodder is shut down. Many accidents occur because precaution is not taken here. The clearing tools are sharp and can even tangle in your clothing. A rod has a tendency to coil inside the sewer. Even though the clearing tool has stopped turning, it doesn't mean the rod cannot suddenly unwind from this torque when the tool is moved. Before making any changes or adjustments, be sure the tool is backed up from any obstructions and 'uncoiled' from any twists.

Selecting the proper tool for the job that is being done takes some experience, and knowledge of what the different tools are designed to do. There are many tools that are used with the rodding machine that have a specific function, similar to mechanical tools. As with mechanical tools, one would not use a screw driver instead of a chisel. It is important to understand what these rodding machine tools do, and how they are used in conjunction with other tools for a specific job. For instance, using a root saw to remove grease instead of augers that are designed for grease removal, will not result in a clean pipe.

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If the rodding machine is being set up to clear a stoppage, a Square bar Corkscrew should be used from the dry manhole, down stream from the stoppage. After the stoppage has been broken loose, you should have some indication of what caused it. The next tool to use would depend on whether the stoppage was caused by roots, grease, or grit. Removing the material from the pipe after a stoppage has been cleared will follow the same procedure as if it were a scheduled maintenance task.

There are many occasions when it will be better to change tools or tool size from the far manhole instead of removing the rod guide hose from the manhole at the machine to do it. This procedure will save a considerable amount of time and effort when cleaning many sections in a given area.

When changing tools at the far manhole, rotation of the tool is stopped. A gaff is used behind the head of the tool, and the rod is slowly pushed up the line as the tool is lifted to the street. When the tool has reached the street, the tool can then be changed with another. NEVER touch the tool on the end of the rod until the rodding machine has been shut down. Many accidents have occurred by not taking the proper precautions here. The tool is then changed, and the rod is pulled slowly back into the machine until the new tool is in the invert before rotation is started.

If roots need to be removed from a pipe it is best to use an auger, followed by a root saw, followed by a finishing tool to clear the roots to the pipe walls. Select an auger, approximately 1 size smaller than the pipe itself, for example if the pipe is 8", use a 6" auger. The auger will be sent up the line to the next manhole, which will pilot a hole for the next tool. At the far manhole, the auger is gaffed up to the street to change to a root saw.

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The root saw that is used can be sized the same as the pipe now, as the auger has piloted a hole through the roots. The root saw is lowered into the manhole then rotation is begun as the tool is pulled back to the rodding machine.

Pulling the root saw as it cuts forces the blade of the saw to cut in the same plane, and allows the rod to absorb the torque through it's entire length in the pipe. The saw is turned relatively quickly in the pipe, and slowly brought to the rodding machine.

Once the tool reaches the rodding machine, many operators will then return the saw to the far manhole to change to a finishing tool such as the spring blade cutters. The saw can be returned at a greater forward speed, as most of the material has been removed. Once the root saw gets to the far manhole, it is gaffed up as the auger was, and a spring blade cutter is installed and returned to the invert. Quickly rotate and bring the tool back slowly so that it can remove any stubborn materials still left on the pipe walls.

Hardened grease can be a problem, especially in areas that have a high concentration of waste oils such as restaurants. This grease can build up to substantial amounts and harden to the pipe walls, making removal difficult unless rodding tools are used. When removing grease, augers are generally used. As with root clearing operations, using a smaller auger than the pipe size, the tool is worked to the far manhole, once there, a pipe sized auger can be attached and pulled back to the machine. Most operators prefer to return the auger to the far manhole to attach a spring blade cutter to scour the pipe walls of the remaining material. It is a good idea to flush the line with water after the hardened grease has been removed.

In some cases grease will be built up to a point that several sized augers will need to be used prior to the

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pipe sized auger. It is important to try to break out this material in small pieces that can either be removed down stream so they will not cause a stoppage further downstream in the system.

Once the cleaning tool has been selected for the job, the operation can begin. Set up of the rodding machine is the most important part of effective rodding. With improper set up, tool and rod damage can occur as well as possible damage to pipes and the machine. The time taken to set up properly at first will not take as long as tearing down and setting up again.

Set up the rodder as outlined, and thread the rod guide hose with the rod, attaching the proper tool using the assembly wrench and assembly turning handle. After lowering the guide hose into the manhole and getting the tool in the pipe, be sure the lower manhole guide brace is properly set up to prevent the end of the hose from pushing back from the pipe invert, and that all bends in the guide hose are removed by pulling the rodding machine forward.

It is important to remove all of the bends in the guide hose so that the rod is not forced to rotate in a severe bend. When the rod is forced to stay in one place in a bend as it is being rotated, the rod will heat up as it is alternately stretched and compressed. If the rod becomes too hot and enters the cool waste water, the temper of the rod metal can be damaged, and the rod is susceptible to breakage at that point.

Once the guide hose has been set up properly, the forward speed and strength need to be set. On hydraulically powered machines made since 1975, there is a pressure gauge with an adjustment valve that forward pressure can be set with.

Rod damage can be caused by too much forward

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pressure on the rod, so this forward pressure should be limited to about 350 lbs. If there is too much pressure on the rod, the rod can be bent in the pipe, and break, or reverse itself causing a tangle.

Most rodding machines are equipped with a footage meter to locate the tool in the line. Be sure that this meter is reset when the tool has been placed in the line so that the location of the tool in the pipe is known at all times. Should an obstruction be encountered that will not allow a rodding tool to pass, the footage should be noted so that a closed circuit inspection camera can be used to find the trouble, or markings on the street can be made to excavate a known problem.

Using the proper controls of the rodder, the tool is pushed into the line a few feet, and rotation is begun. Rotation speed should be set for the tool being used, and the forward speed be set fairly slow, unless the pipe being cleaned is known well. It is best to remember that slow is always best with any pipe cleaning equipment. A cardinal rule of rodding is that the rod can be pushed and pulled without rotation, however, if rotating the rod, it must be pushed or pulled slowly. This will allow the rod to move through any bends in the set up without heating up and breaking.

When the tool engages material, the tool will most likely stop rotating, while the rodding machine continues to turn the rod. If the tool is not retracted away from the material, the rod will twist and cause a loop near the cleaning tool. Once the loop has formed, continued rotation of the rod will cause it to coil inside the pipe like a giant spring. This is known as over torque and can damage rods to the point of breakage.

Over torque can be an operational problem, especially with operators not experienced in rodding. Over torque damage to rods is usually not instantly

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seen, only when the rod breaks in the reel, or gets caught in the drive head does this problem get spotlighted. There are a couple of different ways that over torque can be controlled.

- ◆ When working in a line with roots and grease, while the machine is working, release the reel spin direction lever to neutral to see if the reel stops quickly, or even begins to spin in reverse. If this happens, it means that the tool is lodged, and the rod is relieving the torque pressure. Simply withdraw the rod from the line a few feet, begin rotation again, and continue until the material is penetrated.

- ◆ More experienced operators will use the second approach, and watch the rod carefully as it is working in the pipe. When torque builds up, it is usually indicated by a few things; the pressure gauge will go up as the material is encountered, and, as the rod begins to twist itself, the rod will show evidence of this between the machine and the guide hose anchor. In more advanced stages of torque, the entire guide hose may begin to twist with the rod. Noting these things, the operator will withdraw the rod, while keeping the rod turning, until the tool clears the material, and spins the torque off in the line. The operator then carefully moves back up the pipe and repeats the same procedure until the material has been penetrated.

While this would appear difficult, it is a relatively easy operation to master with some experience. Experience will teach the operator to listen to the sound of the engine as it works the rodding machine during operation. If the engine pulls down, it is an indication that the tool is working in material, and attention should be paid to the rod tension and torque build up. By looking and feeling the controls as you operate the machine, you will quickly master it.

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There are some basic rules of operation that should be observed when running rodding machines;

- ◆ Do not jam the rod into an obstruction. This is the fastest way of breaking a rod or tool in the pipe. Smooth and even operation is required.
- ◆ Do not rotate the rod in one position for an extended period. Heat builds up quickly where the rod bends in the manhole. Keep the rod moving in or out of the machine while rotating.
- ◆ Experience will guide the operator as to the amount of torque that can be applied during the cleaning operation. When torque builds up, retract the tool from the material to relieve it, then return to the material.
- ◆ If the rod should break, or when changing tools at the far manhole, be sure the torque is out of the rod before you handle it. Prodding the rod with a pole or shovel will cause any built up torque to spin off and allow safe handling.
- ◆ Be sure that forward pressure is adjusted to low levels to prevent the rod from being bent and breaking.
- ◆ Do not allow any bends or "S" curves to remain in the guide hose. Rods caught in the bend for extended periods will heat up and be damaged. Pull any bends out by pulling the rodding machine forward.

Precautions and Safety

Once again, emphasis needs to be placed on speed of rod travel and rotation. These two items combined, break or twist most rods. Most machines will be capable of holding close to 1,000 feet of rod which is quite heavy. With the weight of the rod on a spinning reel, considerable twisting power is

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developed; but it also takes some few moments to get it stopped. An operator can get through some difficult stoppages or root problems with skill and patience.

Do not attempt to rod distances greater than from one manhole to the next unless absolutely necessary. Trying to avoid extra set up time can be much more dangerous than normal operation.

When working on a rodding crew, required procedures of operation must be established and followed for each individual. You must know your own job and the jobs of everyone else on the crew so everyone can be familiar with the overall operation.

With constant use, rods do suffer from fatigue” and when a rod breaks, it’s likely/to be in the sewer. Avoid turning the rod without rod travel in the sewer. Heat builds up very quickly at any bend when the rod is turning. Therefore keep it moving at all times if possible.

Porcupine cleaning tools are available for attachment to the power rodder. Their use is not discussed because of potential safety hazards. Other tools can do a similar job in a safer manner. If a porcupine must be used, a winch and tag line must be used for safety.

Maintenance of Rods and Equipment

Sectional rods should have the rod couplings kept tight at all times. These will work loose while rodding, and a visual inspection by the operator even while working the machine will often pick up a coupling that is loose.

Make a practice of running the rod out on top of the ground on occasion and inspect the rod for bent pieces and loose couplings. When they are allowed to stay loose, the rod will wear and become weak at

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that point. Do not throw used couplings away they can be reused.

Continuous rods are driven by rollers pressing on the rod. A clearing tool in the form of a clamp is furnished with the machine and has a very important function. A coarse piece of cloth or similar material is kept in the clamp tool; and when you are ready to pull the rod back into the machine, clamp this tool around the rod at the head of the machine and it will wipe the rod clean as it is returned to the reel. If this grease and grit are allowed to continue passing on into the pressure rollers, they will build up and cause wear on the rod.

Even with a clean rod, the pressure of its being rolled back and forth causes some wear. Therefore the torque on these drive rollers has to be checked and reset. Specifications for the particular machine are furnished by the manufacturer.

Always avoid sharp bends in the guide hose regardless of the type of machine. The metal liner can become bent and distorted. Inspect the guide hose frequently and carefully for wear, mounting, and mechanical damage such as crimping.

Be completely familiar with the clearing machine. Know what operating and maintenance procedures the unit requires.

Inadequate maintenance before rodding a sewer can result in considerable time lost attempting to recover a broken rod. The necessary maintenance items can easily be done on the job:

Sectional Rodder

- ◆ Inspect for loose rod couplings.

- ◆ Keep drive head chain tight.

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- ◆ Inspect for worn drive dogs and improperly adjusted belts.
- ◆ Look for “stacking” of the rod on the reel when bringing the rod back into the reel cage.

Continuous rodder

- ◆ Maintain proper torque on the driver rollers.
- ◆ Examine wear on the rod guide bushings.
- ◆ Inspect for sharp teeth on drive gears. This indicates wear or needed adjustment.

Look for leaky hoses and fitting on hydraulic units. Maintain proper oil level in the hydraulic oil tank. Keep the hydraulic oil filter clean.

Fluctuating oil pressure may be due to hot hydraulic oil. This may or may not be just from continuous use. Be suspicious and check for other problems.

Always keep the rodder, tools, and accessories as clean as possible. The engine should have the maintenance and care as recommended by your shop foreman or manufacturer’s directions.

Hand Rods

With all of the modern equipment available, it is still necessary to have hand rods available. One of the first reasons is that hand rods can be used when and where the modern methods cannot be used effectively. Hand rods are a quick and simple answer for many stoppages. Hand rods are often used on “service request” trucks and for “off-hours” stoppage calls. They are used extensively for emergencies at nights or during weekends. After the stoppage is cleared, thorough cleaning can be done at a later date.

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Often maintenance crews will carry a reel of hand rod on the same work truck used in conjunction with a power rodder. If when clearing a particular area the power rodder cannot be put to use, such as an easement, the hand rod can be used and not leave a section of sewer uncleared and likely forgotten. Also a hand rod can be used from the opposite manhole to free a stuck or broken power rod.

Other maintenance crews may do only hand rodding. This is not uncommon in sanitary districts with hilly areas or in very small districts where the total length of sewer in the system does not warrant routine clearing with other types of equipment. Other factors may be involved, but the main point is that hand rod methods are here to stay at least in the foreseeable future.

Crews and Equipment

The particular job often will dictate how many operators will be needed. However, if a crew is essentially doing only hand rodding, at least two operators are recommended.

The hand rods are regular sectional rods as used on power rodgers. Usually the rod length is 36-inches. This length is easy to control and simple to keep track of footage or number of sections used. The rod is stored in a shallow reel approximately four (4) feet in diameter and so constructed to keep the rod contained on the reel. It is equipped with a removable tripod which allows the reel to be set up quickly near the work site at an angle convenient for operation. When the reel is properly set up on the tripod, the rod can be pulled off or onto the reel allowing the reel to turn freely. Many work trucks are equipped with this reel fastened to the truck. When rodding is needed where the truck cannot be taken, such as an easement, sections of the rod are simply removed from the reel and pulled to the working area by hand.

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Hand rod trailers are available as well that are compact and have the reel mounted at an angle convenient for use. These trailers also have a box for tools and a rack for a three-wheel, gas-powered unit to turn the rod. This power drive is essential, especially when other rodding equipment is not available or usable. The power drive has a light-weight engine with a gear reduction and control which allows the end of the rod to be attached for turning. With a hand control, rotation of the rod can be accomplished to cut roots or make penetration into stoppages very similar to the operation of large power rodders, except the distance of penetration is not as great.

Other than these basic items, reel, rod, power drive and perhaps a trailer unit, tools would include root saws, augers cutter blades, pickup tool, assembly wrench, turning handle rod guide tube and extension pipe, guide tube jack, sand traps, manhole shovel, debris bucket and hand line, manhole pick, hook or lid lifter.

Force Main Cleaning

Force main piping is not generally susceptible to blockages like a gravity sewer. However, the capacity of the force main can be reduced by a buildup of slime or other material on the walls of the pipe which increases friction losses in the pipe. Capacity can also be reduced through the deposition of solids in the pipe invert.

Force mains that are under pressure from the pumps in the pump station do not have clean outs located along the length of the pipe. With the exception of air relief or vacuum release valves, the pipe is usually one continuous section of pipe from the pump station to the discharge end. Unless the force main is very short, none of the previous pipeline cleaning methods are used in cleaning force mains because of the lack of access.

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The most common method of cleaning force mains is using polyurethane swabs better known as poly pigs. Poly pigs are formed polyurethane swabs of various densities and surface coatings. These are inserted into the force main, the force main pressurized behind the pig and as it travels through the pipe, the pig scours the inside of the pipe.

Normally the use of a poly pig requires that the pump station be shut down and that a launching point be available for insertion of the pig and a point to retrieve the pig on the discharge end of the force main. Because this is a somewhat specialized cleaning procedure, contractors that specialize in this type of cleaning method are normally utilized.

Because the pump station must be shut down, provisions must be made for handling incoming wastewater either through bypass pumping or providing adequate storage. Pump stations are not normally designed with launching points inside the station for poly pigs and therefore some piping modifications need to be made to launch the poly pig.

Determining the Need for Force Main Cleaning

One common method of determining condition of the force main is by routine pump station calibration. If this is done on an annual basis, any changes in capacity and discharge heads in the pump station can be identified. These changes however, could also be the result of worn impeller or wear rings needing replacement in the pump. Therefore, you must first verify that the pumps are in good operating condition in order to determine that the force main is a problem.

In addition to performing the pump station calibration annually, if air relief valves are located along the force main, pressure readings can be taken to develop a pressure profile along the force main.

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Force main pressures are an indicator of potential capacity reduction within the pipe .

While the poly pig is flexible and can negotiate around corners and bends and pass through pipe fittings such as increasers and reducers in the pipe line, there may be obstructions such as a butterfly valve instead of a gate valve in the force main which could cause the pig to become hung up. Careful review of as built drawings should indicate any of these potential obstructions. In addition poly pigs have the provision to insert a radio beacon device so the location of the poly pig can be tracked as it travels through the force main.

Set Up

The following factors need to be considered when using this method for cleaning force mains:

- ◆ Provisions must be made for bypassing the pump station or providing alternative storage while the force main is being cleaned.
- ◆ A launching station must be provided for either in the pump station or at the beginning of the force main itself.
- ◆ Provisions must also be made to connect external pumps to the force main once the pig is launched to propel the pig through the force main.
- ◆ Any time the force main is worked on, for example to install the launching station or to launch the pig, the force main must be drained.
- ◆ Provisions must be made to track the pig through the force main in case it gets hung up and a dig up is required to retrieve it.
- ◆ Some means must be provided to retrieve

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the pig at the termination of the force main.

- ◆ Provisions must be made at the termination of the force main to collect and dispose of the material resulting from the cleaning action of the pig.

Chemicals

Uses of Chemicals

Chemicals can be very helpful aids for cleaning and maintaining wastewater collection systems. Proper application of effective chemicals can be used to control roots, grease, odors, concrete corrosion, rodents, and insects. The purpose of this section is to indicate how to determine if chemicals might be effective and how to select, apply and evaluate the effectiveness of chemicals. Where specific chemicals are mentioned, trade names are provided solely for illustrative purposes.

How to Select Chemicals

Words of Caution: Look out for exaggerated claims by promoters. No chemical will stop odors, remove roots, or repair breaks in sewers. Some chemicals may cause more damages than benefits. For example, you may clear a kitchen drain trap with a half a cup of chemical. To clear a similar stoppage in a 36-inch sewer would require tons of chemicals. This procedure would be very expensive and could cause extreme hazards downstream.

Two very important factors must be remembered when evaluating and using chemicals:

Chemicals will not clear stoppages or blockages in sewer mains. Be wary of any chemical that makes this claim. How does the chemical move 100, 200 or 300 feet down a plugged sewer to the stoppage at the proper concentration?

Laboratory or 'desk top' demonstrations work because chemical concentrations are adequate for the amount of water involved. Apply these concen-

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trations in the field and the volume of water in a sewer could require a large amount of costly chemicals to achieve the required concentration at the proper location. Ask your chemical supplier to calculate the exact amounts of chemicals needed to provide the desired chemical concentrations. For example, how much chemical is necessary to produce effective heat ranges in the sewer to dissolve grease or burn roots?

Don't get trapped into thinking you will at least be doing something if you buy a chemical. Very often you are merely contributing to the promoter's income, but not helping your situation. Contact water pollution control regulatory agency officials before using a chemical. Some chemicals are banned, while others are approved for appropriate use.

A Selection Procedure

Ideally chemicals you wish to use have been tested by a respectable laboratory and the results are favorable. Many universities, states, federal agencies and private testing laboratories conduct impartial tests of new chemicals before they are sold. For assistance and guidance regarding the application of chemicals to your particular problem, contact the U.S. Environmental Protection Agency, state water pollution control agencies and professional associations for recommendations. If a chemical has not been tested to your satisfaction, don't buy it.

All chemicals of the herbicide, insecticide, fungicide or rodenticide type require registration under the U.S. Environmental Protection Agency, Pesticides Regulation Division. These chemicals must have an approval number issued by EPA before use to prevent harmful contamination of a water course.

If a chemical does not require an EPA approval number and is untested, attempt to have a recognized laboratory perform the necessary tests.

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Otherwise, you must design your own testing program or risk throwing your agency's funds down the sewer.

Here are some steps to follow if you must develop your own chemical testing program that are fair to your agency and the chemical company.

Ask the salesman to provide documentation of his claims in writing. Realize that he will only provide you with favorable results. A telephone call to the operator who used the chemicals will reveal if the chemicals are still being used successfully and if the costs are reasonable. Phone calls provide the opportunity for you to ask questions and also to obtain information people might be reluctant to put in writing.

Calculate the cost per foot of sewer to be treated before buying and applying the chemical. Costs may be too high even if the chemical works as claimed.

Work with the salesman to select a segment of sewer to serve as a test section (at least between two or more manholes). Develop a procedure for evaluating effectiveness of the chemicals in the test section over a period of time recommended by the salesman. If the salesman refuses to demonstrate his product without charge and with an authoritative evaluation other than his own - **BE VERY CAUTIOUS.**

Take photographs or video tape the existing problems in a test section of sewer **BEFORE** the chemicals applied.

Agree in writing with the salesman the results that should be produced by the chemicals and the method of payment for the chemicals. Determine payment on the basis of effectiveness of chemicals.

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Apply chemicals as directed under the supervision of the salesman. Recalculate and verify dosage rates applied.

Re-televised and photograph or video tape the treated test section of sewer in accordance with your agreement the salesman.

Be sure to keep good records before, during and after testing.

If the chemicals worked as claimed or agreed upon, pay the bill. If the chemicals did not work and there were no agreements regarding partial payments for partial effectiveness, then don't pay. No work, no pay.

Be wary of companies that offer a 'money back guarantee.' How do you get your money back if you are not satisfied? What happens if the company goes bankrupt? A reputable company with a good credit rating and bank references may be worth the risk.

Sometimes the selection of a 'control' sewer may be helpful. No chemicals are applied to problems such as roots in this sewer. The purpose of this line is to provide a means of comparing problem development such as root growth in lines with and without chemicals.

If your agency is too small or without the resources to conduct an extensive testing and evaluation program as outlined in this section, try to use as many of the concepts discussed as possible to protect your agency.

Any company not willing to stand behind their products and subject them to an agreed upon evaluation, does not deserve to use your valuable time trying to sell you questionable products. When your agency has a firm policy regarding the testing

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of chemicals before purchase, the effectiveness of your chemical program will be greatly improved.

Roots - Causes of Root Problems

Let's try to understand how to approach the cure for roots in your wastewater collection system by learning the causes of root problems.

What happens when roots are pruned or cut in a sewer line? The roots in the sewer line will grow similar to the limbs of a tree; thus after each pruning they will send out new growth just back from the cutting. Each time a root is cut, it will add new growth laterally, but also it will increase in diameter. When roots increase in diameter, serious problems develop that in time will break the pipe or open up the joint even more.

When you are starting a chemical program for root control, the following information must be obtained from the manufacturer:

- ◆ Recommended herbicide or herbicides and EPA approval number. Verify information with EPA and other regulatory agencies because rulings sometimes change when new experiences gained.
- ◆ Recommended method of application such as flooding, spraying or foam. Sometimes the application of a combination of two herbicides is more effective than only one herbicide.

Concentration of chemical and amount required to treat a selected sewer line. Also learn the correct way of determining the specified concentration for other sizes and lengths of sewers for future reference.

- ◆ Time of contact of chemical with roots, or time required for the sewer to be flooded or blocked with chemical to achieve root kill.

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- ◆ Preferred meteorological conditions at time of application. Rates of herbicide uptake through roots are largely determined by rates of plant transpiration or water loss from the leaves of the plant.
- ◆ Cost for chemicals and application, including labor and equipment.
- ◆ Hazards to wastewater collection system operators working downstream from section where chemicals will be applied.
- ◆ Effects upon the downstream wastewater treatment plant by the use of the chemical.
- ◆ Effects on receiving waters of wastewater treatment plant effluent.
- ◆ Material Safety Data Sheet (MSDS).

Application (flooding, spraying and foaming)

This is the area where many chemicals fail to perform to the manufacturer's claims and make many maintenance people leery of new chemical products. If specific claims are made as to results to be expected, then the chemical manufacturer should be willing and able to provide SPECIFIC instructions as to method of application, concentration of chemical, and required contact time. Directions for the application of some chemicals suggest that you "dump one can of chemicals in the sewer and if that doesn't work, dump in another can." Haphazard instructions of this type will usually produce haphazard results.

To apply a chemical to control roots, first televise the section to be treated to determine existing conditions. When ready to apply the chemicals, isolate the system to be treated by plugging the upper and lower ends of the sewer line to be treated

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(usually a segment of line between manholes). Mix the chemicals according to manufacturer's directions and safety precautions, and slowly meter the chemicals into the test section of line. If the line is to be flooded, allow the mixture of water and chemical to fill the sewer and manhole to a level three to six inches above the top of the sewer pipe in the upstream manhole. Leave the line plugged and the chemicals in the line for the specified contact time. Maintain constant observation of the system above the plug to prevent flooding of a home or business. Flooding sewers to treat roots can only be done in low flow sewers. Otherwise, a bypass pumping and piping system may have to be devised and installed.

One method of reducing chemical cost is to reuse the chemicals in downstream sections of the sewer. Plug the lower sections of the line and allow the chemicals to flow downstream to the next section of line requiring treatment.

A small addition of chemicals may be necessary to maintain the desired concentration. Some dilution of the original chemical batch usually occurs when the chemical slug flows down to the next test section.

Another method of recycling used chemicals is to pump the chemicals from the test section into a tank and reapply them in another section. Some additional chemicals may have to be added to maintain the desired dosage in the next test section. Depending on the chemical used, be sure to follow manufacturer's recommendations regarding safe handling of chemicals at all times.

Infiltration of water into the sewer line may be expected to wash the chemicals off the roots and decrease the effectiveness of root kills. Treatment of roots during periods when infiltration rates are low usually is more effective.

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Evaluation

Root control by chemicals is not as fast as removing roots by cutting them off with a power rodder, but chemical control is more permanent. Effective chemicals can control roots in a sewer for as long as two to five years.

To evaluate the effectiveness of a chemical root control program, televise test and control sections one week, one month and three months after treatment to evaluate the effectiveness of the chemicals. With proper chemicals and application, root control by the use of effective chemicals is a very desirable preventive maintenance program and is cost effective.

Safety Precautions

Before using any chemicals make sure the field crew has thoroughly read the label on the chemical container and understands the type of chemical, reactions that will occur, safety measures for handling and applying, equipment used for mixing and application, action to be taken if the chemical is spilled or splashed on operators or materials, and clean up. Action in case of an accident includes first aid treatment to be given and how to inform a doctor of the exact chemical compounds involved if a person needs medical aid so the doctor will know how to neutralize the chemical and properly treat the victim.

When handling or mixing any chemical, always wear rubber gloves, an apron, goggles or a face mask for protection. Do not enter manholes without proper precautions. Spillage of root control chemicals on lawns or gardens will kill plants and sterilize soil for long periods of time.

Other Methods of Root Control

This section has emphasized the control of roots in sewers by the use of chemicals. There are other methods of root control.

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First, the best way to control roots is to install sewers that don't leak. Modern pipe materials and joints can be installed without leaks so roots can't enter a sewer. In older sewers where there is the potential for root intrusion, methods of root control include:

- ◆ Eliminating deep rooted trees.
- ◆ Inserting a liner in the sewer (Section 10, Sewer Rehabilitation).
- ◆ Not allowing trees to be planted over sewers.
- ◆ Removing roots and sealing sewer
- ◆ Frequent clearing of roots from sewer.

Another possible approach to killing roots in sewers is by the use of scalding hot water. Roots can be thermally killed in sewers by flooding one manhole section at a time with scalding hot (180° to 210°F) water for 30 minutes. A truck-mounted packaged steam generator is required. The advantages of this system include a good root kill at any time of the year, the killing of rodents and insects, and the liquefying of grease. Limitations of this approach include high energy costs and the problem of handling or disposing of the liquefied grease.

Grease

Grease and soap problems used to be confined to sewer lines that served restaurants or industrial dischargers. These materials were controlled to some degree by grease traps or grease interceptors. With the widespread use of home garbage disposal units, the problem has now spread throughout the collection system.

Problems commonly develop when greases, oils and

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soaps cool and solidify and form a coating or deposit on the walls of a sewer. The rate of build up of a grease deposit depends on the amount of grease carried by the wastewater, the flow and velocity of the wastewater, and the size of the sewer. If the sewer changes slopes (steep to flat), intersects with another sewer, or has dips or other alignment irregularities, then these factors can encourage the development of grease deposits. Sewers larger than 18 inches in diameter tend to have fewer grease problems than smaller sewers because they usually flow more than half full with velocities high enough to prevent the build up of grease.

Most uniform building codes or sewer-use ordinances require commercial and industrial dischargers to install grease traps or grease interceptors if grease is in their wastewater discharges. These units are similar to a septic tank and are designed to allow floatables (greases, oils and soaps) to accumulate on the surface and heavy solids to settle to the bottom. The floatables and solids must be removed on a regular basis.

Responsibility for cleaning and maintaining grease traps and grease interceptors depends on community policy, but usually it is the responsibility of the discharger. Unfortunately many dischargers do not know how to or do not bother to properly clean and maintain grease traps and grease interceptors. Some industries do an excellent job because contents of the traps can reveal that problems have developed in their industrial processes that are causing a loss of profits and also causing an increased sewer-use billing.

Grease traps and interceptors must be thoroughly cleaned. Merely pumping the liquid out of the trap or interceptor does not remove the grease or solids. Frequency of cleaning may vary from twice a month to once every six months, depending on the amount of grease in the wastewater and flow

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conditions.

Field evaluations of grease traps and grease interceptors have revealed that usually they are undesirable and ineffective for the following reasons:

Dischargers (such as restaurants) do not properly clean and maintain the facilities.

In spite of the installation and maintenance of the facilities, grease problems still develop in smaller sewers. Problems develop because the facility is too small, improperly maintained, or the wastewater temperature was so high that the grease did not solidify until it reached the sewer.

Undesirable side effects are produced by grease traps and interceptors in the collection system and the wastewater treatment plant.

Solids deposited on the bottom of the trap or interceptor start to decompose. This decomposition produces odors in the collection system, exerts a greater load on the wastewater treatment plant, and increases the sewer-use charges.

Decomposing material from the trap or interceptor can flow into the wastewater collection system and increase the production of hydrogen sulfide.

When the trap or interceptor is cleaned, a large mass of undesirable material must be disposed of in a sanitary landfill.

In summary, we may be better off without grease traps and grease interceptors, because without them grease gets into the sewer where collection system operators have the knowledge and equipment to handle grease problems better than anyone else. The ultimate solution to grease problems is to educate the sewer users that grease, oil, fat and soap should

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not be discharged into the sewer. These materials should be separated, salvaged and recycled if possible like aluminum cans and waste papers.

Effective grease and soap control with methods available to the collection system maintenance operator include the high velocity cleaner, hydraulic balling, power rodding and bacteria cultures. Many chemicals have been sold in the past and are being sold today to control grease and soap in sewers. These chemicals are sold as bio-acids, digesters, enzymes, bacteria cultures, catalysts, caustics, hydroxides and neutralizers. Many of the compounds are claimed to control odors, remove grease, eliminate roots and accelerate activity in biological treatment processes in treatment plants. By scanning any trade journal, you can easily develop an extensive list of these products. Many have their proper use in specific locations under specified conditions.

CAREFUL EVALUATION OF THE RESULTS PRODUCED BY THESE CHEMICALS AND BACTERIA CULTURES SHOULD BE MADE IN COMPARISON WITH MECHANICAL AND HYDRAULIC CLEANING METHODS USED FOR SEWER LINE MAINTENANCE The ideal control of many troublesome materials is at the source by educating the public that grease, oils, coffee grounds and eggshells should be disposed of in the garbage can along with paper, tin cans and plastic containers. This practice would eliminate some of the homeowners' plumbing problems and make the job of the collection system and treatment plant operators much easier. The only recommendation we offer regarding these types of chemicals is to develop a stringent evaluation program to test these products.

Odors

Odors have long been associated with collection systems and wastewater treatment plants and are primarily caused by the production of hydrogen

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sulfide . Some industrial dischargers produce offensive odors that are not caused by hydrogen sulfide.

Most odors can be controlled in a properly designed cleaned and maintained collection system. Odor problems usually are due to low velocity flows, long transmission times in the collection system, high temperatures and poorly maintained collection systems. If these problems can be corrected, odor problems would be eliminated. Odor control is usually obtained by controlling the production of hydrogen sulfide. Masking agents are used to mask or overpower an undesirable odor. They do not control the production of undesirable odors. In some cases a combination of both odor control and masking agents are used to combat odor problems.

One of the most common causes of odors results when the air flow in the sewer above the flowing wastewater is stopped at a siphon or by a small sewer joining a large sewer so low that an air seal is produced. These problems can generally be cured with air lines or air jumpers. These lines are pipes that take air off the top of the inlet structure and return it at the end of the siphon. Wet wells are seldom the site of substantial sulfide generation, even though they are often the place where odors are released from wastewater. An air line or air bypass around the lift station can be used to control odors released from a wet well if the force main is not too long.

Masking Agents

There are numerous masking agents available on the market which generally consist of a water base and an oil carrier of perfume scents to overpower or mask the objectionable odor. Instead of the sewer smelling like rotten eggs, you can now have your choice of mint, pine, banana, channel #32, or an assortment of other aromas to mask sewer odors.

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Obviously a masking agent does not correct the cause of the odor problem. If the original problem is caused by hydrogen sulfide, you still have the other problems created by high concentrations of hydrogen sulfide that include a poisonous or toxic gas that is flammable and explosive. Also hydrogen sulfide can be converted to sulfuric acid which is very corrosive. Therefore you haven't accomplished anything except to hide a potentially hazardous situation. Probably every agency in the country has used masking agents for the control of odors to satisfy a complaining citizen, but they have not corrected the source of the problem.

Information Needed from Manufacturer

Use of a masking agent requires the following information:

- ◆ Recommended deodorant or masking agent.
- ◆ Method of application drip feed, spray, atomizers or blowers.
- ◆ Feed rates and amount of masking agent required to meet feed rates. Time of application, such as late afternoon and early evening, or periods of maximum odor production.
- ◆ Cost of masking agent.
- ◆ Effect upon wastewater treatment plants with biological treatment processes.
- ◆ Effect upon waters receiving effluent from treatment plant.
- ◆ Safety precautions for operators. Any restrictions on use, especially in residential areas.

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Application of Masking Agents

Manufacturer's procedures must be followed exactly to achieve desired effectiveness. Excessive use of any chemical is discouraged because this practice is the same as throwing money down the sewer. Application may be simply removing the masking agent from a one to 55-gallon container using a hose and needle valve. Allow the masking agent to drip into a manhole or lift station wet well at a rate of so many drops per minute. More elaborate equipment and procedures include the use of timers, blowers, atomizers and specially designed nozzles.

Evaluation

Very careful consideration must be given to these applications because the masking agent is quite expensive. Use may be justified for short time periods until the cause of the problem can be corrected. Remember, masking agents do not eliminate or correct the source of the problem.

Rodents and Insects

Some collection systems are infested with rodents and insects. Rats are a serious problem in some areas because of the threat to public health and the destruction of food. Effective control of this problem requires assistance from the local health department or animal control agency for the development and implementation of a cooperative eradication program. These agencies can establish a vector (a bug, insect, fly or rodent that can transmit infection) control program and can recommend types of poisons and when and where they should be distributed. Tight sewers with proper traps and connections and good manholes can limit rodent problems.

Insect control can be achieved by an effective maintenance program of flushing slow or stagnant lines periodically during the warm summer months or whenever insects from sewers are a problem. A serious insect problem can be caused by small flies that breed and live in trickling filters and sewers. Cooperation with the local health department can

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expedite an effective control program.

Control of insects in manholes is best achieved by an effective maintenance program that keeps manholes clean. Use of water to wash and flush manholes can keep them clean. Spraying manholes with an insecticide for dangerous insects and washing down the manhole are good practices if insects are a problem.

Hydrogen Sulfide

Hydrogen sulfide is one of the most serious problems confronting wastewater collection system operators. The hotter the weather, the flatter the sewers and the longer the flow time to the wastewater treatment plant, the worse the problem becomes. Some of the problems created by hydrogen sulfide include:

- ◆ Paralysis of the respiratory center and death of operators,
- ◆ Rotten egg odors,
- ◆ Corrosion and Possible collapse of sewers, structures and equipment,
- ◆ Loss of capacity of sewer, and
- ◆ A flammable and explosive gas under certain circumstances.

How is Hydrogen Sulfide Produced?

The major portion of the sulfide content in wastewater arises from the conversion of sulfate to sulfide by bacteria in the slime in sewers. Materials containing proteins in the wastes are an equally important food for bacteria that produce hydrogen sulfide. Any sulfur containing compound that is available as a food for slimes that reduces oxygen in the wastewater can produce odorous, reduced

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sulfur compounds, including hydrogen sulfide.

The lower the pH, the more hydrogen sulfide is present as compared to sulfide. Therefore in terms of odor and corrosion control, low pH values in wastewater are most undesirable.

Hydrogen sulfide is not only odorous, but upon escape to the sewer walls can be converted to sulfuric acid by other bacteria. In some cases, solutions of sulfuric acid in excess of 40 percent have been found on walls of the sewer. Where such heavy acid concentrations develop, washing of such areas once a day by such action as rising wastewater flows does not appear to be sufficient to prevent corrosion.

The ppm concentration of hydrogen sulfide in the sewer atmosphere is quite different from that in the wastewater. A concentration of 1 mg/l (ppm) in turbulent wastewater can quickly produce a concentration of 300 ppm in an unventilated atmospheric space.

In a sewer or waste channel flowing partially full, there will almost always be some oxygen present in the air space above the flowing wastewater. However, sulfide forms and is present in the flowing wastewater. ANAEROBIC reactions produce sulfide in the slimes while sulfide oxidation is occurring in the surface of the flow. The net sulfide present represents the difference between the amount produced and the amount oxidized.

In general, the faster and more turbulent the flow, the more oxygen is dissolved, and thus the more sulfide is oxidized to sulfate. However, manhole turbulence and ventilation often cause corrosion damage in areas immediately downstream from a manhole.

Conversely the more sewer slimes arising from

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more wetted walls, from heavy sand and debris in the bottom and from slower flows, the higher the residual sulfide concentration.

Control of Hydrogen Sulfide

Design, using our knowledge about sulfide generation can in many cases, accomplish the control of sulfide release and thus control much of the odor and corrosion. Designers must realize that the higher the wastewater temperature, the greater the production of hydrogen sulfide. Thus designs acceptable in cooler climates may be unacceptable in warmer climates.

Another factor of importance in terms of maintenance is the presence of slimes in sewers. Sulfate is split by bacteria living in the sewer slimes, and the more area or habitat for such slimes, the more sulfide produced and the greater the odor, corrosion, and maintenance problems. The cleaner the sewers the fewer the slime bacteria and the smaller the problem caused by sulfide.

Provision of materials of construction which will be unaffected by the sulfuric acid resulting from sulfide release is an obvious answer to the corrosion problem. Clay pipe, plastic pipe, the lining of reinforced concrete pipe and structures with materials such as PVC, , coal tar epoxy and stainless steel, epoxy lined asbestos-cement pipe, and corrugated steel pipe with asphalt and asbestos linings are materials which have been proposed and/or are offered for this purpose. Clay pipe and reinforced concrete pipe lined with PVC sheets keyed to the concrete are the only materials with a use record long enough at this time to give reliable data for design use. The PVC lining is subject to damage from hard materials floating in the sewer. Where corrosion will occur over some predictable period, sacrificial lining of pipes with high calcium carbonate mortars is used. The entire pipe also can be made using limestone sand and aggregate and high calcium carbonate mortars. Comparative tests have

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shown that pipe made entirely with limestone aggregate will last 3 to 5 times longer than pipe made with ordinary concrete.

Provision of corrosion resistance still leaves the problem of odor control. Where design cannot provide for the natural oxidation of sulfide and corrosion resistant materials of construction are necessary, carefully designed odor control facilities must be installed. Odor control at treatment plant wet wells may be achieved by withdrawing odorous air and passing it up through trickling filters or bubbling it up through aeration tanks in activated sludge plants. This odorous air is moist and often causes corrosion problems in the transmission ducts.

In addition, methods such as activated carbon towers and packed absorption towers have been successfully used for such odorous air. Masking has been used as an interim solution for acute odor problems. Treatment of the exhausted odors is complicated by the fact that the gas is made up of stench materials and solvents. Removal of both major components is necessary.

Compressed air has been successfully injected into force mains by some operators to control problems caused by hydrogen sulfide. This approach is simple and effective in many, but not all situations. Turbulent conditions are critical to dissolve oxygen in the air into the wastewater to successfully prevent sulfide buildup and to oxidize sulfide already present in the wastewater. Aeration of wastewater in lift station wet wells is helpful to keep SEPTIC conditions and production of hydrogen sulfide to a minimum. The procedure is especially effective during low flow periods. Be very careful with aeration in a wet well that you do not cause pump cavitation and pumps to become air bound.

Chemical treatment of the wastewater is used to

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control hydrogen sulfide. Chemicals are expensive, but can be effective over a short time period.

AS A GENERAL SUMMARY, HOWEVER, CHEMICAL TREATMENT CANNOT BE CONSIDERED TO BE A PERMANENT ANSWER FOR MOST LOCATIONS. IT PROVIDES RELIEF UNDER ACUTE CONDITIONS, BUT IS GENERALLY TOO EXPENSIVE FOR CONTINUOUS USE.

The collection system operator must urge that engineers consider the available theory in original design and then, themselves, strive to keep the facilities as close to the design conditions as is possible by use of as logical and as frequent a cleaning schedule as is feasible and the control of waste materials discharged to the collection system. Where this is not possible, resistant materials of construction, odor treatment and chemical dosage in acute situations may be necessary. The maintenance operator's options are limited, but knowledge of the possible causes of trouble and of the available solutions enable the operator to make the most logical use of available forces and procedures.

In the preceding pages you have learned that hydrogen sulfide is toxic, can cause corrosion, and in high concentrations is flammable and explosive under certain conditions. Hydrogen sulfide is produced by sulfur reducing anaerobic organisms that can thrive in a wastewater collection system. These sulfur reducing organisms require the following environment to thrive:

- ◆ The absence of dissolved oxygen (DO) in the wastewater.
- ◆ The presence of sulfate or sulfur compounds. These compounds are present in most wastewaters or are produced by the degradation of materials containing proteins.

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- ◆ The greater the strength (higher BOD) of the wastewater, the greater the rate of sulfide generation.
- ◆ The warmer the temperature of the wastewater, the more favorable the environment.
- ◆ The slower the flow velocity and the dirtier (more debris in) the sewer, the better the conditions for hydrogen sulfide generation.

Chemical control of hydrogen sulfide generation may consist of use of one of the six chemicals listed below in order of popularity of application:

- ◆ Chlorine
- ◆ Hydrogen peroxide
- ◆ Pure oxygen
- ◆ Air
- ◆ Lime
- ◆ Sodium hydroxide

Chlorine

The most widely used chemical for hydrogen sulfide control has been chlorine injected into the wastewater flow at various points along the collection system. Sewer lift stations often serve as injection sites due to the availability of the site and the required utilities such as water and power to operate the chlorination equipment.

Chlorination may be accomplished by the use of chlorine gas and chlorinators or by the addition of a hypochlorite solution. Hypochlorite is available as a dry powder, in tablet form, or as a liquid usually as

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sodium hypochlorite.

When considering the chlorination of a wastewater collection system, beware of the following problems:

- ◆ Chlorine is a highly toxic, oxidizing chemical. Leaving this chemical unattended in or adjacent to residential areas with the constant possibility of leaks may result in serious injury to the public and to private property.
- ◆ Chlorine requires application equipment including evaporators (if use rates are high), chlorinators, injectors, solution diffusers in the sewer line, and possibly an air gap water system with separate injector water pumps. All of this equipment must be properly maintained.

Hydrogen Peroxide

Hydrogen peroxide was first used in the wastewater field for providing additional oxygen to the activated sludge process in wastewater treatment plants. Hydrogen peroxide has been found beneficial in collection systems for hydrogen sulfide and odor control. Wastewater can be kept aerobic by the application of large amounts of hydrogen peroxide.

The hydrogen peroxide you buy in the drugstore for medical purposes has a strength of 3 percent, while the hydrogen peroxide used in a collection system may have a strength from 35 to 50 percent.

Pure Oxygen

With the great thrust to clean up the environment and the desire to control water pollution, many new treatment plants are using pure oxygen activated sludge systems. Pure oxygen systems are widely used by various industries and became known to the public through the space program.

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If a wastewater treatment plant is producing oxygen for the activated sludge process, additional oxygen can be produced for introduction into the main intercepting sewers to control the production of hydrogen sulfide. Injection of gaseous oxygen into wastewater by using compressors and diffusers helps maintain aerobic conditions in the sewer.

Disadvantages of using pure oxygen include:

- ◆ Must be kept free of petroleum products.
- ◆ Uses specially designed compressors, dissolution diffusers, and shut down and purge control systems to prevent ignition hazard that could touch off the explosive condition of the oxygen.
- ◆ Must be isolated from public access.

Pure oxygen systems will not be a common alternative to control sulfide in gravity collection systems. These systems have been used effectively to inject oxygen into wastewater in force mains. When evaluated for use in collection systems, an extensive engineering study and design will be required.

Air

Air is obviously the cheapest chemical available because it is free. There are no hazards to operators involved in handling air. Another advantage of applying air at lift station wet wells is that the resulting turbulence keeps deposits of solid from accumulating during low flows.

A limitation of applying air is the noise from air compressors. The most serious problem using air is the difficulty of transferring sufficient oxygen from the air to the wastewater to produce and maintain aerobic conditions.

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Lime

Lime can be used to control hydrogen sulfide. Addition of lime can increase the pH of the wastewater to a level where hydrogen sulfide will not exist. A disadvantage of this approach is the problem of disposing of lime sludges.

Sodium Hydroxide

Treatment consists of feeding enough sodium hydroxide into a sewer to raise the pH of the wastewater to 12.5 or greater for a half-hour period. The high pH inactivates the slime layer in the sewer and sulfide production stops. In the average sewer with a sulfide problem, this treatment is necessary every two weeks during the summer. In a few cases more frequent treatment is necessary.

Other Chemicals

Potassium permanganate has been tried and found not to be cost effective in most areas. Ozone generators have been used on a small scale and also found not to be cost effective. Power requirements to produce ozone from the atmosphere or even with pure oxygen available to supply the generator have been very costly to date.

Inspecting Collection Systems

Waste water collection systems are intended to be a reliable method of conveying waste water from individual dischargers to waste water treatment plants.

Inspection and testing are the techniques used to gather information to develop operation and maintenance programs to ensure that new existing collection systems serve their intended purposes.

Reasons For Inspection

Inspection and testing are necessary to do the following:

- ◆ Identify existing or potential problem areas in the collection system.
- ◆ Evaluate seriousness of detected problems.
- ◆ Locate the position of the problems.
- ◆ Provide clear, concise and meaningful reports to the supervisors regarding the problems.

Purposes of inspecting and testing

- ◆ Prevent leaks in the waste water collection system from developing.
- ◆ Identify existing leaks so they can be corrected.

Leakage into sewer lines can occur under the following:

- ◆ When the sewer is installed under a water table infiltration can take place which reduces pipe capacity as well as treatment plant hydraulic capacity.

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- ◆ Poor joints, cracked lines are also potential sources of roots entering the sewer.
- ◆ Conversely when the sewer is located above the water table, raw sewerage can exfiltrate the sewer pipe causing contamination of soil and ground water.

Inspecting Collection Systems

Inspection of waste water collection systems is a very important phase of the operation and maintenance of the collection system.

Inspections reveal causes of problems in the collection system.

They also are able to identify beginnings of potential problems.

Types of Collection System Problems

Collection system problems may be created by design, construction, sewer use, operation maintenance or other outside forces or events. Major sources of problems include:

Design related deficiencies

- ◆ The design was did not include provisions for special local conditions such as ability of soil to support pipe and manhole weights, shifting soils and vibrating or crushing forces from traffic.
- ◆ Inadequate provisions for joint flexing and pipe bedding.
- ◆ Plans and specifications not detailed enough or not followed not followed .
- ◆ Improper lime grade, joint installation and shortcuts in bedding, connections and backfilling.

- ◆ Use of inferior or damaged materials.

Inadequate Sewer Use Ordinances

- ◆ Communication between dischargers to sewers and enforcers of ordinances and enforcement.
- ◆ Improper inspection and enforcement of tap-ins or service connections by individuals, plumbers or contractors that result in illegal connections and/or inflow.
- ◆ Changing patterns of population shifts and activities that result in surcharging some sections of the sewer system and excessive residence time of waste water and solids into their sections.
- ◆ Disaster or contingency situations such as explosions, earthquakes, subsidence, waste water flow shifts of major proportions.
- ◆ Problems of a recurrent nature in the collection system such as accumulation of grease, debris and trash that result in stoppages or restrictions that reduce the capacity of the sewer.
- ◆ Problems characteristic of the region such as climate, high sulfate content in waters, high soil or waste water temperatures or rapid root growth in mucky soils that accelerate deterioration of sewers.

Poor coordination between local agencies

- ◆ Street construction and repair as well as activities of other utility agencies should be coordinated.
- ◆ Consideration must be given to previous

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installations of utilities.

- ◆ Provisions must be made for early warnings of accidents by a workable system for handling regular accidental dumps into the sewers.

- ◆ Inadequate O&M program

Inflow and infiltration are major defects in collection systems that can result in failure of the system as well as the hydraulic overloading of the treatment plant.

Inflow and Infiltration

Effects of inflow infiltration in the collection system include:

- ◆ Overflowing manholes

- ◆ Contamination of ground water

- ◆ Contamination of surface water

- ◆ Backups of waste water into basements of business and residential buildings.

Detection and Correction of Inflow

Inflow detection and correction depend upon the type and source of inflow causing the problem.

Inflow is waste water that enters a sewer as a result of a deliberate connection and through broken or deteriorated pipes.

Inflow is normally associated with surface type sources such as cross-connected storm sewers, roof drains, some pipes and manhole covers.

Inflow is normally detected by physical inspection, for example, manholes and close studies.

While closed circuit television inspection may reveal service connections are other sources of inflow, TV inspection is not normally used for identification of inflow.

In many cases ordinances are required to control surface sources of inflow such as basement sump-pumps and down spouts from roof drains.

Generally collection system operators are not required to enforce these regulations nor do they normally have the authority to do so.

Smoke testing is one very effective method of locating the sources of inflow in the collection system. This is discussed in detail in a later section.

In addition to visual inspection and smoke testing, flow monitoring is frequently conducted in sections of the collection system to quantify inflow.

In some cases field verification by TV inspection can be conducted.

Recent studies have indicated that in many cases one of the major sources of infiltration is the lateral connection between the house and the mainline sewer.

Depending on the agency this is generally private property and the responsibility of the agency and therefore is difficult to get repaired because of cost to the homeowner.

Solutions to infiltration problems include:

Manholes

- ◆ Raise room elevation by use of grade rings if not located in streets.

- ◆ Install water tight covers where needed.

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- ◆ Seal covers
- ◆ Seal or repair barrels

Cleanouts, vents and other structures

- ◆ Sealing covers and/or diverting surface waters away from possible areas of entry to a sewer.
- ◆ Repair damaged structures.

Sewer Pipes

- ◆ Seal segments of damaged pipes, joints by pressure grouting.
- ◆ Dig up and replace damaged pipes and joints
- ◆ Line sewer with a plastic liner and/or fiber liner materials.

Exfiltration

When collection systems are installed above the ground water table, infiltration is not normally a problem. In this case it is usually exfiltration or flow that leaves the pipe and flows into the surrounding soil.

Sources of exfiltration can also be detected by the various inspection techniques.

Manhole Inspection

Manholes are frequent sources of inflow and infiltration.

Therefore manhole inspections can be performed fairly quickly and easily and reveal a great deal about the collection system. Typically the following information is observed.

- ◆ Structural condition

- ◆ Flow
- ◆ Evidence of Surcharging
- ◆ Casting and adjusting ring conditions
- ◆ Casting and grade

Equipment Required

- ◆ Inspection report form.
- ◆ Map of the correction system and a route.
- ◆ Manhole lid lifter
- ◆ Scrapers, wire brushes for cleaning the manhole ring.
- ◆ Straightedge 5' or 6' long
- ◆ Adequate personal protective clothing including gloves and safety shoes
- ◆ If located in traffic, adequate traffic control devices
- ◆ Gas detection devices, particularly if any kind of manhole entry will take place.
- ◆ Measuring device with graduations to measure depth of flows, pipe diameters and manhole inverts.
- ◆ A blower and hose for ventilating manhole.
- ◆ Non-sparking tools for use when removing manhole cover.

Normally only one person performs a manhole inspection, however, depending on information that

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agency is acquiring and traffic conditions, additional crew members may be required.

Manhole Inspection Procedure

- ◆ Locate manhole and check area around it for proper drainage.

- ◆ Check the cover and casting are at grade.

- ◆ Test atmospheric condition in manhole by inserting probe of gas detection device through opening in manhole cover. Use caution in case insects are on the underside of the lid.

Observe and record following information:

- ◆ Cracks or breaks in the walls or bottom.

- ◆ Infiltration at any place. Estimate flow in gallons per minute.

- ◆ Joint security - all joints and the manhole should be tight. There should not be any visible cracks that would allow infiltration or exfiltration.

- ◆ Offsets for misalignment of any parts.

- ◆ Root intrusions.

- ◆ Grease accumulations around arch or inside of sewers entering and leaving manhole.

- ◆ Gravel or debris accumulations in invert.

- ◆ Concrete or grout in the invert or pipe causing flow turbulence.

- ◆ Grout bed of frame

- ◆ Condition of steps
- ◆ Debris on shelf or steps
- ◆ Sluggish flow or waste water backing up into the manhole
- ◆ Corrosion

In some cases it may be necessary to clean casting with wire brush and scraper so manhole cover seats properly. Check that cover does not rock when returned to the casting. Occasionally a cover may become warped and therefore will rock and will not seat. This should be replaced.

All new manholes should be inspected prior to inspection.

Existing manholes should be inspected in a one to five year cycle depending on location, condition and other factors.

Other crews working that have manhole covers pulled can also provide manhole inspection. These would include cleaning crews, riding crews or other sewer maintenance crews.

Close Circuit Television Inspections

Until close circuit television was adapted for use for sewer pipeline inspection, we very seldom had any idea on the condition of the pipe in the ground.

Sewer inspection today is an accepted method of evaluating sewer systems.

Agencies either own TV inspection vehicles, contract the work, or they may rent the equipment.

Close circuit television inspection utilizes television camera, either pulled through the sewer or in some cases, when the camera is provided with a tractor

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crawl devices under its own power.

While in the past sewer inspection typically was used in diameters from 4" through 48", cameras, lighting systems, and other hardware are continually developing so that close circuit TV is used in a very wide range of pipe diameters, materials and circumstances.

Purpose of Televising Collection Systems

- ◆ Inspect conditions and determine location of problem areas such as pipe or joint separations, drops, ruptures, leaks, service connections, obstructions, corrosion, pipe alignment and root intrusion.

- ◆ Look for damage to sewers caused by excavation and construction on nearby utilities, paving and building construction.

- ◆ Search for unrecorded connections that may reveal illegal taps, such as industrial storm water or surface drainage.

- ◆ Locate inflow or infiltration sources and amounts.

- ◆ Inspect installed and/or repaired taps or pipes by plumbers, contractors or maintenance crews.

- ◆ Evaluate effectiveness of solutions and equipment in maintaining or correcting problem areas in sewers.

- ◆ Locate buried or lost manholes.

Results of CCTV Inspection Information

Frequently CCTV inspection is used for the following:

- ◆ Require a contractor or construction agency to correct defects observed in new sewers prior to acceptance.
- ◆ Identify or verify exact locations of service connections and other pipe construction points and correct any as built maps as needed.
- ◆ Establish priorities for corrective work in old pipes on a “as needed” basis.
- ◆ Provide for maximum effective and economical use of manpower and equipment for a preventative maintenance program covering an entire collection system
- ◆ Inspect construction of health service connections to the lateral and branch sewers. Determine by observation of those connections if infiltration, roots, debris accumulation and/or some type of internal inflow are adversely affecting the capacity of sewers.

Equipment and Components Required for Televising

TV system consists of the following components which are normally included in some sort of permanently mounted van or trailer.

- ◆ Television camera
- ◆ Camera light
- ◆ Power cable reel and video unit
- ◆ Television picture monitor
- ◆ System power control center or module
- ◆ Portable power source

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- ◆ Camera carrying skids
- ◆ Camera pulling winch
- ◆ Camera return winch
- ◆ Footage counter
- ◆ Fair lead pulleys and hardware
- ◆ Sound power telephone communication system
- ◆ Float liner pipe stringing line.
- ◆ Television cable reel with slip rings.
- ◆ Video tape recording equipment
- ◆ Video footage reel

Crew size

Typically TV inspection crews are two or three person depending on the amount of and type of equipment involved.

The TV operator is usually the lead person of the three person crew, observes the TV monitor, enters data, interprets information and controls the inspection operation.

Operator must be thoroughly experienced in the inspection and repair of sewers and be capable of evaluating conditions found in the pipe.

Knowledge of TV electronics is not required, but could be helpful for troubleshooting the equipment in the field.

A second crew member helps to make the initial

setup and is then stationed at the far manhole to

- ◆ Operate the pulling hand winch or
- ◆ Observe the operation of the power winch or
- ◆ Disconnect the self-propelled camera from the power supply so the power cable can be retracted.

Workers at both manholes must also observe down-hole cable guides or protection devices used to protect the power and winch cable from sharp edges.

Addition crew may be required when working in heavy traffic and congested areas.

Procedure for Close Circuit Television Operation

TV setups are usually from manhole to manhole. However, experienced crews can frequently inspect over multiple manholes.

Camera is normally pulled in the direction of flow or from the upstream manhole to the downstream manhole.

This allows any debris or solid that is disturbed by the camera or the skid to flow downstream but should not build up on the camera.

In some cases such as new construction, camera may be pulled in either direction. However, this should be noted on the log sheet so the information will be consistent with future inspections.

Sewer lines are normally cleaned prior to televising by using high velocity jet machines or some other method of hydraulic cleaning such as balling.

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In the case of heavy debris buildup that would restrict the travel of the camera skid, it may be necessary to use bucket machines, rudders or mechanical equipment to clean prior to televising.

This equipment can also be used for stringing the line to pull the cable through the sewer line. The second method would use a parachute-type of device similar to a C anchor to float the line down.

Generally TV inspection is not effective on lines that have flow that would submerge the camera. In this case it is necessary to seal off the upstream manhole so inspection can be conducted.

Obviously this must be done carefully to protect bypassing or backing up in basements.

Other options are to televise during low flow periods or in extreme cases, bypass pumping to bypass pump around the manhole.

Stringing the line

String the sewer from manhole to manhole. Objective is to bring the pull winch cable from the downstream manhole through the sewer to the upstream manhole for the attachment of the camera.

Any of the methods used to clean sewer lines prior to television inspection can be effective methods to string a line.

High velocity cleaners or power rodders are frequently used. Floating lines for stringing is also possible, however, problems may be encountered due to low spots, roots and partial blockages.

While the line is being strung through the sewer the pull winch is moved to the downstream manhole and set up.

Communications need to be established between downstream and upstream manholes to coordinate winch operation.

The generator set should also be powered up and checked for proper operation including output cycles per second and voltage. Typically this should be 110 to 125 volts and 60 cycles per second \pm one cycle per second.

- ◆ In some cases voltage adjustments may be available on the generator and speed adjustments will alter operating output of the generator.
- ◆ Generator output is critical to camera and electronic system operation.

Skids are installed to accommodate the pipe diameter. Cable and tag line bridles are hooked to the skid.

Camera is connected to the power cable and camera activated to check operation, the light head should also be checked for operation at this time.

Operator should check the camera for focusing to ensure all camera functions will operate once it is lowered into the sewer.

Newer camera systems are able to pan and tilt, have wide angle lenses and a variety of other functions that enable the operator to perform very detailed inspections.

Before placing the camera in the line, shut all power off to the system.

At this point the pull winch cable is attached to the camera skid bridle in the upstream manhole.

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Note that down-hole rollers need to be installed to ensure the cable is not damaged.

If it is necessary to enter the manhole to insert the camera into the sewer line, confined space entry procedures must be followed.

In many cases, television inspection crews have developed equipment and tools to allow them insert the camera without entering the manhole to avoid a confined space entry.

Pull winch operator takes up slack in the cable and the skid pulled into the pipe until the outer edge of the rear skids are even with the manhole. Winch is stopped at this point.

Power to the camera and light head is now applied and the system once again checked for operation before pulling the camera through the line.

At this point footage reading is zeroed, video recorder checked for operation, and adjustments made to counter if necessary because of focal point or camera inserted further into the sewer from the manhole. Generally all measurements are taken from the center of the starting or upstream manhole.

TV operator directs the pull winch, operator to being pulling the camera through the line. Certain commands may be necessary and agreed upon ahead of time to coordinate proper operation of the winches. These include

Pull ahead from the operator at the TV monitor means for the camera to be winched through the sewer at regular speed. This speed and feet per second or minute will vary with the experience of the operator.

The camera is slowed when some object is being approached and it may be desirable to stop.

There are two basic rules that must be followed:

- ◆ While the camera is being moved through the line, the operator must never stop looking at the monitor or picture. Any obstruction that could wedge or damage the camera where the light must be seen in time to stop the camera's forward progress. If the picture is lost for any reason, the forward progress of the camera must be stopped. If the picture cannot be reestablished again, the camera must be pulled backwards out of the line.

If communications with the operator at the pull winch are lost, progress must be stopped immediately. For most crews a shouted signal from one member indicates a loss of this communication.

If the pull winch operator begins to experience excessive drag on the cable, this fact must be immediately reported to the TV operator and the operation halted to check the cable guide devices for wedging of the cable.

If the pull winch operator begins to experience excessive drag on the cable, this fact must be immediately reported to the TV operator and the operation halted to check the cable guide devices ("downhole rollers") for wedging of the cable.

Pull the camera back a few feet to see what could cause the drag or possible wedging. An out of round pipe can cause wedging.

If a camera and skid assembly become locked or wedged in a pipe and the pull cables break, the sewer must be dug up to recover the camera.

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Therefore, it is very important that the TV operator and the worker operating the pull winch at the far (downstream) manhole develop an exact understanding of voice communications among themselves.

Logging and Recording Television Inspections

Television inspection of a pipeline requires that all data are observed and recorded.

The operator of the TV monitor must determine what is to be recorded, photographed, or video taped.

Most television inspection records are placed on a standard log. Each operator may desire to slightly redesign a log sheet especially for their particular needs. There is certain basic information that should be included on sewer line television report forms.

- ◆ This information includes agency name, date, location, map number, TV operator's name, type of pipe and identification of section being televised (man hole numbers).

Other information that could be helpful yet not critical include

- ◆ a sketch showing the direction of flow in the sewer line
- ◆ the direction of the TV inspection
- ◆ a north arrow
- ◆ identification number of equipment being used
- ◆ video tape identification number,

- ◆ “new work” or “in use” sewer designation
- ◆ name of inspector or concerned individual present.

Coded initials and symbols or numbers are used for simplicity and to save time.

Video tape recordings are used to record the inspection process.

While most video tape recorders have the ability to record the voice of the TV operator when describing the condition of the sewer, defects observed, and the footage of the situation being viewed.

Video footage readout systems are helpful, but a TV operator’s actual description and comments are very useful when replaying the video tape in an office for someone who is not very familiar with the conditions in the collection system.

It is only necessary to video tape DEFECTS in active sewer lines. Taping the entire pipe run, unless it is for a specific presentation or purpose, would become quite costly and soon create tape storage problems for most agencies.

Taping the entire pipe run when inspecting sewer lines for acceptance of a new project is highly recommended, however. A comparison tape can then be made several months later into the contractor’s guarantee period to check for slower developing faults that could seriously affect the long-term performance of a sewer line.

Special Precautions in Televising Collection Systems

Certain types of conditions encountered when televising sewers require special precautions. The operator and the crew should brief each other on

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the procedures to follow in the event these situations are encountered and there is a risk of damage or wedging of the camera in the sewer.

Offset joints restrict the pipe diameter and can cause a camera to wedge tightly in place rather than pass through. Two different types of common offsets require two different procedures.

A horizontal offset is where the joint section is shown to be out of alignment to the right or left. As an operator gains experience in reading the severity of these offsets, the operator will know if the camera assembly can pass these or not.

Attempting to force the camera past such an obstruction can cause it to be wedged so tightly that the tag line winch cannot pull the camera back out the sewer.

Two types of vertical offsets may be encountered and each requires a different procedure.

A 'DROP JOINT' is where the camera must drop down to get into the next section of pipe.

A 'JUMP JOINT' is where the camera has to be lifted up in order to get into the next section of pipe.

If the camera becomes wedged tight in the pipe, excavation to recover the camera will be necessary.

When the camera goes under water to a point where the top half of the pipe cannot be clearly seen, the operator is no longer able to see obstructions or offset joints adequately to prevent wedging or damage.

If the submerged section of the sewer must be inspected, carefully assess the precautions neces-

sary with respect to plugging the line for any length of time.

Flow bypass pumping and working during low flow times must be considered in high volume lines to avoid the possibility of incurring property damage from wastewater backing up into residences and businesses.

One method of televising through low spots or sags in the line is to use a high velocity cleaner with closed end nozzle to clean directly ahead of the TV camera.

The jet of water from the nozzle will push the water clear of the pipe for a short distance.

When the TV picture becomes submerged again, stop the high velocity cleaner and allow the water to flow out the pipe.

Start the high velocity cleaner again and repeat until the submerged section has been inspected.

When coming out of a situation where the camera has been under water, it is possible for the viewport to become fouled with grease or other surface debris. In most cases the decrease in visibility will be negligible, but it is possible to have a foggy or indistinct picture which can reduce the visual inspection effectiveness. There are several things that can be attempted to clear the viewport.

Other obstructions might include protruding service connections (protruding taps), objects sticking into a pipe, pieces of broken pipe protruding into the pipe, and heavy root developments.

A rule of common sense is applicable at this point.

RULE: IF A SITUATION IN A PIPE PRESENTS

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A RISK TO THE CAMERA AND THE TELEVISION EQUIPMENT, IT IS OBVIOUSLY A SITUATION WHICH REQUIRES EXCAVATION AND REPAIR. UP TO THAT POINT, THE CAMERA HAS DONE ITS JOB AND IT CAN BE PULLED BACK OUT AND USED IN OTHER LOCATIONS WHILE THE NECESSARY REPAIRS ARE BEING MADE TO THE PIPELINE. TO RISK DAMAGE AND THE NEED TO REPAIR THE CAMERA CAN PRODUCE UNNECESSARY COSTS. THIS RISK ALSO CAN PREVENT THE USE OF THE TELEVISION EQUIPMENT WHILE CAMERA REPAIRS ARE BEING MADE.

Camera tumbled or off-vertical conditions should not be a problem. A properly designed camera and skid assembly should right itself in a straight pipe run.

Even if a camera is inverted and the picture is upside-down, moving the camera back and forth should cause it to return to the upright position.

Bends and some types of offset joints in a pipe can cause a camera to get tilted. This is usually a temporary condition.

If a camera does not right itself in a few feet, it is an indication that something is wrong. A cable could be tangled in the skid assembly, or a root clump has fouled the assembly.

A foggy or indistinct picture, after getting a sharp picture in a pipe, indicates that the viewport and possibly the optical lens of the camera have become fogged.

This can take place shortly after a camera has started down the pipe, or it can occur after a camera has pulled past a service with hot or very warm water dumping out of it.

When fogging takes place in a pipe after passing a service with hot water flowing out, simply stop the camera and wait for a few minutes.

The warmth will be picked up by the glass parts and defogging will take place. Also the hot water may be cooled by the discharge of water from a fire hydrant.

Steam resulting from water striking the hot light assembly can be ignored. It will not last long and provides no serious problem to the picture.

Do not allow grease to accumulate on the light head. If the heat from the light ignites the grease, the light head could be damaged beyond repair. Also the fumes and stench from the burning grease that comes out the manhole has a horrible odor.

Be aware of the possibility that the TV camera could encounter explosive gas mixtures in a sewer. The heat from the light head may be sufficient to ignite explosive gas mixtures. Therefore, it is very important that a municipality or contractor use gas detection equipment prior to allowing manhole access to employees or equipment. **DO NOT OPERATE A TV CAMERA IN ANY LINE THAT TESTS POSITIVE FOR EXPLOSIVE GASES.**

If a sewer is flowing so full that the TV camera will be submerged, plug the sewer at the entrance to the upper manhole and televise the line as soon as the water drops. **BE CAREFUL THAT THE WASTE-WATER HELD BEHIND THE PLUG DOES NOT BACK UP INTO SOMEONE'S HOME OR FLOW OUT THE TOP OF A MANHOLE.**

Final Check of Television Survey and Footage Test

Before removing TV equipment from the manhole and turning in the television log sheet, every entry should be checked for readability, accuracy, and

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cleanliness.

Poorly written entries or errors in the coded entries can cause costly losses. Dirty logs can make some of the notes and numbers unreadable.

Some types of footage meters can develop large errors during a television operation. In most instances this is due to slippage in the measuring device, or frequent backing and forwarding of the camera.

To determine if such an error has taken place, compare footage meter distance with distance between manholes shown on wastewater collection system map. If a difference of more than one percent exists, use a tape and measure the distance between the manholes.

Also be aware of the fact that maps may contain distance errors. When repairs are necessary, distance errors can be very critical.

If the TV operator determines that the errors are too erratic, the operator should see that repairs are made to the footage meter and the line be retelevised.

Corrections on line distances, tap locations and other items should be routed to the mapping section so maps can be corrected.

If a difference of more than one percent in the total distance measured and the footage recorded on the log is evident, add an error factor to the log.

This error factor will be the amount of the difference.

Give the error factor a sign which shows how the television log should be corrected.

Establishment of the error factor is important when it becomes necessary to excavate some point for repairs to the sewer.

The correct distance permits a person to determine that some defect observed by the camera has to be a certain distance from the upstream manhole.

If the error factor were not available, a person might dig at the logged footage, find that there was an error and then not know which direction and how far exploratory excavation should be made.

Smoke Testing

Purpose of Smoke Testing

Use of smoke for testing sewers is best done when the groundwater is low so any cracks will leak smoke. Realize that the location of smoke on the ground surface does not necessarily reveal where the smoke is escaping underground, but only the path of travel to the ground surface. Smoke testing of wastewater collection systems is used to determine:

- ◆ The sources of entry to the collection system of surface waters, also called surface inflow. This includes rain or storm waters, street or surface wash waters, and in some cases, Irrigation waters.
- ◆ Positive proof that buildings or residences are connected to a wastewater collection system.
- ◆ Location of certain types of illegal connections to a wastewater collection system. Included with these connections are such things as roof leaders or downspouts, yard drains, industrial drains, and some types of cooling tower water drains.
- ◆ Location of broken sewers due to settling of foundations, manholes and other structures.

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- ◆ Location of 'lost' manholes and diversion points.

Equipment

All of the following equipment are used or are applicable to a smoke testing operation:

- ◆ Blower unit . This is usually a squirrel cage blower with a gasoline engine and belt drive. The average blower capacity will be over 1,700 CFM and under 3,000 CFM. The blower will have a base with a rubber gasket underneath the base that permits it to set over and force a blast of air into an open manhole.
- ◆ Pipe plugs to isolate two sections of pipe between three adjacent manholes. These may be mechanical or inflatable.
- ◆ Where there are high wastewater flows that prevent safe plugging of a line to be smoke tested, heavy canvas or curtains with weights or sandbags on the bottom may be used to confine the smoke to the section being tested.
- ◆ Smoke bombs of the three minute or five minute duration type.

WARNING: USE ONLY MAILABLE SMOKE BOMBS SPECIFIED TO BE SAFE AND TO HAVE NO TOXIC OR RESIDUAL EFFECTS. NEVER USE MILITARY TYPES OF COLORED OR SIGNAL SMOKE BOMBS FOR THIS APPLICATION DUE TO EXPLOSIVE DANGER AS WELL AS DANGER FROM CONTACT TO OPERATORS AND PROPERTY.

Preparations

Smoke testing of wastewater collection systems has a chance to affect the occupants of buildings connected to the line being tested. Such factors as defects in the sewer system of the buildings, dry

traps, defective wax ring under commodes, vents terminated in an attic, or clean out plugs missing from sewers can cause smoke to enter the building.

Adequate preparation plus good advance public relations is a necessity in order to avoid panic or severe alarm among persons having the smoke enter a building or a home.

Warn the public in advance when and where smoke testing is planned. An announcement should be published in a local paper and be prominently displayed and distributed in the area to be smoke tested. Occupants should be requested to run some water into sewers that are not used regularly before the test starts to fill traps that may have dried out.

THE LOCAL FIRE AND POLICE DEPARTMENTS MUST BE THOROUGHLY BRIEFED ON THE SMOKE TESTING OPERATION AND ITS SAFETY. In addition, the fire department should be advised of the area to be smoke tested at the start of each day of testing. If possible, it is a good idea to have a vehicle from the fire department with one or two members of that department accompanying the smoke testing operation.

TO ALL OCCUPANTS AND RESIDENTS:

THE CITY WILL BE CONDUCTING LEAK TESTS IN THE SANITARY SEWER SYSTEM BY BLOWING SMOKE INTO THESE PIPES. THIS SMOKE WILL REVEAL SOURCES OF SEWER ODORS IN YOUR NEIGHBORHOOD AS WELL AS PLACES WHERE STORM AND OTHER SURFACE WATERS ARE ENTERING THE SANITARY SYSTEM.

A SPECIAL, NONTOXIC SMOKE WILL BE USED IN THESE TESTS. THIS SMOKE IS MANUFACTURED FOR THIS PURPOSE, LEAVES NO RESIDUALS OR STAINS AND HAS NO EFFECTS ON PLANT AND ANIMAL LIFE. THE SMOKE HAS A DISTINCTIVE, BUT NOT UNPLEASANT, ODOR. VISIBILITY AND ODOR LAST ONLY A FEW MINUTES, WHERE THERE IS ADEQUATE VENTILATION.

BECAUSE THE PLUMBING APPLIANCES IN YOUR HOUSE OR BUILDING ARE CONNECTED TO THE SANITARY SEWER SYSTEM, SOME OF THIS SMOKE MAY ENTER

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YOUR HOUSE IF THE VENTS CONNECTED TO YOUR BUILDING'S SEWER PIPES ARE INADEQUATE, DEFECTIVE OR IMPROPERLY INSTALLED. TRAPS UNDER SINKS, TUBS, BASINS, SHOWERS AND OTHER DRAINS ARE DRY, DEFECTIVE, IMPROPERLY INSTALLED OR MISSING. PIPES, CONNECTIONS AND SEALS OF THE WASTEWATER DRAIN SYSTEM IN AND UNDER YOUR BUILDING ARE DAMAGED, DEFECTIVE, HAVE PLUGS MISSING OR ARE IMPROPERLY INSTALLED. ALL RESIDENTS ARE ADVISED THAT IF TRACES OF THIS SMOKE OR ITS ODOR ENTERS YOUR HOUSE OR BUILDING, IT IS AN INDICATION THAT GASES AND ODORS FROM THE SEWER ALSO MAY ENTER. THESE CAN BE BOTH UNPLEASANT AND DANGEROUS AS WELL AS A HEALTH HAZARD TO THE OCCUPANTS. LOCATION, IDENTIFICATION AND CORRECTION OF THE SOURCE OF SMOKE THAT ENTERS YOUR HOUSE IS URGENTLY ADVISED. WHILE THE CITY WILL RENDER ALL POSSIBLE COOPERATION, THE CORRECTION OF ANY DEFECTS IN THE PIPES AND SEWER ON PRIVATE PROPERTY IS THE RESPONSIBILITY OF THE OWNER. THE SERVICES OF A PROFESSIONAL PLUMBER ARE ADVISED. IF YOU HAVE ANY QUESTIONS OR DESIRE MORE INFORMATION, PLEASE TELEPHONE THE CITY OFFICES DURING REGULAR OFFICE HOURS.

All operators who will participate in the smoke testing should be fully trained and daily briefed in the proper method of handling persons who discover smoke in their homes or smoke coming up all over their yard and around their house. Anticipate that such a circumstance will occur and that it can have a potential for generating considerable concern among certain types of individuals.

Operators on the team should be drilled in the concept that any smoke entering a building or residence reveals that gases from the sewer can and do enter the building. Prompt correction of the problems by the owner is necessary for the health and safety of the building's occupants.

Where smoke is coming from a drain in a plumbing fixture, first inspect the trap water seal to determine if the trap is dried out or is defective.

Where a trap is dried out and unlikely to be used, suggest that the traps be filled with mineral oil. Do not put mineral oil into a trap that will be used occasionally.

A missing wax ring under a commode is easy to identify and to tell a householder how to solve. In any event, a plumber can replace a wax ring.

There are conditions where an observer and recorder may enter private property, therefore adequate consideration of, and good public relations with owners and occupants must be exercised.

A city or agency attorney should be advised of the smoke testing methods and some of the possible adverse results. Although there is no basis for damage or tort (civil) claims from a building owner for smoke disturbance or alleged damage to interiors, such claims may require defense by an attorney. Discuss with the attorney what kind of information and reports are needed if any incidents or difficulties arise during smoke testing.

Crew that does smoke testing should inspect the area to be tested in advance in order to become familiar with the area.

Crew Size

The average smoke testing crew consists of five persons. One person in charge and four observers and recorders .

When there is a high flow in the pipeline to be tested and a chance of surcharging and overflowing an upstream manhole above the plugged off test section, a sixth person is needed to keep watch on the manhole.

When a manhole that must be watched appears to be subject to surcharge and overflow, use of a sandbag on a rope is perhaps the best answer. The sandbag plug may be pulled up long enough to allow the manhole to drain, then replaced as required. For best results, sandbags are tied in the middle so the chance of loss is decreased as much as possible.

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Another method of closing off a pipe run for smoke testing where high flows exist is the use of curtains. These are pieces of canvas with weights on the bottom or a similar material with a rigid frame member along the top edge. They are lowered on a rope until they touch the surface of the flow and then they are tied in place. These curtains must be tight around the edges to prevent smoke leaks.

Operation

At the start of the operation, the smoke blower is located over the manhole and the ends of the pipes plugged at the next adjacent manholes. Smoke testing should not be attempted on windy days. Even a very light breeze can disperse a wisp of smoke before it is visible at a vent or the source of a leak.

The blower is started and allowed to force air into the pipe system for five to ten minutes or longer (depending on volume of sewer being tested) before any smoke bomb is lit.

The purpose of forcing air into the pipe system is to get an air flow established. Since air has weight and inertia, it sometimes takes even longer than five or ten minutes to achieve a flow of air through a pipe system. Once a flow of air is properly established, the air will carry the telltale smoke along with it rather than have the blower try to push a wad of smoke into a pipe system.

Once the air flow is established, one or more smoke bombs are lit and lowered into the manhole at the blower on metal chains, or short lengths of wire. Hooks made of coat hanger wire are often used for this purpose.

Smoke bombs have a cardboard cylinder with the smoke making chemicals inside and a single paper cover on the outside. The cardboard cylinder has perforations where the smoke escapes at frequent

locations and these can be located with fingertip pressure. The perforated holes provide suitable places for a wire hook to be inserted in the smoke bomb.

As soon as the bomb has been lit and put into the manhole, the observers and recorders move out according to prearranged plans. One observer takes one side of the street and moves away from the manhole being smoked, observing the buildings on that side of the street. Another observer moves in the same direction on the other side of the street. The other two observers move in the opposite direction after inspecting the immediate area outside of the manhole.

Where proper building plumbing exists, smoke will come from the roof vents of the building drain system.

The observers must look at all other parts of the building (inside and outside) and its grounds (front, back and side yards) for other indications of smoke from illegal connections.

Before moving on to the next house or building, the observer takes a careful look at the foundation of the building, particularly where the house service pipe would usually pass under the foundation footing.

The observer will cover one side of the distance between the manhole smoked and the next adjacent manhole that has been plugged.

In the event the smoke supply of the first bomb runs out before the area is fully observed, a second or additional bombs may be needed. One five-minute bomb is usually all that is needed (100,000 cubic feet of smoke) for a two-city block run, or approximately six hundred feet of pipe run. Where there are time consuming conditions in the inspection

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process, as many as five or six bombs may be necessary.

Recording

Observers should record every building and the observed results of the smoke test.

Any location where smoke is showing should be fully described and recorded. If smoke shows at the windows inside of an unoccupied building, it should be recorded with a note stating that the building appeared to be vacant or may have had occupants that were absent at the moment.

When this occurs, the observer should place a copy of the public announcement where someone entering the house will find it. Letting such a person know that any odd odor found in the building could come from the sewer is a point of safety as well as concern. Also notify the health department or police to be sure corrective action is started immediately and that people are not allowed to live in the house until the problem is corrected. Making people vacate and stay out of a building is the responsibility of the health department and police department, not the job of the collection system operator.

Whenever possible, photograph illegal situations. Photos are a valuable record.

Other Considerations When Smoke Testing

Smoke testing may be used to locate points of inflow or exfiltration, but does not measure the amount of inflow or exfiltration.

Basement sump pumps have little chance of detection by smoke even when they have discharge connections to the building sewer. This is due to the usually required use of check valves in any sump pump tie-in to a building sewer and also the fact that the intake is submerged in water which

forms a trap.

Where smoke appears at the vent pipe of a house, it is positive evidence that the house is connected to a sewer that is being smoked. Service districts which have monthly billings to property owners connected to a wastewater collection system thus have definite proof of a connection.

Where no smoke appears at a house vent, it does not mean that such a house is not connected to the sewer.

- ◆ Tests have shown that there are many houses with drain grade defects in service connection pipes, or may even have a trap installed in such a pipe.
- ◆ Many buildings that are connected to combined sewers have traps in the service line.
- ◆ Some buildings that may have been on a septic tank in the past may still be on such a tank with a connection from the discharge of the tank to the sewer. Under these circumstances, a well designed tank with baffles as required or an old tank with collapsed pipes and baffles may not permit the smoke to pass through.

There are some cities and counties in the United States where modern enforcement of plumbing codes fails to adequately protect a service district. The admission of smoke into a building from sewer smoke testing usually indicates a health or plumbing code violation in the building's utilities. If smoke is found in a building, look for a dry trap from a basement shower, toilet or drain that has not been used recently before deciding there is a violation.

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Dye Testing

Purpose

Dye testing is being used to establish positively if certain facilities or fixtures are connected to a wastewater collection system. Illegal connections can be identified using dye tests. If wastewater is overflowing or reaching a creek, river or estuary, dye testing can be used to identify the overflowing or leaking sewer.

Also dyes are used to reveal interconnections between sanitary and storm sewers. Specially manufactured dyes are available for this type of testing. Examples of typical dye tests include:

Buildings that may not show smoke at vents during smoke tests due to dips or traps in the service connection pipes can be dye tested,

Where yard drain or storm drain is suspected of being tied to the building sewer or a lateral sewer, a dye test is useful, and

Any suspected situation of inflow or surface drainage may be checked out by using a dye.

Other uses of dye testing include estimating the velocity of flow and testing for infiltration and exfiltration. By pulling a bag of dye up a sewer and stopping at short intervals, an area of exfiltration can be located that could not be seen on a TV inspection such as an open joint that is in line and on grade.

Equipment

Contact the water pollution control agency to determine if there are any regulations regarding the use of dyes.

Two types of safe and harmless but effective dyes are available for dye testing. Powder in cans or containers is measured by a spoon or small dipper. Tablets of the dye are slower to dissolve than the

powder form, but are less messy and are sometimes more desirable than the powder for this reason. The dye is the only piece of equipment needed. Regardless of the type of dye, dissolve it in the flow. A tablet may sink into a sump or wet well and not circulate with the usual flow.

CAUTION: Some dyes may leave a stain if spilled. These stains can be very difficult to remove.

Operation

For the purpose of maintaining good public relations, the public should be notified of your plans for dye testing programs. This is especially so when it becomes necessary to perform work within private property

While one operator applies the dye to the suspected location, another operator maintains a watch at the next downstream manhole from the location

Where a plumbing fixture is used, such as a closet bowl or basin, the water is turned on and the dye powder or tablet is dropped directly into the drain.

Where there is no immediate supply of water, such as a roof gutter or storm drain in dry weather, pouring a bucket of water with dye powder is suggested. The amount of water and dye needed depends on the distance to the next manhole and the existing flow.

Based on an assumed velocity of flow, an estimate may be made of the expected flow time to the downstream manhole. Allow plenty of time because the dye often takes much longer than expected

Use of powdered dye can be difficult and messy on a windy day. When the wind blows, either pre-mix the dye in water or enclose a quantity of the powder dye in either kleenex tissue or toilet paper. Once wind scatters a powdered dye, the dye is

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impossible to collect and nearby residents of homes and businesses can become very upset when the dye lands on their property, gets wet and causes stains on their buildings, autos, clothes and landscaping

When a number of dye tests are to be conducted on the same line or section of a sewer system, the dye testing should start at the facility farthest downstream and progressively work upstream for the other dye tests. Otherwise, if you dye the facilities upstream first, the flow is then contaminated with dye, and you then must wait several hours or until the next day to conduct additional tests

When the tests are completed, record whether or not the service is connected

Pipeline Lamping

Purpose: Lamping sewers from manhole to manhole has been done for many years. The purpose of lamping is to establish that a section of pipe is straight and open or that it is not. Lamping also permits an inspector to visually examine conditions in a pipe within viewing distance of the manhole, usually a very few feet in this case. Larger sewers are easier to lamp than small sewers.

Equipment

A bright source of light and a mirror are all that are needed for simple lamping. In some cases, two or more mirrors are used to direct sunlight from the surface of the ground into the manhole to another mirror and then into the line

Manpower: Four persons are usually needed for pipeline lamping, provided the two workers topside can easily contact the other if help is needed.

One operator enters a manhole and either looks up the pipeline directly or looks up the sewer using a mirror. For smaller sewer lines, a mirror may be

required. The operator in the manhole can use the mirror both to reflect sunlight and at the same time to look into the sewer

A second operator enters the next manhole up or down the line and shines a bright light directly down the pipe towards the first operator. The light or mirror is moved around to be sure the light is directed down the pipe. If the first operator can see the light, the line is deemed to be open and straight. If the light is not seen, the line is deemed to be either "off-line" or "obstructed."

When the first operator is able to see the light, an operator topside is notified who signals the crew directing the light. Signals or voice communications must be established between crews when the light is directed down the sewer and when it is seen at the other end of the sewer

Best lamping results are obtained by rotating the light source around the inside of the pipe. This method will produce more information than a stationary light

Another device used for lamping is an inverted (upside down) periscope with a changeable focal length from zero to 500 feet. A light source is introduced in the same manhole where the periscope is inserted. The results are quite graphic and the optical system can be calibrated to produce suitable readings within acceptable tolerances

Lamping is an economical and fast method of determining if a sewer line is straight and clear of obstructions. However, in small diameter sewers it has limited use and alternative methods must be used to establish their condition. More popular methods include low pressure air testing and CCTV inspection. In large sewers where the flow can be diverted or held, the sewer can be walked and inspected using a good light or a hand held camera

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Lamping should never be used as the sole means of acceptance testing of new sewer lines. The existence of cracks, infiltration or other pipe problems which do not affect pipe alignment are difficult, if not impossible, to detect by this method.

Safety/Survival

SEWER FUMES KILL PAIR, STOP WOULD-BE RESCUERS
JOB SURVEY REVEALS DISMAL PERFORMANCE BY WASTEWATER
INDUSTRY
SEWER WORKER KILLED
DITCH COLLAPSE KILLS ONE
POISONOUS GAS KILLS 7, INJURES 28
SAFETY SURVEY REVEALS FATALITY INCREASES
BACK INJURIES COST 10 BILLION DOLLARS IN WORKERS'
COMPENSATION CLAIMS
MAN BURIED ALIVE
COLLECTION SYSTEMS LEAD RISE IN INJURY RATES
WASTEWATER INDUSTRY RETAINS #1 STATUS AS THE LEAST SAFE
INDUSTRY

FIGMENTS OF THE IMAGINATION? NO! These are actual statements taken from a variety of recent sources.

Throughout the world most living things devote considerable time and energy to survival. At every level of life whether it be human beings, animals, insects, fish, or fowl, survival occupies a great part of every living hour. Intelligent people not only try to protect themselves from injury or death, but they also strive to protect their fellow human beings and especially their immediate families and coworkers. An accident is a tragedy for your family and others who depend on and love you, as well as for yourself.

This section is one of the most important section in the entire course since it deals directly with your ability to survive by avoiding a fatality or disabling accident when working in the collection system environment.

No other skill more clearly demonstrates the professionalism of the collection system operator than his

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or her ability to carry out a work assignment safely. An amateur may perform all of the tasks of a collection system operator, but a truly professional operator will do a better job, will do it more quickly, and will always do it more safely.

Unfortunately, even the formal surveys conducted by the various organizations such as the WPCF and National Safety Council do not accurately reflect the seriousness of the problem. The 1985 WPCF Safety Survey, for example, reports only three fatalities in collection systems. There are, however, far more fatalities and injuries which occur throughout the nation in collection systems. Many agencies do not participate in these surveys, and the fatalities and injuries that do occur are often not reported and, therefore, are not incorporated into the statistics. As grim as the numbers game seems, it is actually far worse than portrayed by the formal surveys. A more accurate estimate of fatalities in collection system operations nationwide is between 2500 and 3000 per year. It is tragic that, in many agencies, collection system operators are not even remotely aware of the hazards that they face in the everyday performance of their tasks. The key to the safety/survival is YOU.

In recent years a considerable amount of information has been compiled regarding fatalities and injuries in the collection system field. The findings only confirm what many have known for some time:

- ◆ Mayors, city council members, city administrators, department heads, safety department personnel or consulting engineers are not-usually the victims of accidents and fatalities.

- ◆ Collection system operators, line supervisors or others who are directly involved and

exposed to hazards while doing everyday routine tasks are the ones who experience the injuries and fatalities.

- ◆ Formal procedures and/or safety equipment generally are not being used when accidents occur, although they are frequently available for the injured operators.

- ◆ Time and resources for investigations, analysis and implementation of safety programs were always available after the incident, i.e., money, equipment, and training.

One or more of three common factors are usually missing:

- ◆ Awareness
- ◆ Responsibility
- ◆ Commitment

The accidents listed at the beginning of this section could probably have been prevented if the operators involved had been aware of the hazards, had assumed some responsibility for their own safety/survival, and had made a commitment to that responsibility.

In no other industry in the United States today is a safety/survival program more critical than in collection system agencies, as our injury records so clearly demonstrate. The cost of human suffering is incalculable.

Consider the effect, for example, on you and your family if you had to spend the rest of your life with only one eye, because you failed to wear safety glasses while working around a pump and the coupling happened to disintegrate while you were

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inspecting it.

Or what if a wrench drops out of your coworker's pocket while he is leaning over the entrance tube to the lift station? It strikes you in the head at the bottom of the entrance tube, traveling at about 75 miles per hour. How much pain and anguish could you have spared yourself and your family by taking the time to put on a hard hat?

Obviously, accidents have a significant economic impact as well as the human suffering toll. For example, workers compensation rates, liability insurance, disability insurance, and other similar costs are directly related to our performance in an agency or company. In recent years, all of these costs have skyrocketed, imposing an economic hardship on many agencies and communities. These are budgetary resources which are no longer available for use in other areas such as collection system operation, maintenance, training, equipment, and salaries.

Professionalism

This is substantiated by the figures reported in the 20th Annual Water Pollution Control Federation (WPCF) Safety Survey Report, which reviews data on injuries and fatalities based on information submitted by 1,334 agencies in the United States and Canada in 1985. This analysis reports:

- ◆ 50% of all injuries occurred to employees with 0-5 years of wastewater experience.

- ◆ 74% of the injured had 0-10 years' experience.

- ◆ 72% of all injuries were attributed to non-certified employees.

Safety/survival is directly related to your level of professionalism which in turn is directly related to

knowledge and ultimately certification.

As your collection system continues to expand, it is imperative that your level of professionalism increase as well through increased knowledge. Nowhere is this more obvious than in your Collection System Safety/Survival Program.

The overall objective of this section is to make you **AWARE** of the hazards of working in the collection system environment. The other two factors, **RESPONSIBILITY** and **COMMITMENT**, will be up to you.

The Numbers Game Or How Dangerous Is The Collection System?

Multiple hazards exist in the performance of the collection system operator's routine daily tasks and work assignments. Awareness of these hazards will enable you to take responsibility for your own safety. The following brief review is intended to refresh your memory about these hazards:

SLIPS

Wet wells, metering flumes or other structures with live flows can be and usually are extremely slippery because of the accumulation of slime and/or the very humid atmosphere. Emergencies, pumps station failures, or other difficult situations which are often caused by bad weather require extra caution. For those who work in the northern climates, snow, ice, frost and demand extra caution in below-freezing temperatures in the winter time.

FALLING OBJECTS

In lift stations and manholes, take precautions against falling objects. When working in a pre-fabricated type of lift station, never stand directly under the entrance tube, particularly when raising or lowering materials/supplies/tools. Even if such objects are placed in a container of some type, they could tip out and fall or the container could bump the sidewalls and dislodge dirt or debris. Similarly, when operators are working in manholes, take care

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not to place tools and materials close to the manhole rim where they can be accidentally kicked into the manhole.

INFECTIONS AND INFECTIOUS DISEASES

We know that collection systems are not the cleanest places to work. Every collection system operator must realize that wastewater is contaminated with possibly every kind of infectious microorganism that can be carried in wastewater. Like the medical doctor, the collection system operator may be exposed to many of the **PATHOGENIC ORGANISMS** from the entire community in which you work. Also like the doctor, personal health depends to a great extent upon your personal cleanliness. Both you and the doctor must wash your hands before smoking or eating. Fortunately, neither profession suffers an unusually high incidence of infection. This may be because both recognize the importance of personal cleanliness. It is also possible that collection system operators develop immunities to infectious diseases and that the records reporting diseases are inadequate.

Diseases or infections that collection system operators could come in contact with on the job include:

- ◆ Typhoid and paratyphoid fever
- ◆ Cholera
- ◆ Bacillary dysentery
- ◆ Amoebic dysentery
- ◆ Roundworm and other worm infections
- ◆ Tuberculosis
- ◆ Poliomyelitis

- ◆ Infectious hepatitis
- ◆ Leptospirosis (Weil's disease)
- ◆ Tetanus

How can you determine if you have contracted one of these diseases? The best indication is that you don't feel well. If you have headaches, feel sick to your stomach, have diarrhea, feel feverish or sleepy, you should see your physician. Prompt action by your physician can save you a lot of pain and trouble in the future and also help protect your family, friends and your fellow operators.

Public Health officials generally agree that tetanus, polio and typhoid infections are especially hazardous for anyone coming in contact with wastewater. Typhoid, once was considered the most dangerous water-borne infection, is now more easily cured by recent medical discoveries. Immunization against typhoid is only about 60 percent effective. Polio immunization (especially Salk vaccine) is effective and simple to administer, but this is still a very dangerous disease, especially to younger operators. Tetanus is easy to prevent but difficult to treat and is considered the most dangerous of the three diseases. **ALL THREE DISEASES SHOULD BE INCLUDED IN THE COLLECTION SYSTEM OPERATOR'S IMMUNIZATION SCHEDULE WITH BOOSTER SHOTS AT RECOMMENDED INTERVALS.**

Tetanus immunization recommendations have changed in recent years. In the past, it was recommended that a booster shot be given as frequently as once year. However, recent research indicates that if this schedule is maintained, sensitization can occur in three to five years resulting in loss of protection. Prior to receiving a tetanus booster, you should check with either local or state health departments to determine the recommended frequency of

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the booster shots. In some cases this recommendation is now every ten years unless a specific incident occurs.

The AIDS virus is a new concern for collection system operators. As of January, 1986, the Centers for Disease Control in Atlanta, Georgia, provided the following information:

Over 95% of all AIDS cases have been related in some way to intimate sexual contact, drug abuse, or blood transfusions. There is no evidence at this time to indicate that the AIDS virus is transmitted through contact with raw sewage (urine and feces).

There has never been a recorded case of AIDS that can be attributed to working in the wastewater collection and treatment industry. This has been true to even the large gay population areas.

Although it cannot be definitely said that AIDS is not contracted through contact with raw wastewater, all evidence points in this direction. Hopefully future research will be able to define exactly how the AIDS virus can be transmitted .

For further information, the Centers for Disease Control can be reached by calling their hotline at 1-800-342-AIDS. Local health departments are also useful sources of up-to-date information about AIDS.

Common sense along with protective clothing and personal cleanliness will go a long way to protect you from infections.

LACERATIONS AND CONTUSIONS (Tears and Bruises)

Much of our daily work involves working with hand tools, heavy equipment, and machines that are rusted, corroded, or nearly inaccessible. Planning each job and using the right tools in good operating

condition will minimize smashed knuckles and thumbs.

FALLS

Manhole steps are notorious for giving way after a period of exposure to the frequently corrosive atmosphere where they are installed. Pump station dry and wet well access is usually by ladder rather than stairs. Atmospheric conditions, rain, and snow will all make ladder rungs slippery. Under no circumstances should you try climbing or descending ladders or manhole steps one-handed while carrying tools/equipment.

EXPLOSIONS

Each year throughout the country, there are numerous explosions in collection systems caused by a buildup of explosive gases in the sewer line or underground structure. Such buildups are very unpredictable and can come from any number of sources such as natural gas leaks, vehicle tank truck accidents that release flammable material into storm and/or sanitary sewer, or flammable material discharges from industries.

Anyone who has seen the results of an explosion either in a sewer, a digester, or other type of enclosure, is well aware of the havoc that can be caused by just the right explosive mixture of air and an explosive gas. Too rich a mixture or too lean a mixture of a combustible gas will not explode. But when the mixture of air and gas is within the level of explosive limits, a spark from an automobile, an improper tool, or even a shoe nail, as well as the more obvious open flame or cigarette may set off the explosion. Only extremely well trained and knowledgeable persons (such as gas company experts) should consider working around such dangerous atmospheres and then only when proper ventilation and hazard removal or elimination has been verified as impossible (carbon dioxide fire extinguishers have been used by experts to dilute explosive mixtures when necessary).

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Experts from the gas company may be called upon in an emergency to work in or near explosive mixtures. **THESE SPECIALLY TRAINED OPERATORS** with years of experience can be trusted to perform such dangerous work if no other feasible alternatives exist. A true expert is a person who always knows and works within their own limits with plans for backup or alternative action if suddenly confronted with a new emergency.

Special insight can be gained by discussing explosive hazards with your local fire department personnel. If your agency has pretreatment facility inspectors or industrial waste inspectors, they should have a knowledge of the areas that are most likely to discharge hazardous combustible materials to the wastewater system but if they don't, it is your responsibility to locate these potentially hazardous sources. Another good way to gain assistance when searching for sources of hazardous gases is to contact your local gas company. Many times explosive conditions are caused by leaking gas mains, service lines or underground fuel storage tanks. In combined wastewater collection systems where any spill of gasoline on a public street may find its way into the collection system, particularly hazardous conditions can develop as far as explosive mixtures are concerned.

POISONOUS OR TOXIC GASES

This situation might arise anytime, anywhere, from a variety of sources ranging from natural decomposition of the organic solids in wastewater to toxic chemical dumping, or reactions from two or more chemicals.

A number of toxic gases are found in the wastewater collection system. Hydrogen sulfide is the most dangerous and most likely to be encountered because it is generated during the **ANAEROBIC DECOMPOSITION** of organic matter and it is heavier than air and tends to concentrate near the bottom of enclosed spaces. Hydrogen sulfide

smells like rotten eggs but unfortunately, our noses tend to lose their sensitivity to hydrogen sulfide and become unreliable detectors. Many operators as well as their would-be rescuers have been killed by this gas. Other toxic or poisonous gases found in collection systems include carbon monoxide, ammonia and chlorine. Industrial chemical discharges can release dangerous gases through accidents, leaks or illegal discharges. Toxic spills from highway and railway accidents also reach the sewers.

OXYGEN DEFICIENT ATMOSPHERES

A safe supply of oxygen is essential to you in the environment in which you must work. ANY concentration of OTHER GASES can reduce the amount of oxygen available for life support. A shortage of oxygen to the operator produces a shortage of oxygen to the brain, which in turn makes the operator less alert. If you are less alert, you may not recognize the danger until you are too weak to get out. Each year many operators die from toxic sulfide, a shortage of oxygen, or from falls acts in attempts to escape without help operator is mentally disabled, at least in part, gas or insufficient oxygen.

The views of experts and legal regulations vary regarding safe levels of oxygen, as do individual needs concerning the amount of oxygen required to support life. Your health and the amount of energy expended are considerations in determining the amount of oxygen that you need. It is generally agreed that anything less than 19.5 percent of oxygen in the breathing atmosphere is a signal to the trained collection system operator to be especially careful and request more ventilation. Measure the percent of oxygen in the air at the work site. You must realize that through normal draft ventilation the gases exiting the collection system through an open working manhole could be just as toxic as the atmosphere in the collection system. Any time the percent of oxygen in a manhole starts

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dropping below the percent topside, increase the ventilation. Carry properly calibrated oxygen level measuring devices which sound an alarm when a dangerous condition exists rather than a device where you must read a meter and then decide if the oxygen level is deficient.

Ironically, one of the most dangerous situations occurs during the new construction inspection period. You may be required to visually inspect the inside of a newly constructed pipeline, but such a pipeline ordinarily has no provision for introducing ventilating air to maintain a safe environment. This is frequently the site of operator suffocation in the collection system. Other collection system structures where an oxygen deficient atmosphere may be encountered include confined spaces such as manholes, sewer lines and wet wells.

Beware of the possibility of excessively high levels of oxygen, too. High oxygen levels won't harm you, but they increase the hazards of explosion and fires. Hazardous levels of oxygen can result from the use of pure oxygen for hydrogen sulfide in collection systems and in the activated sludge process of wastewater treatment plants. An upper limit of 21.9 percent in working atmospheres is suggested.

STRAINS OR RUPTURES

By virtue of our work, pulling manhole covers, maneuvering equipment in tight places such as pumps and motors, we open ourselves up to strains and ruptures of all types. Back injuries are probably the most serious since, in most cases, the parts that make up your backbone are not able to repair themselves and damage is often cumulative. It is extremely important to understand and use proper techniques when working in the collection system environment, since an injury could have a drastic impact on your ability to earn a living or enjoy life as you get older.

TRAFFIC MISHAPS

This is an especially high risk area in that we must frequently access a collection system from streets and roadways. Given the number of careless and inattentive drivers we see every day, it certainly makes sense to take all the precautions necessary for maximum protection when working in streets and roadways.

BITES (INSECTS, BUGS, RODENTS, SNAKES)

Bites can range from inconvenient to very serious. In some parts of the country black widow spiders, poisonous snakes, and scorpions find collection system facilities and structures such as manholes, metering enclosures and electrical control enclosures ideal places to live. Use gloves and protective clothing and stay alert.

EXCAVATIONS AND TRENCH SHORING

Cave-ins rank among the top causes of fatalities in the collection system. You should not, under any circumstances, enter a trench unless you fully understand and insist on adequate safety precautions.

As a collection system operator, you may be asked to inspect or advise about collection system construction or repair excavations made by your agency or by contractors working for your agency. Along with the engineer, you may be the most informed professional to re-examine, inspect, and help enforce OSHA safety laws. Watch out for your own safety and that of your fellow operators.

Deep excavations (5 feet or deeper) without shoring or with improper shoring have allowed cave-ins that have killed many operators. There is a great temptation to “short-cut” the possible expense and time-consuming labor of shoring and a contractor principally interested in making a profit may be tempted to save on shoring or other safety measures. As a

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trained collection system operator, you should take seriously your responsibility to be on the lookout for such hazardous operations.

DROWNING

Drowning is probably an unpleasant way to die, but drowning in raw wastewater has to be worse. Use extreme care when working in high velocity sewers such as metering flumes and observe all of the confined space precautions to avoid losing consciousness and falling into the wastewater.

Confined space precautions include use of safety harness, life lines, and two people topside to watch, assist and help remove the in-line worker by winch or their own physical strength if the worker gets into trouble.

FIRE

Fire hazards, primarily in lift stations, develop from a number of sources. Of particular interest is the risk that fire could easily block the limited access into pump stations or other structures where we normally work, thus trapping an operator.

ELECTRICAL SHOCK

This hazard exists in virtually all of our facilities and is made even more threatening by the damp atmosphere and adverse working conditions in which we must work. There is a misconception that only high voltage kills. That is not the case, however, since relatively low voltage, even 120 volts, will kill you as quickly and effectively as 480 volts. Under no circumstances should you do electrical work that you are not qualified to perform or not authorized to perform.

NOISE

Engine-driven pumps, standby power generators, large ventilation blowers, air compressors, jack hammers, concrete cut-off saws and high velocity cleaners are examples of equipment noise we are

exposed to which can result in permanent hearing loss over a period of time unless adequate hearing protection is worn.

Curiously enough, workers for other industries, such as construction and mining, are exposed to these same hazards as well as many others. Yet, in comparison to those industries, we have retained the number one position as the LEAST safe industry. This ranking is substantiated by nationwide industry surveys through the Water Pollution Control Federation (WPCF) and the National Safety Council. The National Safety Council survey reports an injury frequency rate for collection system operators of 4-1/2 times the 1984 average for all industrial workers. This same survey also reports that the severity rate for operator injuries is almost five times the average rate for other industrial workers. These figures may seem academic and irrelevant. They are not. They relate directly to your chances for a long, healthy life. What they say is that YOU are at serious risk of suffering a very severe work-related injury every time you go to work. The good news is, you can change the odds. Your participation in this course is an excellent beginning. We now know that 72 percent of operator injuries are attributable to non-certified operators and that 72 percent of those who are injured are non-certified operators. So, while certification is no guarantee of good health, the statistics clearly suggest that certification in some way improves your chances.

MAJOR TYPES OF ACCIDENTS AND INJURIES

Three major types and causes of accidents accounted for 81 percent of all the injuries reported to the Water Pollution Control Federation

- ◆ 43.4% sprains and strains resulting either from lifting, pulling or pushing objects, awkward position or sudden twist, or slips are the leading causes of accidents reported.

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- ◆ 23.8% struck by objects either stationary, moving, sharp, falling, or flying.
- ◆ 14.2% falling either to different levels from platforms, ladders, or stairs or on the same surface.

The parts of the collection system operator's body that are frequently injured are the back, hands and legs

- ◆ 27.0% of the accidents are back injuries which lead the category of most common parts of the body injured.,
- ◆ 13.2% are hand injuries, and
- ◆ 12.9% are leg injuries, which is consistent with national trends by industrial workers.

In spite of the poor safety record of the collection system industry, 63.3 percent of the agencies reporting had a formal safety program. However, based on the numbers above, the safety programs obviously are not always effective. If you are currently working in the wastewater industry, you can expect at least a one-in-ten chance of experiencing a disabling injury.

In summary, it should be readily apparent at this time just how important safety/survival is to every collection system operator. It should be obvious to you that the operator is the person who is most frequently exposed through everyday work assignments and has the greatest to lose in terms of injury or death. Therefore, operators should share a larger portion of the responsibility for developing effective safety/ survival practices when performing these work assignments. A comprehensive Safety/ Survival Program greatly increases operator involvement and minimizes risks to the operators in the field. The remainder of this chapter will ad-

Safety/Survival Program Benefits

dress the operator's role in a safety/survival program, and will provide an overview of how an effective safety program operates. This information should provide you with the tools to initiate a program or to strengthen an existing program, since it forms the basis for the first of the three factors required for safety, awareness through knowledge.

Industry and government experiences repeatedly show strong evidence that the human and economic benefits of accident prevention far outweigh the investment in training and protective devices necessary for a sound safety/survival program. Personal injuries and economic factors such as work interruptions and output delays are two of the primary considerations.

Humanitarian

First and foremost, the greatest return in a safety/survival program is the prevention of human suffering, either in the form of permanent disability or even death .

Economic

Although it may not be readily apparent, the economic savings resulting from an effective safety/survival program are enormous. An accident is evidence of inefficiency that affects both the quality and quantity of productive effort. Costs associated with lost work output, damaged equipment and material, higher insurance premiums, employee morale, the loss of experienced operators, and the training of new operators are all related economic factors. The direct economic loss to you and/or your family in the case of permanent disability or death is even more significant. It is apparent, too, that your responsibility to taxpayers is an economic factor since a higher cost for the services you perform will have to be passed on to them.

Your safety and that of your colleagues should be the first consideration in the performance of your

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duties and assigned tasks in the collection system. The basis for your program should be:

Establishing a Safety/Survival Program

Typically, the structure within an agency for a safety program consists of the following levels:

- ◆ Administration Department which states, “We will have a safety program”;
- ◆ Safety Department which says, “We will help with the resources”; and
- ◆ Safety Committee which is “where the corrective action is”

Depending on the size of your operation, there may be some additional levels of safety/survival activity in between these levels, but this basically describes a typical structure. Perhaps a little more difficult, however, is the definition of the responsibilities in each of these areas.

Safety/Survival Program Responsibilities Top Administration

(Top administration could be the mayor, city council members, agency directors, or other top management personnel involved with policy making aspect of your agency.)

- ◆ They bear the overall responsibility for promoting the concept of an effective safety/survival program.
- ◆ They approve policies and procedures that are developed through cooperative efforts at other levels.
- ◆ They require, as a condition of employment, that all personnel learn and follow safety procedures and policies.

- ◆ They are responsible for ensuring adequate budget resources in terms of equipment, personnel, or other issues related to the funding and the support of your safety/survival program.
- ◆ They monitor the effectiveness of the program and communicate with regulatory agencies as required.

Safety Department Staff

- ◆ They coordinate and distribute rules and regulations.
- ◆ They provide safety program resources
- ◆ They provide some form of facility safety inspections.
- ◆ They provide support for training and programs which might include audio-visual, equipment and materials, books, or other resources.
- ◆ They conduct ongoing evaluation of safety procedures with revisions as required based on recommendations and discussions with personnel at the operating level (the Safety Committee).
- ◆ Manager, Supervisor, Field Personnel

This is the final level of responsibility, those actually involved in the day-to-day operation of the collection system. As stated earlier, this is where all the action is and rightfully so, since this is where all of the expertise should be in terms of safety and survival. After all, we should be the ones who are most knowledgeable about how to safely perform our work and should not wait for somebody at the administrative level to tell us how they think it should be done.

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Supervisors and managers who are involved in everyday operations are critical to the success of collection system operations, they are responsible for the safety/survival program.

- ◆ They must be aware of safety rules and regulations that apply to each task.
- ◆ They are responsible for the safety of other personnel who work in or pass through their area of supervision.
- ◆ They are responsible for new employee orientation.
- ◆ They are responsible for job safety instruction and safety training within their area.
- ◆ They are responsible for identifying unsafe practices and conditions as well as taking adequate action to correct those within their authority.
- ◆ They should investigate injury-producing accidents and property damage accidents within their area of supervision
- ◆ They must make a firm commitment to a safety/survival program in order to develop appropriate safety attitudes in personnel. Obviously, education, personal examples, and active participation in the program are essential to its success.
- ◆ They are responsible for promoting and enforcing the use of recommended personal protective equipment. They may be given fines and/or prison sentences if found negligent in any of the above areas that contributed to a fatal accident.

Field personnel are obviously the major factor in the success or failure of your program which will be measured by injuries, possible disability or death. The responsibilities of the operators in the field include:

- ◆ They are RESPONSIBLE for learning and following all safety procedures and policies.

- ◆ They must be willing to make a COMMITMENT to the safety/survival program and assume the RESPONSIBILITY to make the program a part of the daily routine. (Once again, it is in our best interest to make the program work since we are the ones who are normally involved in the injuries, disabilities, and fatalities.

Even if the other two levels in the safety program are not effective, you can have a major impact on the success of the program by participating at your level. Draw on your field experience to help develop or modify procedures and policies through an active safety committee. Encourage others at all levels to participate with you.

Disciplinary action can be an effective tool, if required, in maintaining safety policies and procedures. Note: No one should be expected to work with another operator who endangers their safety. Report dangerous field incidents to your immediate supervisor in writing. If you are placed in this type of situation, do not feel intimidated about reporting it.

Operators must also participate in developing their own formal safety program which would include monthly meetings, a safety committee, and weekly tailgate sessions.

Tailgate sessions are short (ten minutes plus or minus) discussions that help focus on safety/sur-

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vival as part of everyday, routine, collection system operator tasks. Topics can be specific to the job or related to home safety and seasonal events such as holidays. Virtually any topic that relates to safe practices will help inform operators and raise their level of awareness about safety.

Safety Committee

An active committee with operating personnel is another extremely effective tool in developing your safety/survival program. Depending on the nature of your organization, it could be comprised of the following:

Representatives from each area of the collection system such as office personnel, electrical/mechanical maintenance, and operators.

Representatives from other operating departments within your agency if you don't have a large enough collection system staff. Street, water, parks or other areas share many of the same safety/survival problems. Set up subcommittees to identify specific issues; for example, an equipment subcommittee might review and make recommendations on improving safety-related issues with the various equipment used. A policy/procedure subcommittee could also be established and would participate in developing/revising policy and procedures.

Members of the committee may be responsible for establishing a monthly program, which would include developing the resources. The resource personnel could be from your safety department or from an outside source, depending on the topic.

The Safety Committee reviews, analyzes and determines how each accident occurred and why. The Committee must recommend training procedures and distribute information to other workers to prevent similar accidents. If the injured worker

was not paying attention or just plain careless, then better tailgate safety meetings are needed. If the accident resulted from an unsafe act, use of the wrong tool, or improper use of a piece of equipment, then training procedures need to be changed to correct the safety hazard. If new equipment or training aids are needed, the Safety Committee must identify these needs, justify them to the safety officer and management, acquire the necessary equipment and aids, and implement their use. The Safety Committee must consist of expert workers who know and can justify what is needed and not just request “stuff” and “things” because it sounds like a good idea.

Safety/Survival Program Policies

Safety policies are established to ensure that all operators understand and follow safe procedures at all times. The policies included here are typical examples of policies which should exist in your agency. These may not meet your local or state requirements, but can be used as a starting point to help you define your agency’s policies. A good policy statement will clearly define the conditions under which it applies, the behaviors required of employees, and the penalty for failure to comply with the policy.

CONFINED SPACE POLICY

The purpose of this policy is to establish guidelines for personnel engaging in work that would require entry into structures, including those under construction, that fall under the definition of confined space.

The definition of a confined space used for this policy is: “A space which by design has limited openings for entry and exit; and/or natural ventilation which could contain or produce unfavorable atmospheric conditions; and is not intended or designed for continuous employee occupancy.”

The types of confined spaces typically encountered

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in our work include, but are not necessarily limited to, sewer manholes, sewer lines, junction structures, valve vaults, metering vaults, pumping station wet wells, storage tanks, pits and silos.

All confined space work shall be performed with strict adherence to the "Confined Space Work Procedure." No one shall perform or order to be performed any work contrary to this procedure.

Failure to comply with this policy will result in disciplinary action.

LOCKOUT POLICY

The purpose of this policy is to establish guidelines for personnel required to work on machinery or equipment in facilities owned and operated by this agency.

The definition of "work" on machinery or equipment used for this policy is: "maintenance, inspection, cleaning, adjusting, servicing, or clearing of blocked or jammed machinery or equipment."

All work shall be performed in strict adherence to the "Lock-Out Procedure." No one shall perform or order to be performed any work contrary to this procedure.

Failure to comply with this policy will result in disciplinary action.

EYE PROTECTION POLICY

The purpose of this policy is to establish guidelines for the wearing of eye protection devices.

All employees shall wear proper eye protection devices when working in any facility capable of producing eye injury, including those under construction where the environment may contain

physical and/or chemical agents or radiation.

Proper eye protection devices shall consist of, but not necessarily be limited to the following: safety glasses with side shields, splash goggles, face shields, welding helmets and welding goggles, all of a type specifically approved by the Safety Officer. Contact lenses are allowed in office areas only, unless written approval is obtained from the Safety Officer.

All work performed shall be performed in strict adherence to the "Eye Protection Procedure." No one shall perform or order to be performed any work contrary to this procedure.

Failure to comply with this policy will result in disciplinary action.

SAFETY VEST POLICY

The purpose of this policy is to establish guidelines for the wearing of safety vests (warning vests).

All employees working on or within ten (10) feet of a roadway traveled by motorized vehicles shall be provided with and required to wear warning vests of high visibility. Warning vests will be bright orange in color with reflectorized material attached thereon, as approved by the Safety Officer.

The definition of a roadway used for this policy is: "That portion of a highway improved, designed or ordinarily used by vehicular traffic." The following areas shall be considered to fall under the classification of a roadway: freeways, highways, state roads, county roads, township roads, secondary roads, streets, alleys, drives, avenues, parkways or on the shoulders or berms, or on the median adjacent to roadways.

All work shall be performed in strict adherence to the "Safety Vest Policy." No one shall perform or

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order to be performed any work contrary to this policy.

Failure to comply with this policy will result in disciplinary action.

HARD HAT POLICY

The purpose of this policy is to establish guidelines for the wearing of hard hats.

All employees working on or in any agency facility, including those under construction, will be provided with and shall be required to wear a hard hat at all times. All hard hats shall be of a type specifically approved by the Safety Officer. Exceptions to this policy may be granted only by the supervisor, provided this exclusion has been reviewed and approved by the Safety Officer. (Note: Bump caps shall not be considered a substitute for hard hats.)

The possession and care of hard hats is the responsibility of each employee. Any defective or damaged hard hat shall be taken out of service immediately. The altering of hard hats in any way, manner, or form is strictly prohibited.

All work shall be performed in strict adherence to the "Hard Hat Policy." No one shall perform or order to be performed any work contrary to this policy.

Failure to comply with this policy will result in disciplinary action.

SEAT BELT POLICY

The purpose of this policy is to establish guidelines for the wearing of seat belts

All employees occupying any agency vehicle, while in motion at speeds greater than 5 miles-per hour, shall wear both the lap and shoulder safety

devices at all times. (Note: Gas or electric carts, intended for in-plant use only, are excepted from this policy.)

All vehicles that have defective or otherwise inoperative safety belt devices shall be removed from service until the deficiency has been corrected.

Failure to comply with this policy will result in disciplinary action.

The above are examples of policies that are typically found in an agency. There are many additional regulations enforced by Minnesota OSHA that should be covered by each agencies policies as well.

This section is intended to provide you with an overview of safety and is not intended to cover the mandatory training requirements established by OSHA.

Records

Unfortunately accidents do happen in spite of all of our efforts. To prevent similar accidents from happening in the future, an "Accident Report" should be completed as soon as possible after an accident.

