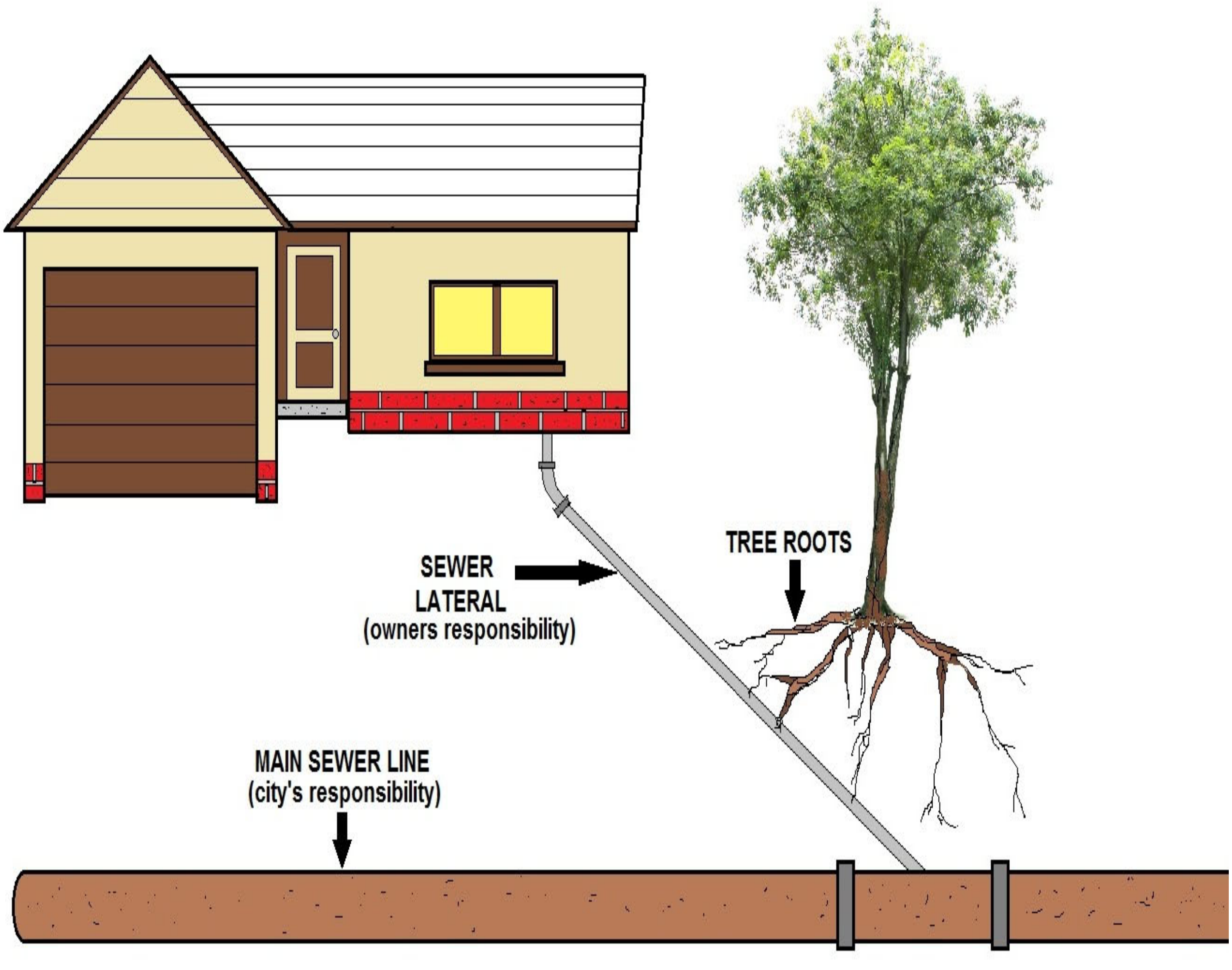
COLLECTIONS
OPERATION AND MAINTENANCE
PROFESSIONAL DEVELOPMENT
CONTINUING EDUCATION COURSE



SEWER LATERAL

Technical Learning College

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TLC recommends that you download and save this pdf document and assignment to your computer desktop and open it with Adobe Acrobat DC reader.

Adobe Acrobat DC reader is a free computer software program and you can find it at Adobe Acrobat's website.

You can complete the course by viewing the course on your computer or you can print it out. This course booklet does not have the assignment (the test). Please visit our website and download the assignment (the test).

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Internet Link to Assignment…
http://www.abctlc.com/downloads/PDF/CollectionOandMASS.pdf

State Approval Listing Link, check to see if your State accepts or has pre-approved this course. Not all States are listed. Not all courses are listed. Do not solely trust our list for it may be outdated. It is your sole responsibility to ensure this course is accepted for credit. No refunds.

Professional Engineers; Most states will accept our courses for credit but we do not officially list the States or Agencies acceptance or approvals.

State Approval Listing URL…
http://www.abctlc.com/downloads/PDF/CEU%20State%20Approvals.pdf

You can obtain a printed version from TLC for an additional $149.95 plus shipping charges.

All downloads are electronically tracked and monitored for security purposes.

Some States and many employers require the final exam to be proctored.

Do not solely depend on TLC's Approval list for it may be outdated.

A second certificate of completion for a second State Agency $50 processing fee.

Most of our students prefer to do the assignment in Word and e-mail or fax the assignment back to us. We also teach this course in a conventional hands-on class. Call us and schedule a class today.

Responsibility

This course contains EPA's federal rule requirements. Please be aware that each state implements wastewater collections /safety regulations that may be more stringent than EPA's or OSHA's regulations. Check with your state environmental agency for more information. You are solely responsible in ensuring that you abide with your jurisdiction or agency's rules and regulations.

Important Information about this Manual

This manual has been prepared to educate employees in the general awareness of dealing with complex wastewater collection procedures and requirements for safely handling hazardous and toxic materials. The scope of the problem is quite large, requiring a major effort to bring it under control. Employee health and safety, as well as that of the public, depend upon careful application of safe sewer collection procedures.

This manual will cover general laws, regulations, required procedures and generally accepted policies relating to wastewater collection systems. It should be noted, however, that the regulation of wastewater and other hazardous materials is an ongoing process and subject to change over time. For this reason, a list of resources is provided to assist in obtaining the most up-to-date information on various subjects.

This manual is not a guidance document for employees who are involved with pollution control or wastewater treatment. It is not designed to meet the requirements of the United States Environmental Protection Agency (EPA) or Department of Labor-Occupational Safety and Health Administration (OSHA) or state environmental or health departments.

This course manual will provide general educational training guidance of Wastewater Collection. This document is not a detailed wastewater collection or treatment textbook or a comprehensive source book on occupational safety and health.

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It cannot be assumed that this manual contains all measures and concepts required for specific conditions or circumstances. This document should be used for educational guidance and is not considered a legal document.

Individuals who are responsible for the collection of wastewater or the health and safety of workers at wastewater sewer facilities should obtain and comply with the most recent federal, state, and local regulations relevant to these sites and are urged to consult with OSHA, EPA, and other appropriate federal, state, health, and local agencies.

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Technical Learning College's Scope and Function

Welcome to the Program,

Technical Learning College (TLC) offers affordable continuing education for today's working professionals who need to maintain licenses or certifications. TLC holds several different governmental agency approvals for granting of continuing education credit.

TLC's delivery method of continuing education can include traditional types of classroom lectures and distance-based courses or independent study. TLC's distance based or independent study courses are offered in a print - based distance educational format. We will beat any other training competitor's price for the same CEU material or classroom training.

Our courses are designed to be flexible and for you to finish the material at your convenience. Students can also receive course materials through the mail. The CEU course or e-manual will contain all your lessons, activities and instruction to obtain the assignments. All of TLC's CEU courses allow students to submit assignments using e-mail or fax, or by postal mail. (See the course description for more information.)

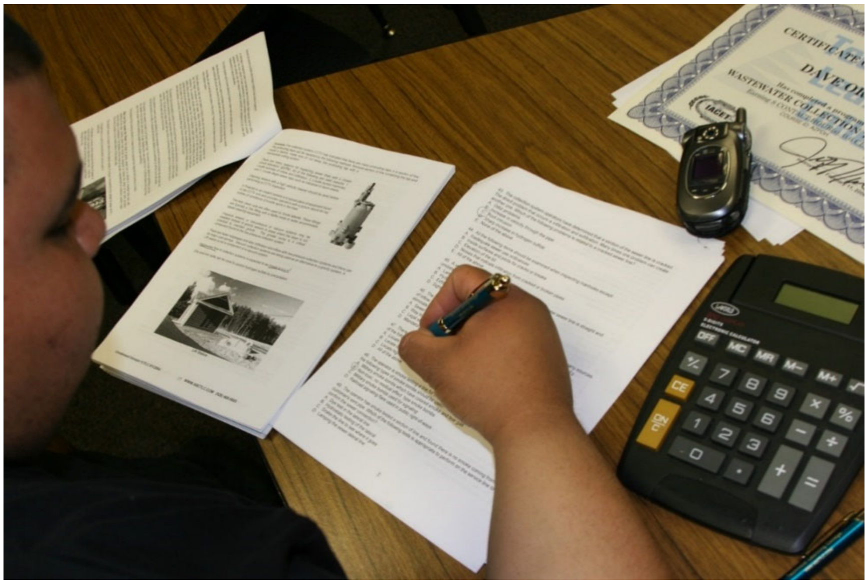
Students have direct contact with their instructor—primarily by e-mail or telephone. TLC's CEU courses may use such technologies as the World Wide Web, e-mail, CD-ROMs, videotapes and hard copies. (See the course description.) Make sure you have access to the necessary equipment before enrolling; i.e., printer, Microsoft Word and/or Adobe Acrobat Reader. Some courses may require proctored closed-book exams, depending upon your state or employer requirements.

Flexible Learning
At TLC, there are no scheduled online sessions or passwords you need contend with, nor are you required to participate in learning teams or groups designed for the "typical" younger campus based student. You will work at your own pace, completing assignments in time frames that work best for you. TLC's method of flexible individualized instruction is designed to provide each student the guidance and support needed for successful course completion.

Course Structure
TLC's online courses combine the best of online delivery and traditional university textbooks. You can easily find the course syllabus, course content, assignments, and the post-exam (Assignment). This student-friendly course design allows you the most flexibility in choosing when and where you will study.

Classroom of One
TLC offers you the best of both worlds. You learn on your own terms, on your own time, but you are never on your own. Once enrolled, you will be assigned a personal Student Service Representative who works with you on an individualized basis throughout your program of study. Course specific faculty members (S.M.E.) are assigned at the beginning of each course providing the academic support you need to successfully complete each course. Please call or email us for assistance.

Satisfaction Guaranteed
We have many years of experience, dealing with thousands of students. We assure you, our customer satisfaction is second to none. This is one reason we have taught more than 40,000 students.



We welcome you to do the electronic version of the assignment and submit the answer key and registration to us either by fax or e-mail.

If you need this assignment graded and a certificate of completion within a 48-hour turn around, prepare to pay an additional rush charge of $50.

Contact Numbers
Fax (928) 468-0675
Email Info@tlch2o.com
Telephone (866) 557-1746

CEU Course Description

Collections Operation and Maintenance CEU Training Course

This course will cover the basic collection system maintenance issues, dye testing, smoke testing, camera inspection, hydraulic and mechanical cleaning procedure and basic lift station maintenance. Proper function of sanitary sewer systems is vital to protect public health, property, and waterways in the surrounding area. Most utilities have a management, operation and maintenance (MOM) plan to ensure their system is in working order.

This CEU course is designed for the continuing education, knowledge, and enhancement of Wastewater Collection system Operators, Pretreatment/Industrial Wastewater Operators and Wastewater Treatment Operators. The target audience for this course is the person interested in working in a wastewater treatment or collections facility and/or wishing to maintain CEUs for certification license or to learn how to do the job safely and effectively, and/or to meet education needs for promotion. This is not a comprehensive wastewater treatment or collections manual.

This CEU training course will review various wastewater collection methods, related construction and confined space subjects. This course is general in nature and not state specific but will contain different wastewater collection methods, rules, policies, electricity, pump, safety, operator certification and lift station information. This information is essential to properly operate any wastewater collection system. You will not need any other materials for this course.

Final Examination for Credit
Opportunity to pass the final comprehensive examination is limited to three attempts per course enrollment.

Upon Successful Completion of this Course, You Will Receive

- 8 Continuing Education Unit/eight contact training hours. Check the state approval listing for more information or check with your state agency for approval.
- A frameable certificate of competition.

Course Procedures for Registration and Support
All of Technical Learning College's distance learning courses have complete registration and support services offered. Delivery of services will include; e-mail, web site, telephone, fax, and mail support. TLC will attempt immediate and prompt service.

When a student registers for a correspondence course, he/she is assigned a start date and an end date. It is the student's responsibility to note dates for assignments and keep up with the course work.

If a student falls behind, he/she must contact TLC and request an end date extension in order to complete the course. It is the prerogative of TLC to decide whether to grant the request. All students will be tracked by a unique number assigned to the student.

Instructions for Written Assignments
The *Collections Operation and Maintenance* CEU Training course uses a multiple choice style answer key. You can write your answers in this manual or type out your own answer key. TLC would prefer that you fill out and fax, or e-mail the final examinations to TLC, but it is not required.

Feedback Mechanism (examination procedures)
Each student will receive a feedback form as part of their study packet. You will be able to find this form in the front of the course assignment or lesson.

Security and Integrity
All students are required to do their own work. All lesson sheets and final exams are not returned to the student to discourage sharing of answers. Any fraud or deceit and the student will forfeit all fees and the appropriate agency will be notified.

Grading Criteria
TLC will offer the student either pass/fail or a standard letter grading assignment. If TLC is not notified, you will only receive a pass/fail notice.

Required Texts
The *Collections Operation and Maintenance* CEU training course will not require any other materials. This course comes complete. No other materials are needed.

Environmental Terms, Abbreviations, and Acronyms
TLC provides a glossary that defines, in non-technical language, commonly used environmental terms appearing in publications and materials. It also explains abbreviations and acronyms used throughout EPA and other agencies. You can find the glossary in the rear of the manual.

Recordkeeping and Reporting Practices
TLC will keep all student records for a minimum of seven years. It is your responsibility to give the completion certificate to the appropriate agencies. TLC will mail a copy to any State that requires a copy from the Training Provider.

ADA Compliance
TLC will make reasonable accommodations for persons with documented disabilities. Students should notify TLC and their instructors of any special needs. Course content may vary from this outline to meet the needs of this particular group.

Prerequisites: None

Note to Students
Keep a copy of everything that you submit. If your work is lost you can submit your copy for grading. If you do not receive your certificate of completion or quiz results within two or three weeks after submitting it, please contact your instructor. We expect every student to produce his/her original, independent work.

Any student whose work indicates a violation of the Academic Misconduct Policy (cheating, plagiarism) can expect penalties as specified in the Student Handbook, which is available through Student Services; contact them at (928) 468-0665. A student who registers for a Distance Learning course is assigned a **"start date"** and an **"end date."**

It is the student's responsibility to note due dates for assignments and to keep up with the course work. If a student falls behind, she/he must contact the instructor and request an extension of her/his ***end date*** in order to complete the course. It is the prerogative of the instructor to decide whether or not to grant the request.

Continuing Education Units
You will have 90 days from receipt of this manual to complete it in order to receive your Continuing Education Units (**CEUs**) or Professional Development Hours (**PDHs**). A score of 70% is necessary to pass this course. If you should need any assistance, please visit our Assistance Page on the website. Please e-mail all concerns and the final test to info@tlch2o.com.

Educational Mission
The educational mission of TLC is:

To provide TLC students with comprehensive and ongoing training in the theory and skills needed for the environmental education field,

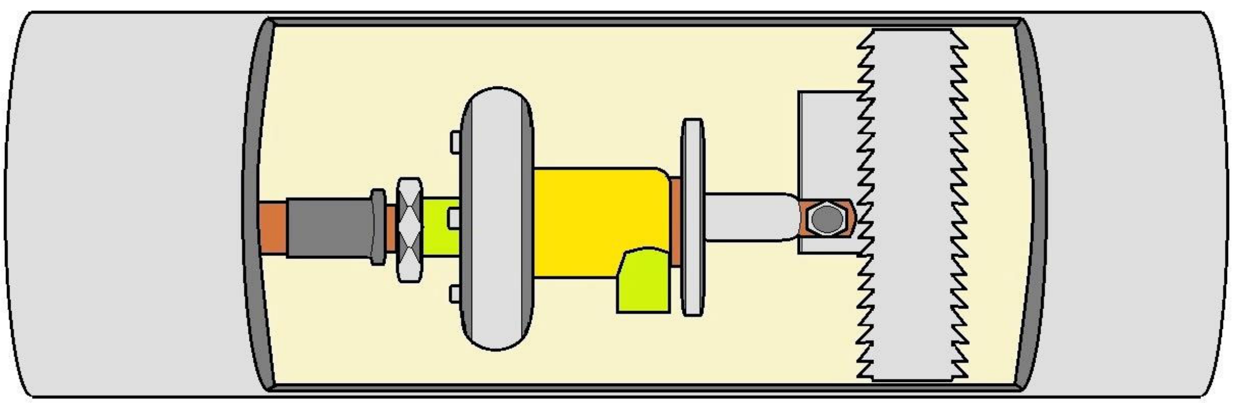
To provide TLC students with opportunities to apply and understand the theory and skills needed for operator certification,

To provide opportunities for TLC students to learn and practice environmental educational skills with members of the community for the purpose of sharing diverse perspectives and experience,

To provide a forum in which students can exchange experiences and ideas related to environmental education,

To provide a forum for the collection and dissemination of current information related to environmental education, and to maintain an environment that nurtures academic and personal growth.

Course Objective: To provide eight contact hours of continuing education training in effective and efficient wastewater collection inspection methods, cleaning, and general maintenance concerns.



ROOT CUTTER FOR SEWER LINE

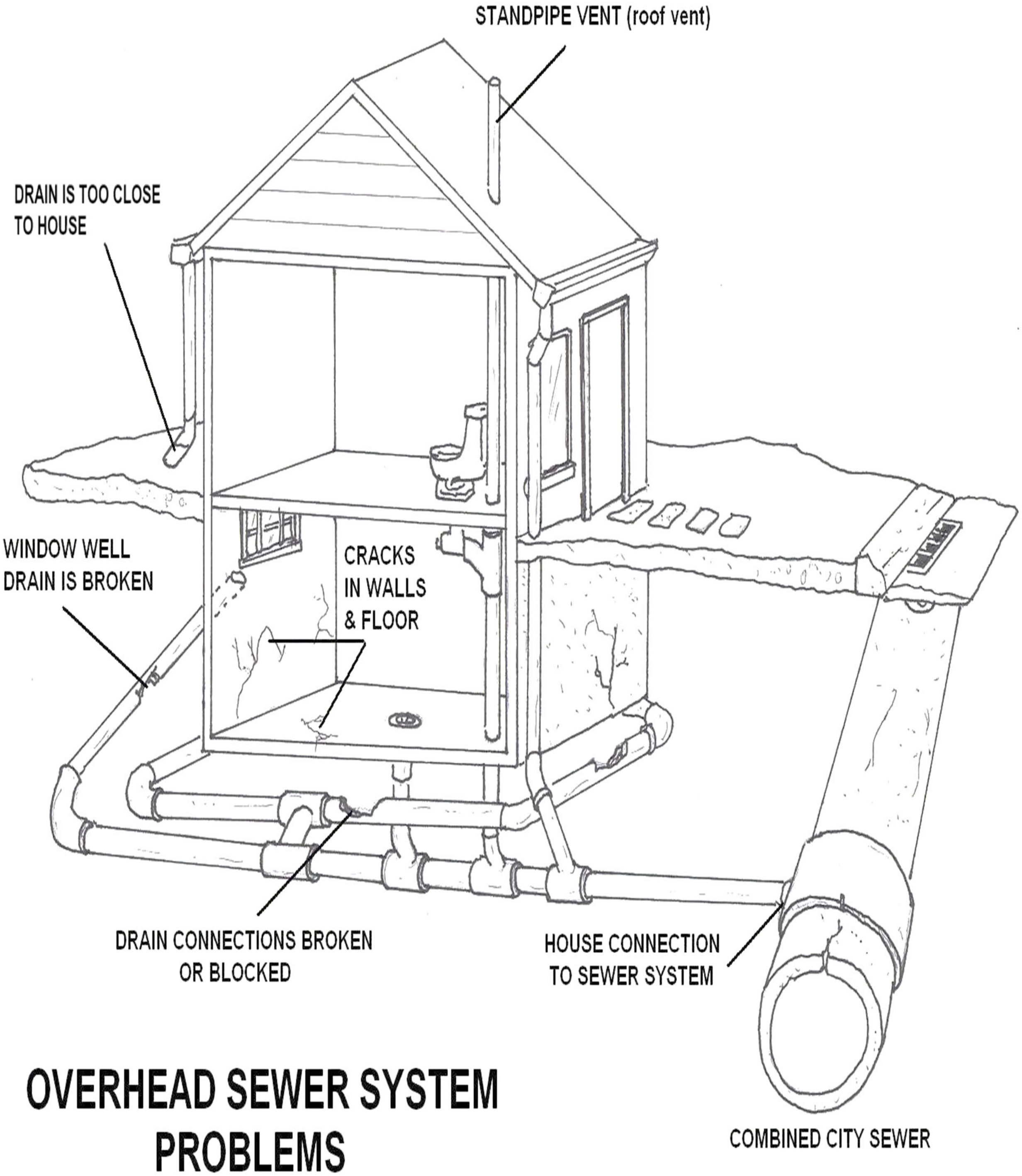

STANDPIPE VENT (roof vent)
DRAIN IS TOO CLOSE TO HOUSE
WINDOW WELL DRAIN IS BROKEN
CRACKS IN WALLS & FLOOR
DRAIN CONNECTIONS BROKEN OR BLOCKED
HOUSE CONNECTION TO SEWER SYSTEM
OVERHEAD SEWER SYSTEM PROBLEMS
COMBINED CITY SEWER

TABLE OF CONTENTS

Hyperlink to the Glossary and Appendix
http://www.abctlc.com/downloads/PDF/WWTGlossary.pdf

Topic Legend

This CEU course covers several educational topics/functions/purposes of conventional wastewater collection operations. The topics listed below are to assist in determining which educational area is covered in a specific topic area:

CO: Having to do with the wastewater collections system. Could be regular or emergency work. This is O&M training for collection operators.

CRAO: The regulatory and compliance component. May be a requirement of the NPDES or discharge permit, compliance, non-compliance, process control and local limits. This along with the EPA information is to satisfy the regulatory portion of your operator training.

ELECTRICAL (SPARK): This section has to do with electrical principles and difficult math calculations. Maybe good for credit for those who hold an electrician or instrumentation certification. This may be considered O&M training for many operators.

FLUID MECHANICS (FM): Having to do with hydraulic or fluid mechanics. A highly technical and specialized engineering field. This may be considered O&M training for many operators or credit for pump engineers or pump mechanics.

MOTOR: Having to do with the electrical-mechanical portion of moving water. This may be considered O&M training for many operators. Maybe good for credit for those who hold an electrician or instrumentation certification.

O&M: This area is for normal operation and/or maintenance of the plant or sewer collection system. O&M training for many operators.

PUMP ENGINEERING (PE): The technical science of pumping and pump performance principles. May be a law or theory or calculation related to pumping. Information that a pump engineer or collection operator may need.

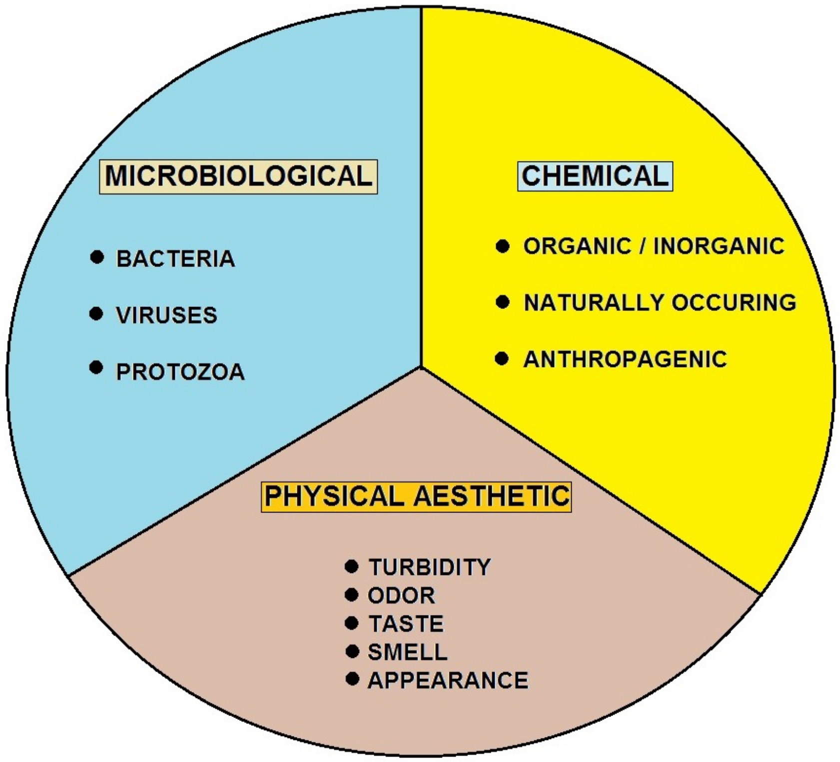
SAFETY: This area is describing process safety procedures. Safety or general training for many operators.

SCADA: Having to do with data acquisition and control methods. Remote operation of pumps and motors from a distant location or cell phone. Maybe good for credit for those who hold an electrician or instrumentation certification.

SCIENCE (SCI): Having to do with scientific principles, laws or theories. A principle that can be observed or repeated in the Laborotory. May be good for laboratory or engineering credit.

TECHNICAL: The mechanical or physical treatment process/component. O&M training for many operators.

WQ: Having to do with water quality or pollutants. May be a requirement of your NPDES or discharge permit. This along with the EPA information is to satisfy the regulatory portion of your operator training.



WATER QUALITY BROKEN DOWN INTO 3 BROAD CATEGORIES

Sewage and Pollution

Sewage contains nutrients of every type; phosphorus, nitrogen, sodium, potassium, iron, calcium and compounds such as fats, sugars and proteins. Microorganisms use these substances as a "food" source for energy, for the synthesis of cell components and to maintain life processes.

Many types of microorganisms can be found in the wastewater treatment system. However, the types of organisms that will dominate will be the ones that are best suited to the "environment" or conditions in the system. Wastewater treatment systems are designed to foster an "environment" that suits a certain type of microorganism. These microorganisms not only remove organic wastes from the water, but they also "settle out" as solid material for easy removal. Wastewater treatment operators are required to maintain the right conditions in the treatment system for the right type of microorganisms.

While there are many different microbes used in sewage treatment, there are three well-known microbes that play an instrumental role in keeping sewage clean. Each of these types of bacteria help the treatment process in a unique way to ensure there is little to no impact on the surrounding environment.

List of Collection Acronyms used in this Course

Acronym	Full Phrase
AA	Approval Authority
AO	Administrative Order
BAT	Best Available Technology Economically Achievable
BCT	Best Conventional Pollutant Control Technology
BMP	Best Management Practices
BMR	Baseline Monitoring Report
BOD5	5-day Biochemical Oxygen Demand
BPJ	Best Professional Judgment
BPT	Best Practicable Control Technology Currently Available
CA	Control Authority
CFR	Code of Federal Regulations
CIU	Categorical Industrial User
CSO	Combined Sewer Overflow
CWA	Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972) Pub. L. 92-500, as amended by Pub. L. 95-217, Pub. L. 95-576, Pub. L. 96-483, Pub. L. 97-117, and Pub. L. 100-4, 33 U.S.C. 1251 et seq.
CWF	Combined Wastestream Formula
CWT	Centralized Waste Treater
DMR	Discharge Monitoring Report
DSE	Domestic Sewage Exclusion
DSS	Domestic Sewage Study
ELG	Effluent Limitations Guideline
EPA	Environmental Protection Agency
EPCRA	Emergency Preparedness and Community Right to Know Act
ERP	Enforcement Response Plan
FDF	Fundamentally Different Factors
FR	Federal Register
FWA	Flow Weighted Average
GPD	Gallons per Day
IU	Industrial User
LEL	Lower Explosive Limit
MAHL	Maximum Allowable Headworks Loading
MAIL	Maximum Allowable Industrial Loading
MGD	Million Gallons per Day
MSDS	Material Safety Data Sheet
NAICS	North American Industry Classification System (replaces SIC 1998)
NOV	Notice of Violation
NPDES	National Pollutant Discharge Elimination System
NRDC	Natural Resources Defense Council
NSPS	New Source Performance Standard
O&G	Oil and Grease
O&M	Operations and Maintenance

OCPSF	Organic Chemicals, Plastics, and Synthetic Fibers
P2	Pollution Prevention
PCI	Pretreatment Compliance Inspection
PCS	Permit Compliance System
PIRT	Pretreatment Implementation Review Task Force
POTW	Publicly Owned Treatment Works
PSES	Pretreatment Standards for Existing Sources
PSNS	Pretreatment Standards for New Sources
QA/QC	Quality Assurance/Quality Control
RCRA	Resource Conservation and Recovery Act
SIC	Standard Industrial Classification
SIU	Significant Industrial User
SPCC	Spill Prevention Control and Countermeasures
SNC	Significant Noncompliance
SSO	Sanitary Sewer Overflow
SUO	Sewer Use Ordinance
TCLP	Toxicity Characteristic Leaching Procedure
TIE	Toxicity Identification Evaluation
TOMP	Toxic Organic Management Program
TRE	Toxicity Reduction Evaluation
TRI	Toxic Release Inventory
TSS	Total Suspended Solids
TTO	Total Toxic Organics
USC	United States Code
UST	Underground Storage Tank
WET	Whole Effluent Toxicity
WWTP	Wastewater Treatment Plant

Strange Stories from the Collections System

"City battles giant sewer blob" — this straight-out-of-science-fiction headline got us thinking about what goes on after we flush.

LEWISTON, Maine -- A large, mysterious blob has taken over a major sewer line in the city of Lewiston, leaving public works crews stumped as to how to budge it. According to city officials, the stretch of 12-inch pipe on Main Street backed up on Jan. 13, and the city has been trying unsuccessfully to clear the line ever since.

Deputy Public Services Director Kevin Gagne told News 8 the doughy, 90-foot mass is comprised of grease, flour and rags. Gagne said the city has chosen to replace the 170-foot line at a cost of between $40,000 and $60,000. Work is expected to begin this week.

Alligators

Search tells us that, for the most part, the idea that alligators live in city sewers is an urban legend. Homeowners concerned about the state of their own pipes search for sewer cleaning and sewer cameras, while vacationers seek sewer tourism and other forms of urban exploration. Forget about alligators and rats; raccoons rule several sewers.

Comments: Believe it or not there is a grain of truth behind this legend, namely the documented capture of an eight-foot alligator at the bottom of an East Harlem manhole in 1935, though no one assumed that it actually lived down there. It was theorized at the time that the creature must have tumbled off a steamer visiting the northeast "from the mysterious Everglades, or thereabouts," and swam up the Harlem River. It met an unfortunate end at the hands of the teenage boys who found it.

Birth of an urban legend

The earliest published reference to alligators in the sewer -- in what Jan Harold Brunvand refers to as the "standardized" form of the urban legend ("baby alligator pets, flushed, thrived in sewers") -- can be found in the 1959 book, *The World Beneath the City*, a history of public utilities in New York City written by Robert Daley. Daley's source was a retired sewer official named Teddy May, who claimed that during his tenure in the 1930s he personally investigated workers' reports of subterranean saurians and saw a colony of them with his own eyes. He also claimed to have supervised their eradication. May was a colorful storyteller, if not a particularly reliable one.

'New York White'

The tale was well known throughout the United States by the late 1960s, when, according to folklorist Richard M. Dorson, it came to be associated with another icon of sewer lore, the mythical "New York White" -- an especially potent, albino strain of marijuana growing wild from seeds spilled out of baggies hastily flushed down toilets during drug raids. Not that anyone had ever actually seen the stuff, much less smoked it. It was impossible to harvest, you see, because of all the alligators down there.

The reason we speak of all this as folklore, not fact, is that herpetologists pooh-pooh the very idea of alligators thriving in the New York City sewer system. It's cold down there most of the time, they point out -- freezing cold during the winter -- and alligators require a warm environment year-round to survive, much less reproduce and burgeon into colonies. And if the cold didn't kill them off, the polluted sewer water certainly would.

Actual New York City gator sightings:

Adding fodder to the legend is the intriguing fact that wayward alligators -- escaped or abandoned pets, we assume -- do occasionally turn up in the streets of New York City, never failing to cause a ruckus.

For example:

November 2006 - A two-foot-long caiman is captured outside an apartment building in Brooklyn. Police say it "snapped and hissed" at them.

June 2001 - A small alligator (actually a caiman, as it turned out) was spotted and eventually captured in Central Park.

The experts speak:

"I would bring leftovers from lunch, a long line and a hook, and spend a part of each day in the sewers looking for alligators. I saw rats, cockroaches — probably caught a lot of sicknesses — but I never saw anything like an alligator."

— *Frank Indiviglio, herpetologist*

"It’s like the Loch Ness Monster or the Big Foot. People believe in those stories up to a point that it does make sense."

— *Esteban Rodriguez, NYC sewer worker*

Wastewater Collection Pre-Quiz *Answers are at the end of Quiz*.

1. Your collection system requires a new sewer main line. Who would be the best source of information for instructions on how to lay and join new sewer pipes?
A. Manufacturer
B. A local plumbing contractor
C. Utility inspector
D. Grading and drainage inspector

2. In many sewer installations, low pressure air testing is necessary to determine the tightness of the pipe. In instances where ground water levels are higher that the sewer lines, the new pipes are usually tested around_______ to _______ psi above any outside water pressure on the pipe.
A. 3, 5
B. 7, 10
C. 10, 14
D. 15, 22

3. A good manager will establish a good record-keeping system to help in analyzing many problems that occur. Records such as outside services versus in-house personnel costs could result in saving money by hiring personnel to handle jobs typically farmed out. For the purposes of budgeting and justifying the costs the manager will:
A. Present all bills to the board
B. Hide the excessive costs in other lines of the budget
C. Beg for budget increases by verbal communication only
D. Plot the costs to ease understanding the need for personnel
E. None of the above, at least at my yard

4. Managers and supervisors maintain a personnel file on each employee. These files contain information about the employee. Which of the following should not be found in the employee file?
A. Accident reports
B. Budget requirement to justifying employee hiring
C. Attendance analysis
D. Performance evaluations

5. Sewer lines made of __________ types of pipe should be tested with a mandrel to measure for ___________ and joint offsets.
A. flexible, deflection
B. ductile iron, tightness
C. clay, stress cracks
D. cement, thickness

6. What is the one most important reason for having a wastewater collection system?
A. Prevent disease
B. Keep the waste out of sight
C. To allow for gravity feed
D. To alleviate the foul smell
E. Both C & D

7. Many public agencies are having a difficult time stretching their financial resources to meet all the demands they face from both internal and external sources. What is the best thing a collection system operator can do to help in meeting these challenges?
A. Provide good collection system maintenance, operation, and inspection
B. Agree to work only 4 hours of overtime a week
C. Donate unused vacation and sick time back to the utility
D. None of the above

8. An operator should have a good understanding of the terms used in wastewater collection systems. What description best explains the term "*combined wastewater*"?
A. A mixture of surface runoff and industrial wastewater
B. A mix of domestic wastewater and storm water
C. A blend of domestic and industrial wastewater
D. Both A and B
E. None of the above

9. A term used often in a collection system is the term "*grade ring*". What best describes a grade ring as used in the collection system?
A. The bell end of the pipe that must be placed down slope
B. A precast concrete ring of various heights to raise the manhole cover
C. A surveyors tool used to mark grade along the trench
D. None of the above

10. Two words are used to describe a collection system; they are the words '*sanitary*' and '*wastewater*'. Which is the correct definition of the term *'sanitary collection system'*?
A. The pipe system prior to being used
B. The combination of domestic and industrial waste
C. A collection system used only for storm water
D. A collection system used only for domestic waste

11. Ideally wastewater collection systems are designed and constructed to provide a minimum velocity of _____ ft per second to ensure the waste in maintained in suspension.
A. 4.32
B. 6.20
C. 2.00
D. 8.25

12. A ball is traveling down a 12 inch sewer line and you see it at your manhole at 1:52:00 p.m. Your partner, at the next manhole 350 feet away, said the ball went past her at 1:55:02 p.m. The estimated surface velocity in the sewer is:
A. 9.65 ft/sec
B. 1.9 ft/sec
C. 116.7 ft/sec
D. 3.97 ft/sec

13. Which of the following types of pipe materials would not be suitable for use in a wastewater collection system?
A. Asbestos cement pipe
B. Uncoated black iron pipe
C. Polyethylene

14. Channel corrections are usually required for___________ and _____________ in older manholes to reduce the causes of turbulent flows and restrictions to flow in the incoming lines.
A. Tee intersections, basin channels
B. Wye channels, ell turns
C. Lateral flows, sweeping turns
D. Flat bottoms, low steps

15. The coefficient value used to represent the channel or pipe roughness in Manning's formula for computing flows in gravity sewers is called the:
A. "R" factor
B. "N" factor
C. Abrasion value
D. Both A and B

16. The type of waste that can generally be consumed by bacteria and other small organisms is called:
A. Microbes
B. Organic waste
C. Inorganic waste
D. Mineral waste
E. None of the above

17. What is the name given to a chamber, connected to the flow in the main channel by a small inlet, where the liquid level is measured to determine the flow in the main channel?
A. Flow meter
B. Measuring well
C. Stilling well
D. Venturi chamber

18. The primary purpose of lubrication in the maintenance of equipment is to reduce the _________ and _________ between two surfaces.
A. Galling, bonding
B. Wear, tear
C. Friction, heat
D. Roughness, friction

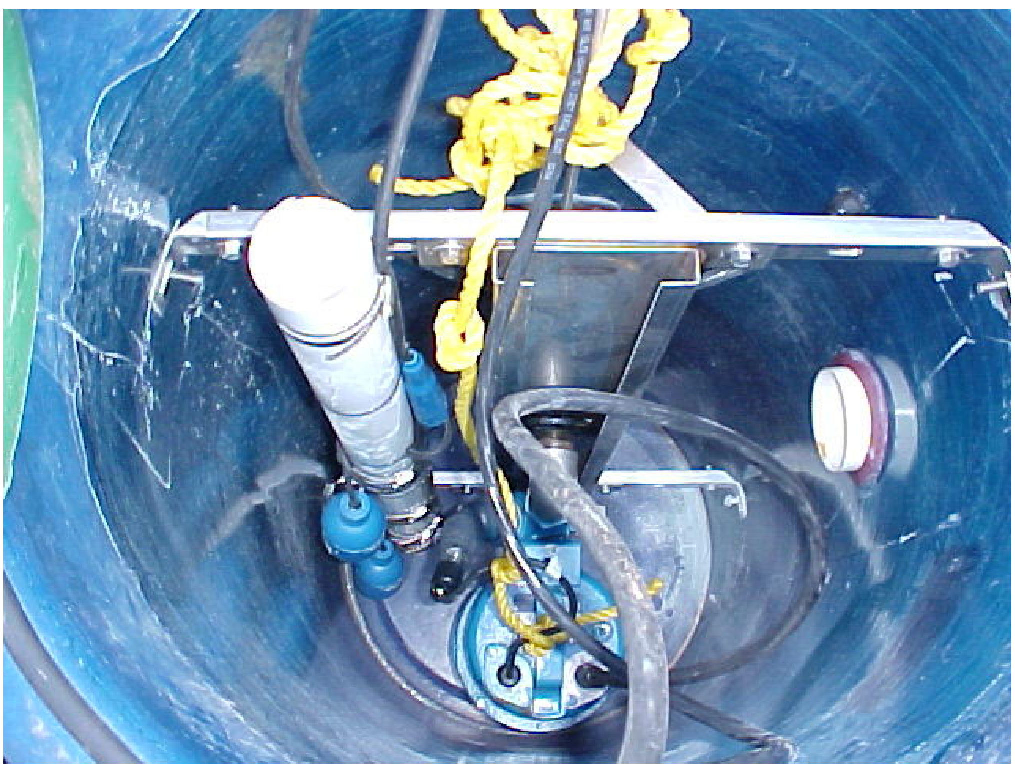
19. One important point to remember when using a portable centrifugal trash pump is to:
A. Always locate the pump as close as possible to the water surface being pumped.
B. Always locate the pump as close as possible to the discharge pond
C. A high suction lift will dramatically increase the discharge volume
D. A high discharge head will decrease the need for a high suction lift

20. The two terms that are frequently used to describe the incoming and outgoing conductors of circuit breakers, motor starters, and other devices are called?
A. Hot lead, ground wire
B. Amperage in, voltage out
C. Line side, load side
D. Time delay fuse, circuit breaker

Answers to Quiz

1. A
2. A
3. D
4. B
5. A
6. A
7. A
8. D
9. B
10. D
11. C
12. B
13. B
14. A
15. D
16. B
17. C
18. C
19. A
20. C

Installation of grinder pump for a low-pressure system.



Low-Pressure System
Inside a grinder pump found outside a home, the inlet is 3 inches and outlet is only $1^{1}/_{2}$ inches.

Chapter 1- WASTEWATER COLLECTION SECTION

Section Focus: You will learn the basics of the wastewater collection. At the end of this section, you the student will be able to describe the basics of the gravity collection system. There is a post quiz at the end of this section to review your comprehension and a final examination in the Assignment for your contact hours.

Scope/Background: As a pretreatment inspector, you will need knowledge of many different concerns of the collections and wastewater treatment systems in order to properly identify the pretreatment (pass-through or interference) problem. Master's level knowledge of the collection system is essential for all pretreatment inspectors.

Collection System and its Purpose

Every house, restaurant, business, and industry produces waste. Wastewater collection protects public health and the environment by removing this infectious waste and recycling the water. A network of interconnected pipes accepts the flow from each building's sewer connection and delivers it to the treatment facilities. In addition to what homes and businesses flush down the drain, the system also collects excess groundwater, infiltration liquids, and inflow water. Wastewater collection is therefore a comprehensive liquid waste removal system.

The fluid waste distributed through this system is about 98% water. The waste floats on, is carried along by, and goes into suspension or solution in water. Possible waste includes anything that can be flushed down the drain--human excretion, body fluids, paper products, soaps and detergents, foods, fats, oil, grease, paints, chemicals, hazardous materials, solvents, disposable and flushable items; the list is almost infinite. This mixture of water and wastes is called *"wastewater."* In the past, it was known as *"sewage,"* but this term is now falling out of favor because it refers specifically to domestic sanitary wastewater, like toilet flushing, which represents only a portion of the entire fluid waste content.

"Wastewater" is a more accurate description and has become the standard term for this fluid waste because it encompasses the total slurry of wastes in water that is gathered from homes and businesses.

Collection System Defined
A system composed of gravity pipes, manholes, tanks, lift stations, control structures, and force mains that gather used water from residential and nonresidential customers and convey the flow to the wastewater treatment plant.

Wastewater systems collect and dispose of household wastewater generated from toilet use, bathing, laundry, and kitchen and cleaning activities.

Any structure with running water, such as a house or office, must be connected to one of the following wastewater disposal systems:

- **Centralized** systems are *public sewer systems* that serve established towns and cities and transport wastewater to a central location for treatment.

- **Decentralized** systems do not connect to a public sewer system. Wastewater may be treated on site or may be discharged to a private treatment plant.

Centralized Systems
Large-scale public sewer systems (municipal wastewater treatment plants) are centralized systems. These systems generally serve established cities and towns and may provide treatment and disposal services for neighboring sewer districts. Where appropriate, centralized systems are preferred to decentralized systems, as one centralized system can take the place of several decentralized systems. Centralized systems are more economical, allow for greater control, require fewer people, and produce only one discharge to monitor instead of several. However, decentralized systems can be useful, and this option should be evaluated on a case-by-case basis.

Decentralized Systems
Homes and other buildings that are not served by public sewer systems depend on decentralized septic systems to treat and dispose of wastewater. Most decentralized systems are on-site systems (wastewater is treated underground near where it is generated).

On-site systems are the most common wastewater treatment system used in rural areas. These systems can be a single septic system and drainfield serving one residence or a large soil absorption system serving an entire subdivision. Wastewater in decentralized systems can also be treated by a small, private wastewater treatment plant. These plants can have similar treatment processes and equipment as centralized systems but on a smaller scale.

Sewer Main
In a centralized wastewater treatment system, the sewer to which sewer connections are made from individual residences.

Trunk Lines
Sewer pipes measuring more than 12 inches in diameter and having a capacity of 1 to 10 million gallons per day. Trunk lines connect smaller sewer pipes, or collectors, to the largest transport pipes or interceptors.

Collectors
Small sewer pipes measuring twelve inches or less in diameter.

Gravity Sewage Collection System

Publicly owned treatment works (POTWs) collect wastewater from homes, commercial buildings, and industrial facilities and transport it via a series of pipes, known as a collection system, to the treatment plant.

Collection systems may flow entirely by gravity, or may include lift stations that pump the wastewater via a force main to a higher elevation where the wastewater can then continue on via gravity. Ultimately, the collection system delivers this sewage to the treatment plant facility. Here, the POTW removes harmful organisms and other contaminants from the sewage so it can be discharged safely into the receiving stream.

New sewer manhole with sewer mains before final burial.

Without treatment, sewage creates bad odors, contaminates water supplies, and spreads disease. Today, more than 16,000 sewage treatment plants exist in the U.S. treating more than 32 billion gallons per day of wastewater.

Modern sewer vactor or Camel. It is wise to make friends with the collection crews. The collection crews can greatly assist you in your enforcement efforts and can tell you lots of information, only if you develop a relationship with them.

Combined Sewer Overflows (CSOs)

Combined sewer systems are designed to collect both sanitary wastewater and storm water runoff. During dry weather, combined sewers carry sanitary waste to a POTW. During wet weather, the combined sanitary waste and storm water can overflow and discharge untreated wastewater directly to a surface water through a combined sewer overflow (CSO).

In 1994, the EPA published a CSO Control Policy (59 FR 18688). CSOs are regulated as point sources, and require NPDES permits.

The CSO Control Policy includes Nine Minimum Controls (NMC) for CSO management, which are requirements for any CSO NPDES Permit:

- ✓ Proper operation and regular maintenance programs for the sewer system and the CSOs;
- ✓ Maximum use of the collection system for storage;
- ✓ Review and modification of pretreatment requirements to ensure that CSO impacts are minimized;
- ✓ Maximization of flow to the POTW for treatment;
- ✓ Prohibition of CSOs during dry weather;
- ✓ Control of solid and floatable materials in CSOs;
- ✓ Establishment of pollution prevention programs;
- ✓ Public notification to ensure that the public receives adequate notification of CSO occurrences and CSO impacts;
- ✓ Monitoring to effectively characterize CSO impacts and the efficacy of CSO controls.

Development of a Long Term Control Plan (LTCP) is also required for management of CSOs. For more information, visit the EPA Wet Weather information page, which includes a graphic representation of Urban Wet Weather Flows.

A Vactor clearing a Manhole.

Collection System Operators' Purpose

Collection system operators are charged with protecting public health and the environment, and therefore must have documented proof of their certifications in the respective wastewater management systems. These professionals ensure that the system pipes remain clear and open. They eliminate obstructions and are constantly striving to improve flow characteristics. They keep the wastewater moving underground, unseen and unheard. Because this wastewater collection system and the professionals who maintain it operate at such a high level of efficiency, problems are very infrequent. So much so that the public often takes the wastewater collection system for granted. In truth, these operators must work hard to keep it functioning properly.

Centralized sewer systems are generally broken out into three different categories: sanitary sewers, storm sewers, and combined sewers. Sanitary sewers carry wastewater or sewage from homes and businesses to treatment plants. Underground sanitary sewer pipes can clog or break, causing unintentional *"overflows"* of raw sewage that flood basements and streets. Storm sewers are designed to quickly get rainwater off the streets during rain events.

Chemical, trash and debris from lawns, parking lots, and streets are washed by the rain into the storm sewer drains. Most storm sewers do not connect with a treatment plant, but instead drain directly into nearby rivers, lakes, or oceans. Combined sewers carry both wastewater and storm water in the same pipe. Most of the time, combined sewers transport the wastewater and storm water to a treatment plant.

However, when there is too much rain, combined sewer systems cannot handle the extra volume and designed "overflows" of raw sewage into streams and rivers occur. The great majority of sewer systems have separated, not combined, sanitary and storm water pipes.

Leaking, overflowing, and insufficient wastewater collection systems can release untreated wastewater into receiving waters. Outdated pump stations, undersized to carry sewage from newly developed subdivisions or commercial areas, can also create a potential overflow hazard, adversely affecting human health and degrading the water quality of receiving waters. The maintenance of the sewer system is therefore a continuous, never-ending cycle.

As sections of the system age, problems such as corroded concrete pipe, cracked tile, lost joint integrity, grease, and heavy root intrusion must be constantly monitored and repaired. Technology has improved collection system maintenance with such tools as television camera assisted line inspection equipment, jet-cleaning trucks, and improvements in pump design. Because of the increasing complexity of wastewater collection systems, collection system maintenance is evolving into a highly skilled trade.

According to a recent Clean Water Needs Survey conducted by the USEPA, the U.S. will have to invest more than $10 billion to upgrade existing wastewater collection systems, over $20 billion for new sewer construction, and nearly $44 billion to improve sewer overflows, to effectively serve the projected population. As the infrastructure in the United States and other parts of the world ages, increasing importance is being placed on rehabilitating wastewater collection systems. Cracks, settling, tree root intrusion, and other disturbances that develop over time deteriorate pipelines and other conveyance structures that comprise wastewater collection systems, including stormwater, sanitary, and combined sewers.

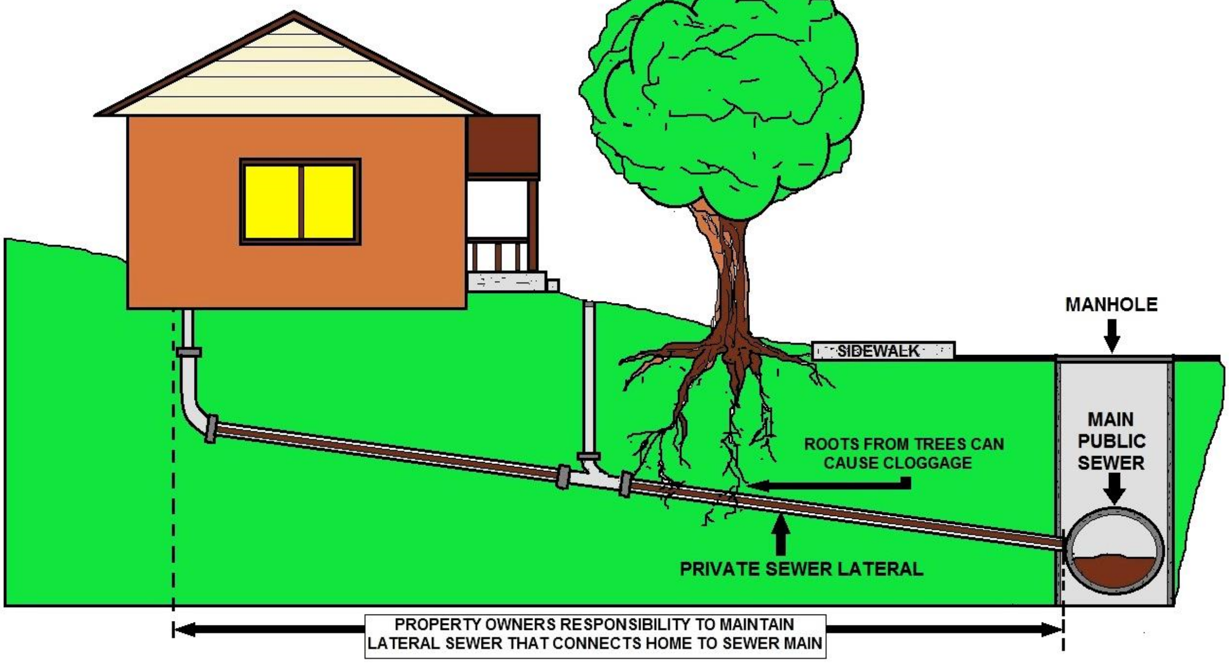
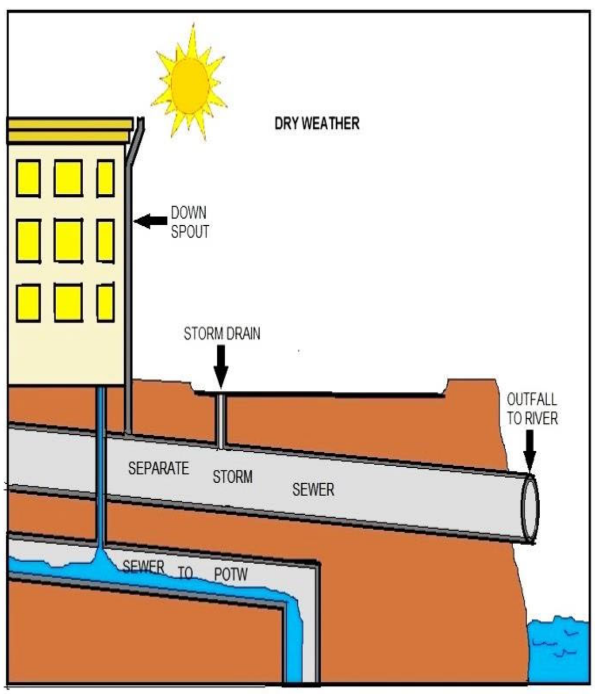
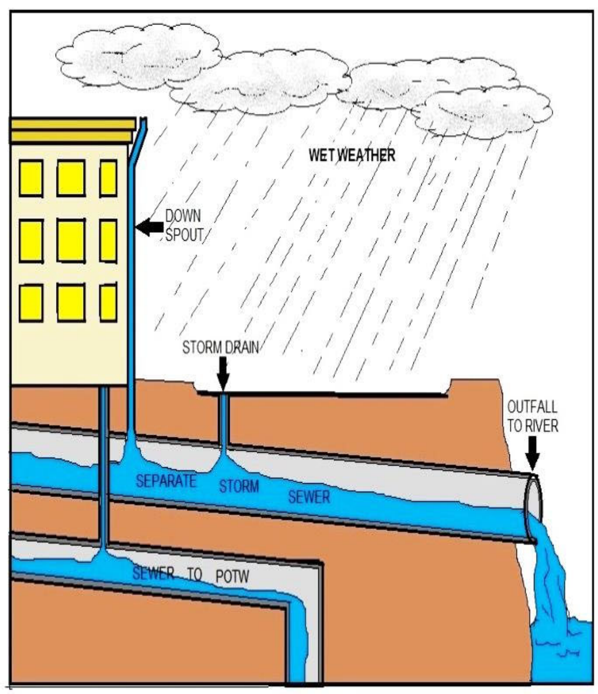


DIAGRAM OF SEWER LATERAL





Collections Daily Operations

The Sewer Cleaning Truck above is 38 feet long and 9 feet wide. The attached tank has a capacity of 1500 gallons and can hold 10 cubic yards of debris. The truck is equipped with a high pressure cleaning head that can move 800 feet down a sanitary line at 2500 PSI.

Out of sight, out of mind—that's your sanitary sewer collection system. Until there comes that inevitable emergency call due to a stoppage, then you have upset residents with sewage backed up in their toilets. A very economical and quick method of determining if a new sewer line is straight and unobstructed is called *"Lamping"* and can be done with a mirror and a bright source of light, for example a headlight at night or sunlight.

Video inspection coupled with a good cleaning program can be a highly effective maintenance tool. By cleaning and root sawing your lines, restrictions caused by debris, roots and grease buildup can be prevented—thus drastically reducing the number of emergency backups and surcharge calls.

Sewage collection systems that have video inspection closed circuit television (CCTV) and cleaning programs, report drastic reductions in the number of emergency calls because the system was cleaned and potential trouble spots were located prior to problems occurring.

Top photograph, new manhole. Bottom, a repaired sewer main after being damaged by the water distribution department using a backhoe without locates.

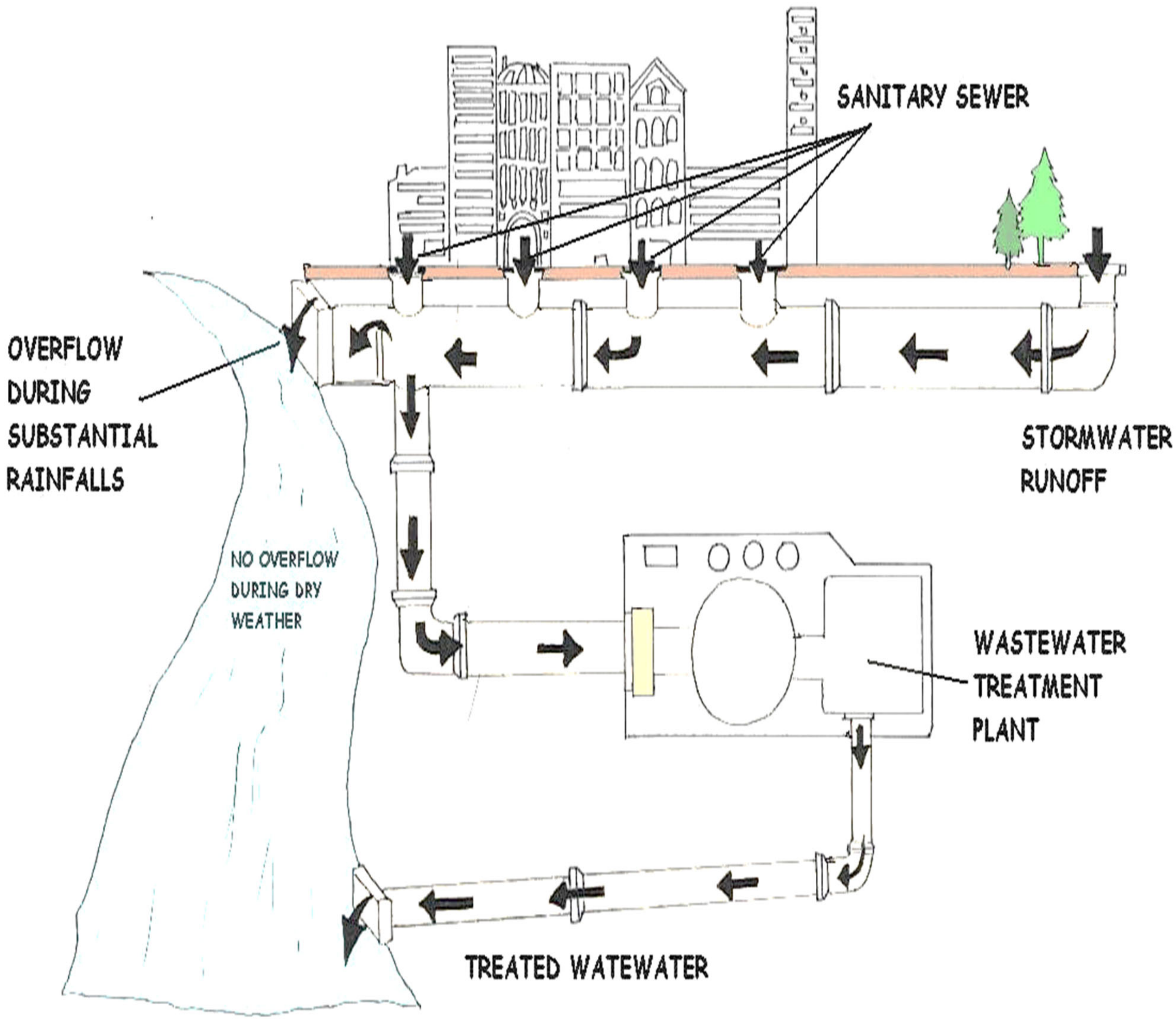
Rule to Protect Communities from Overflowing Sewers

The Environmental Protection Agency (EPA) has clarified and expanded permit requirements under the Clean Water Act for 19,000 municipal sanitary sewer collection systems in order to reduce sanitary sewer overflows.

The requirements will help communities improve some of our Nation's most valuable infrastructure –our wastewater collection systems–by requiring facilities to develop and implement new capacity, management, operation, and maintenance programs and public notification programs.

The 19,000 systems covered by this rule include 4,800 municipal satellite collection systems that will be directly regulated under the Clean Water Act for the first time. These requirements will result in fewer sewer overflows, leading to healthier communities, fewer beach closures, and fish and shellfish that are safer to eat.

Various damage from undesirable materials in the sewer system. Bottom, heavy grease from not being regularly pumped. Photograph credit John Bougham.



The complexity and expense associated with a utility's CMOM or MOM programs is specific to the size and complexity of the Publicly Owned Treatment Works (POTW) and related infrastructure. Factors such as population growth rate and soil/groundwater conditions also dictate the level of investment that should be made.

Understanding the Gravity Sanitary Sewer System

A Sanitary Sewer has Two Main Functions:

- To convey the designed peak discharge.
- Transport solids so that the deposits are kept at a minimum.

Sanitary sewers are designed to transport the wastewater by utilizing the potential energy provided by the natural elevation of the earth resulting in a downstream flow. This energy, if not designed properly, can cause losses due to free falls, turbulent junctions, and sharp bends. Sewer systems are designed to maintain proper flow velocities with minimum head loss. However, higher elevations in the system may find it necessary to dissipate excess potential energy.

Design flows are based on the quantity of wastewater to be transported. Flow is determined largely by population served, density of population, and water consumption. Sanitary sewers should be designed for peak flow of population. Stormwater inflow is highly discouraged and should be designed separate from the sanitary system.

Gravity-flow sanitary sewers are usually designed to follow the topography of the land and to flow full or nearly full at peak rates of flow and partly full at lesser flows. Most of the time the flow surface is exposed to the atmosphere within the sewer and it functions as an open channel. At extreme peak flows the wastewater will surcharge back into the manholes. This surcharge produces low pressure in the sewer system.

In order to design a sewer system, many factors are considered. The purpose of this topic is to aid in the understanding of flow velocities and design depths of flow. The ultimate goal for our industry is to protect the health of the customers we serve. This is achieved by prevention of sewer manhole overflows.

Sewer System Capacity Evaluation - Testing and Inspection

The collection system owner or operator should have a program in place to periodically evaluate the capacity of the sewer system in both wet and dry weather flows and ensure the capacity is maintained as it was designed. The capacity evaluation program builds upon ongoing activities and the everyday preventive maintenance that takes place in a system.

The capacity evaluation begins with an inventory and characterization of the system components. The inventory should include the following basic information about the system:

- Population served
- Total system size (feet or miles)
- Inventory of pipe length, size, material and age, and interior and exterior condition as available
- Inventory of appurtenances such as bypasses, siphons, diversions, pump stations, tide or flood gates and manholes, etc., including size or capacity, material and age, and condition as available
- Force main locations, length, size and materials, and condition as available
- Pipe slopes and inverts
- Location of house laterals - both upper and lower

The system then undergoes general inspection which serves to continuously update and add to the inventory information.

Capacity Limitations
The next step in the capacity evaluation is to identify the location of wet weather related SSOs, surcharged lines, basement backups, and any other areas of known capacity limitations. These areas warrant further investigation in the form of flow and rainfall monitoring and inspection procedures to identify and quantify the problem. The reviewer should ensure that the capacity evaluation includes an estimate of peak flows experienced in the system, an estimate of the capacity of key system components, and identification of the major sources of I/I that contribute to hydraulic overloading events.

The capacity evaluation should also make use of a hydraulic model. This model will help identify areas where there is a need to alleviate capacity limitations. Short and long term alternatives to address hydraulic deficiencies should be identified, prioritized, and scheduled for implementation. A sewer inspection is an important part of a sewer system capacity evaluation and determining your options or alternatives.

Flow Monitoring
Fundamental information about the collection system is obtained by flow monitoring. Flow monitoring provides information on dry weather flows as well as areas of the collection system potentially affected by I/I. Flow measurement may also be performed for billing purposes, to assess the need for new sewers in a certain area, or to calibrate a model.

There are three techniques commonly used for monitoring flow rates:
(1) permanent and long-term,
(2) temporary, and
(3) instantaneous.

Permanent installations are done at key points in the collection system such as the discharge point of a satellite collection system, pump stations, and key junctions. Temporary monitoring consists of flow meters typically installed for 30-90 days. Instantaneous flow metering is performed by collection system personnel, one reading is taken and then the measuring device is removed.

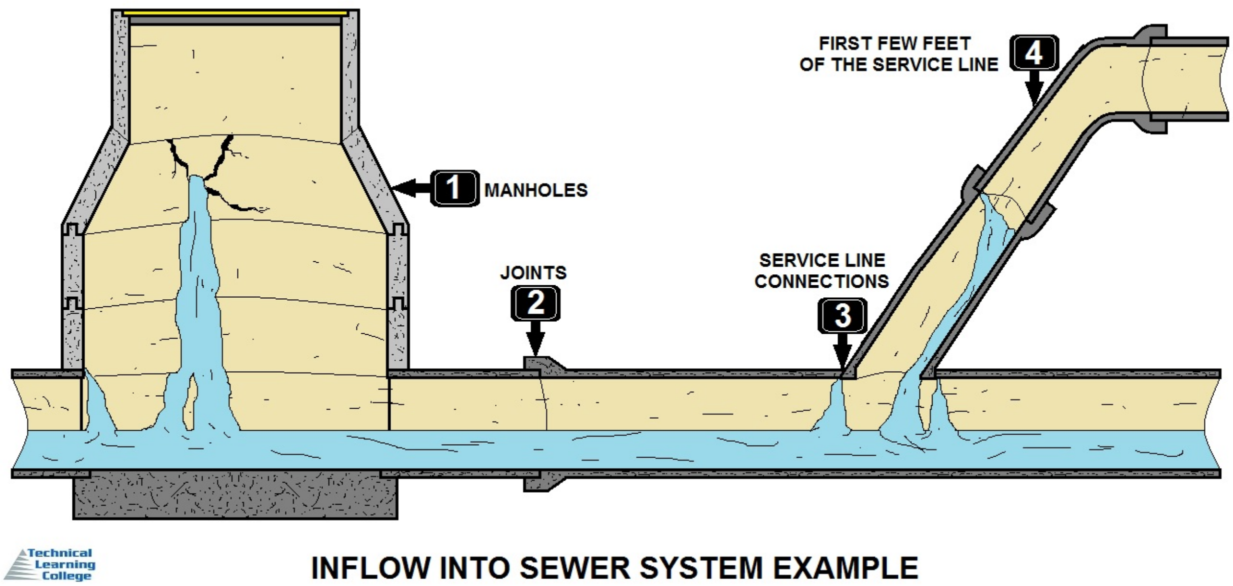
The collection system owner or operator should have a flow monitoring plan that describes their flow monitoring strategy, or should at least be able to provide the following information:

- Purpose of the flow monitoring
- Location of all flow meters
- Type of flow meters
- Flow meter inspection and calibration frequency

Flow Monitoring Plan
A flow monitoring plan should provide for routine inspection, service, and calibration checks (as opposed to actual calibration). In some cases, the data is calibrated rather than the flow meter. Checks should include taking independent water levels (and ideally velocity readings), cleaning accumulated debris and silt from the flow meter area, downloading data (sometimes only once per month), and checking the desiccant and battery state. Records of each inspection should be maintained.

Infiltration and Inflow Sub-Section

What is Infiltration/Inflow (I/I)?
Infiltration occurs when groundwater enters the sewer system through cracks, holes, faulty connections, or other openings. Inflow occurs when surface water such as storm water enters the sewer system through roof downspout connections, holes in manhole covers, illegal plumbing connections, or other defects.



INFLOW INTO SEWER SYSTEM EXAMPLE

The sanitary sewer collection system and treatment plants have a maximum flow capacity of wastewater that can be handled. I/I, which is essentially clean water, takes up this capacity and can result in sewer overflows into streets and waterways, sewer backups in homes, and unnecessary costs for treatment of this water. It can even lead to unnecessary expansion of the treatment plants to handle the extra capacity. These costs are passed on to the consumer.

I&I (Infiltration and Inflow)

- Infiltration is water (typically groundwater) entering the sewer underground through cracks or openings in joints.
- Inflow is water (typically stormwater or surface runoff) that enters the sewer from grates or unsealed manholes exposed to the surface.

Determining I/I
Flow monitoring and flow modeling provide measurements and data used to determine estimates of I/I. Flow meters are placed at varying locations throughout the sewer collection system to take measurements and identify general I/I source areas. Measurements taken before and after a precipitation event indicate the extent that I/I is increasing total flow. Both infiltration and inflow increase with precipitation. Infiltration increases when groundwater rises from precipitation, and inflow is mainly stormwater and rainwater. Rainfall monitoring is also performed to correlate this data.

Identifying Sources of I/I
A Sewer System Evaluation Survey (SSES) involves inspection of the sewer system using several methods to identify sources of I/I:

> **Visual inspection** - accessible pipes, gutter and plumbing connections, and manholes are visually inspected for faults.
> **Smoke testing** – smoke is pumped into sewer pipes. Its reappearance aboveground indicates points of I/I. These points can be on public property such as along street cracks or around manholes, or on private property such as along house foundations or in yards where sewer pipes lay underground.
> **TV inspection** – camera equipment is used to do internal pipe inspections. The City will usually have one 2-3 person crew that can perform TV inspection on over 20 miles of sewer pipe per year.
> **Dye testing** – Dye is used at suspected I/I sources. The source is confirmed if the dye appears in the sewer system.

Sources of I/I are also sometimes identified when sewer backups or overflows bring attention to that part of the system. The purpose of the SSES is to reduce these incidences by finding sources before they cause a problem.

I/I Source Treatments
Repair techniques include manhole wall spraying, trenchless sewer pipe relining, manhole frame and lid replacement, and disconnecting illegal plumbing, drains, and roof downspouts.

Structural problems can cause major headaches. CCTV is one of the best tools available to check the condition of your buried assets. During CCTV field inspections, pipe defects and maintenance issues are discovered and classified using a standardized coding system. Following data analysis, structural condition information is used to estimate a pipe's performance, remaining useful life and to plan for the future and make decisions about pipe repair or replacement.

CCTV inspections also reveal maintenance issues, which aid the manager in making any necessary operation or maintenance changes.

- Collapses
- Fractures
- Sags
- Infiltration
- Inflow

Hydraulic Capacity
Hydraulic capacity is a primary performance measure for a wastewater collection system. Capacity (both hydraulic and treatment) can be taken up by clean water entering the sewer collection system. It may be obvious, based on dry weather and wet weather flows, that rainwater or groundwater inflow or infiltration (I/I) is a problem.

CCTV evaluation can determine the specific location and cause of I/I in many cases, however, flow data gathered by flow meters has been used to guide sewer system capacity management for decades.

Flow data can be used as a tool in condition assessment either to identify areas for further CCTV inspection or to quantify the severity of I/I identified during CCTV work.

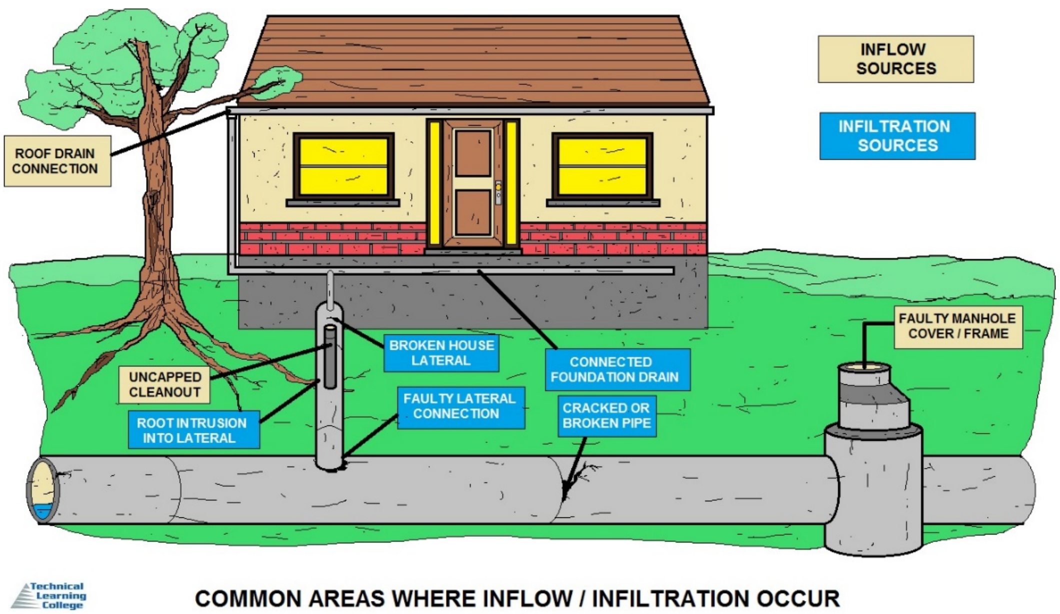
- Excess flow
- Infiltration
- Inflow

Fortunately, there are several actions you can take after a manhole inspection reveals I&I.

Here are a few:
1. Replace the manhole covers.
a. Cost – approximately $200 per cover.
b. I&I reduction could be $350 per year or more if the covers are submerged during rain events.

2. Chemical grouting to seal up leaky joints.
a. Cost – $500 and up.
b. Reduction could be as much as $5,000 per year per manhole.

3. Line the manhole.
a. Cost – approximately $3,000.
b. Could reduce costs by $20,000 per year per manhole.



COMMON AREAS WHERE INFLOW / INFILTRATION OCCUR

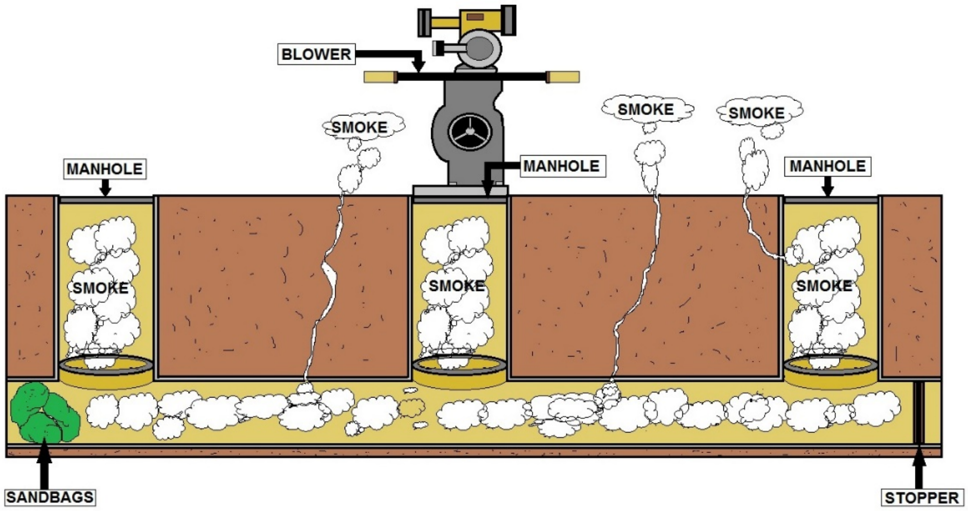
Efficient Identification of Excessive I/I

The owner or operator should have in place a program for the efficient identification of excessive I/I. The program should look at the wastewater treatment plant, pump stations, permanent meter flows, and rainfall data to characterize peaking factors for the whole system and major drainage basins. The reviewer should evaluate the program, including procedures and records associated with the flow monitoring plan. Temporary meters should be used on a “roving” basis to identify areas with high wet weather flows. Areas with high wet weather flows should then be subject to inspection and rehabilitation activities.

Sewer System Testing

Sewer system testing techniques are often used to identify leaks which allow unwanted infiltration into the sewer system and determine the location of illicit connections and other sources of stormwater inflow.

Two commonly implemented techniques include smoke testing and dyed water testing. Regardless of the program(s) implemented by the owner or operator, the reviewer should evaluate any procedures and records that have been established for these programs.



SMOKE TEST IN SEWER MAIN

The reviewer should also evaluate any public relations program and assess how the owner or operator communicates with the public during these tests (i.e., when there is a possibility of smoke entering a home or building).

Smoke testing is a relatively inexpensive and quick method of detecting sources of inflow in sewer systems, such as down spouts, or driveway and yard drains, and works best for detecting cross connections and point source inflow leaks.

Smoke testing is not typically used on a routine basis, but rather when evidence of excessive I/I already exists. With each end of the sewer of interest plugged, smoke is introduced into the test section. Sources of inflow can then be identified when smoke escapes through them.

Areas Usually Smoke Tested

- Drainage paths
- Ponding areas
- Cellars
- Roof leaders
- Yard and area drains
- Fountain drains
- Faulty service connections
- Abandoned building sewers

If the collection system owner or operator implements a regular program of smoke testing, the program should include a public notification procedure.

The owner or operator should also have procedures to define:

- How line segments are isolated.
- The maximum amount of line to be smoked at one time.
- The weather conditions in which smoke testing is conducted (i.e., no rain or snow, little wind and daylight only).

The results of positive smoke tests should be documented with carefully labeled photographs. Building inspections are sometimes conducted as part of a smoke testing program and, in some cases, may be the only way to find illegal connections. If properly connected to the sanitary sewer system, smoke should exit the vent stacks of the surrounding properties. If traces of the smoke or its odor enter the building, it is an indication that gases from the sewer system may also be entering. Building inspections can be labor intensive and require advanced preparation and communication with the public.

Dye Testing

Dyed water testing may be used to establish the connection of a fixture or appurtenance to the sewer. It is often used to confirm smoke testing or to test fixtures that did not smoke. As is the case with smoke testing, it is not used on a routine basis, but rather in areas that have displayed high wet weather flows. Dyed water testing can be used to identify structurally damaged manholes that might create potential I/I problems. This is accomplished by flooding the area close to the suspected manholes with dyed water and checking for entry of dyed water at the frame-chimney area, cone or corbel, and walls of the manhole.

Sewer System Inspection

Visual inspection of manholes and pipelines is the first line of defense in the identification of existing or potential problem areas. Visual inspections should take place on both a scheduled basis and as part of any preventive or corrective maintenance activity. Visual inspections provide additional information concerning the accuracy of system mapping, the presence and degree of I/I problems, and the physical state-of-repair of the system. By observing the manhole directly and the incoming and outgoing lines with a mirror, it is possible to determine structural condition, the presence of roots, condition of joints, depth of debris in the line, and depth of flow.

The reviewer should examine the records of visual inspections to ensure that the following information is recorded:

- Manhole identification number and location.
- Cracks or breaks in the manhole or pipe (inspection sheets and/or logs should record details on defects.)
- Accumulations of grease, debris, or grit
- Wastewater flow characteristics (e.g., flowing freely or backed up.)
- Inflow - Infiltration (presence of clear water in or flowing through the manhole.)
- Presence of corrosion.
- Offsets or misalignments.
- Condition of the frame.
- Evidence of surcharge.
- Atmospheric hazard measurements (especially hydrogen sulfide.)
- If repair is necessary, a notation as to whether a work order has been issued.

Inflow and Infiltration Calculation/Determination Terms

Average Annual Flow - The total annual volume divided by 365 days. This value is approximated by the mean of the twelve monthly average flows.

Average Annual Infiltration - The average of the monthly minimum flows.

Average Annual Inflow - From the average annual flow, subtract the base sanitary flow and average annual infiltration.

Average Dry Weather Flow (ADW) - Flow during a period of extended dry weather (7 to 14 days) and seasonally high groundwater. Flow includes sanitary flow and infiltration, and excludes significant industrial and commercial flows (assumes no inflow during dry weather conditions).

Base Sanitary Flow (BSF) - The portion of wastewater which includes domestic, commercial, institutional, and industrial sewage and specifically excludes infiltration and inflow. (See Estimating Base Flow, below).

Delayed Inflow volume - The portion of total inflow which is generated from indirect connections to the collection system or connections which produce inflow after a significant time delay from the beginning of a storm. Delayed inflow sources include: sump pumps, foundation drains, indirect sewer/drain cross-connections, etc. Rainfall induced infiltration cannot be distinguished from delayed inflow and is therefore included as part of delayed inflow. Delayed inflow sources have a gradual impact on the collection system and flow decreases gradually upon conclusion of the rainfall event, and after peak inflow caused by direct connections.

Direct Inflow Volume- The portion of total inflow volume which is from direct connections to the collection system such as catch basins, roof leaders, manhole covers, etc. These inflow sources allow stormwater runoff to rapidly impact the collection system.

Dry Weather Flow (DWF) - All flow in a sewer (includes sanitary flow and infiltration) except that caused directly by rainfall. Measured during a period of extended dry weather (7 to 14 days) and seasonally high groundwater. Groundwater

Infiltration (GWI) – Measured during average dry weather flow period (see above). The average of the low nighttime flows (midnight to 6 am) per day for the same time period, minus significant industrial or commercial nighttime flows.

Hydrograph - A graph showing stage (the height of a water surface above an established datum plane), flow, velocity, or other property of water with respect to time. Infiltration - Water other than sanitary wastewater that enters a sewer system from the ground through defective pipes, pipe joints, connections, or manholes. Infiltration does not include inflow.

Inflow - Water other than sanitary wastewater that enters a sewer system from sources such as roof leaders, cellar/foundation drains, yard drains, area drains, drains 4 from springs and swampy areas, manhole covers, cross connections between storm sewers and sanitary sewers, and catch basins. Inflow does not include infiltration.

Inflow volume - The total volume of inflow from a single storm event including both direct and delayed inflow. Total inflow is the area between the storm event hydrograph and the dry weather hydrograph.

Maximum Daily Flow - The highest flow during a 24 hour period.

Maximum Daily Infiltration - The highest daily flow at seasonal high groundwater after a dry period of three days or more minus the base sanitary flow.

Maximum Weekly Infiltration - The highest 7 day average flow at high groundwater after a dry period of three or more days minus the base sanitary flow.

Maximum Monthly Infiltration - The highest monthly average flow during dry or minimal rain period minus the base sanitary flow.

Maximum Daily Inflow - The highest daily wet weather flow minus the base sanitary flow and the infiltration prior to the rain event.

Maximum Weekly Inflow (includes delayed infiltration) - The highest 7 day average wet weather flow minus the base sanitary flow and the infiltration prior to the rain event.

Maximum Monthly Inflow - The highest monthly flow after subtracting the base sanitary flow and infiltration.

Peak Hourly Dry Weather Flow - The highest one hour flow after a dry period of three or more days.

Peak Hourly Inflow - The highest one hour flow rate during wet weather minus the base sanitary flow and the infiltration prior to the rain event.

Peak Hourly Wet Weather Flow – The highest one hour flow during a significant rain event.

Peak Infiltration- The highest nighttime (midnight to 6 am) flow during high groundwater (usually in early spring).

Peak Instantaneous Wet Weather Flow - The peak flow during a significant rain event day when the ground water is seasonally high.

Peaking Factor - The ratio of peak hourly flow to average daily flow.

Rainfall-Induced Infiltration - The short-term increase in infiltration which is the result of a rain event. Rainfall-induced infiltration is a portion of delayed inflow.

Wet Weather Flow- The highest daily flow during and immediately after a significant storm event. Includes sanitary flow, infiltration and inflow.

Monitoring Flows

The sanitary portion of the wastewater flow can be estimated through two methods, which can be used to 'check' each other - flow meter data and water consumption (if all sewer customers are on metered water). The first method is to analyze the wastewater flow data at the treatment facility during a dry weather period of 7 to 14 days. It is useful to choose the dry weather period during seasonal high water as you will be able to determine the peak infiltration rate at the same time.

From the flow data, calculate the average daily flow for the dry weather period (Average Dry Weather – ADW - flow). The base sanitary flow (BSF) can be estimated by subtracting the groundwater infiltration (GWI) flow from the average daily dry weather wastewater (ADW) flow. (See Estimating Infiltration below).

In the second method, water usage records can be used to estimate the base sanitary flow for the sewered population. The best time to estimate flow using this method would be when outdoor water uses are low and wastewater from a residential area can be assumed to be the same as the billed water use. In the northeast, this would typically be in the winter months prior to landscaping and swimming pool use. Groundwater infiltration can be estimated as the difference between the monitored wastewater flow and the billed water use.

Estimating Infiltration
Groundwater infiltration (GWI) can be estimated from influent flow data collected during a dry weather period at high groundwater. The dry weather period selected should be the same period as for estimating the BSF, however, it is more important to estimate GWI during high seasonal ground water. Dry weather is defined as when it has been at least three days without a rain event. During dry weather, inflow is expected to be zero.

During seasonal high groundwater, which usually occurs after snow melt and soil thaw, infiltration will be at its highest. During this period, the infiltration rate can be quantified by averaging the nighttime flows (midnight to 6 am) over several days, during dry weather conditions. The nighttime flows can be assumed to be mostly groundwater (after subtracting significant industrial or commercial nighttime flows). In most cases, the GWI rate will approximate the maximum weekly infiltration. The maximum daily infiltration will be higher and maximum monthly infiltration will be lower.

Estimating Inflow
Inflow represents the influence of wet weather on the sewer system and is calculated by subtracting out the sanitary wastewater and infiltration flow during a time that the system has been influence by rain.

Flow data during a significant storm event should be compared to the dry weather data immediately preceding the storm when groundwater conditions are similar. The rate and volume of inflow can be estimated by subtracting the base sanitary flow and infiltration flow data from the wet weather flow data. The peak inflow rate and the total inflow volume can be calculated from the flow records.

The peak inflow rate is the largest rate difference, over a one hour period, between the storm event flow data and the dry weather flow prior to the event.

The total inflow volume from a storm event can be apportioned into two components: direct inflow and delayed inflow.

Direct inflow is the portion of the inflow which rapidly increases soon after the start of the storm and decreases swiftly upon conclusion of the event. The time it takes for inflow from the nearest sub-basin to reach the treatment facility can be estimated as the time difference between initiation of the storm event and the increase in observed flow. The direct inflow ends at a time after the conclusion of the storm approximately equal to the inflow response time from the furthest sub-basin.

Delayed inflow is the portion of the inflow which decreases gradually upon conclusion of the storm and after the peak inflow caused by direct connections.

Delayed inflow is the inflow beginning at the conclusion of direct inflow and ending at a time when dry weather flow resumes. It is expected that a portion of the delayed inflow includes rainfall-induced infiltration.

In some cases, a second storm will impact the flow data before dry weather flow resumes. When this occurs, the expected delayed inflow can be extrapolated from the flow data collected prior to the second storm.

Estimating Infiltration and Inflow (I&I)

Maximum monthly I&I rate can be estimated by subtracting the BSF from the maximum monthly average flow. Average annual I&I rate can be estimated by subtracting the BSF rate from average annual flow rate. Annual I&I volume can be estimated by multiplying the average annual I&I rate by 365 days.

Sewer Flow Capacity

Most sewers are designed with the capacity to flow half full for less than 15 inches in diameter; larger sewers are designed to flow at three-fourths flow. The velocity is based on calculated peak flow, which is commonly considered to be twice the average daily flow. Accepted standards dictate that the minimum design velocity should not be less than 2 fps (0.60 m/sec) or generally greater than 10 fps (3.5 m/sec) at peak flow.

A velocity in excess of 10 fps (3.5 m/sec) can be tolerated with proper consideration of pipe material, abrasive characteristics of the wastewater, turbulence, and thrust at changes of direction. The minimum velocity is necessary to prevent the deposition of solids.

Summary

Sewers and treatment facilities are designed around expected average and maximum flows. Excess storm and groundwater entering the sewer system through I&I robs the system of its valuable capacity, puts a burden on operation and maintenance, and reduces the life expectancy of the treatment facility.

Sewer surcharging, back-ups and overflows all require emergency response and contribute to disruption of operations. Integrating I&I investigation and corrective action into a municipality’s normal public works budget can allow an incremental approach to continuous improvement and help defer capacity expansion projects.

Low-Pressure System Description and Operation

Vacuum Sewers

Wastewater from one or more homes flows by gravity to a holding tank known as the valve pit. When the wastewater level reaches a certain level, sensors within the holding tank open a vacuum valve that allows the contents of the tank to be sucked into the network of collection piping. There are no manholes with a vacuum system; instead, access can be obtained at each valve pit. The vacuum or draw within the system is created at a vacuum station. Vacuum stations are small buildings that house a large storage tank and a system of vacuum pumps.

Vacuum sewer systems are limited to an extent by elevation changes of the land. Rolling terrain with small elevation changes can be accommodated, yet steep terrain would require the addition of lift stations like those used for conventional sewer systems. It is generally recommended that there be at least 75 properties per pump station for the use of a vacuum sewer system to be cost effective.

This minimum property requirement tends to make vacuum sewers most conducive for small communities with a relatively high density of properties per acre. The maintenance and operation of this system requires a full-time system operator with the necessary training. This can make the operation and maintenance costs of vacuum sewers exceed those of other systems.

Applications

Vacuum collection and transportation systems can provide significant capital and ongoing operating cost advantages over conventional gravity systems, particularly in flat terrain, high water table, or hard rock areas. Vacuum sewer systems are installed at shallow depths, significantly reducing excavation, shoring and restoration requirements, and minimizing the disruption to the community. The alignment of vacuum mains is extremely flexible, without the need for manholes at changes in grade or direction.

Vacuum sewer mains can skip over and around other services or obstacles and can be used to achieve uphill flow. Turbulent velocities of 5 to 6m/sec are developed as the sewage and air passes through the interface valve. This disintegrates solids and reduces the risks of sewer blockages in a correctly designed and constructed vacuum system.

No electricity is required at the interface valve, enabling the system to be installed in virtually any location. Fractures in gravity systems may go undetected for a long time. A leak in a vacuum main will raise an alarm within minutes of the break. The mains have to be repaired for sewage transport to continue, ensuring up to date maintenance and eliminating deterioration and infiltration.

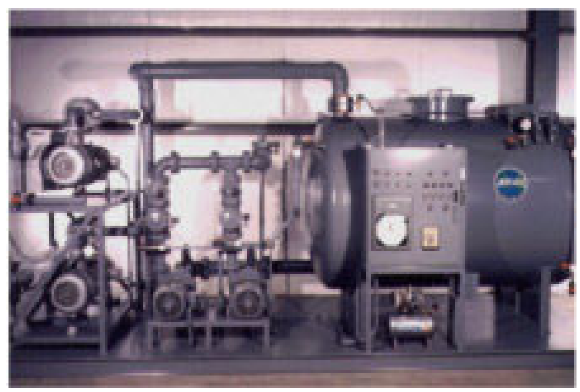
Due to the shallow depth of the installation, additional connections can be quickly and simply made by a small construction crew, thus reducing the disruption and restoration work normally required for conventional gravity sewers. Vacuum collection and transport systems have many applications in industry for collecting all forms of liquid waste, including toxic and radioactive fluids. Collection pipes may be installed above ground, overhead or in utility ducts.

The versatility of the vacuum sewer system can be employed in a variety of locations and situations, such as:

- Rural community sewerage schemes.

- Industrial redevelopments.
- Camping and caravan sites.
- New residential and industrial developments.
- Existing towns (especially where narrow streets or congested service corridors occur).
- Diversion of small sea outfalls.
- Hospital effluent collection.
- Airports/Shopping centers.
- Railway services.
- Replacement of failed gravity systems.
- Petrol-chemical industry.
- Food processing plants.
- Roof drainage.
- Retrofitting factories for the management of segregated wastestreams.
- Collection of toxic and radioactive waste.
- Condensate collection systems.
- Factory sewerage.
- Leachate from landfills.
- Spillage around tank farms.
- Collecting used oil and fluids.
- River and lakeside communities.
- Quayside redevelopments.
- Arctic communities.

Vacuum Interface Valves



There is an interface between the vacuum within the vacuum mains and the atmospheric pressure is maintained within the vacuum interface chamber. When sewage is entering the system from a source and the sewage level in the chamber rises, it pressurizes air in the 63mm sensor line. This air pressure is transmitted by a hose to the controller/sensor unit, which opens the valve and the wastewater is rapidly drawn into the vacuum main. This suction of the sewer creates a vortex in the sump and air is drawn into the sewer with the sewage.

As the valve opens, a pneumatic timer in the controller/sensor unit starts a pre-set time cycle. The timer holds the valve open for sufficient time to draw all the sewage out of the sump and allows a designated amount of air to enter the system. The interface valve is capable of serving at least four equivalent tenements, and multiple valve chambers may be installed to serve higher flow rates. No electricity is required at the valve chamber. The vacuum valve is automatically operated by the pressure generated with the rising sewage level and the pneumatic timer, and actuated by the vacuum in the sewer.

Differential air pressure is the driving force in vacuum sewer systems. The vacuum sewer lines are under a vacuum of 16"-20" Hg (-0.5 to -0.7 bar) created by vacuum pumps located at the vacuum station. The pressure differential between the atmospheric pressure and the vacuum in the sewer lines of 7 to 10 psi (0.5 - 0.7 bar) provides the energy required to open the vacuum interface valves and to transport the sewage. Sewage flows by gravity from homes into a collection sump.

When 10 gallons (40 liters) accumulates in the sump, the vacuum interface valve located above the sump automatically opens and differential air pressure propels the sewage through the valve and into the vacuum main. Sewage flows through the vacuum lines and into the collection tank at the vacuum station.

Sewage pumps transfer the sewage from the collection tank to the wastewater treatment facility or nearby gravity manhole. There are no electrical connections required at the home. Power is necessary only at the vacuum station.

Valve Pit Package

The Valve Pit Package connects the homes to the vacuum sewer system. Raw sewage flows by gravity from up to four homes into a sealed fiberglass sump. Located above the sewage sump and surrounded by a fiberglass valve pit is a 3" (90 mm) vacuum interface valve, which is pneumatically controlled and operated. Vacuum from the sewer line opens the valve and outside air from a breather pipe closes it.

Sewage level sensing is remarkably simple. As the sewage level rises, air trapped in the empty 2" (50 mm) diameter sensor pipe pushes on a diaphragm in the valve's controller/sensor unit, signaling the valve to open. When ten gallons of sewage accumulates in the sump the valve automatically opens. The differential air pressure propels the sewage at velocities of 15-18 feet per second (4.5 - 5.5 m/s), disintegrating solids while being transported to the vacuum station. The valve stays open for four to six seconds during this cycle.

Atmospheric air used for transport enters through the 4" (100 mm) screened air intake on the gravity line. There are no odors at this air inlet due to the small volumes of sewage (10 gallons - 40 liters) and short detention times in the sump. The valve is 3" and designed for handling nominal 3" (75 mm) solids. Homes connected to vacuum sewers don't require any special plumbing fixtures. Typically one valve pit package serves two homes. Install the valve pit package in the street, if desired. With the optional traffic cast iron cover the valve pit package has a water loading rating.

Vacuum Lines

Vacuum sewer lines are installed in narrow trenches in a saw tooth profile for grade and uphill transport. Vacuum lines follow grade for downhill transport. Vacuum lines are slightly sloped (0.2%) towards the collection station. Unlike gravity sewers that must be laid at a minimum slope to obtain a 2 ft./sec. (0.6 m/s) scouring velocity, vacuum has a flatter slope since a high scouring velocity is a feature of vacuum sewage transport.

Line Sizes

The vacuum service line from the valve to the main in the street is 3" diameter (90 mm). The vacuum mains are 4", 6", 8" and 10" diameter (110 mm to 250 mm) schedule 40 or SDR 21 gasketed PVC pipe. PE pipe can also be used. In general, a potential vacuum loss is associated with every lift. This limits the length of each vacuum line to about 2 to 3 miles (3 to 5 km) in flat terrain. Elevation changes can extend or reduce this range. Longer distances are possible depending on local topography.

Vacuum Station
The vacuum station is similar in function to a lift station in a gravity sewer system. Sewage pumps transfer the sewage from the collection tank, through a force main, to the treatment plant. Unlike a lift station, the vacuum station has two vacuum pumps that create vacuum in the sewer lines and an enclosed collection tank.

Vacuum Pumps
The vacuum pumps maintain the system vacuum in the 16" to 20" mercury vacuum (-0.5 to -0.7 bar) operating range. Vacuum pumps typically run 2 to 3 hours each per day (4 to 6 hours total) and don't need to run continuously since the vacuum interface valves are normally closed. As sewage enters the system, driven by air at atmospheric pressure, the system vacuum will slowly decrease from 20" to 16" Hg. The vacuum pumps are sized to increase the system vacuum from 16" to 20" Hg in three minutes or less.

Typical vacuum pump sizes are 10, 15, and 25 horsepower (7.5, 11 and 18.6 kw). Busch rotary vane vacuum pumps are standard. The two non-clog sewage pumps are each sized for peak flow. The collection tank is steel or fiberglass and is sized according to flow, with typical sizes ranging from 1,000 to 4,000 gallons (3.8 to 15 cubic meters). The incoming vacuum lines connect individually to the collection tank, effectively dividing the system into zones. A stand-by generator keeps the vacuum sewer system in operation during extended power outages. An automatic telephone dialer alerts the operator to alarm conditions.

Review
Pressure Sewers
Instead of relying on gravity, pressure sewers utilize the force supplied by pumps, which deliver the wastewater to the system from each property. Since pressure sewers do not rely on gravity, the system's network of piping can be laid in very shallow trenches that follow the contour of the land.

There are two kinds of pressure sewer systems, based upon the type of pump used to provide the pressure. Systems that use a septic tank/effluent pump combination are referred to as STEP pressure sewers.

Like the small diameter gravity system, STEP pressure sewers utilize septic tanks to settle out the solids; this allows for the use of piping that is extremely narrow in diameter. The effluent pump delivers the wastewater to the sewer pipes and provides the necessary pressure to move it through the system. The other type of pressure sewer uses a grinder pump.

Wastewater from each property goes to a tank containing a pump with grinder blades that shred the solids into tiny particles. Both solids and liquids are then pumped into the sewer system. Because the effluent contains a mixture of solids as well as liquids, the diameter of the pipes must be slightly larger. However, grinder pumps eliminate the need to periodically pump the septic tanks for all the properties connected to the system.

Both the STEP and grinder systems are installed with high water alarms. Because of the addition of the pumps, pressure sewers tend to require more operation and maintenance than small diameter gravity sewers.

Operators can usually be hired on a part time basis, as long as someone is on call at all times. Operators will need training on both the plumbing and electrical aspects of the system.

Manhole Sub-Section

Manholes should undergo routine inspection typically every one to five years. There should be a baseline for manhole inspections (e.g., once every two years) with problematic manholes being inspected more frequently. The reviewer should conduct visual observation at a small but representative number of manholes for the items listed below.

There are various pipeline inspection techniques, the most common include: lamping, camera inspection, sonar, and CCTV. These will be explained further in the following sections.

Sewer System Inspection Techniques
Sewer inspection is an important component of any maintenance program. There are a number of inspection techniques that may be employed to inspect a sewer system. The reviewer should determine if an inspection program includes frequency and schedule of inspections and procedures to record the results. Sewer system cleaning should always be considered before inspection is performed in order to provide adequate clearance and inspection results.

Additionally, a reviewer should evaluate records maintained for inspection activities, including whether information is maintained on standardized logs, and should include:

- Location and identification of line being inspected.
- Pipe size and type.
- Name of personnel performing inspection.
- Distance inspected.
- Cleanliness of the line.
- Condition of the manhole with pipe defects identified by footage from the starting manhole.
- Results of inspection, including estimates of I/I.

When designing a wastewater system, the design engineer begins by first determining the types and quantities of sewage to be handled. This is accomplished through a careful study of the area to be served. The design engineer bases his design on the average daily use of water per person in the area to be served. A typical value is 100 gallons per person per day. But, the use of water is not constant.

Use is greater in the summer than in the winter and greater during the morning and evening than it is in the middle of the day or at night. Therefore, the average daily flow (based on the average utilization) is multiplied by a peak flow factor to obtain the design flow.

Typical peak flow factors range from 4 to 6 times for small areas down to 1.5 to 2.5 times for larger areas. An allowance for unavoidable infiltration of surface and subsurface water into the lines is sometimes added to the peak flow to obtain the design flow.

A typical infiltration allowance is 500 gallons per inch of pipe diameter per mile of sewer per day. From the types of sewage and the estimated design flow, the engineer can then tentatively select the types, sizes, slopes, and distances below grade of the piping to be used for the system.

Upon acceptance of the preliminary designs, final design may begin. During this phase, adjustments to the preliminary design should be made as necessary, based upon additional surveys, soil analysis, or other design factors. The final designs should include a general map of the area that shows the locations of all sewer lines and structures.

They also should include detailed plans and profiles of the sewers showing ground elevations, pipe sizes and slopes, and the locations of any appurtenances and structures, such as manholes and lift stations.

Construction plans and details are also included for those appurtenances and structures.

Newly finished Manhole and Laterals

Lead and Oakum Joint, Compression Joint and No-Hub Joints
These types of joints are used to connect cast-iron soil pipes (CISP) and fittings. In lead and oakum joints, oakum (made of hemp impregnated with bituminous compound and loosely twisted or spun into a rope or yarn) is packed into the hub completely around the joint, and melted lead is poured over it. In compression joints, an assembly tool is used to force the spigot end of the pipe or fitting into the lubricated gasket inside the hub. A no-hub joint uses a gasket on the end of one pipe and a stainless steel shield and clamp assembly on the end of the other pipe.

Mortar or Bituminous Joints
This type of joint is common to vitrified clay and concrete pipes and fittings. Mortar joints may be made of grout (a mixture of cement, sand, and water).

The use of ***SPEED SEAL JOINTS*** (rubber rings) in joining vitrified clay pipe has become widespread. Speed seal joints eliminate the use of oakum and mortar joints for sewer mains. This type of seal is made a part of the vitrified pipe joint when manufactured. It is made of polyvinyl chloride and is called a plastisol joint connection

Closed Circuit Television (CCTV) Inspection Sub-Section

Camera Inspection
Lamping involves lowering a still camera into a manhole. The camera is lined up with the centerline of the junction of the manhole frame and sewer. A picture is the taken down the pipe with a strobe-like flash. A disadvantage of this technique is that only the first 10-12 feet of the pipe can be inspected upstream and downstream of the access point. Additionally, it has limited use in small diameter sewers. The benefits of this technique include not requiring confined space entry and little equipment and set-up time is required.

Camera inspection is more comprehensive than lamping in that more of the sewer can be viewed. A still camera is mounted on a floatable raft and released into a pipe. The camera takes pictures with a strobe-like flash as it floats through the sewer pipe. This technique is often employed in larger lines where access points are far apart. Similar to lamping, portions of the pipe may still be missed using this technique.

Obviously, there also must be flow in the pipe for the raft to float. This technique also does not fully capture the invert of the pipe and its condition. Sonar is a newer technology deployed similarly to CCTV cameras, and described in more detail below.

The sonar emits a pulse which bounces off the walls of the sewer. The time it takes for this pulse to bounce back provides data and an image of the interior of the pipe, including its structural condition. A benefit of this technique is that it can be used in flooded or inaccessible sections of the sewer. The drawback is that the technique requires heavy and expensive equipment.

Sewer scanner and evaluation is an experimental technology where a 360-degree scanner produces a full digital photograph of the interior of the pipe. This technique is similar to sonar in that a more complete image of a pipe can be made than with CCTV, but not all types of sewer defects may be identified as readily (i.e., infiltration, corrosion).

Closed Circuit Television (CCTV) Inspections
Closed Circuit Television (CCTV) inspections are a helpful tool for early detection of potential problems. This technique involves a closed-circuit camera with a light which is self-propelled or pulled down the pipe. As it moves it records the interior of the pipe. CCTV inspections may be done on a routine basis as part of the preventive maintenance program, as well as part of an investigation into the cause of I/I.

CCTV, however, eliminates the hazards associated with confined space entry. The output is displayed on a monitor and videotaped. A benefit of CCTV inspection is that a permanent visual record is captured for subsequent reviews.

A remotely controlled TV camera on the top left is utilized by crews to identify and video tape problem areas within the system. By using this equipment, staff can determine what the cause of the problem is, what materials will be needed for repair, and where the problem area is.

Repairs can be made quickly without digging up large areas to find and correct a problem, as was done in the past. There are many reasons for inspecting sewer lines with a closed circuit television (CCTV). All of the following are valid reasons; locating sources of inflow and infiltration, locating buried manholes, and locating illegal sewer taps such as industrial or storm drains.

The Televising Van should be equipped with two cameras, one color camera for televising main sanitary lines and one color or black & white camera for televising house services (connection from the main sanitary line to a house).

Sewer Flow Measurements

Flow measurements performed for the purpose of quantifying I/I are typically separated into three components: base flow, infiltration, and inflow. Base flow is generally taken to mean the wastewater generated without any I/I component. Infiltration is the seepage of groundwater into pipes or manholes through defects such as cracks, broken joints, etc. Inflow is the water which enters the sewer through direct connections such as roof leaders, direct connections from storm drains or yard, area, and foundation drains, the holes in and around the rim of manhole covers, etc.

Many collection system owners or operators add a third classification: rainfall induced infiltration (RII). RII is stormwater that enters the collection system through defects that lie so close to the ground surface that they are easily reached. Although not from piped sources, RII tends to act more like inflow than infiltration.

In addition to the use of flow meters, which may be expensive for a small owner or operator, other methods of inspecting flows may be employed, such as visually monitoring manholes during low-flow periods to determine areas with excessive I/I. For a very small system, this technique may be an effective and low-cost means of identifying problem areas in the system which require further investigation.

Inside a new manhole, the Invert is the inside bottom of the pipe. The Invert is used to determine the depth which is used to determine the Rise or Slope of the pipe.

The formula for figuring the slope is: rise divided by run.

Smoke Testing is accomplished by forcing a non-toxic smoke into the sewer system and looking for locations where it is improperly exiting.

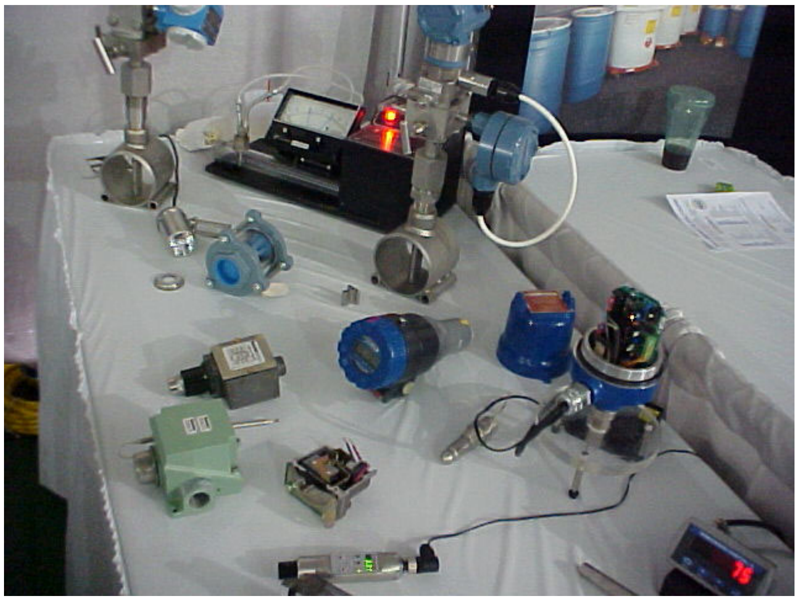
These locations are considered illegal connections in that they allow stormwater directly or indirectly to enter the sanitary sewer system.

Typical illegal connections found are roof drains tied directly into the system, abandoned customer sewer lines that were not properly capped, as well as an occasional broken sewer line.

Raising the Ring, jackhammer, install the crown, patch the street.

Sewer Flow Capacity

Most sewers are designed with the capacity to flow half full for less than 15 inches in diameter; larger sewers are designed to flow at three-fourths flow. The velocity is based on calculated peak flow, which is commonly considered to be twice the average daily flow. Accepted standards dictate that the minimum design velocity should not be less than 0.60 m/sec (2 fps) or generally greater than 3.5 m/sec (10 fps) at peak flow. A velocity in excess of 3.5 m/sec (10 fps) can be tolerated with proper consideration of pipe material, abrasive characteristics of the wastewater, turbulence, and thrust at changes of direction. The minimum velocity is necessary to prevent the deposition of solids.



Examples of various sewer flow measuring devices

The Use of a Dye at the Manhole to Determine the Velocity is Done as Follows:

1. Insert dye upstream and begin timing until the dye is first seen at the downstream manhole (t_1); and
2. Total the travel time, and the insertion time from the time the dye is no longer seen at the downstream manhole (t_2).

Once this is complete, add ($t_1 + t_2$) then divide it by 2. This will give you the total average time for the dye. In order to calculate the velocity the travel time is divided by the distance between manholes (note that the time needs to be converted to seconds):

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

There are devices available to measure flow measurements; they all are based on the principle of the cross-sectional area of the flow in a sewer line. This is done by using the table below. Once this has been determined, then the following equations can be used:
Q, cubic feet of flow = Area, sq ft multiplied by Velocity, ft/sec

d/D	Factor	d/D	Factor	d/D	Factor	d/D	Factor
0.01	0.0013	0.16	0.0811	0.31	0.2074	0.46	0.3527
0.02	0.0037	0.17	0.0885	0.32	0.2167	0.47	0.3627
0.03	0.0069	0.18	0.0961	0.33	0.2260	0.48	0.3727
0.04	0.0105	0.19	0.1039	0.34	0.2355	0.49	0.3827
0.05	0.0174	0.20	0.1118	0.35	0.2350	0.50	0.3927
0.06	0.0192	0.21	0.1199	0.36	0.2545	0.51	0.4027
0.07	0.0242	0.22	0.1281	0.37	0.2642	0.52	0.4127
0.08	0.0294	0.23	0.1365	0.38	0.2739	0.53	0.4227
0.09	0.0350	0.24	0.1449	0.39	0.2836	0.54	0.4327
0.10	0.0409	0.25	0.1535	0.40	0.2934	0.55	0.4426
0.11	0.0470	0.26	0.1623	0.41	0.3032	0.56	0.4526
0.12	0.0534	0.27	0.1711	0.42	0.3130	0.57	0.4625
0.13	0.0600	0.28	0.1800	0.43	0.3229	0.58	0.4724
0.14	0.0668	0.29	0.1890	0.44	0.3328	0.59	0.4822
0.15	0.0739	0.30	0.1982	0.45	0.3428	0.60	0.4920

This table works as follows:

To determine the cross-sectional flow for a 12-inch sewer main with a flow depth of 5 inches you would first:

d or depth 5 inches divided by **D** or diameter 12 inches equals 0.42 **d/D.** using the table above find the correct factor for 0.42 d/D.

The factor equals 0.3130, now calculate the cross-sectional area using the following formula:

$$\text{Pipe Cross-sectional Area, sq ft} = \frac{(\text{Factor})(\text{Diameter, in})^2}{144 \text{ sq in/sq ft}}$$

$$\frac{(0.3130)(12 \text{ in})^2}{144 \text{ sq in/sq/ft}}$$

$$= 0.0313 \text{ sq ft}$$

Once the Velocity and the cross-sectional area have been determined, the calculation for flow rate is used. This formula is as followed:

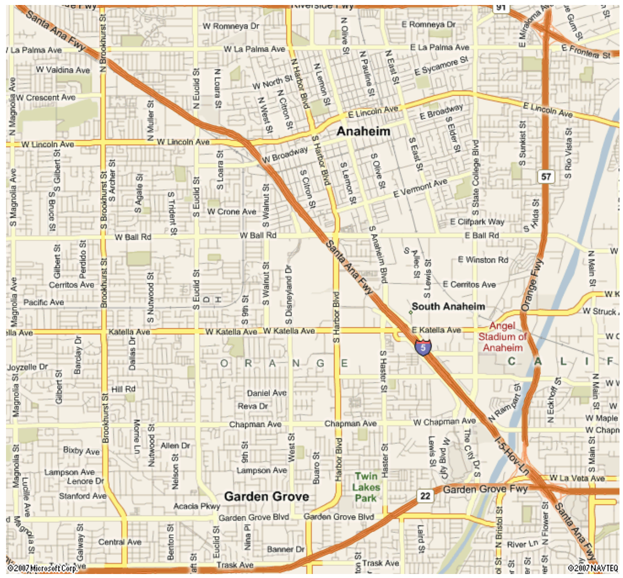
Q, cubic feet per second = (Area, sq ft) (Velocity, ft/sec)

Once this calculation is made, cubic feet can be converted to gallons by multiplying it by 7.48 gal/cubic feet and seconds can be converted to minutes, hours or days by multiplying the gallons with the time.

Sewer Line Mapping

The importance of maintaining accurate, current maps of the collection system cannot be overstated. Efficient collection system maintenance and repairs are unlikely if mapping is not adequate. Collection system maps should clearly indicate the information that personnel need to carry out their assignments. The collection system maps should contain information on the following:

- Main, trunk and interceptor sewers
- Building/house laterals
- Manholes
- Cleanouts
- Force mains
- Pump stations
- Service area boundaries
- Other landmarks (roads, water bodies, etc.)



Collection system maps should have a numbering system that uniquely identifies all manholes and sewer cleanouts. The system should be simple and easy to understand. Manholes and sewer cleanouts should have permanently assigned numbers and never be renumbered. Maps should also indicate the property served and reference its cleanout.

Sewer line maps should indicate the diameter, the length between the centers of manholes, and the slope or direction of flow. The dimensions of easements and property lines should be included on the maps. Other information that should be included on maps are access and overflow points, a scale, and a north arrow. All maps should have the date the map was drafted and the date of the last revision. Although optional, maps often include materials of pipe construction.

Maps may come in different sizes and scales to be used for different purposes. Detailed local maps may be used by maintenance or repair crews to perform the duties. However, these detailed local maps should be keyed to one overall map that shows the entire system.

Geographic Information System (GIS)

GIS technology has made the mapping and map updating process considerably more efficient. GIS is a computerized mapping program capable of combining mapping with detailed information about the physical structures within the collection system. If a GIS program is being used by the owner or operator, the reviewer should ask if the program is capable of accepting information from the owner or operator's management program.

Specific procedures should be established for correction of errors and updating maps and drawings. Field personnel should be properly trained to recognize discrepancies between field conditions and map data and record changes necessary to correct the existing mapping system. Reviewers should check to see that maps and plans are available to the personnel in the office and to field personnel or contractors involved in all engineering endeavors.

Key Design Characteristics

- Line locations, grades, depths, and capacities
- Maximum manhole spacing and size
- Minimum pipe size
- Pumping Station dimensions and capacities
- Drop manholes
- Flow velocities and calculations (peak flow and low-flow)
- Accessibility features
- Other technical specifications (e.g., materials, equipment)

New Sewer Construction

The owner or operator should maintain strict control over the introduction of flows into the system from new construction. New construction may be public (i.e., an expansion of the collection system) or private (i.e., a developer constructing sewers for a new development).

Quality sanitary sewer designs keep costs and problems associated with operations, maintenance, and construction to a minimum. Design flaws are difficult to correct once construction is complete.

The reviewer should be aware that this has historically not been adequately addressed in some collection systems. The owner or operator should have standards for new construction, procedures for reviewing designs and protocols for inspection, start-up, testing, and approval of new construction. The procedures should provide documentation of all activities, especially inspection.

Reviewers should examine construction inspection records and be able to answer the following:

- Does the volume of records seem reasonable given system size?

- Do records reflect that the public works inspectors are complying with procedures?

The state or other regulatory authority may also maintain standards for new construction. The standards held by the owner or operator should be at least as stringent. Start-up and testing should be in accordance with the manufacturers' recommendations where applicable, and with recognized industry practices. Each step of the review, start-up, testing, and approval procedures should be documented.

The owner or operator approval procedure should reflect future ease of maintenance concerns. After construction is complete, a procedure for construction testing and inspection should be used. Construction supervision should be provided by qualified personnel such as a registered professional engineer.

See the ladder-right on top photograph. See the collection crew under the steel plate and no shoring or trench protection. It looks like the steel plate is falling in, just another death trap for the uneducated and unsafe collection worker.

The Vactor can be a very dangerous piece of equipment. Always use this equipment in the most safest manor.

Wastewater Collection Section Summary

Primary Collection System Problems
a. Fats, oil, and greases (FOG) are a major problem; this is primarily applicable to municipal wastestreams.

b. Odors, particularly those related to sulfides (H_2S), are a constant concern, as are other mercaptans and some indoles (skatole).

c. In many wastewater streams, particularly in industrial ones, problems center on highly toxic anions/cations that require chemical treatment of one sort or another.

d. Various POTW's proscribe effluent limitations on phosphates, nitrates, and various other organic entities.

Structural Sewer Problems
Structural problems can cause major headaches. CCTV is one of the best tools available to check the condition of your buried assets. During CCTV field inspections, pipe defects and maintenance issues are discovered and classified using a standardized coding system. Following data analysis, structural condition information is used to estimate a pipe's performance, remaining useful life and to plan for the future and make decisions about pipe repair or replacement.

CCTV inspections also reveal maintenance issues, which aid the manager in making any necessary operation or maintenance changes.

- Collapses
- Fractures
- Sags
- Infiltration
- Inflow

Hydraulic Capacity
Hydraulic capacity is a primary performance measure for a wastewater collection system. Capacity (both hydraulic and treatment) can be taken up by clean water entering the sewer collection system. It may be obvious, based on dry weather and wet weather flows, that rainwater or groundwater inflow or infiltration (I/I) is a problem.

CCTV evaluation can determine the specific location and cause of I/I in many cases, however, flow data gathered by flow meters has been used to guide sewer system capacity management for decades.

Flow data can be used as a tool in condition assessment either to identify areas for further CCTV inspection or to quantify the severity of I/I identified during CCTV work.

- Excess flow
- Infiltration
- Inflow

Wastewater Collection Post Quiz

Internet Link to Assignment…
http://www.abctlc.com/downloads/PDF/CollectionOandMASS.pdf

Collection System Defined
1. Decentralized systems are public sewer systems that serve established towns and cities and transport wastewater to a central location for treatment.
A. True B. False

2. Homes and other buildings that are not served by public sewer systems depend on ____________________ septic systems to treat and dispose of wastewater.

3. Most decentralized systems are _____________ systems (wastewater is treated underground near where it is generated).

4. Centralized systems are more inexpensive, allow for greater control, require fewer people, and produce only one discharge to monitor instead of several. However, ____________________systems can be useful, and this option should be evaluated on a case-by-case basis.

5. __________________ are designed to collect both sanitary wastewater and storm water runoff.

Collection System Operators' Purpose
6. Collection system operators are charged with protecting public health and the environment, and therefore must have documented proof of their certifications in the respective ____________________.

7. _____________________ and the professionals who maintain it operate at such a high level of efficiency, problems are very infrequent.

8. Collection system operators ensure that the system pipes remain clear and open. They eliminate obstructions and are constantly striving to improve flow characteristics. They keep the wastewater moving underground, unseen and unheard.
A. True B. False

9. Underground sanitary sewer pipes can clog or break, causing unplanned "overflows" of raw sewage that flood basements and streets.
A. True B. False

10. Storm sewers are not designed to quickly get rainwater off the streets during rain events.
A. True B. False

11. Combined sewers deliver both wastewater and storm water in the same pipe. Most of the time, combined sewers transport the wastewater and storm water to a treatment plant.
A. True B. False

12. The public often takes the wastewater collection system for granted. In truth, these operators must work hard to keep it functioning properly.
A. True B. False

13. When there is too much rain, combined sewer systems cannot handle the extra volume and designed "overflows" of raw sewage into streams and rivers occur. The great majority of sewer systems have separated, not combined, sanitary and storm water pipes.
A. True B. False

14. The maintenance of the sewer system is a semi-continuous cycle.
A. True B. False

15. Outdated pump stations, undersized to carry sewage from newly developed subdivisions or commercial areas, will not create any potential overflow hazards, adversely affecting human health and degrading the water quality of receiving waters.
A. True B. False

Understanding Gravity Sanitary Sewers

16. Sanitary sewers are planned to transport the wastewater by utilizing the ________________ provided by the natural elevation of the earth resulting in a downstream flow.

17. Sewer systems are designed to maintain proper flow velocities with?

Sewer System Capacity Evaluation - Testing and Inspection

18. The collection system owner or operator should have a program in place to periodically evaluate this ________________________ in both wet and dry weather flows and ensure the capacity is maintained as it was designed.

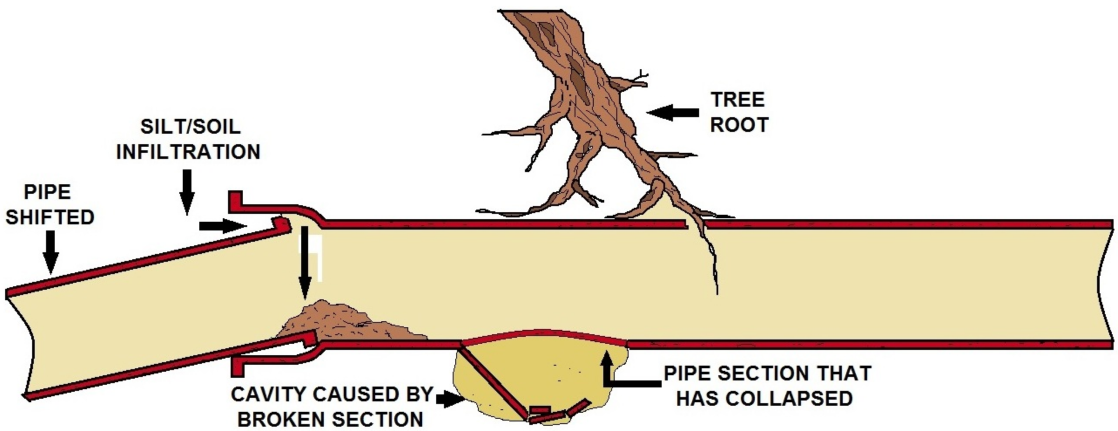
Answers

1. False, 2. Decentralized, 3. Onsite, 4. Decentralized, 5. Combined sewer systems, 6. Wastewater management system, 7. Wastewater collection system, 8. True, 9. True, 10. False, 11. True, 12. True, 13. True, 14. False, 15. False, 16. Potential energy, 17. Minimum head loss, 18. Capacity of the sewer system

Chapter 2- COLLECTION SYSTEM O&M SECTION

Section Focus: You will learn the basics of the operation and maintenance of the collection system. At the end of this section, you the student will be able to describe the basics of proper operation and maintenance of the wastewater collection system. There is a post quiz at the end of this section to review your comprehension and a final examination in the Assignment for your contact hours.

Scope/Background: As a collection operator / pretreatment inspector, you will need knowledge of many different concerns of the collections and wastewater treatment systems in order to properly identify the problem. Master's level knowledge of the collection system is essential for all collections personnel.



BROKEN SEWER PIPE

Operation and maintenance of wastewater collection systems on a trouble or emergency basis has been the usual procedure and policy in many systems. Planned operation and preventive maintenance of the collection system has been delayed or omitted, primarily for political or financial reasons.

Routine preventative operations and maintenance activities for wastewater collection lines shall be performed by the system's personnel and outside contractors. A qualified outside contractor can also be utilized to perform hydraulic cleaning using a jet hydro-vac combination truck and mechanical cleaning using a rodding machine. Routine operations and maintenance activities including cleaning and removing roots from small and large diameter lines. The system's goal should be a minimum of cleaning between 20-30% of the sewers every year.

Closed-circuit television (CCTV) is used to assess the condition of the sewers. There are four types of activities that the system or a CCTV contractor can also perform:
1) inspect new work,
2) inspect condition of older portions of the wastewater collection system,
3) routine inspection of approximately 10% of the wastewater collection, and 4) problem identification to determine the cause of selected overflow events. Manhole inspection, manhole coating (to prevent concrete deterioration) and manhole painting (for roach control) are also routinely performed.

Sewer filled with grass will damage your system, pumps, and upset the wastewater treatment system. Require your industrial users like golf courses to install grass, grease, and sand/oil interceptors.

Certain compounds and undesirable solids, like grease and grass clippings, can disturb this delicate balance and necessary process at the wastewater treatment facility.

There are compounds and mixtures that should never be introduced into a sanitary sewer system. These destructive compounds include but are not limited to: cleaning solvents, grease (both household and commercial), oils (both household and commercial), pesticides, herbicides, antifreeze and other automotive products.

Sewer Cleaning and Inspection Sub-Section

Inspection and testing are the techniques used to gather information to develop operation and maintenance programs to ensure that new and existing wastewater collection systems serve their intended purposes on a continuing basis. Inspection and testing are necessary to do the following:

- Identify existing or potential problem areas in the collection system,
- Evaluate the seriousness of detected problems,
- Locate the position of problems, and
- Provide clear, concise and meaningful reports regarding problems.

Two major purposes of inspecting and testing are to prevent leaks from developing in the wastewater collection system and to identify existing leaks so they can be corrected. The existence of leaks in a wastewater collection system is a serious and often expensive problem. When a sewer is under a water table, infiltration can take place and occupy valuable capacity in the sewer and the downstream treatment plant. Sewers located above a water table can exfiltrate, allowing raw wastewater to pollute soil and groundwater.

As sewer system networks age, the risk of deterioration, blockages, and collapses becomes a major concern. As a result, municipalities worldwide are taking proactive measures to improve performance levels of their sewer systems. Cleaning and inspecting sewer lines are essential to maintaining a properly functioning system; these activities further a community's reinvestment into its wastewater infrastructure.

Inspection Techniques
Inspection programs are required to determine current sewer conditions and to aid in planning a maintenance strategy. Ideally, sewer line inspections need to take place during low flow conditions. If the flow conditions can potentially overtop the camera, then the inspection should be performed during low flow times between midnight and 5 AM, or the sewer lines can be temporarily plugged to reduce the flow.

Most sewer lines are inspected using one or more of the following techniques:

- Closed-circuit television (CCTV).
- Cameras.
- Visual inspection.
- Lamping inspection.

Television (TV) inspections are the most frequently used, most cost efficient in the long term, and most effective method to inspect the internal condition of a sewer. CCTV inspections are recommended for sewer lines with diameters of 0.1-1.2 m (4 - 48 inches.) The CCTV camera must be assembled to keep the lens as close as possible to the center of the pipe. In larger sewers, the camera and lights are attached to a raft, which is floated through the sewer from one manhole to the next. To see details of the sewer walls, the camera and lights swivel both vertically and horizontally.

In smaller sewers, the cable and camera are attached to a sled, to which a parachute or droge is attached and floated from one manhole to the next. Documentation of inspections is very critical to a successful operation and maintenance (O&M) program.

CCTV inspections produce a video record of the inspection that can be used for future reference. In larger sewers where the surface access points are more than 300 1000 linear feet apart, camera inspections are commonly performed. This method requires less power than the CCTV, so the power cable is smaller and more manageable. Inspections using a camera are documented on Polaroid or digital still (computer jpeg) photographs that are referenced in a log book according to date, time, and location.

Visual inspections are vital in fully understanding the condition of a sewer system. Visual inspections of manholes and pipelines are comprised of surface and internal inspections. Operators should pay specific attention to sunken areas in the groundcover above a sewer line and areas with ponding water.

In addition, inspectors should thoroughly check the physical conditions of stream crossings, the conditions of manhole frames and covers or any exposed brickwork, and the visibility of manholes and other structures. For large sewer lines, a walk-through or internal inspection is recommended. This inspection requires the operator to enter a manhole, the channel, and the pipeline, and assess the condition of the manhole frame, cover, and chimney, and the sewer walls above the flow line.

When entering a manhole or sewer line, it is very important to observe the latest Occupational Safety and Health Administration confined space regulations. If entering the manhole is not feasible, mirrors can be used. Mirrors are usually placed at two adjacent manholes to reflect the interior of the sewer line. Lamping inspections are commonly used in low priority pipes, which tend to be pipes that are less than 20 years old.

Lamping

Lamping is also commonly used on sewer projects where funds are extremely limited. In the lamping technique, a camera is inserted and lowered into a maintenance hole and then positioned at the center of the junction of a manhole frame and the sewer. Visual images of the pipe interior are then recorded with the camera.

Several specialized inspection techniques have been recently developed worldwide. This includes: Light-line based and sonar-based equipment that measures the internal cross-sectional profile of sewer systems.

Sonar technology could be very useful in inspecting depressed sewers (inverted siphons), where the pipe is continually full of water under pressure. Melbourne Water and CSIRO Division of Manufacturing Technology have introduced a new technology called PIRAT, which consists of an in-pipe vehicle with a laser scanner. This instrument is capable of making a quantitative and automatic assessment of sewer conditions. The geometric data that is gathered is then used to recognize, identify, and rate defects found in the sewer lines.

Manhole Inspections - Sewer Inspections Recommendations

The information provided if employed is a good starting point for an inspection.

Manhole inspections should yield a report with the following information at a minimum:

- Exact location of the manhole;
- Diameter of the clear opening of the manhole;
- Condition of the cover and frame, including defects that would allow inflow to enter the system;
- Whether cover is subject to ponding or surface runoff;
- The potential drainage area tributary to the defects;
- Type of material and condition of the chimney corbel cone and walls;
- Condition of steps and chimney and frame-chimney joint;
- Configuration of the incoming and outgoing lines (including drops); and
- Signs of frame-chimney leakage or damage to the frame's seal

Additionally, the following data can be obtained by entering the manhole and using equipment such as portable lamps, mirrors, rulers, and probe rods:

- Type of material and condition of apron and trough;
- Any observed infiltration sources and the rate of infiltration;
- Indications of height of surcharge;
- Size and type of all incoming and outgoing lines; and
- Depth of flow indications of deposition and the characteristics of flow within all pipes.
- The condition of the manhole shaft;
- Any leakage in the channel;
- Any leakage between the manhole wall and the channel;
- Any damage or leakage where pipeline connects to the manhole; and
- Any flow obstructions.

Television Inspections
Sewer pipe inspections of small diameter sewers for infiltration are most effective when a closed circuit television camera is employed.

Television inspections should provide the following information:

- Definitions of problem(s)
- Determine if problem is in municipal sewer or private property sewer
- Effectiveness of existing cleaning program
- Future sewer cleaning requirements
- Sewer rehabilitation needs
- Ability to assess whether trenchless technology or excavation and replacement can solve the problem
- Ability to project repair budget
- Information to plan a permanent solution

Planning is Required to Define the Inspections Goals.

Inspections are performed to:

- Identify maintenance problems
- Determine general sewer conditions
- Identify extraneous flows

The following data is useful to have prior to beginning the inspection:

- Sewer map or as-built plans to locate sewer
- Site specific data
- accessibility of deploying equipment at manholes
- depth of flow in sewer
- pipe diameter
- traffic connections
- safety requirement
- sewer cleaning
- sewer backup records
- sewer cleaning records
- influence of pump station discharges
- influence of industrial discharges

If such records are not available or kept, then a system to retain such information should be established.

During the CCTV inspection the following information should be obtained:

Pipe structural condition	Pipe material	Joints
Joint interval distance	Pipe cracks	Root intrusion
Debris, sediment and/or oil and grease	Service connections	type
quadrant location	building number	active or inactive
rate of infiltration	Infiltration and inflow	Alignment
Sewer types	Sewer location	Sewer surface cover (depth)
Roadway surface material	Time of day	Weather conditions

Inspection for Sources of Inflow

- are most readily achieved through smoke testing and/or dye testing.

Smoke Testing of Sewers is Done to Determine:

- stormwater sewer connections
- proof that buildings or residences are connected to the sanitary sewer
- illegal connections such as roof leaders or downspouts, yard drains and industrial drains
- location of broken sewers due to settling of foundations, manholes and other structures
- location of uncharted manholes and diversion points

Dye testing can be used to verify connections of drains to sanitary or storm sewers. Dye testing can be used to verify the findings of smoke testing.

Suggested Inspection And Maintenance Frequencies	
Task	**Frequency in Years**
Video inspection/line testing (typical)	3 to 15
Video inspection/line testing (problem area)	1 to 3
Field check (problem area)	1
Walk alignment	1
Manhole/line lamping (typical)	3 to 15
Manhole/line lamping (problem area)	1 to 3
Cleaning (typical)	3 to 15
Cleaning (problem area)	0.5 to 3
System assessment	1
Source: Nelson, Richard E. “Collection System Maintenance: How Much is Enough?” Operation Forum, July 1996	

Sewer Cleaning Techniques and Schedules

To maintain its proper function, a sewer system needs a cleaning schedule. There are several traditional cleaning techniques used to clear blockages and to act as preventative maintenance tools. When cleaning sewer lines, local communities need to be aware of EPA regulations on solid and hazardous waste as defined in 40 CFR 261. In order to comply with state guidelines on testing and disposal of hazardous waste, check with the local authorities.

Hydraulic cleaning developments have also been emerging on the international frontier. France and Germany have developed several innovative flushing systems using a 'dam break' concept.

Hydrass

France has developed a flushing system called the Hydrass. The design of the Hydrass consists of a gate that pivots on a hinge to a near horizontal position. As the gate opens and releases a flow, a flush wave is generated that subsequently washes out any deposited sediments. Germany has also developed a similar system called GNA Hydroself®. This is a flushing system that requires no electricity, no maintenance and no fresh water. The Hydroself® consists of a hydraulically-operated gate and a concrete wall section constructed to store the flush water. This system can be installed into a large diameter sewer. There appears to be no limit on the flushing length, as more flush water may be stored without incurring any additional construction or operating costs.

Another example of such a technology is seen in the Brussels Sewer System. A wagon with a flushing vane physically moves along the sewer and disturbs the sediments so that they are transported with the sewer flow.

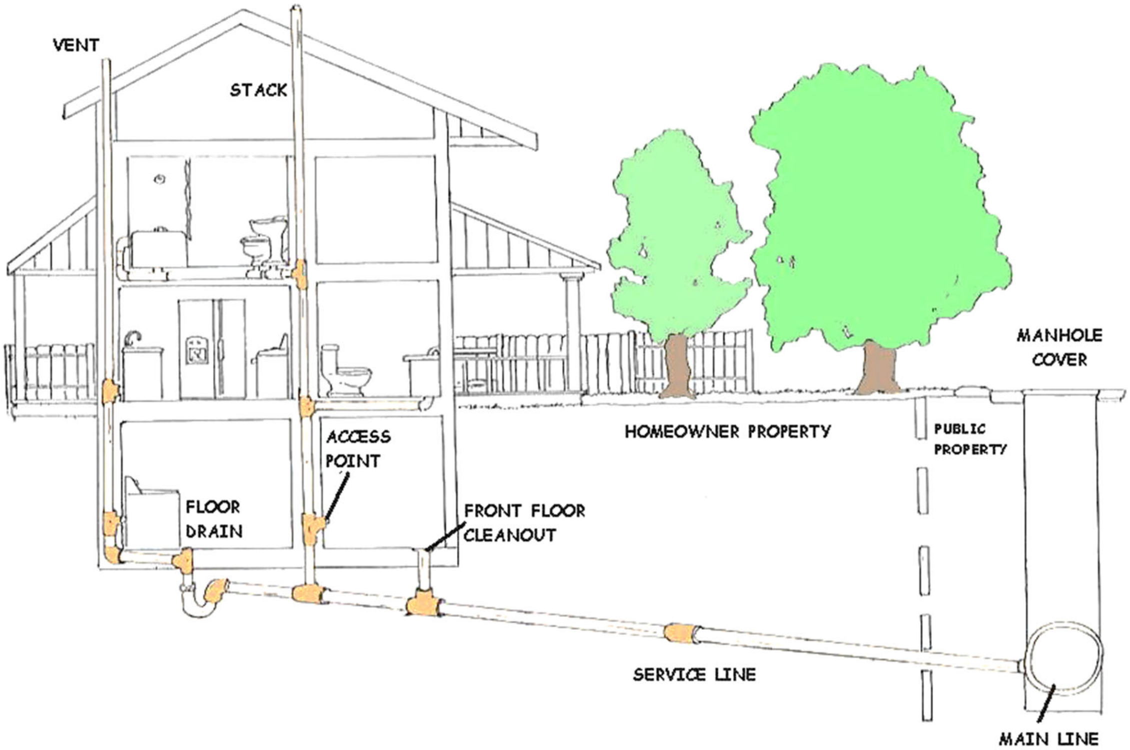
Public Education

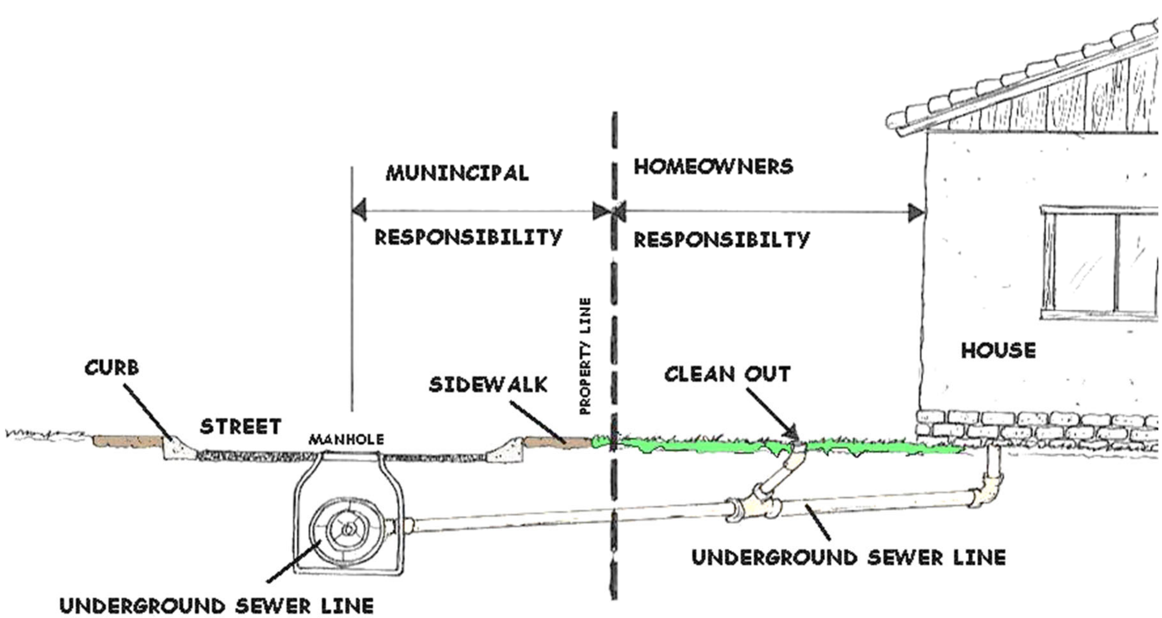
Although all of these methods have proven effective in maintaining sewer systems, the ideal method of reducing and controlling the materials found in sewer lines is education and pollution prevention. The public needs to be informed that common household substances such as grease and oil need to be disposed in the garbage in closed containers, and not into the sewer lines. This approach will not only minimize a homeowner's plumbing problems, but will also help keep the sewer lines clear.

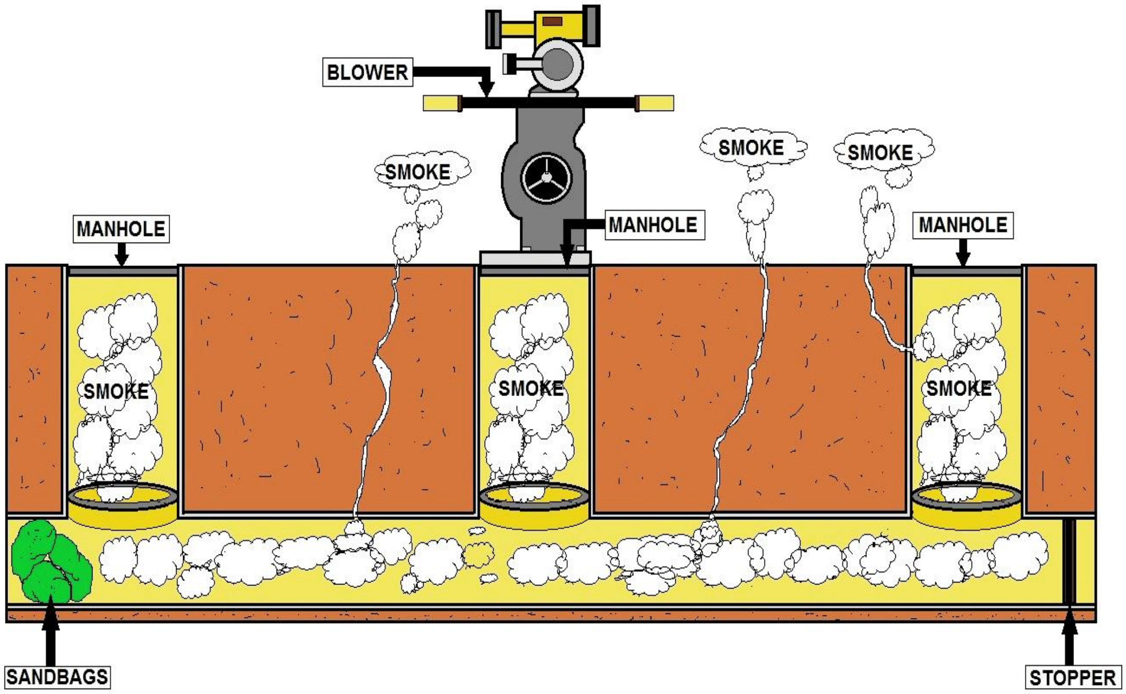
In recent years, new methodologies and accelerated programs have been developed to take advantage of the information obtained from sewer line maintenance operations. Such programs incorporate information gathered from various maintenance activities with basic sewer evaluations to create a system that can remedy and prevent future malfunctions and failures more effectively and efficiently.

Some systems have attempted to establish a program that would optimize existing maintenance activities to reduce customer complaints, sanitary sewer overflows, time and money spent on sewer blockages, and other reactive maintenance activities. Their plan is based on maintenance frequencies, system performance, and maintenance costs over a period of time. This plan was developed using Geographical Information System (GIS) and historical data to show areas of complaints, back-ups, and general maintenance information for the area.

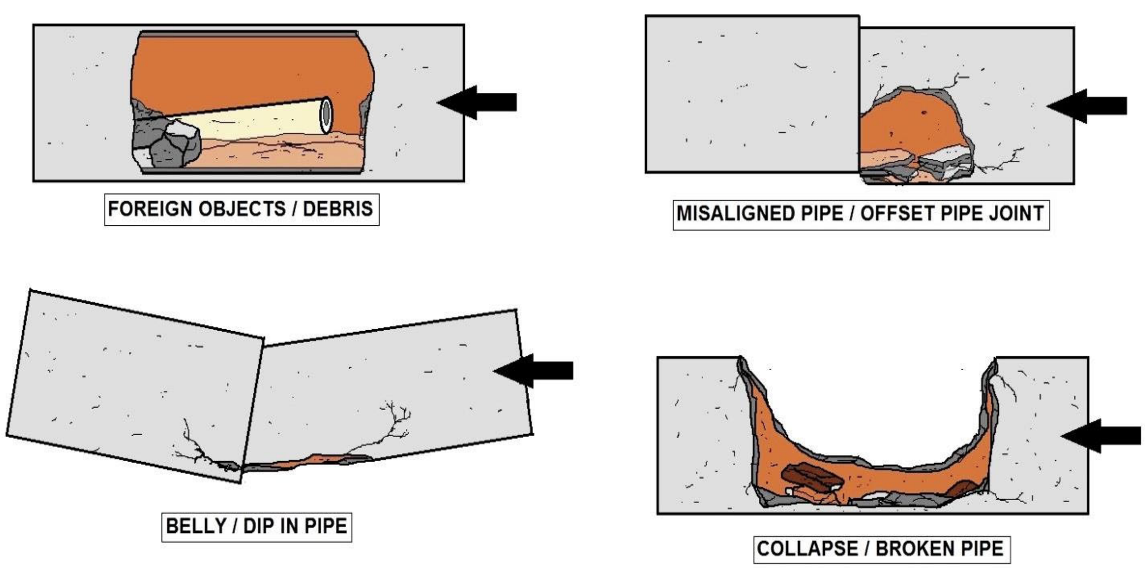
Homeowner Sewer Diagrams





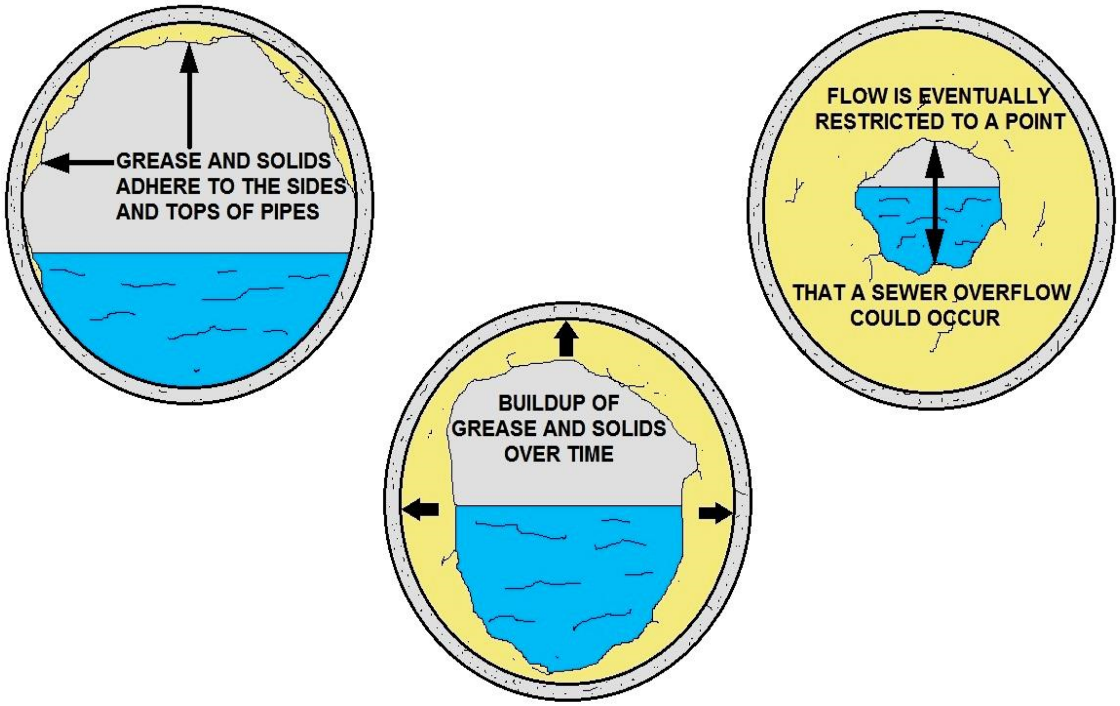


SMOKE TEST IN SEWER MAIN

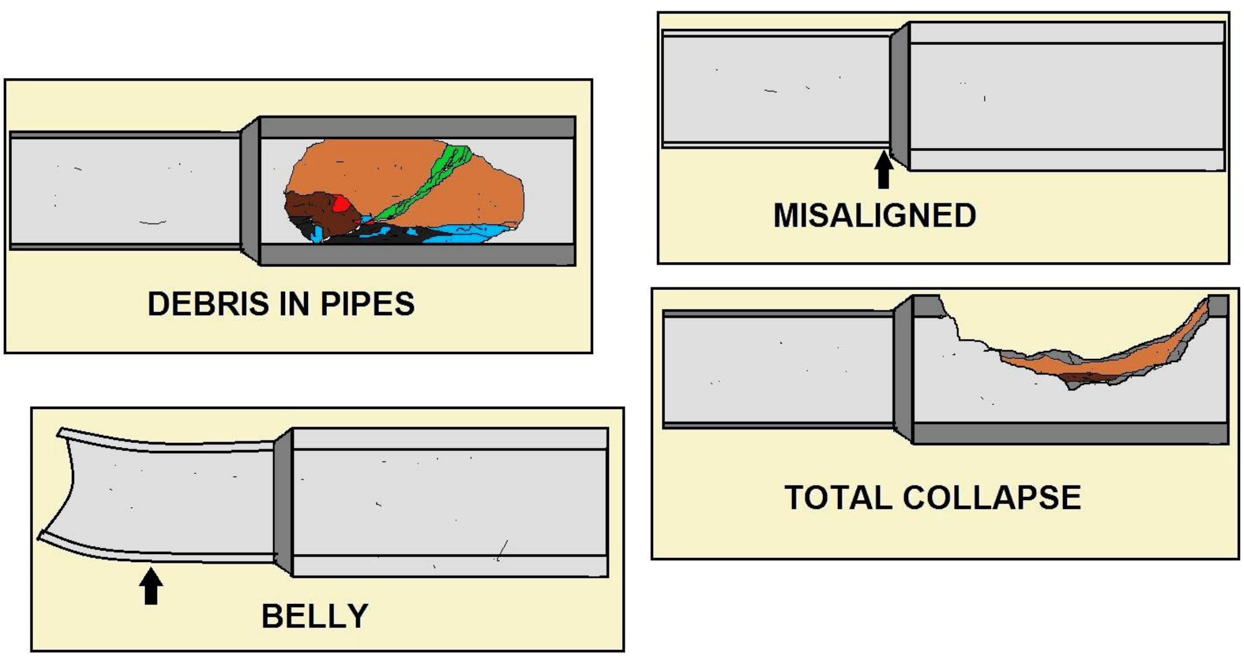


COMMON CAUSES OF SEWER LATERAL BLOCKAGES

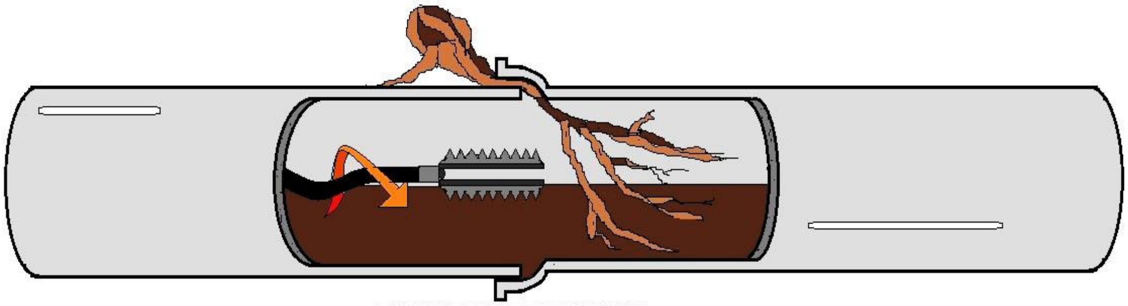
Common Sewer Problems and Solutions Diagrams



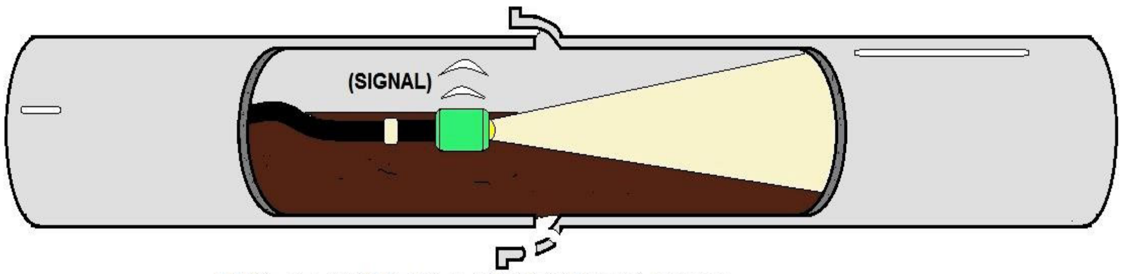
EFFECTS OF GREASE AND SOLIDS ON SEWER FLOW



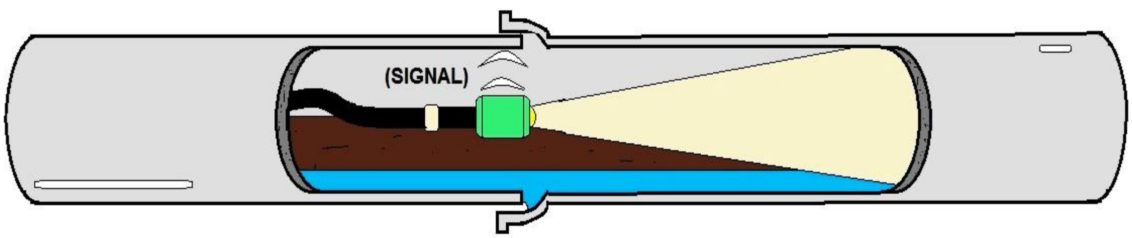
DAMAGED SEWER PIPE EXAMPLES



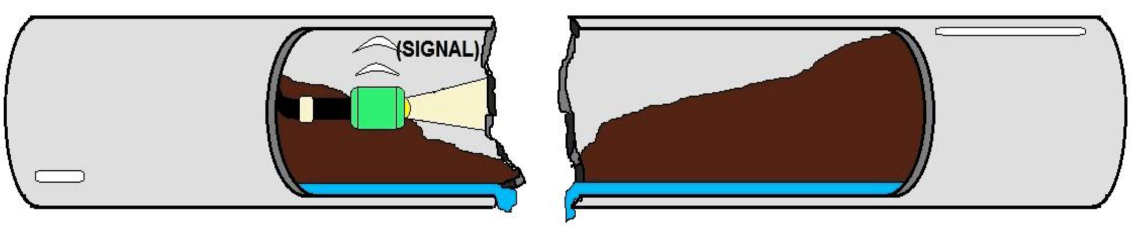
ROOT INTRUSION
(CLEANED WITH A CABLE FITTED WITH A ROOT-CUTTING BLADE)



MIS-ALIGNED / CRACKED PIPE
(A CAMERA IS USED TO SHOW THE LOCATION OF THE PROBLEM VIA A SIGNAL)

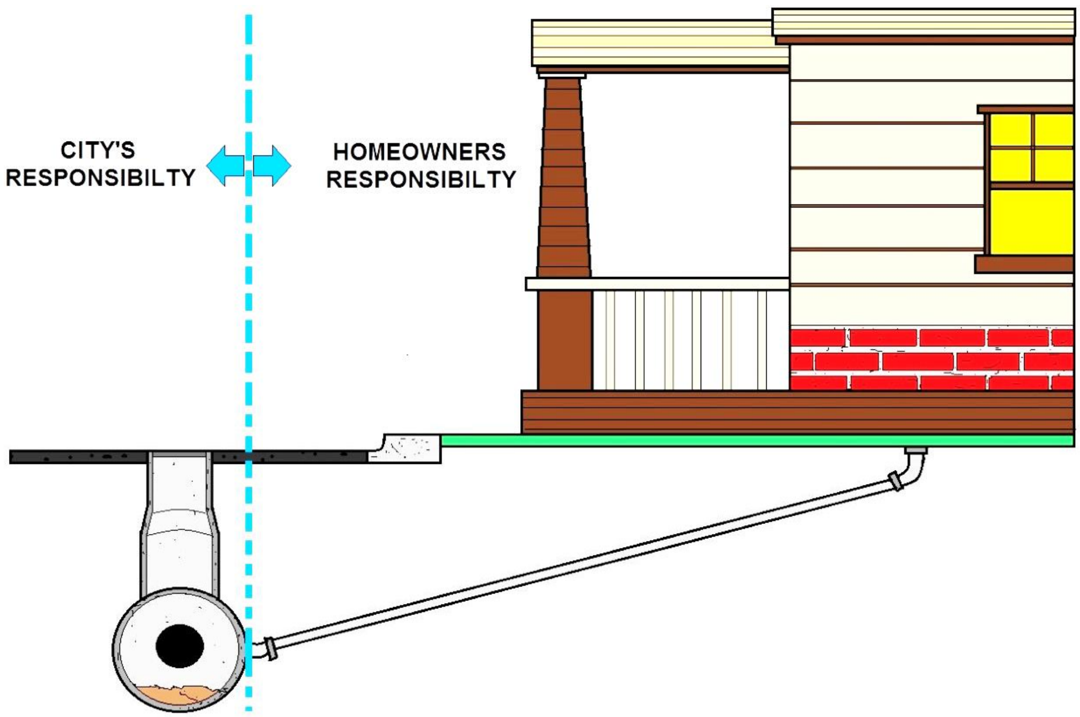


PIPE WITH A BELLY
(A CAMERA IS USED TO SHOW THE LOCATION OF THE PROBLEM VIA A SIGNAL)

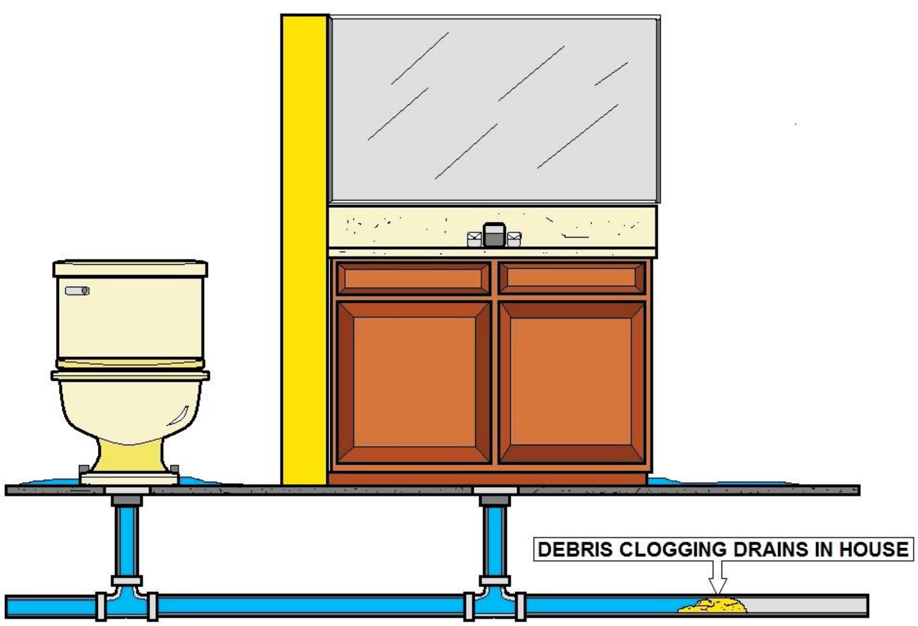


PIPE THAT HAS BEEN CRUSHED
(A CAMERA IS USED TO SHOW THE LOCATION OF THE PROBLEM VIA A SIGNAL)

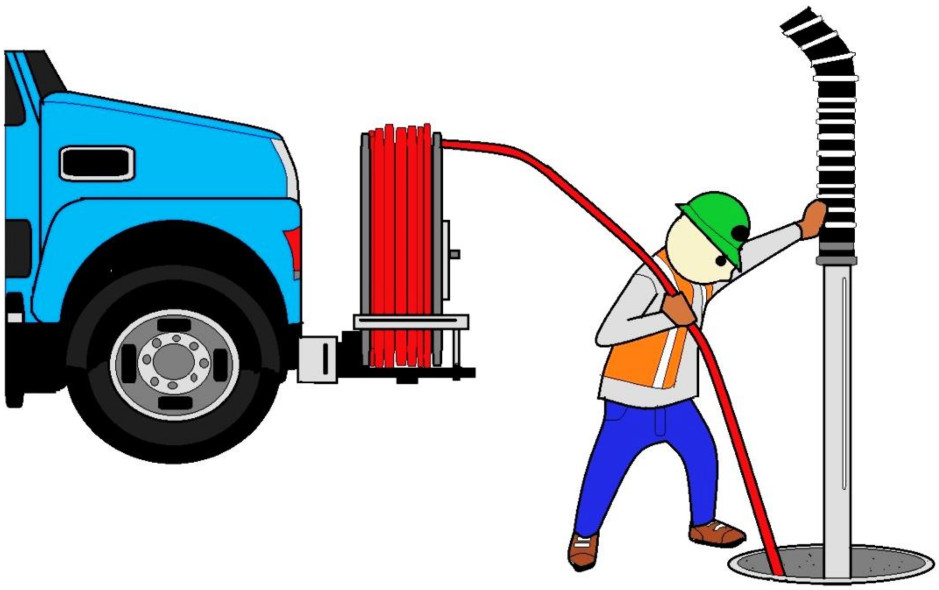
MAJOR SEWER PIPE PROBLEM DIAGRAM



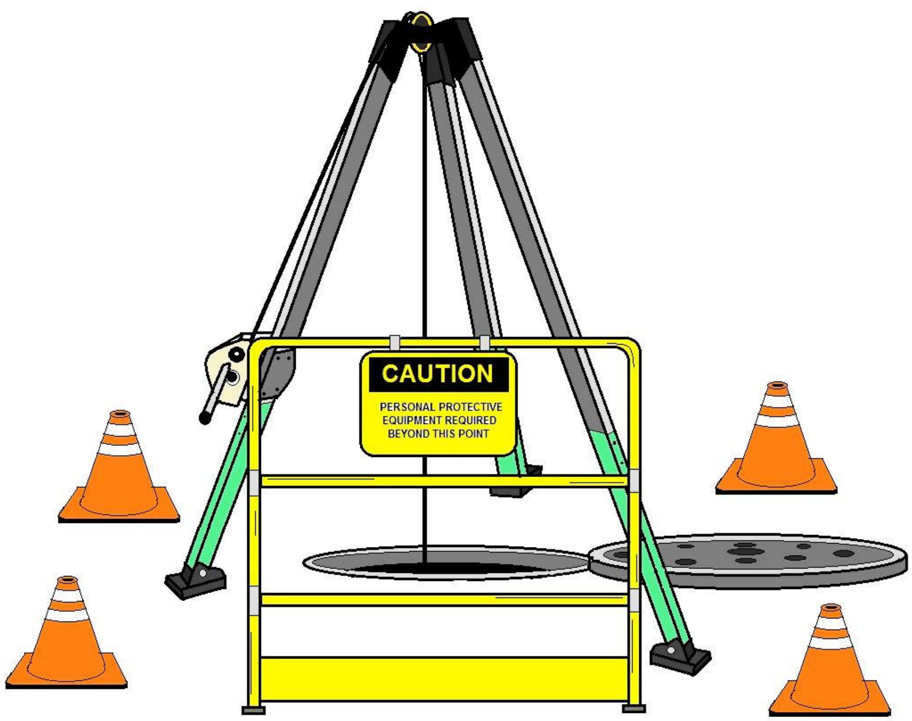
DESIGNATING SEWER MAINTENANCE RESPONSIBILTY



EXAMPLE OF A CLOGGED SEWER LINE

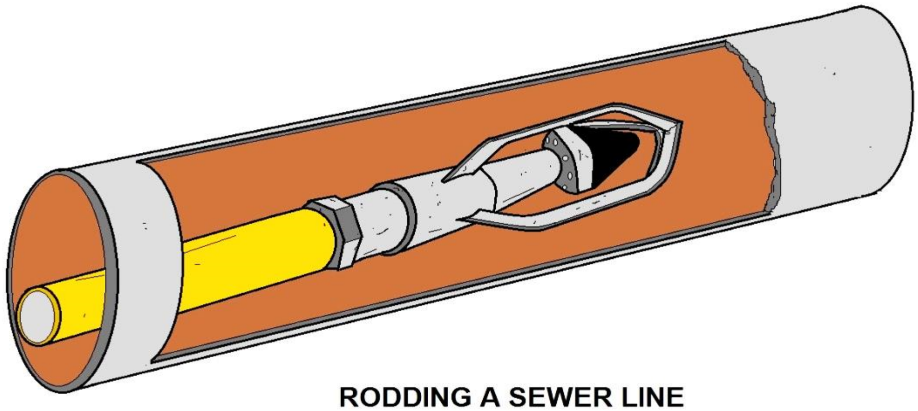


USING A VACUUM TRUCK TO CLEAN SEWER



SAFETY EQUIPMENT TO ENTER A SEWER SAFELY

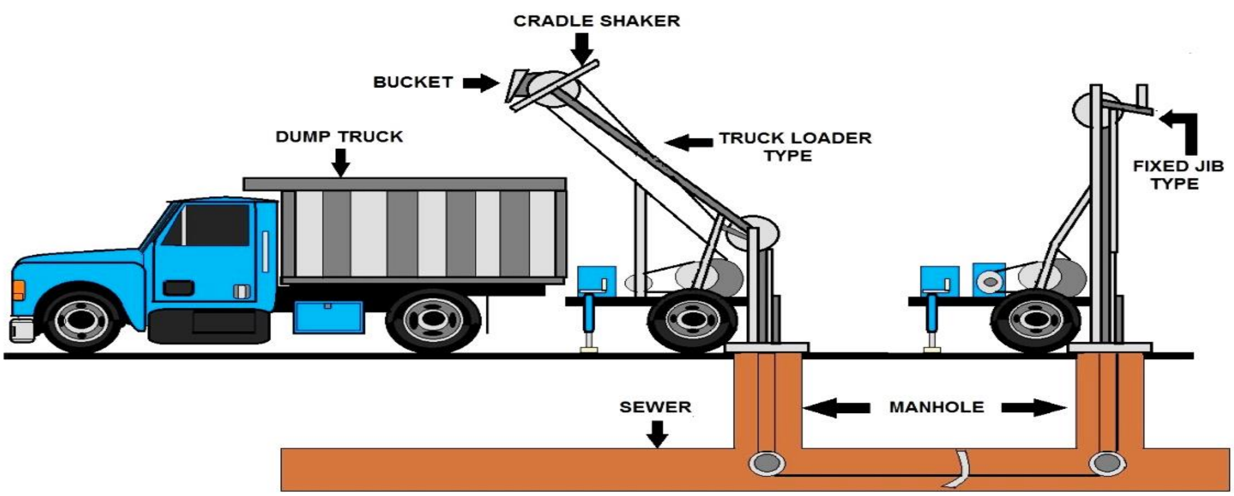
Sewer Technology Uses and Applications Diagrams



RODDING A SEWER LINE

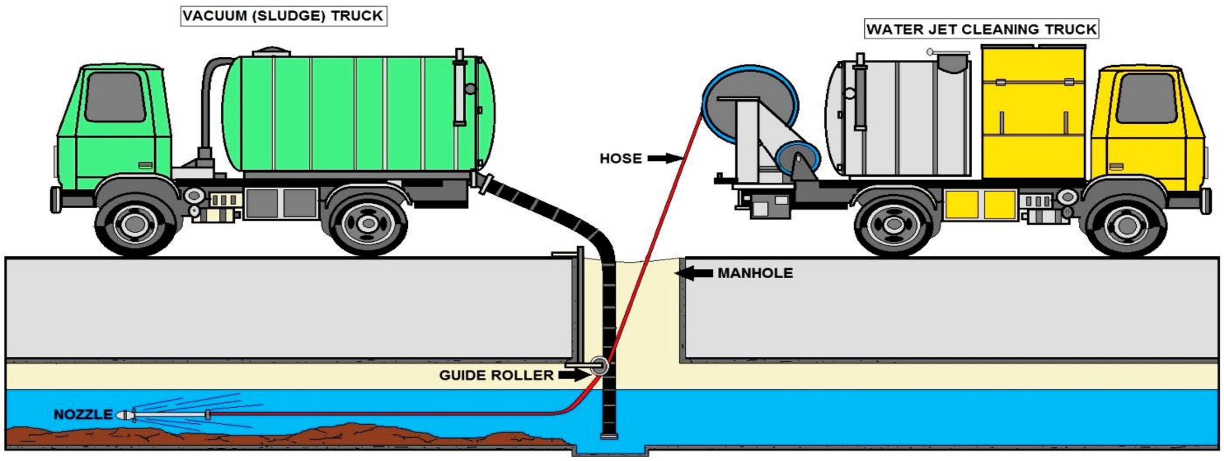
As a collection system operator, you will need knowledge of many different concerns in order to properly identify the problem and sometimes you'll need to order the remedy, solution or correction.

Mechanical
Rodding
• Uses an engine and a drive unit with continuous rods or sectional rods.
• As blades rotate, they break up grease deposits, cut roots, and loosen debris.
• Rodders also help thread the cables used for TV inspections and bucket machines.
• Most effective in lines up to 12 inches in diameter.



TRAILER MOUNTED BUCKET MACHINES

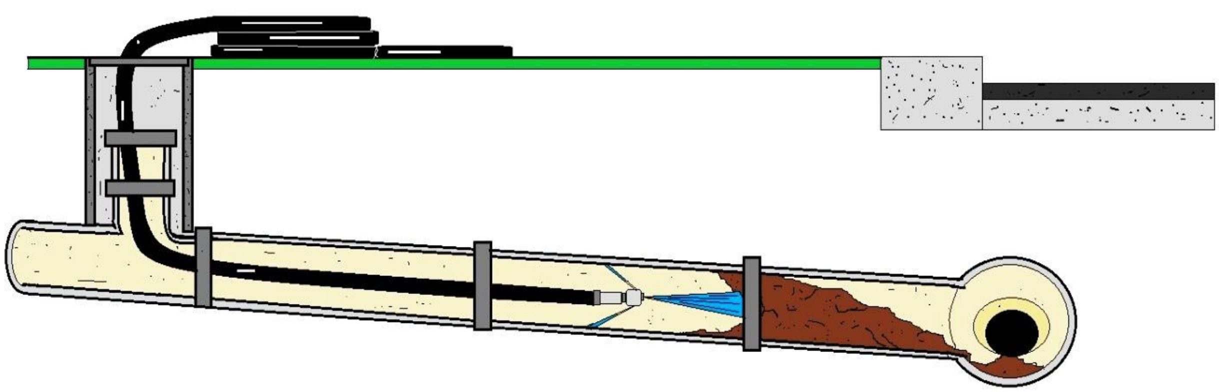
Bucket Machine
• Cylindrical device, closed on one end with 2 opposing hinged jaws at the other.
• Jaws open and scrape off the material and deposit it in the bucket.
• Partially removes large deposits of silt, sand, gravel, and some types of solid waste.



HYDRAULIC SEWER CLEANING PROCESS

Hydraulic
Balling
• A threaded rubber cleaning ball that spins and scrubs the pipe interior as flow increases in the sewer line.
• Removes deposits of settled inorganic material and grease build-up.
• Most effective in sewers ranging in size from 5-24 inches.

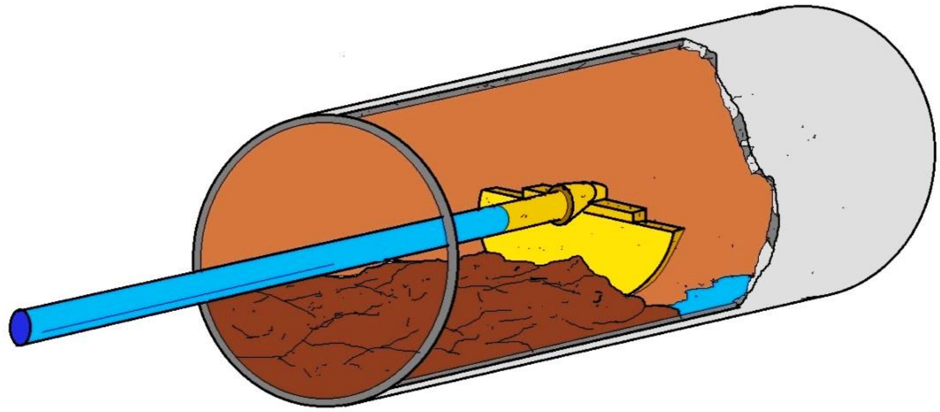
Flushing
• Introduces a heavy flow of water into the line at a manhole.
• Removes floatables and some sand and grit.
• Most effective when used in combination with other mechanical operations, such as rodding or bucket machine cleaning.



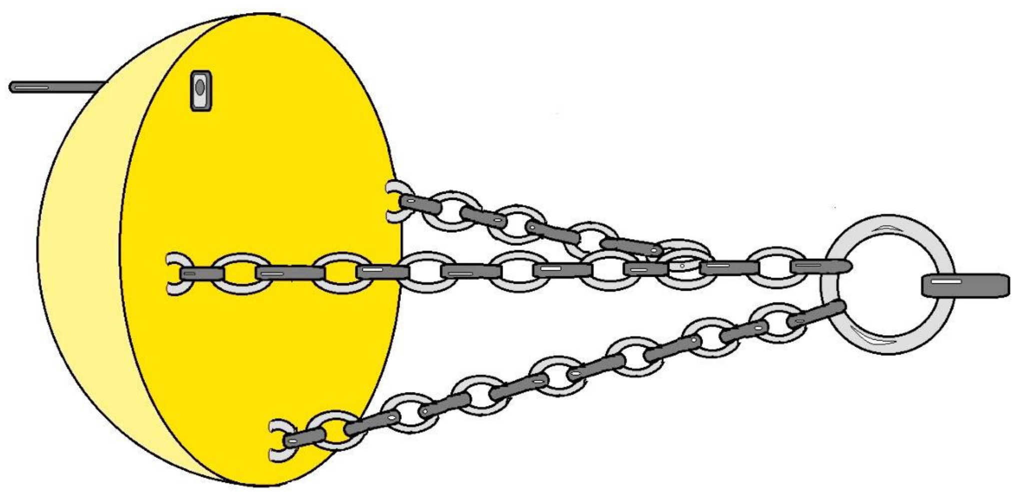
JETTING A SEWER LINE

Jetting
• Directs high velocities of water against pipe walls.
• Removes debris and grease build-up, clears blockages, and cuts roots within small diameter pipes.
• Efficient for routine cleaning of small diameter, low flow sewers.

Sewer Cleaning - Technology Applications Diagrams



DROP SCRAPER



SEWER SCRAPER

Scooter

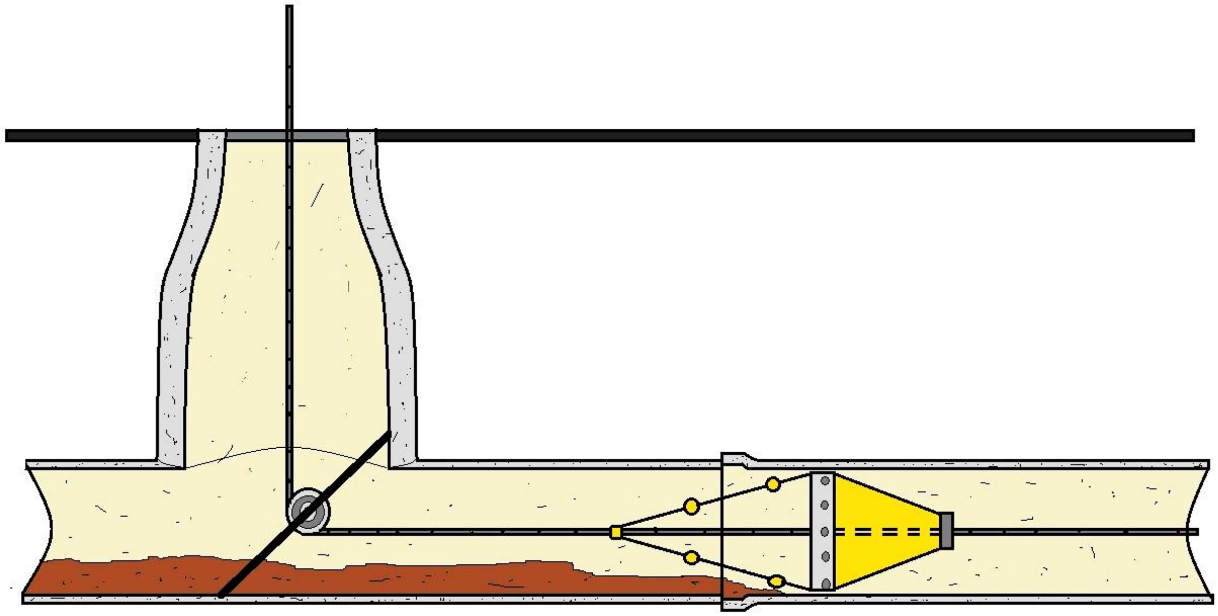
- Round, rubber-rimmed, hinged metal shield that is mounted on a steel framework on small wheels. The shield works as a plug to build a head of water.
- Scours the inner walls of the pipe lines.
- Effective in removing heavy debris and cleaning grease from line.

Kites, Bags, and Poly Pigs

- Similar in function to the ball.
- Rigid rims on bag and kite induce a scouring action.
- Effective in moving accumulations of decayed debris and grease downstream.

Silt Traps

- Collect sediments at convenient locations.
- Must be emptied on a regular basis as part of the maintenance program.



SEWER KITE DIAGRAM

Grease Traps and Sand/Oil Interceptors

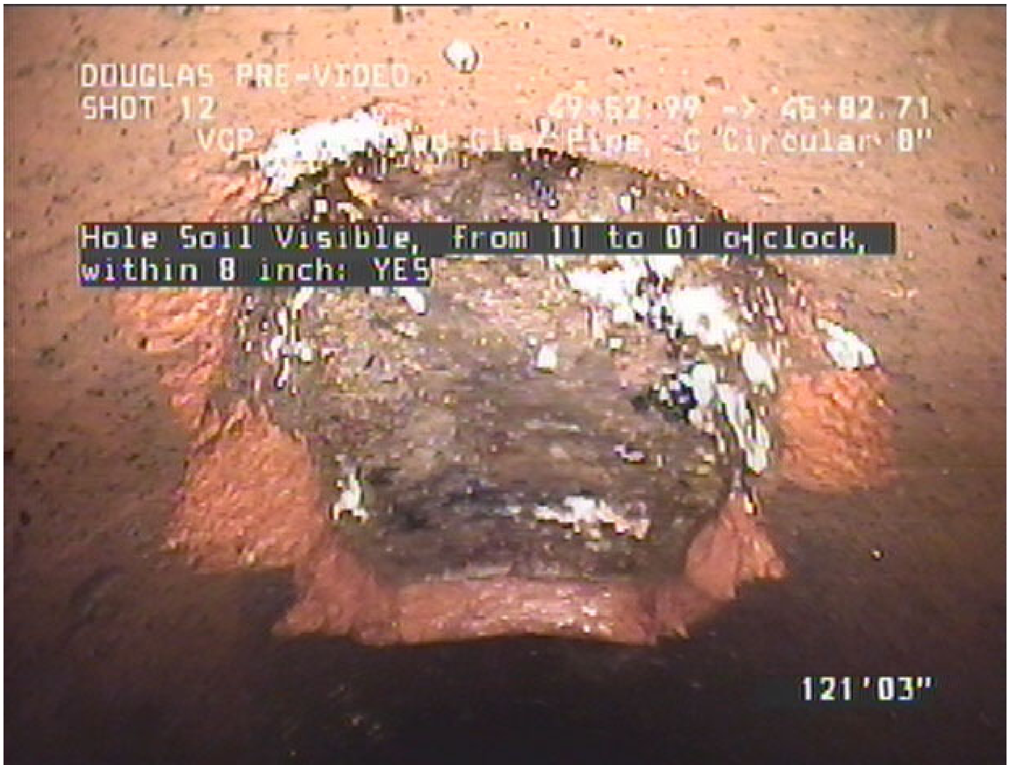
- The ultimate solution to grease build-up is to trap and remove it.
- These devices are required by some uniform building codes and/or sewer-use ordinances.
Typically sand/oil interceptors are required for automotive business discharge.
- Need to be thoroughly cleaned to function properly.
- Cleaning frequency varies from twice a month to once every 6 months, depending on the amount of grease in the discharge.
- Need to educate restaurant and automobile businesses about the need to maintain these traps.

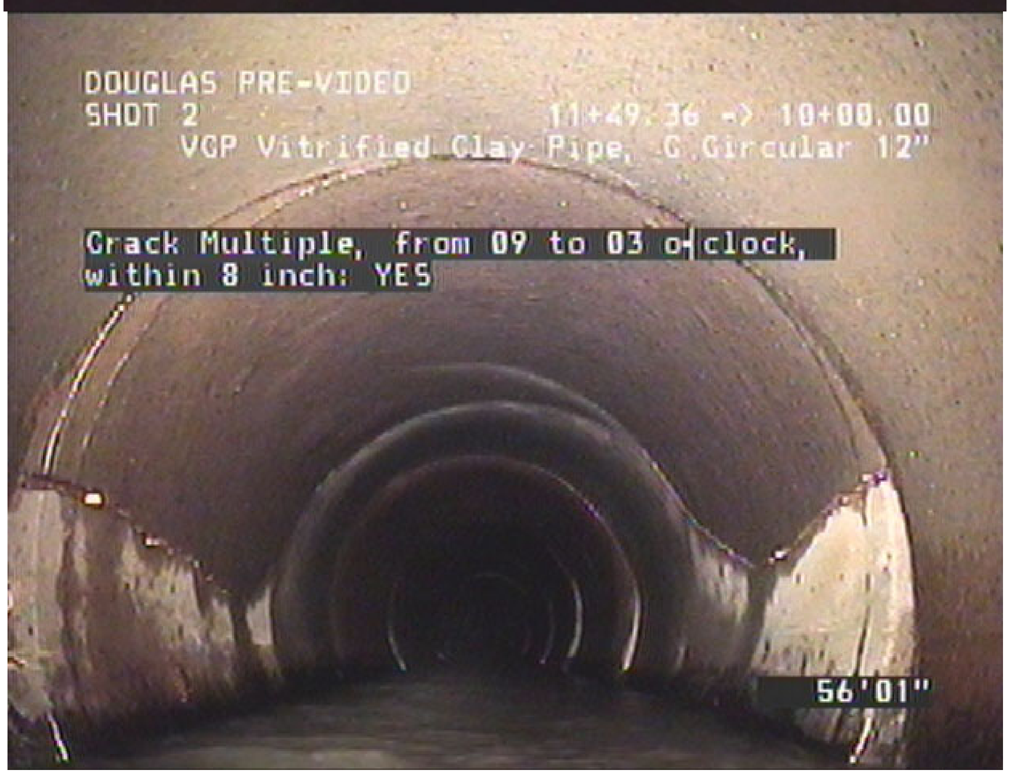
Chemicals

Before using these chemicals review the Safety Data Sheets (SDS) and consult the local authorities on the proper use of chemicals as per local ordinance and the proper disposal of the chemicals used in the operation. If assistance or guidance is needed regarding the application of certain chemicals, contact the U.S. EPA or state water pollution control agency.

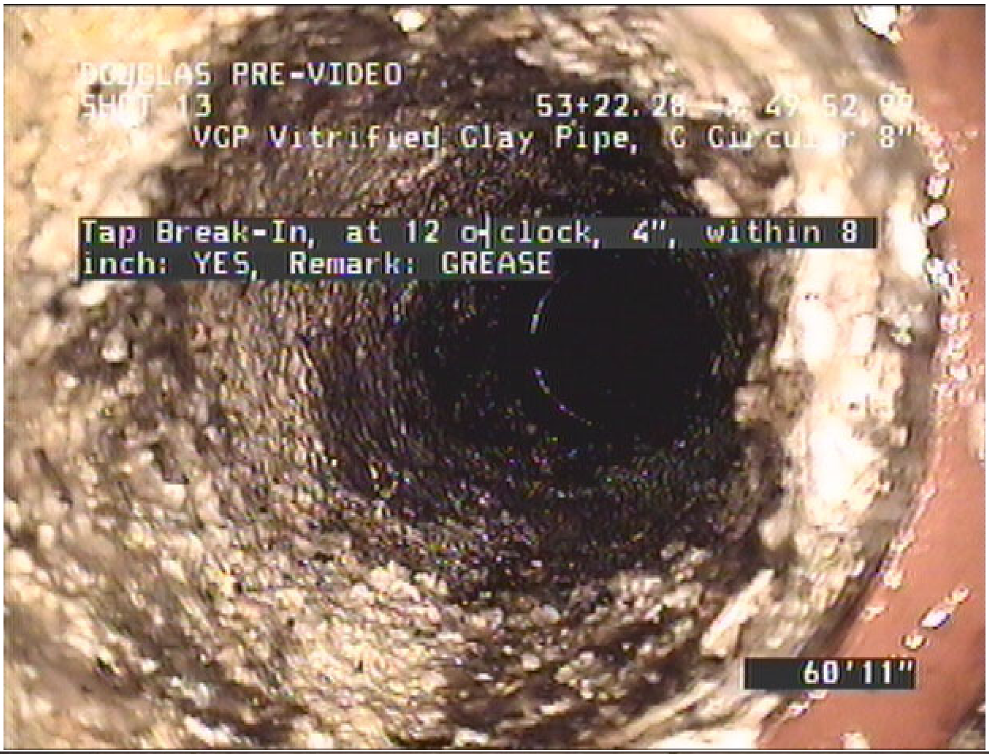
- Used to control roots, grease, odors (H_2S gas), concrete corrosion, rodents and insects.
- *Root Control* - longer lasting effects than power rodder (approximately 2-5 years).
- *H_2S gas* - some common chemicals used are chlorine (Cl_2), hydrogen peroxide (H_2O_2), pure
Oxygen (O_2), air, lime ($Ca(OH_2)$), sodium hydroxide (NaOH), and iron salts.
- *Grease and soap problems* - some common chemicals used are bioacids, digester, enzymes, bacteria cultures, catalysts, caustics, hydroxides, and neutralizers.

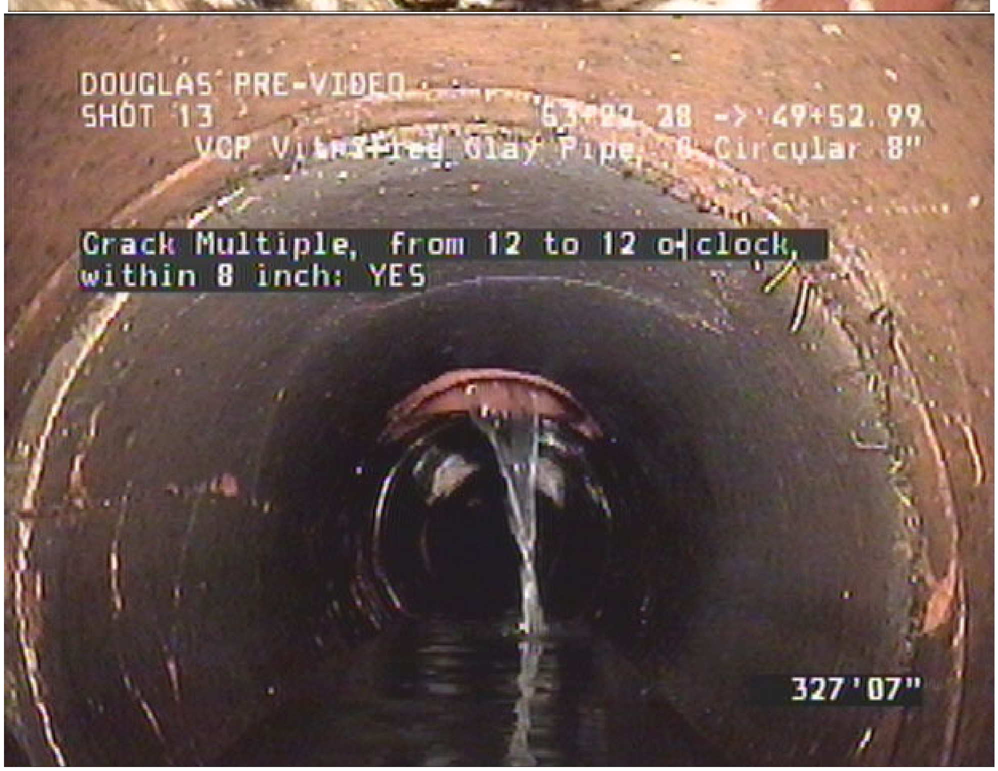
Source: Information provided by Arbour and Kerri, 1997 and Sharon, 1989.





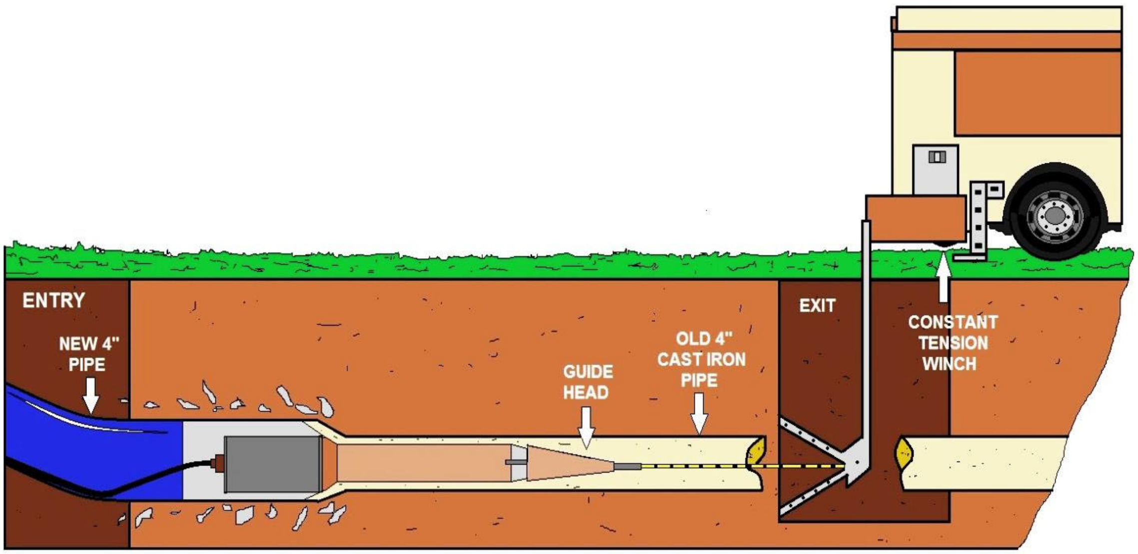
Photographs courtesy of Propipe.





Photographs courtesy of Propipe.

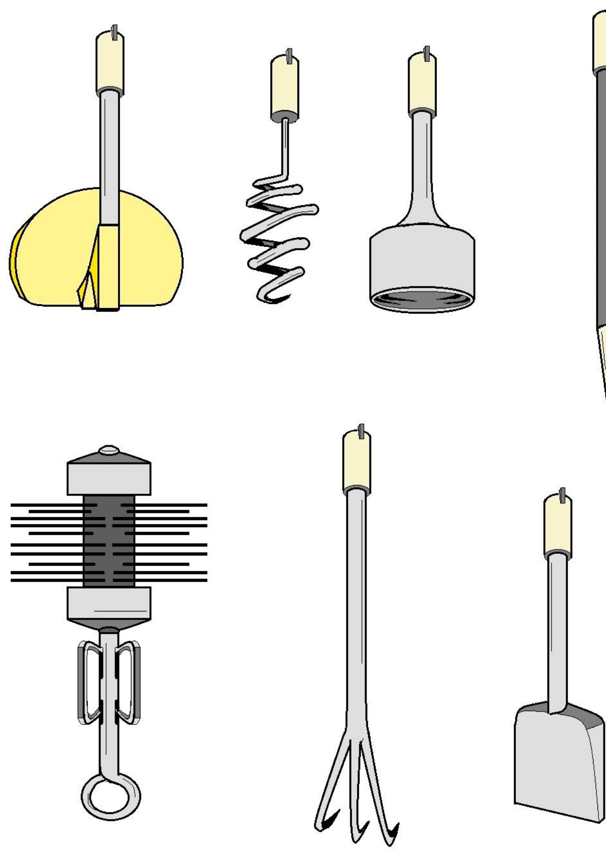
More on Sewer Cleaning Procedures



TRENCHLESS SEWER REPAIR DIAGRAM

Most cities that take advantage of sewer cleaning procedures are able to determine that as the maintenance frequency increased, there was an increase in system performance. It is recommended for 70 inspections and maintenance activities for every 30 cleanings. Inspections are considered more important because they help define and prevent future problems. A study performed by the American Society of Civil Engineers reports that the most important maintenance activities are cleaning and CCTV inspections. A maintenance plan attempts to develop a strategy and priority for maintaining pipes based on several of the following factors:

- Problems- frequency and location; 80 percent of problems occur in 25 percent of the system (Hardin and Messer, 1997).
- Age- older systems have a greater risk of deterioration than newly constructed sewers.
- Construction material- pipes constructed of materials that are susceptible to corrosion have a greater potential of deterioration and potential collapse. Non-reinforced concrete pipes, brick pipes, and asbestos cement pipes are examples of pipes susceptible to corrosion.
- Pipe diameter/volume conveyed- pipes that carry larger volumes take precedence over pipes that carry a smaller volume.
- Location- pipes located on shallow slopes or in flood prone areas have a higher priority.
- Force main vs. gravity-force mains have a higher priority than gravity, size for size, due to the complexity of the cleaning and repairs.
- Subsurface conditions- depth to groundwater, depth to bedrock, soil properties (classification, strength, porosity, compressibility, frost susceptibility, erodibility, and pH).
- Corrosion potential- Hydrogen Sulfide (H_2S) is responsible for corroding sewers, structures, and equipment used in wastewater collection systems. The interior conditions of the pipes need to be monitored and treatment needs to be implemented to prevent the growth of slime bacteria and the production of H_2S gases.



COMMON SEWER CLEANING TOOLS

Limitations of Cleaning Methods

• Sewer Cleaning and Stoppage Section- this section responds to customer complaints, pinpoints problems within the lines, and clears all blockages.

• TV Section- this section locates defects and building sewer connections (also referred to as taps) within the system.

• Preventive Maintenance Section- this section cleans and inspects the lines and also provides for Quality Assurance and Quality Control (QA/QC).

Most of collection inspections use CCTV system. However, a large percent of the lines in the worst and oldest sections of the system are inspected visually. Visual inspections are also used in the most recently installed lines and manholes.

The collection system will normally utilize a variety of cleaning methods including jetting, high velocity cleaning, rodding, bucket machining, and using stop trucks (sectional rods with an attached motor).

As part of a preventive maintenance approach, most collection system operators also have been using combination trucks with both flush and vacuum systems. To control roots, most collection system operators uses a vapor rooter eradication system which can ensure that no roots return to the line for up to five years. The cleaning and inspection crews will usually consist of two members to operate each of the combination trucks and TV trucks.

Detailed Cleaning Methods

The purpose of sewer cleaning is to remove foreign material from the sewer and generally is undertaken to alleviate one of the following conditions:

- Blockages (semisolid obstructions resulting in a virtual cessation of flow). These generally are dealt with on an emergency basis, although the underlying cause can be treated preemptively.
- Hydraulic capacity. In some cases, sediment, roots, intrusions (connections or other foreign bodies), grease, encrustation and other foreign material restrict the capacity of a sewer, causing surcharge or flooding. Cleaning the sewer may alleviate these problems permanently, or at least temporarily.
- Pollution caused by either the premature operation of combined wastewater overflows because of downstream restrictions to hydraulic capacity or pollution caused by the washing through and discharge of debris from overflows during storms.
- Odor caused by the retention of solids in the system for long periods resulting in, among other things, wastewater turning septic and producing hydrogen sulfide.
- Sewer inspections, where the sewer needs to be cleaned before inspection. This requirement most often occurs when using in-sewer CCTV inspection techniques.
- Sewer rehabilitation where it is necessary to clean the sewers immediately before the sewer being rehabilitated.

Common cleaning methods include jet rodding, manual rodding, winching or dragging, cutting, and manual or mechanical digging. The method usually is determined in advance and is normally contingent on the pipe type and size and on the conditions expected in the pipe.

Jet Rodding
This method depends on the ability of high-velocity jets of water to dislodge materials from the pipe walls and transport them down the sewer. Water under high pressure (approximately 2000 psi) is fed through a hose to a nozzle containing a rosette of jets sited so the majority of flow is ejected in the opposite direction of the flow in the hose. These jets propel the hose through the sewer and dislodge the materials on the sewer walls. A range of nozzles is available to cope with the different pipe diameters and materials encountered. The hoses, nozzles, water supply and necessary pumps usually are incorporated in a purpose-built vehicle.

Rodding
This method is generally a manual push-pull technique used to clear blockages in smaller-diameter, shallow sewer systems typically not exceeding (10 in. in diameter or 6 ft. in depth. For sewer greater than 10 in. in diameter, the rods tend to wander are not very effective. The distance from the access point is limited to approximately 60 ft.

Dragging
This is a technique where custom buckets are dragged through the sewer and the material deposited into skips.

Cutting
This method generally is used for removing roots from sewers. High-pressure water jet cutters have been developed for removing even more solid intrusions, such as intruding

connections. Care is required to eliminate damage to the existing sewer structure.

Manual or Mechanical Digging

Traditionally used in larger-diameter sewers, this method involves manually excavating the material and placing it in buckets for removal. As the sewer system can be hazardous, the technique now is used infrequently. High-pressure jet equipment also can be used manually in larger sewers.

Balling, Jetting, Scooter

In general, these methods are only successful when necessary water pressure or head is maintained without flooding basements or houses at low elevations. Jetting - The main limitation of this technique is that cautions need to be used in areas with basement fixtures and in steep-grade hill areas.

Balling

Balling cannot be used effectively in pipes with bad offset joints or protruding service connections because the ball can become distorted.

Scooter

When cleaning larger lines, the manholes need to be designed to a larger size in order to receive and retrieve the equipment. Otherwise, the scooter needs to be assembled in the manhole. Caution also needs to be used in areas with basement fixtures and in steep-grade hill areas.

Bucket Machine

This device has been known to damage sewers. The bucket machine cannot be used when the line is completely plugged because this prevents the cable from being threaded from one manhole to the next. Set-up of this equipment is time-consuming.

Flushing

This method is not very effective in removing heavy solids. Flushing does not remedy this problem because it only achieves temporary movement of debris from one section to another in the system.

High Velocity Cleaner

The efficiency and effectiveness of removing debris by this method decreases as the cross-sectional areas of the pipe increase. Backups into residences have been known to occur when this method has been used by inexperienced operators. Even experienced operators require extra time to clear pipes of roots and grease.

Kite or Bag

When using this method, use caution in locations with basement fixtures and steep-grade hill areas.

Rodding

Continuous rods are harder to retrieve and repair if broken and they are not useful in lines with a diameter of greater than 300 mm (0.984 feet) because the rods have a tendency to coil and bend. This device also does not effectively remove sand or grit, but may only loosen the material to be flushed out at a later time. Source: U.S. EPA, 1993.

Sewer – Hydraulic Cleaning Sub-Section

The purpose of sewer cleaning is to remove accumulated material from the sewer. Cleaning helps to prevent blockages and is used to prepare the sewer for inspections. Stoppages in gravity sewers are usually caused by a structural defect, poor design, poor construction, an accumulation of material in the pipe (especially grease), or root intrusion. Protruding traps (lateral sewer connections incorrectly installed so that they protrude into the main sewer) may catch debris, which then causes a further buildup of solids that eventually block the sewer.

Results of Various Flow Velocities
Velocity Result
2.0 ft/sec...............................Very little material buildup in pipe.
1.4-2.0 ft/sec.........................Heavier grit (sand and gravel) begin to accumulate.
1.0-1.4 ft/sec.........................Inorganic grit and solids accumulate.
Below 1.0 ft/sec....................Significant amounts of organic and inorganic solids accumulate.
1.0 to 1.4 feet per second, grit and solids can accumulate leading to a potential blockage.

Sewer Cleaning Methods
There are three major methods of sewer cleaning: hydraulic, mechanical, and chemical.

Hydraulic cleaning (also referred to as flushing) refers to any application of water to clean the pipe. Mechanical cleaning uses physical devices to scrape, cut, or pull material from the sewer.

Chemical cleaning can facilitate the control of odors, grease buildup, root growth, corrosion, and insect and rodent infestation.

Sewer Cleaning Records
The backbone of an effective sewer cleaning program is accurate recordkeeping. Accurate recordkeeping provides the collection system owner or operator with information on the areas cleaned. Typical information includes

- Date, time, and location of stoppage or routine cleaning activity
- Method of cleaning used
- Identity of cleaning crew
- Cause of stoppage
- Further actions necessary and/or initiated
- Weather conditions

The owner or operator should be able to identify problem collection system areas, preferably on a map. Potential problem areas identified should include those due to grease or industrial discharges, hydraulic bottlenecks in the collection system, areas of poor design (e.g., insufficiently sloped sewers), areas prone to root intrusion, sags, and displacements. The connection between problem areas in the collection system and the preventive maintenance cleaning schedule should be clear.

The owner or operator should also be able to identify the number of stoppages experienced per mile of sewer pipe. If the system is experiencing a steady increase in stoppages, the reviewer should try to determine the cause (i.e., lack of preventive maintenance funding, deterioration of the sewers due to age, an increase in grease producing activities, etc.).

Parts and Equipment Inventory
An inventory of spare parts, equipment, and supplies should be maintained by the collection system owner or operator. The inventory should be based on the equipment manufacturer's recommendations, supplemented by historical experience with maintenance and equipment problems. Without such an inventory, the collection system may experience long down times or periods of inefficient operation in the event of a breakdown or malfunction. Files should be maintained on all pieces of equipment and major tools. The owner or operator should have a system to assure that each crewmember has adequate and correct tools for the job.

The owner or operator should maintain a yard where equipment, supplies, and spare parts are maintained and personnel are dispatched. Very large systems may maintain more than one yard. In this case, the reviewer should perform a visual survey at the main yard. In small to medium size systems, collection system operations may share the yard with the department of public works, water department, or other municipal agencies. In this case, the reviewer should determine what percentage is being allotted for collection system items. The most important features of the yard are convenience and accessibility.

The reviewer should observe a random sampling of inspection and maintenance crew vehicles for equipment as described above. A review of the equipment and manufacturer's manuals aids will determine what spare parts should be maintained.

The owner or operator should then consider the frequency of usage of the part, how critical the part is, and finally, how difficult the part is to obtain when determining how many of the part to keep in stock. Spare parts should be kept in a clean, well-protected stock room.

Owner or Operator - Point to Note
The owner or operator should have a procedure for determining which spare parts are critical for the proper operation of the collection system. Similar to equipment and tools management, a tracking system should be in place, including Guide for Evaluating CMOM Programs at Sanitary Sewer Collection Systems procedures on logging out materials, and when maintenance personnel must use them.

The owner or operator should be able to produce the spare parts inventory and clearly identify those parts deemed critical. The reviewer should evaluate the inventory and selected items in the stockroom to determine whether the specified numbers of these parts are being maintained.

Sewer Maintenance - Advantages and Disadvantages

The primary benefit of implementing a sewer maintenance program is the reduction of SSOs, basement backups, and other releases of wastewater from the collection system due to substandard sewer conditions. Improper handling of instruments and chemicals used in inspecting and maintaining sewer lines may cause environmental harm.

Examples include:

- Improperly disposing of collected materials and chemicals from cleaning operations.
- Improperly handling chemical powdered dyes.
- Inadequately maintaining inspection devices.

Visual Inspection
In smaller sewers, the scope of problems detected is minimal because the only portion of the sewer that can be seen in detail in near the manhole. Therefore, any definitive information on cracks or other structural problems is unlikely. However, this method does provide information needed to make decisions on rehabilitation.

Camera Inspection
When performing a camera inspection in a large diameter sewer, the inspection crew is essentially taking photographs haphazardly, and as a result, the photographs tend to be less comprehensive.

Closed Circuit Television (CCTV)
This method requires late night inspection and as a result the TV operators are vulnerable to lapses in concentration. CCTV inspections are also expensive and time consuming. The video camera does not fit into the pipe and during the inspection it remains only in the maintenance hole.

Lamping Inspection
As a result, only the first 10 feet of the pipe can be viewed or inspected using this method.
Source: Water Pollution Control Federation, 1989. Some instruments have a tendency to become coated with petroleum based residues and if not handled properly they can become a fire hazard. The following case study provide additional case study data for sewer cleaning methods.

Fairfax County, Virginia
The Fairfax County Sanitary Sewer System comprises over 3000 miles of sewer lines. As is the case with its sewer rehabilitation program, the county's sewer maintenance program also focuses on inspection and cleaning of sanitary sewers, especially in older areas of the system. Reorganization and streamlining of the sewer maintenance program, coupled with a renewed emphasis on increasing productivity, has resulted in very significant reductions in sewer backups and overflows during the past few years.

1998, there were a total of 49 such incidents including 25 sewer backups and 24 sewer overflows. The sewer maintenance program consists of visual inspections, scheduled sewer cleanings based on maintenance history, unscheduled sewer cleanings as determined by visual or closed circuit television inspections, and follow-up practices to determine the cause of backups and overflows.

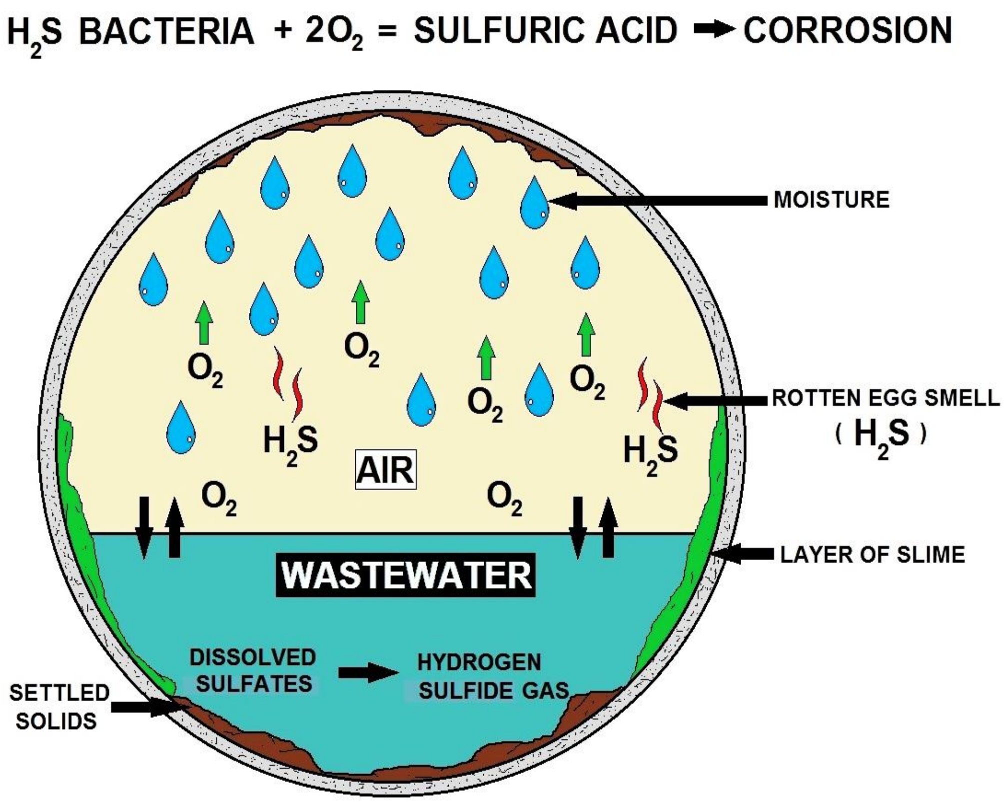
Visual inspections are carried out by using a mirror attached to a pole; however, use of portable cameras has been recently introduced to enhance the effectiveness of visual inspections.

Older areas of the sewer system are inspected every two years; whereas, the inspection of relatively new areas may be completed in 3 to 4 years. Cleaning is an important part of pipe maintenance.

Sewer line cleaning is prioritized based on the age of the pipe and the frequency of the problems within it. The county uses rodding and pressurized cleaning methods to maintain the pipes.

Bucket machines are rarely used because cleaning by this method tends to be time consuming. Many cities use mechanical, rather than chemical, methods to remove grease and roots. Introducing chemicals into the cleaning program may require hiring an expert crew, adopting a new program, and instituting a detention time to ensure the chemicals' effectiveness.

Record keeping is also vital to the success of such a maintenance program. The county has started tracking the number of times their sewer lines were inspected and cleaned and the number of overflows and backups a sewer line experienced. This information has helped the county re-prioritize sewer line maintenance and adapt a more appropriate time schedule for cleaning and inspecting the sewer lines.



HOW CORROSION FORMS IN SEWER PIPING

Sewer System Rehabilitation Sub-Section

The collection system owner or operator should have a sewer rehabilitation program. The objective of sewer rehabilitation is to maintain the overall viability of a collection system. This is done in three ways:

(1) ensuring its structural integrity;

(2) limiting the loss of conveyance and wastewater treatment capacity due to excessive I/I; and

(3) limiting the potential for groundwater contamination by controlling exfiltration from the pipe network.

The rehabilitation program should build on information obtained as a result of all forms of maintenance and observations made as part of the capacity evaluation and asset inventory to assure the continued ability of the system to provide sales and service at the least cost. The reviewer should try to gain a sense of how rehabilitation is prioritized. Priorities may be stated in the written program or may be determined through interviews with system personnel.

There are many rehabilitation methods; the choice of methods depends on pipe size, type, location, dimensional changes, sewer flow, material deposition, surface conditions, severity of I/I, and other physical factors. Non-structural repairs typically involve the sealing of leaking joints in otherwise sound pipe.

Structural repairs involve either the replacement of all or a portion of a sewer line, or the lining of the sewer. These repairs can be carried out by excavating, usually for repairs limited to one or two pipe segments (these are known as point repairs) or by trenchless technologies (in which repair is carried out via existing manholes or a limited number of access excavations).

The rehabilitation program should identify the methods that have been used in the past, their success rating, and methods to be used in the future. A reviewer who wants further guidance on methods of rehabilitation may consult the owner's or operator's policies regarding service lateral rehabilitation, since service laterals can constitute a serious source of I/I.

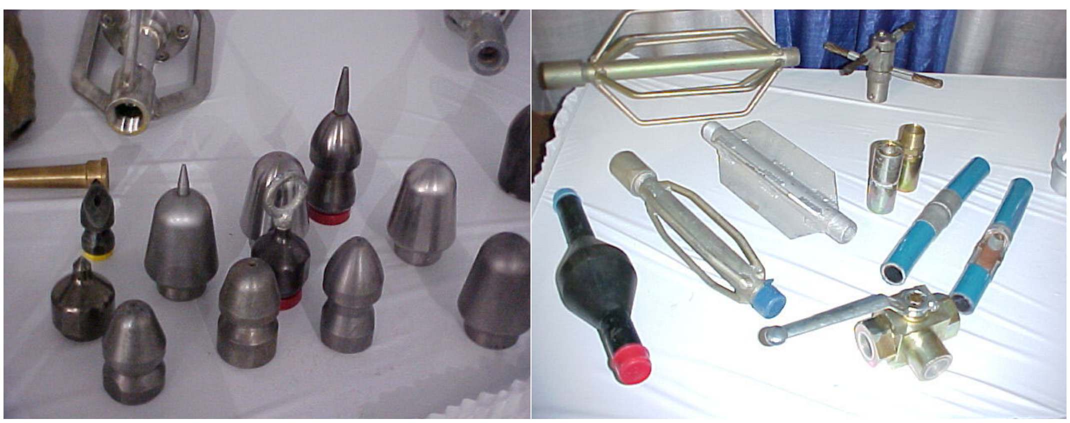
Manholes should not be neglected in the rehabilitation program. Manhole covers can allow significant inflow to enter the system because they are often located in the path of surface runoff.

Manholes themselves can also be a significant source of infiltration from cracks in the barrel of the manhole. The owner or operator should be able to produce documentation on the location and methods used for sewer rehabilitation. The reviewer should compare the rehabilitation accomplished with that recommended by the capacity evaluation program.

When examining the collection system rehabilitation program, the reviewer should be able to answer the following questions:

- Is rehabilitation taking place before it becomes emergency maintenance?
- Are recommendations made as a result of the previously described inspections?
- Does the rehabilitation program take into account the age and condition of the sewers?

The sewer vacuum truck utilizes both a high pressure stream of water and a vacuum system to clean and remove built up debris from sewer lines. These versatile vehicles are also used to clean lift station wet wells, stormwater catch basins, and to perform excavations to locate broken water or sewer lines. It reduces repair times and costs by over 50%.



Above, various Jetter or hydraulic cleaning attachments.

Root intrusion

Tree Roots vs. Sanitary Sewer Lines

Root Growth in Pipes

Roots require oxygen to grow, they do not grow in pipes that are full of water or where high ground water conditions prevail. Roots thrive in the warm, moist, nutrient rich atmosphere above the water surface inside sanitary sewers. The flow of warm water inside the sanitary sewer service pipe causes water vapor to escape to the cold soil surrounding the pipe. Tree roots are attracted to the water vapor leaving the pipe and they follow the vapor trail to the source of the moisture, which are usually cracks or loose joints in the sewer pipe. Upon reaching the crack or pipe joint, tree roots will penetrate the opening to reach the nutrients and moisture inside the pipe. This phenomenon continues in winter even though trees appear to be dormant.

Problems Caused by Roots Inside Sewers

Once inside the pipe, roots will continue to grow, and if not disturbed, they will completely fill the pipe with multiple hair-like root masses at each point of entry. The root mass inside the pipe becomes matted with grease, tissue paper, and other debris discharged from the residence or business. Homeowners will notice the first signs of a slow flowing drainage system by hearing gurgling noises from toilet bowls and observing wet areas around floor drains after completing the laundry. A complete blockage will occur if no remedial action is taken to remove the roots/blockage. As roots continue to grow, they expand and exert considerable pressure at the crack or joint where they entered the pipe. The force exerted by the root growth will break the pipe and may result in total collapse of the pipe. Severe root intrusion and pipes that are structurally damaged will require replacement.

Tree Roots in Sewer

Tree roots growing inside sewer pipes are generally the most expensive sewer maintenance item experienced by City residents. Roots from trees growing on private property and on parkways throughout the City are responsible for many of the sanitary sewer service backups and damaged sewer pipes.

Homeowners should be aware of the location of their sewer service and refrain from planting certain types of trees and hedges near the sewer lines. The replacement cost of a sanitary sewer service line as a result of damage from tree roots may be very expensive.

Pipes Susceptible to Root Damage

Some pipe material is more resistant to root intrusion than others are. Clay tile pipe that was commonly installed by developers and private contractors until the late 1980's is easily penetrated and damaged by tree roots. Concrete pipe and PVC pipe may also allow root intrusions, but to a lesser extent than clay tile pipe. PVC pipe is more resistant to root intrusion because it usually has fewer joints. The tightly fitting PVC joints are less likely to leak as a result of settlement of backfill around the pipe.

Root Spread

During drought conditions and in winter, tree roots travel long distances in search of moisture. As a general rule, tree roots will extend up to 2.5 times the height of the tree, and some species of trees may have roots extending five to seven times the height of the tree.

Root Growth Control
The common method of removing roots from sanitary sewer service pipes involves the use of augers, root saws, and high pressure flushers. These tools are useful in releasing blockages in an emergency, however, cutting and tearing of roots encourages new growth. The effect is the same as pruning a hedge to promote faster, thicker, and stronger regrowth.

Roots removed by auguring are normally just a small fraction of the roots inside the pipe. To augment the cutting and auguring methods, there are products available commercially that will kill the roots inside the pipe without harming the tree. The use of products such as copper sulfate and sodium hydroxide are not recommended because of negative environmental impacts on the downstream receiving water. Also, these products may kill the roots but they do not inhibit regrowth.

The more modern method used throughout Canada and the United States for controlling root growth involves the use of an herbicide mixed with water and a foaming agent. The foam mixture is pumped into the sewer pipe to kill any roots that come into contact with the mixture. New root growth will be inhibited from three to five years after the treatment, according to the manufacturers.

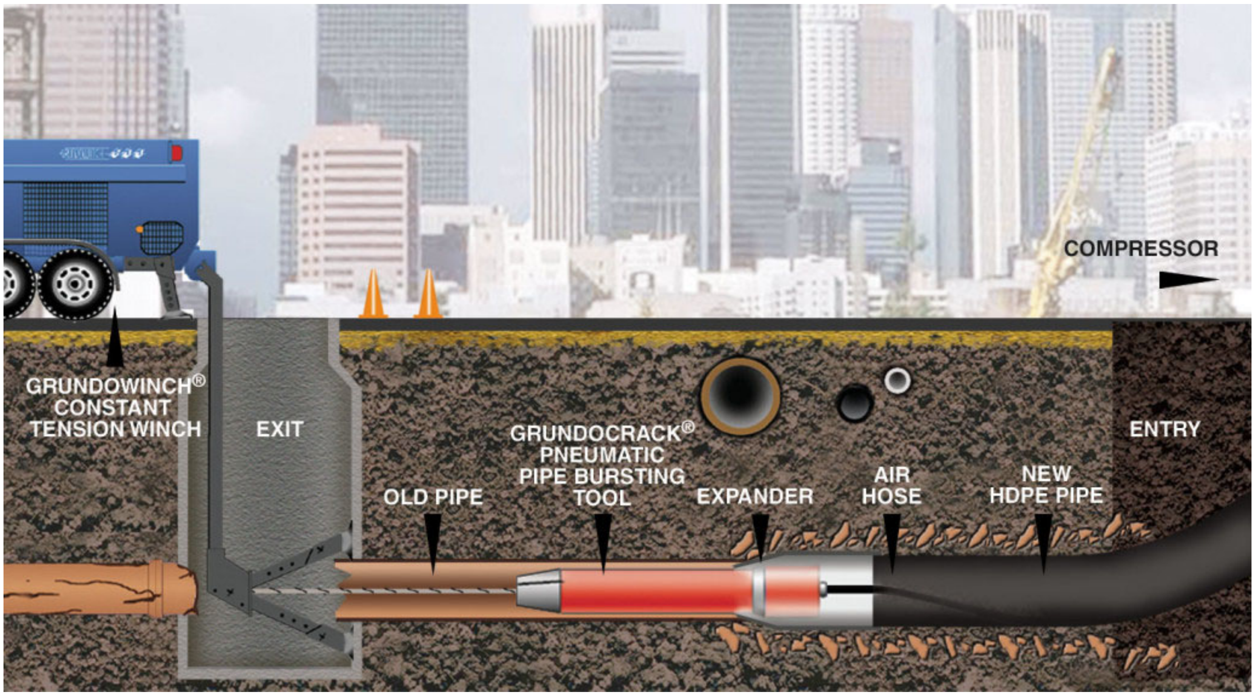
FlexKid is an accessory for Ripper tools designed to clear roots and other blockages from sewer pipes. The unit readily passes through pipes and around or over typical obstructions like offset joints, hand taps and debris. Available for pipes 18 inches and larger, it features durable cable and easy attachment to the rear of any root-cutting motor. It is designed for quick setup and quick size changes in field. No underground (in-manhole) assembly is required, and no manhole modification is necessary.

The Knocker is a chain cleaner designed to use in conjunction with The Ripper. The Ripper positions The Knocker's chain-knocking action in the center of the pipe and keeps the chain from hanging up on offsets and hand-taps. The Ripper follows up by removing loose debris - leaving pipes cleaner than any other sewer cleaning tool - period.

Courtesy of DML, LLC
419 Colford Avenue
West Chicago, Il 60185
Phone (630) 293-3653
rootripper@ameritech.net

Pipe Bursting Section

Pipe bursting can be just as effective as digging trenches and replacing the older sewer, but without the digging. With the pipe bursting method, roads, customer's yards and landscaping is spared the damage caused by digging long trenches, and repairing the damage when the job is done.

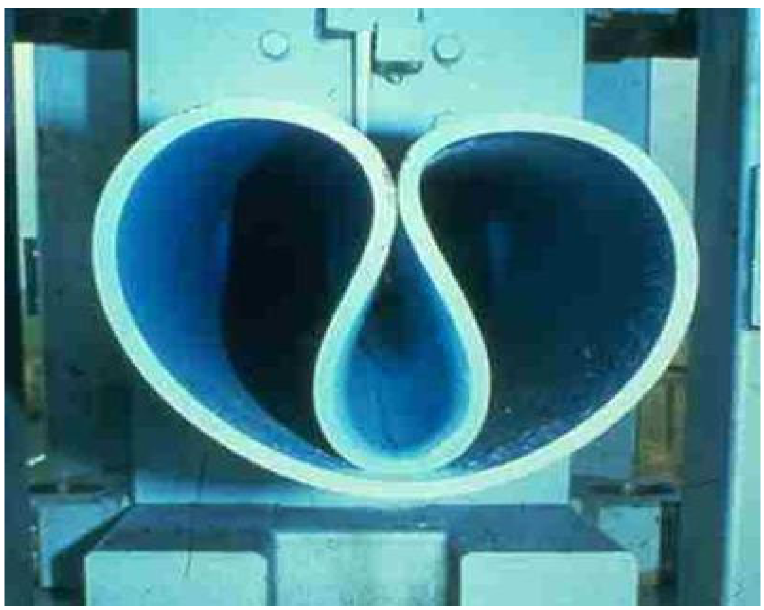


Cast iron and clay sewer lines often have more points of failure than high density polyethylene pipe or HDPE because they have more joints and joins. HDPE pipe is seamless, and so introduces fewer potential points of failure.

Bursting Pipe Procedure

- Insertion pit is excavated.
- Deteriorated host pipe is broken outward by means of an expansion tool and new pipe (black) is towed behind the bursting machine.
- Laterals reconnected by excavation after job is done.
- Pneumatic (static) head has no moving internal parts and expands existing pipe through pulling.
- New pipe can be PE, PP, PVC or GFR
- No reduction in capacity; can often upsize the new pipe
- Requires bypass or diversion of flow
- Not suitable for all materials: can replace vitrified clay, cast iron, unreinforced concrete, & some PVC

Old sewer lines are often made of cast iron and clay. These old sewer lines eventually crack and fail to drain properly. Roots and debris make their way into old sewer lines causing repeated obstructions and service calls.



Fold and Formed Pipe

- HDPE or PVC pipe is deformed in shape & inserted into host pipe
- Liner is pulled through existing line, heated and pressurized to original shape
- Bypass or diversion of flow required
- Laterals reconnected internally
- No grouting or excavation
- No joints or seams

Smoking out Sewer Leaks

*An overview of smoke testing, an important part of successful **I & I** studies.*
By Paul Tashian, Superior Signal Company, Inc.

Used extensively for over 40 years, smoke testing has proven to be a vital ingredient of successful inflow and infiltration (I&I) studies. It is as important now as it has ever been, as growing municipalities increase demands on aging, often deteriorating collection systems. In addition, programs such as the EPA's new CMOM (capacity, management, operations, and maintenance) emphasize a focus on proactive, preventive maintenance practices. Smoke testing is an effective method of documenting sources of inflow and should be part of any CMOM program.

Just as a doctor would require the aid of several instruments to evaluate the status of one's health, various test methods should be used in performing a complete sanitary sewer evaluation survey (SSES). In addition to smoke testing, these could include dyed water testing, manhole inspection, TV inspection, flow monitoring, and more. Specializing in sanitary sewer evaluation surveys, Wade & Associates of Lawrence Kansas states a reduction of 30 to 50% in peak flows can be expected as a result of implementing these types of programs.

Smoke testing is a relatively simple process, which consists of blowing smoke mixed with larger volumes of air into the sanitary sewer line, usually induced through the manhole.

The smoke travels the path of least resistance and quickly shows up at sites that allow surface water inflow. Smoke will identify broken manholes, illegal connections (including roof drains, sump pumps, yard drains and more), uncapped lines, and will even shows cracked mains and laterals providing there is a passageway for the smoke to travel to the surface.

Although video inspection and other techniques are certainly important components of an I&I survey, research has shown that approximately 65% of all extraneous stormwater inflow enters the system from somewhere other than the main line. Smoke testing is an excellent method of inspecting both the mainlines, laterals and more. Smoke travels throughout the system, identifying problems in all connected lines, even sections of line that were not known to exist, or thought to be independent or unconnected. Best results are obtained during dry weather, which allows smoke better opportunity to travel to the surface.

Necessary Equipment

Blowers; Most engineering specifications for smoke testing identify the use of a blower able to provide 1750 cfm (cubic feet of air per minute), however in today's world it seems to be the mindset that bigger is better. New smoke blowers on the market can deliver over 3000 cfm, but is this really needed? Once the manhole area is filled, the smoke only needs to travel sections of generally 8 or 10-inch pipe.

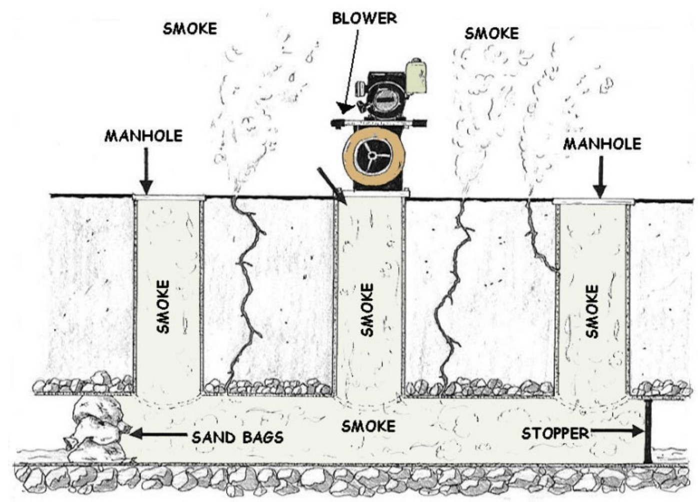
Moving the air very quickly is useless if the blower does not have the static pressure to push that air/smoke through the lines. If you've used high CFM blowers and found that smoke frequently backs up to the surface, this may be your problem.

Blowers
There are two types of blowers available for smoke testing sewers: squirrel cage and direct drive propeller. In general, squirrel cage blowers are usually larger in size, but can provide more static pressure in relation to CFM.

The output of the squirrel cage type is usually adjustable by alternating pulleys and belts to meet the demands of the job. Propeller style blowers are usually more compact and generally offer approx. 3,200 CFM.

Other than reducing the engine throttle, the output is not adjustable since the fan blade is attached directly to the engine shaft. If purchasing a smoke blower you should ask the manufacturer if the CFM and static pressure output they are quoting is the specification of the propeller itself (uninstalled/free air), or if it is the actual performance when installed in the blower assembly. These two numbers can vary significantly.

Smoke Types
There are two types of smoke currently offered for smoke testing sewers, classic smoke candles and smoke fluids.



Smoke candles were first used for testing sewers when the process began its popularity back in 1961, and continue to be the most widely used. They are used by simply placing a smoke candle on the fresh air intake side of the blower. Once ignited, the exiting smoke is drawn in with the fresh air and blown down into the manhole and throughout the system. Smoke candles are available in various sizes that can be used singularly or in combination to meet any need. This type of smoke is formed by a chemical reaction, creating a smoke which contains a high content of atmospheric moisture. It is very visible even at low concentrations, and extremely effective at finding leaks.

Another available source of smoke is a smoke fluid system. Although they have just recently been more aggressively marketed, smoke fluids became available for sewer testing shortly after smoke candles, some 30 years ago. They can certainly be used effectively, but it is important to understand how they work. This system involves injecting a smoke fluid (usually a petroleum based product) into the hot exhaust stream of the engine where it is heated within the muffler (or heating chamber) and exhausted into the air intake side of the blower.

One gallon of smoke fluid is generally less expensive than one dozen smoke candles; however smoke fluids do not consistently provide the same quality of smoke.

When using smoke fluid, it is important to understand that as fluid is injected into the heating chamber (or muffler) it immediately begins to cool the unit. The heating chamber will eventually reach a point where it is not hot enough to completely convert all the fluid to smoke, thus creating thin/wet smoke. This can actually happen quickly, depending on the rate of fluid flow. If the smoke has become thin it can be especially difficult to see at greater distances.

Blocking off sections of line is usually a good idea with any type of smoke, but becomes almost a necessity when using smoke fluid.

Some manufactures have taken steps to address this issue, and now offer better flow control, fluid distribution, and most importantly *insulated heating chambers* to help maintain necessary temperatures.

Safety

Maybe one of the more talked about, yet least understood aspects of smoke testing is the use and safety of these products. As manufacturers have become more competitive, some marketing programs and advertisements have implied danger in the use of competitive types of smoke products. Laboratory reports, scientific studies, and even Material Safety Data Sheets can be quite confusing to most of us who are not trained or qualified to make scientific judgments on this data. Having this information delivered to us in the form of advertising can be dangerous, as most of us tend to believe what we read.

An author of an associated industry publication once stated… "*Do not use smoke bombs, as they give off a toxic gas*". Although the author quotes no scientific literature to support this statement, competitive propaganda has made such implications. It is interesting to note that the same exact statement could be made for smoke fluids. Smoke from fluid is created in the exhaust system of the engine, which contains carbon monoxide. Is carbon monoxide not a toxic gas?

Other statements that have been made include warnings to wear a respirator while smoke testing. While certain manufacturers have issued this warning about competitive products, they do not qualify the statement, nor do they mention the fact that the same thing could be said of their own product. The fact is that a respirator should be worn whenever a person would be exposed to ANY substance in quantities that exceeded OSHA limits. The bottom line on safety is that it is important to use common sense.

All smokes, candles, and fluids can be used safely and effectively when used as directed. When planning to smoke test, it is important to develop a proactive public notice program. Ads in local papers, door hangers, mailers, as well as door to door inquiries are recommended. It is helpful to educate the public as to why the test is being performed and the positive benefits to the community. In addition, it should instruct residents on what to do and who to call if smoke should enter their homes.

It is also important to notify local police and fire departments daily, as to where and when smoke testing will be taking place. Reducing stormwater inflow into collection systems means reduced chances of overflows, less emergency maintenance and less money spent on treatment. If these are goals of your organization, consider smoke testing as a fairly easy, inexpensive, and effective way of achieving your objectives.

Paul Tashian is employed by Superior Signal Company Inc., a manufacturer of all types of smoke testing equipment, and a major contributor to the original development of smoke testing practices. Paul can be reached at (732) 251-0800, or ptashian@superiorsignal.com.

Also, thanks to Wade & Associates (a company specializing in sanitary sewer evaluation surveys) for offering reference material, and providing artwork and photographs used in this article. For information on Wade's services call (785) 841-1774, or visit www.wadeinc.com.

Operation and Maintenance Summary

Maintaining wastewater collection infrastructure – pump stations, force mains, and sewers – is an integral component of the proper management of a treatment system and critical to preventing illegal wastewater releases. Effective preventive maintenance programs have been shown to significantly reduce the frequency and volume of untreated sewage discharges, help communities plan for the future and save money on emergency response.

The compelling reason to perform a condition assessment of your collection system is to preserve the existing valuable infrastructure, minimize O&M and avoid emergencies and unexpected costs. Condition assessment of your collection system is an investment in managing risk. Knowing the structural condition of your underground assets will allow you to avoid emergencies, prioritize repair and replacement projects, and plan for the future. In a condition assessment, data and information are gathered through observation, direct inspection, investigation, and monitoring.

Written Protocol

An analysis of the data and information helps determine the structural, operational, and performance status of capital infrastructure assets. A good written protocol, consistently applied, will help define the assessment. Use new data collection techniques to get the most out of your program. Implementing a pro-active program based on information and systematic assessment removes some of the politics and second-guessing from decision-making.

Performing a condition assessment has a cost, but prioritizing work by focusing on critical assets and the maintenance and replacement needs for your collection system is an essential step toward better management.

Condition Assessments

Maintenance issues are the leading cause of backups and overflows of collection systems. Condition assessment helps utilities discover maintenance and capacity issues before they become maintenance problems. Knowing how your collection system really works will identify Trouble Spots and lead to preventive maintenance decisions, rather than being reactive to the consequences of emergency incidents.

Implementing a pro-active program based on information and systematic assessment provides a manager with the tools to improve decision-making and solid information on which to base staffing and funding decisions.

- grease
- roots
- debris

Record Keeping

Record keeping of sewer maintenance, inspections and repairs meets several needs of the sewer system. Records help simplify and improve work planning and scheduling, including integrating recurring and on-demand work. Measuring and tracking of workforce productivity and developing units costs for various activities are a few of the record keeping benefits. Records of sewer maintenance, service line maintenance, and sewer main and service line repairs should be kept and maintained. Examples of record forms are found herein.

Operations and Maintenance Post Quiz

1. The system's goal should be a minimum of cleaning between _______________% of the sewers every year.

Sewer Cleaning and Inspection

2. As sewer system networks age, the risk of deterioration, this _________________________, and collapses becomes a major concern.

3. __________________ are essential to maintaining a properly functioning system; these activities further a community's reinvestment into its wastewater infrastructure.

Identify the Cleaning Method

4. Directs high velocities of water against pipe walls. Removes debris and grease build-up, clears blockages, and cuts roots within small diameter pipes. Efficient for routine cleaning of small diameter, low flow sewers.

5. Round, rubber-rimmed, hinged metal shield that is mounted on a steel framework on small wheels. The shield works as a plug to build a head of water. Scours the inner walls of the pipe lines. Effective in removing heavy debris and cleaning grease from line.

6. Similar in function to the ball. Rigid rims on bag and kite induce a scouring action. Effective in moving accumulations of decayed debris and grease downstream.

7. Most effective in lines up to 12 inches in diameter. Uses an engine and a drive unit with continuous rods or sectional rods. As blades rotate, they break up grease deposits, cut roots, and loosen debris.

8. Partially removes large deposits of silt, sand, gravel, and some types of solid waste. Cylindrical device, closed on one end with 2 opposing hinged jaws at the other. Jaws open and scrape off the material and deposit it in the bucket.

9. A threaded rubber cleaning ball that spins and scrubs the pipe interior as flow increases in the sewer line. Removes deposits of settled inorganic material and grease build-up. Most effective in sewers ranging in size from 5-24 inches.

10. Introduces a heavy flow of water into the line at a manhole. Removes floatables and some sand and grit. Most effective when used in combination with other mechanical operations, such as rodding or bucket machine cleaning.

More on Sewer Cleaning Procedures
A maintenance plan attempts to develop a strategy and priority for maintaining pipes based on several of the following factors:

11. ________________- frequency and location; 80 percent of problems occur in 25 percent of the system.

12. Force main vs. gravity-force mains have a higher priority than gravity, size for size, due to the complexity of the ______________________.

13. ________________ - Hydrogen Sulfide (H_2S) is responsible for corroding sewers, structures, and equipment used in wastewater collection systems. The interior conditions of the pipes need to be monitored and treatment needs to be implemented to prevent the growth of slime bacteria and the production of H_2S gases.

14. ________________- pipes that carry larger volumes take precedence over pipes that carry a smaller volume.

Limitations of Cleaning Methods
15. __________________ will normally utilize a variety of cleaning methods including jetting, high velocity cleaning, rodding, bucket machining, and using stop trucks.

16. The cleaning and inspection crews will usually consist of two members to operate each of the?

Detailed Cleaning Methods
The purpose of sewer cleaning is to remove foreign material from the sewer and generally is undertaken to alleviate one of the following conditions:

17. _____________________ is caused by either the premature operation of combined wastewater overflows because of downstream restrictions to hydraulic capacity or pollution caused by the washing through and discharge of debris from overflows during storms.

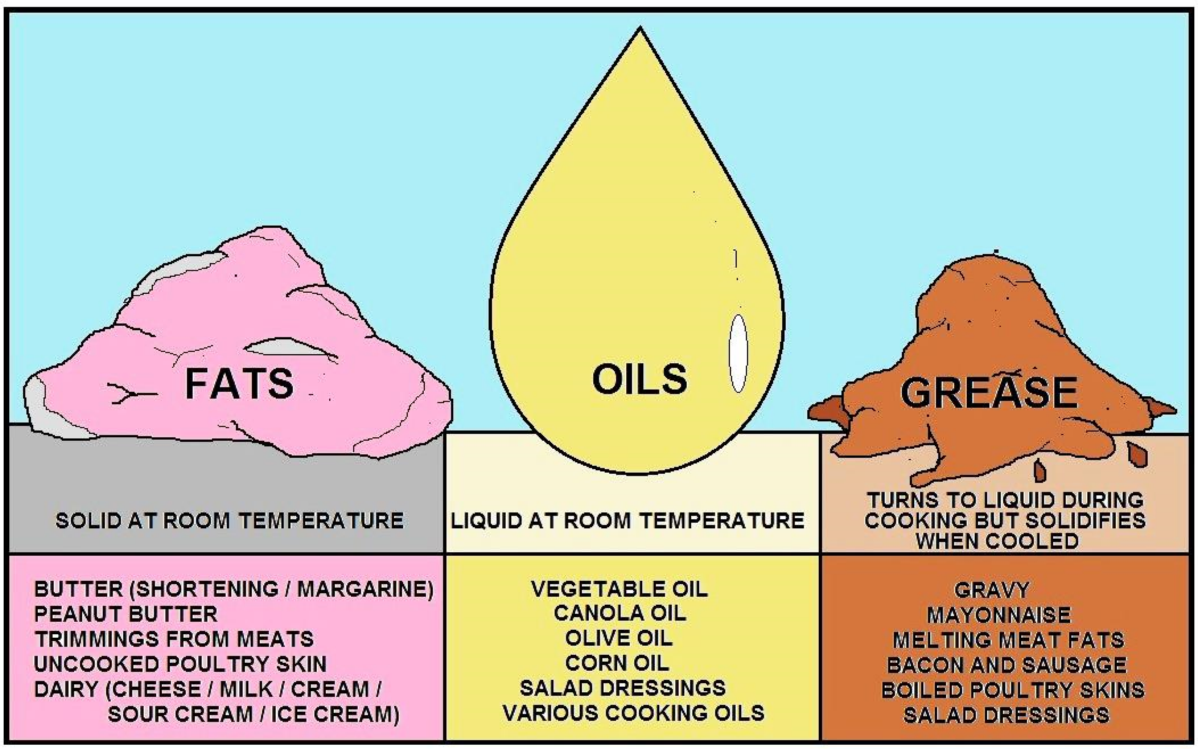
18. ______________________ is caused by the retention of solids in the system for long periods resulting in, among other things, wastewater turning septic and producing hydrogen sulfide.

Answers
1. 20-30, 2. Blockages, 3. Cleaning and inspecting sewer lines,4. Jetting, 5. Scooter, 6. Kites, Bags, and Poly Pigs, 7. Mechanical Rodding, 8. Bucket Machine, 9. Hydraulic Balling, 10. Flushing, 11. Problems, 12. Cleaning and repairs, 13. Corrosion potential, 14. Pipe diameter/volume conveyed, 15. The collection system, 16 Combination trucks and TV trucks, 17. Pollution, 18. Odor

Chapter 3- FATS, OILS AND GREASE SECTION

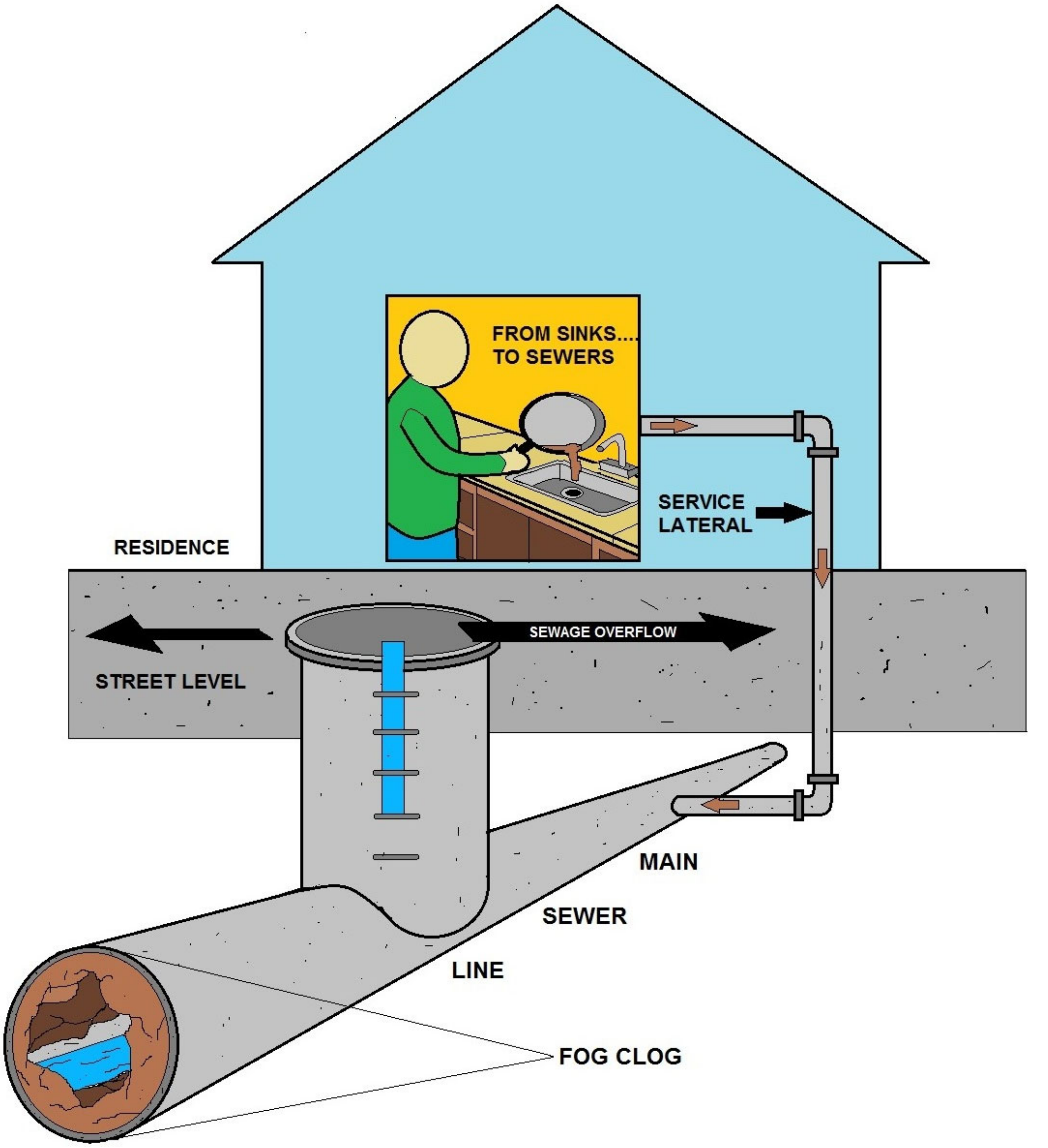
Section Focus: You will learn the basics of the Clean Water Act, the need for FOG fats, oils and grease regulation and enforcement. At the end of this section, you the student will be able to describe the need for fats, oils and grease regulation, enforcement and public education. There is a post quiz at the end of this section to review your comprehension and a final examination in the Assignment for your contact hours.

Scope/Background: The CWA made it unlawful to discharge any pollutant (FOG) from a point source into navigable waters, unless a permit was obtained. EPA's National Pollutant Discharge Elimination System (NPDES) permit program controls discharges. Food service establishments deal with large volumes of FOG on a daily basis. FOG can have a very negative impact if not handled properly. It can cause serious damage to the sewer system, your property and that of your neighbors, as well as, damage the environment and public health concerns. Cleanup of sewer overflows can be very costly and this expense translates to higher bills for sewer customers. By being aware of what FOG can do to your surroundings, it is easier to take that extra minute to do your part and prevent FOG from ending up in the sewer.



FOG (FATS/OILS/GREASE) CONTRIBUTORS

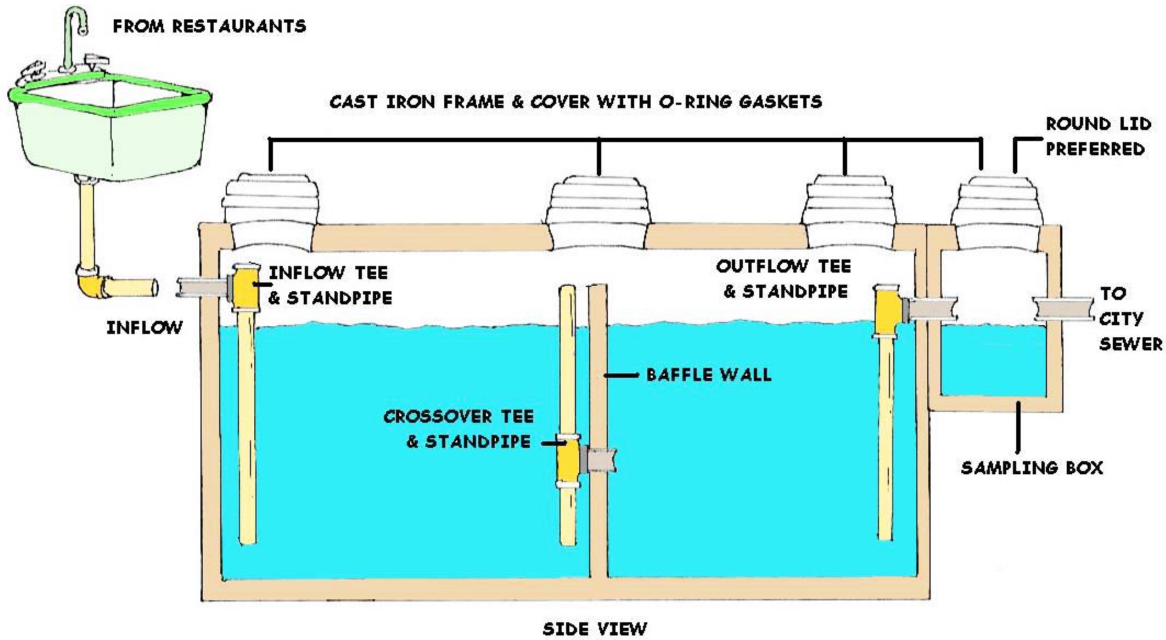
Most stoppages in the sewer system are caused by grease. It is best to have a strong FOG Ordinance that prevents restaurants from dumping grease into the system. You as the regulator will need a process of back charging the restaurants that do clog the sewers as payment for cleaning. As a pretreatment inspector, you will visit many restaurants for grease violations.



HOW SEWERS ARE CLOGGED BY GREASE DIAGRAM

Keeping Fats, Oils, and Grease out of the Sewer System
Fats, oils, and grease—FOG—comes from meat fats in food scraps, cooking oil, shortening, lard, butter and margarine, gravy, and food products such as mayonnaise, salad dressings, and sour cream.

FOG poured down kitchen drains accumulates inside sewer pipes and cause damage to the collection system. As the FOG builds up, it restricts the flow in the pipe and can cause untreated wastewater to back-up into homes and businesses, resulting in high costs for cleanup and restoration.



Cooking grease coats pipelines much like fatty foods clog human arteries. The grease clings to the insides of the pipe, eventually causing blockage and potential sewer spills. By following a few simple steps, customers can help prevent costly sewer spills in the future.

- All cooking oil (this includes salad oil, frying oil and bacon fat) should be poured into an old milk carton, frozen juice container, or other non-recyclable package, and disposed of in the garbage.
- Dishes and pots that are coated with greasy leftovers should be wiped clean with a disposable towel prior to washing or placing in the dishwasher.
- Instead of placing fat trimmings from meat down the garbage disposal, place them in a trash can.

Vactor

FOG Problems
Manholes can overflow into parks, yards, streets, and storm drains, allowing FOG to contaminate local waters, including drinking water. Exposure to untreated wastewater is a public-health hazard and is an EPA violation. FOG discharged into septic systems and drain fields can cause malfunctions, resulting in more frequent tank pump-outs and other expenses.

Restaurants, cafeterias, and fast-food establishments spend tens of thousands of dollars on plumbing emergencies each year to deal with grease blockages and pump out grease traps and interceptors. Some cities also charge businesses for the repair of sewer pipes and spill cleanup if they can attribute the blockage to a particular business.

Some cities also add a surcharge to wastewater bills if a business exceeds a specified discharge limit. These expenses can be a significant.

Communities spend billions of dollars every year unplugging or replacing grease-blocked pipes, repairing pump stations, and cleaning up costly and illegal wastewater spills. Excessive FOG in the sewer system can affect local wastewater rates. So, keeping FOG out of the sewer system helps everyone in the community.

Controlling Fats, Oils, and Grease Discharges from Food Service Establishments
FOG gets into our sewer collection system mainly from residential customers pouring the substances down their drains and from commercial food preparation establishments with inadequate grease controls. Fats, oils and grease are a byproduct of cooking and are mostly found in the following:

- ✓ Meats
- ✓ Cooking oil
- ✓ Lard or shortening
- ✓ Butter or margarine

Our sewer system is not designed to handle or treat these substances in excess. Over time, without proper disposal of fats, oils and grease, they build up in the sewer system and eventually block collection pipes and sewer lines, resulting in sewer backups and overflows on streets, properties and even in customers' homes and/or businesses. Overflows may also impact the environment negatively and can result in contamination of ponds, streams or rivers.

Food Service Establishments (FSEs)
Food Service Establishments (FSEs) are a significant source of fats, oil and grease (FOG) because of the amount of grease used in cooking. POTW Commercial FOG Programs are generally developed to assist restaurants and other FSEs with proper handling and disposal of their FOG. Through implementation of Best Management Practices (BMPs), these establishments should be able to significantly reduce the amount of FOG that goes down their drains. This will minimize back-ups and help business owners comply with the POTW's requirements.

To work effectively, sewer systems need to be properly maintained, from the drain to the treatment plant. If wastes are disposed of correctly, the POTW's sewer system can handle them without any problem.

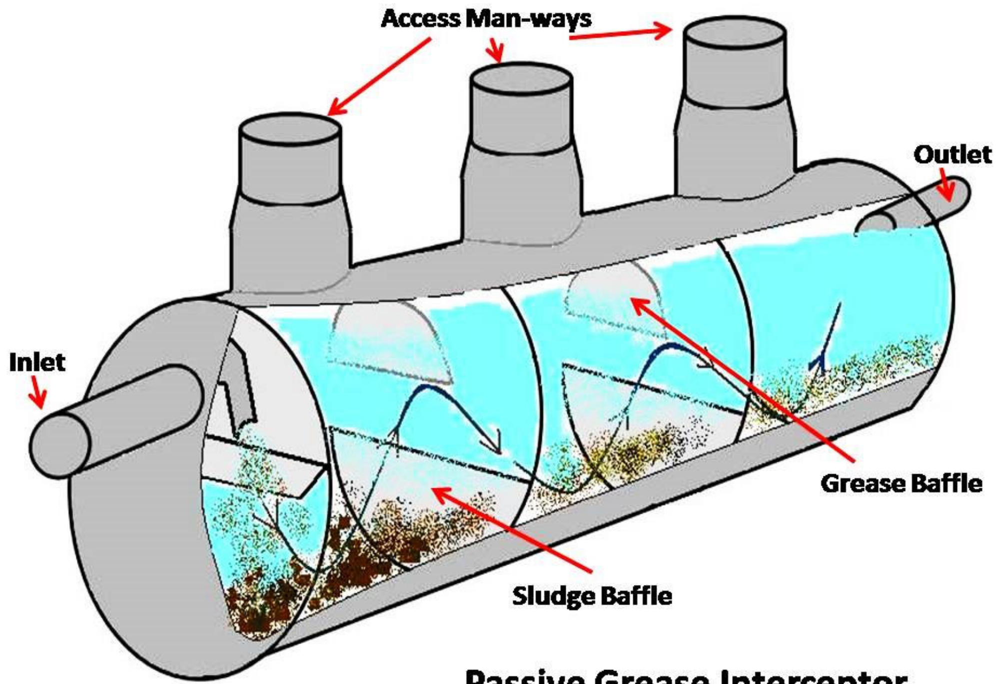
Grease Trap

The trap prevents excess grease from getting into the sewer system from existing plumbing lines within facilities. Traps are small and are usually installed inside a facility. Generally, they range in size from 20 gallons per minute (gpm) to 50 gpm.

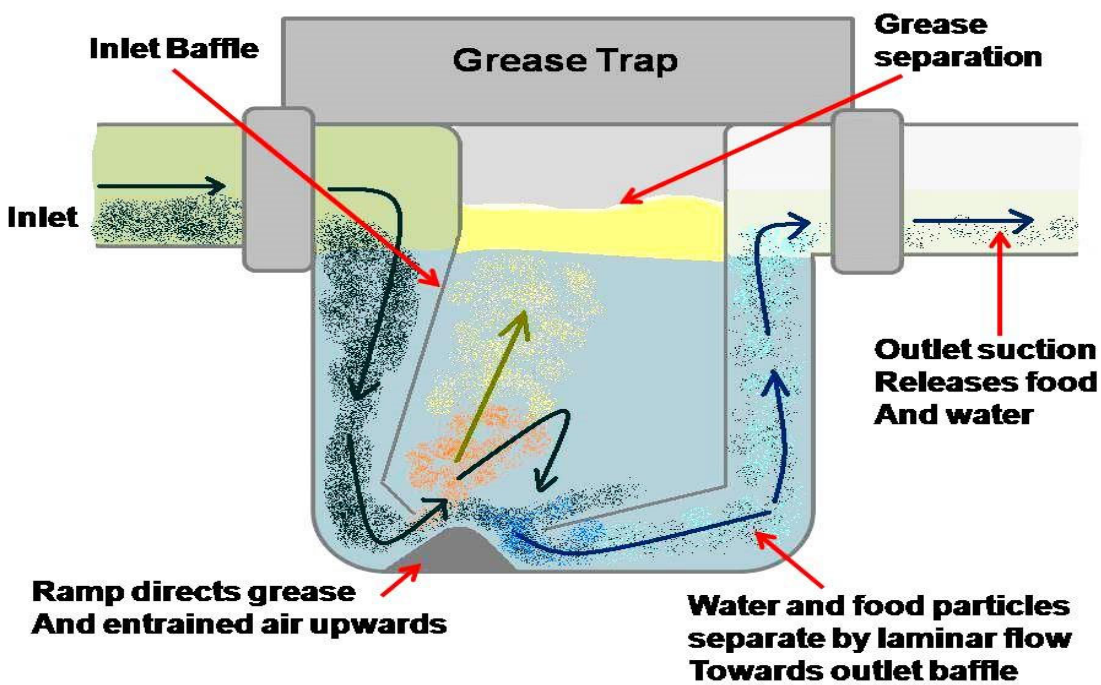
Infloor grease trap being removed and replaced with a grease interceptor.

Looking down into a grease interceptor commonly used in a commercial food service operations.

Grease Interceptor Diagrams

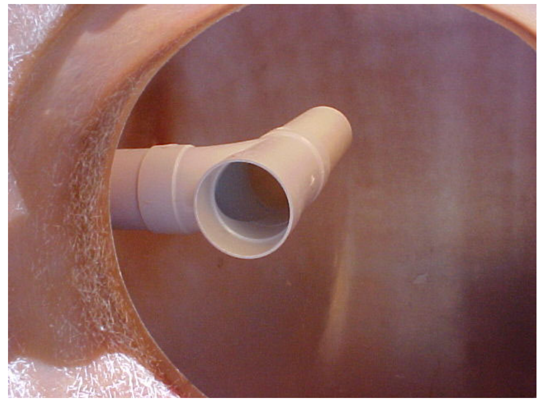


Passive Grease Interceptor



Grease Interceptor Sub-Section

High-volume or new establishments use grease interceptors that are larger than the traps and are installed underground, outside of a facility. Grease is actually "intercepted" in these concrete or fiberglass tanks before it reaches the sewer main. Grease interceptors should be accessible by three manhole covers, and a sample box. Interceptors and traps cause the flow of water to slow down, allowing the grease to naturally float to the top of the tank for easy removal.



New fiberglass three compartment grease interceptor. You will need to fill the interceptor with water before connecting it to the sewer main.

Plan Checks and Inspections
All plans for new commercial food establishments (including new construction remodels and retrofits) should receive a plan review from the POTW. This review assures that appropriate grease-removal equipment is installed during construction.

Grease Blockages
Shortly after sewer-spills caused by grease are reported or discovered, POTW inspectors investigate facilities within the immediate area. A determination is made as to which commercial facilities contributed to the blockage, and more in-depth inspections are conducted at those facilities.

Where appropriate, additional requirements and/or procedures are put in place. When requirements are made for additional grease-removal equipment, the facility is given a due date to comply.

A Notice of Violation, with an administrative fee, is issued once a facility has passed its final due date. Administrative hearings, permit revocation, and ultimately, termination of sewer service may occur for those facilities that remain out of compliance.

Regular Grease Inspection
Regular inspection and maintenance is essential to the proper operation of a grease removal device. The local ordinance should require a minimum cleaning frequency of once every six months.

However, that frequency will increase depending on the capacity of the device, the amount of grease in the wastewater, and the degree to which the facility has contributed to blockages in the past.

Regular cleaning at the appropriate interval is necessary to maintain the rated efficiency of the device. Equipment that is not regularly maintained puts the food service facility at risk of violating the sewer use ordinance, and this may not be known until an overflow and violation have occurred.

Most POTWs suggest businesses start with quarterly cleanings and should be done when 75 percent of the retention capacity of the unit is 75 percent full of accumulated grease. A large measuring stick and/or a clear piece of conduit may be used to determine the depth of the grease accumulation. You should require that restaurants contract with a licensed grease hauler to remove it from the premises for appropriate disposal.

Choosing a Grease Hauler

When you speak to a restaurant owner, inform them that while selecting a grease hauler, be aware that services and prices can vary. Minimum services should include:

- Complete pumping and cleaning of the interceptor and sample box, rather than just skimming the grease layer.
- Deodorizing and thorough cleaning of affected areas, as necessary.
- Disposal/reclamation at an approved location.
- Notes concerning the condition of the interceptor
- Complete pumping and cleaning record.

The restaurant owner and grease hauler should agree on an adequate cleaning frequency to avoid blockage of the line. Waste grease from a kitchen is recyclable for use in making soap, animal feed, etc. Grease from a grease trap or interceptor may not be reused in this way. For recyclable grease, some POTWs recommend that all facilities have waste grease containers with tight fitting lids that are either secondarily contained or kept in a bermed area to protect floor drains and storm drain inlets from spills.

Keeping up-to-date Records

Careful record keeping is one of the best ways to ensure that the grease removal device is being cleaned and maintained on a regular basis. City codes and ordnances require records be maintained for a minimum of three to five years.

Other Types of Devices

A grease trap may be approved in lieu of an interceptor for full service food service facilities only in very limited circumstances when space is not available. Grease traps may also be approved by the Industrial Pretreatment Program for facilities such as delicatessens and small bakeries that produce small quantities of oil, grease, or fat. Refer to the International Plumbing Code for requirements related to grease traps such as installation of flow-control devices, flow rates, and other structural requirements.

Please Note: Flow restrictors are required for grease traps because they increase retention time and efficiency.

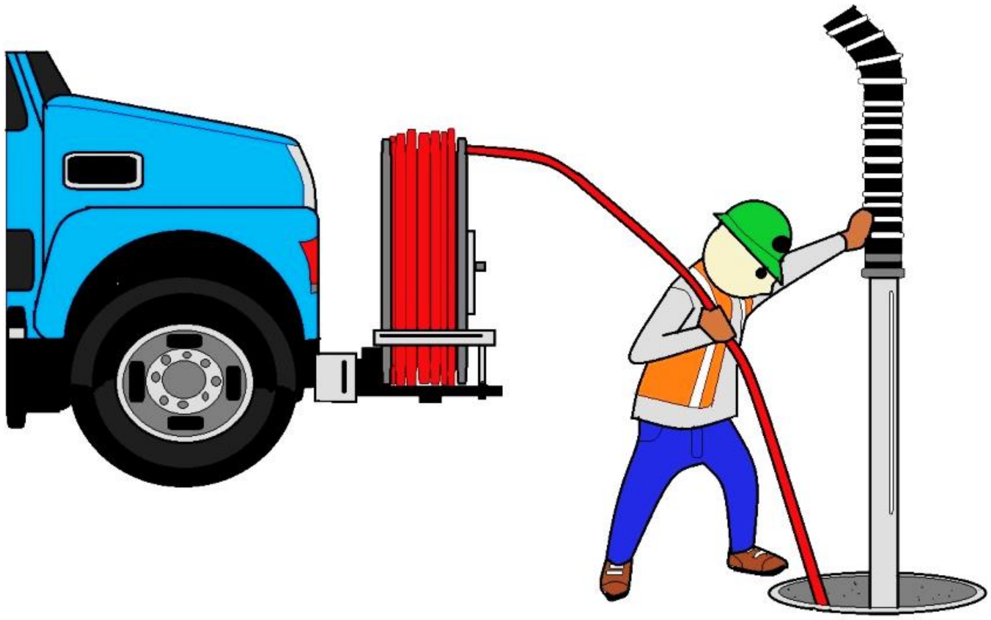
Automatic grease skimming devices collect small volumes of water and remove grease into a side container at preset times each day. Usually, special approval from the Industrial Pretreatment Staff or the POTW is required to install one of these devices in lieu of a grease interceptor.

Magic Grease "Bugs" and Bacterial Additives
Manufacturers of bacterial additives claim that their products remove grease and enhance the performance of grease traps and interceptors. Such additives cannot be substituted for a grease removal device and regular inspection and maintenance.
If a customer decides to use an additive, they need to make sure the product you select is not an emulsifier, which simply keeps grease in suspension temporarily and allows it to flow to the sewer system.

Obtaining necessary permits
• Building departments prefer in-ground installations that drain by gravity to the sanitary sewer. Avoid pumps and other mechanical devices in your connection to the sewer if possible.
• The interceptor or grease trap needs to be properly sized in accordance with the International Plumbing Code, IAPMO, or local ordinance.

Chain Cutter
This tool is attached to the flush truck. When water pressure is applied, the 3 chains at the head spin at tremendous speeds. These spinning chains will cut roots, grease build-up, and even a protruding tap.

This is a sewer line that has a large amount of grease buildup that will be cut out. Grease gets into the sewer line by pouring grease left over from cooking, down the kitchen sink.



USING A VACUUM TRUCK TO CLEAN SEWER
Often the Vactor is called out to clean out the above concerns.

The POTW needs businesses and individuals to do their part to maintain the system because repeated repairs are disruptive to residences and businesses alike. Furthermore, proper disposal by commercial establishments is required by law.

Interceptors and Traps- Plan Checks and Inspections

As a collection operator, you will need knowledge of many different concerns in order to properly identify the problem.

All plans for new commercial food establishments (including new construction remodels and retrofits) should receive a plan review from the POTW. This review assures that appropriate grease-removal equipment is installed during construction.

Grease Blockages
Shortly after sewer-spills caused by grease are reported or discovered, POTW inspectors or Collection Inspectors investigate facilities within the immediate area. A determination needs to be made as to which commercial facilities contributed to the blockage, and more in-depth inspections are conducted at those facilities. Where appropriate, additional requirements and/or procedures are put into place. When requirements are made for additional grease-removal equipment, the facility is given a due date to comply. A Notice of Violation (NOV), with an administrative fee, is issued once a facility has passed its final due date. Administrative hearings, permit revocation, and ultimately, termination of sewer service may occur for those facilities that remain out of compliance.

Regular Grease Inspection
Regular inspection and maintenance is essential to the proper operation of a grease removal device. The local ordinance should require a minimum cleaning frequency of once every six months. However, that frequency will increase depending on the capacity of the device, the amount of grease in the wastewater, and the degree to which the facility has contributed to blockages in the past.

Regular cleaning at the appropriate interval is necessary to maintain the rated efficiency of the device. Equipment that is not regularly maintained puts the food service facility at risk of violating the sewer use ordinance, and this may not be known until an overflow and violation have occurred.

Most POTWs suggest businesses start with quarterly cleanings that should be done when 75 percent of the retention capacity of the unit is full of accumulated grease. A large measuring stick and/or a clear piece of conduit may be used to determine the depth of the grease accumulation.

You should contract with a licensed grease hauler to remove it from the premises for appropriate disposal.

Choosing a Grease Hauler
When the customer needs to select a grease hauler, they should be aware that services and prices can vary.

Minimum services should include:
• Complete pumping and cleaning of the interceptor and sample box, rather than just skimming the grease layer.

• Deodorizing and thorough cleaning of affected areas, as necessary.

• Disposal/reclamation at an approved location.

• Notes concerning the condition of the interceptor.

• Complete pumping and cleaning record.

The Customer and the hauler should agree on an adequate cleaning frequency to avoid blockage of the line.

Recyclable grease storage
Waste grease from a kitchen is recyclable for use in making soap, animal feed, etc. Grease from a grease trap or interceptor may not be reused in this way.

For recyclable grease, some POTWs recommend that all facilities have waste grease containers, with tight fitting lids, that are either secondarily contained or kept in a bermed area to protect floor drains and storm drain inlets from spills.

Keeping up-to-date Records
Careful record keeping is one of the best ways to ensure that your grease removal device is being cleaned and maintained on a regular basis. City codes and ordnances require records be maintained for a minimum of three to five years.

Other Types of Devices
Often but not always, a grease trap or several traps may be approved in lieu of an interceptor for full service food service facilities only in very limited circumstances when space is not available.

Grease traps may also be approved by the Industrial Pretreatment Program for facilities such as delicatessens and small bakeries that produce small quantities of oil, grease, or fat. Refer to the Plumbing Code for requirements related to grease traps such as installation of flow-control devices, flow rates, and other structural requirements.

Please Note: flow restrictors are required for grease traps because they increase retention time and efficiency. Automatic grease skimming devices collect small volumes of water and remove grease into a side container at preset times each day.

Usually, special approval from the Industrial Pretreatment Staff or the POTW is required to install one of these devices in lieu of a grease interceptor.

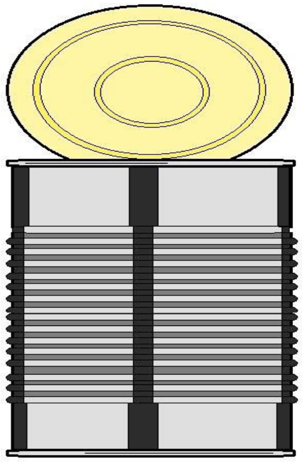
Magic Grease Eating "Bugs" and Bacterial Additives
Manufacturers of bacterial additives claim that their products remove grease and enhance the performance of grease traps and interceptors. Such additives cannot be substituted for a grease removal device, cleaning, regular inspection and maintenance.

If a customer decides to use an additive, they need to make sure the product you select is not an emulsifier, which simply keeps grease in suspension temporarily and allows it to flow to the sewer system.

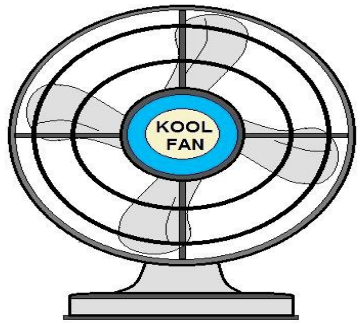
Obtaining Necessary Permits - Fixture Unit Loading Calculation

- Building departments prefer in-ground installations that drain by gravity to the sanitary sewer. Avoid pumps and other mechanical devices in your connection to the sewer if possible.
- The interceptor or grease trap needs to be properly sized (fixture unit loading) in accordance with the International Plumbing Code, IAPMO, or local ordinance.

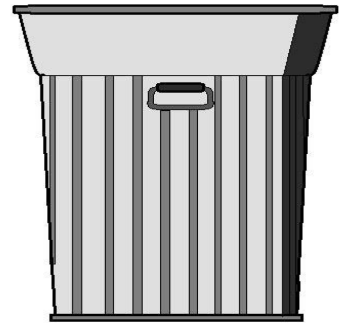
Controlling FOG Discharges



CAN IT



COOL IT



TRASH IT

METHODS OF PROPER GREASE DISPOSAL

FOG wastes are generated at FSEs as byproducts from food preparation activities. FOG captured on-site is generally classified into two broad categories: yellow grease and grease trap waste. Yellow grease is derived from used cooking oil and waste greases that are separated and collected at the point of use by the food service establishment.

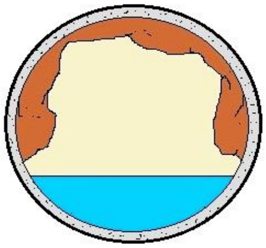
The annual production of collected grease trap waste and uncollected grease entering sewage treatment plants can be significant and ranges from 800 to 17,000 pounds/year per restaurant.

The National Pretreatment Program already provides the necessary regulatory tools and authority to local pretreatment programs for controlling interference problems. Under the provisions of Part 403.5(c)(1) & (2), in defined circumstances, a POTW must establish specific local limits for industrial users to guard against interference with the operation of the municipal treatment works.

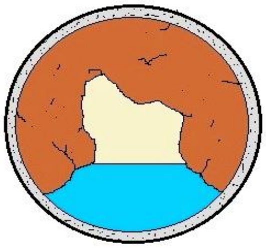
Consequently, pretreatment oversight programs should include activities designed to identify and control sources of potential interference and, in the event of actual interference, enforcement against the violator.

Food service establishments can adopt a variety of best management practices or install interceptor/collector devices to control and capture the FOG material before discharge to the collection system.

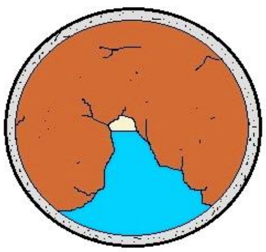
For example, instead of discharging yellow grease to POTWs, food service establishments usually accumulate this material for pick up by consolidation service companies for re-sale or re-use in the manufacture of tallow, animal feed supplements, bio-fuels, or other products. Additionally, food service establishments can install interceptor/collector devices (e.g., grease traps) in order to accumulate grease on-site and prevent it from entering the POTW collection system.



THE START OF BLOCKED PIPE BEGINS WITH SOLIDS AND GREASE COLLECTING ON TOP AND SIDES OF PIPE INTERIOR.



OVER TIME, THE BUILD-UP INCREASES WHEN GREASE AND DEBRIS ARE WASHED DOWN A DRAIN.



EXCESSIVE ACCUMULATION RESTRICTS THE FLOW OF WASTEWATER THAT CAN RESULT IN AN OVERFLOW OF SANITARY SEWER

HOW SEWER BLOCKAGES FORM

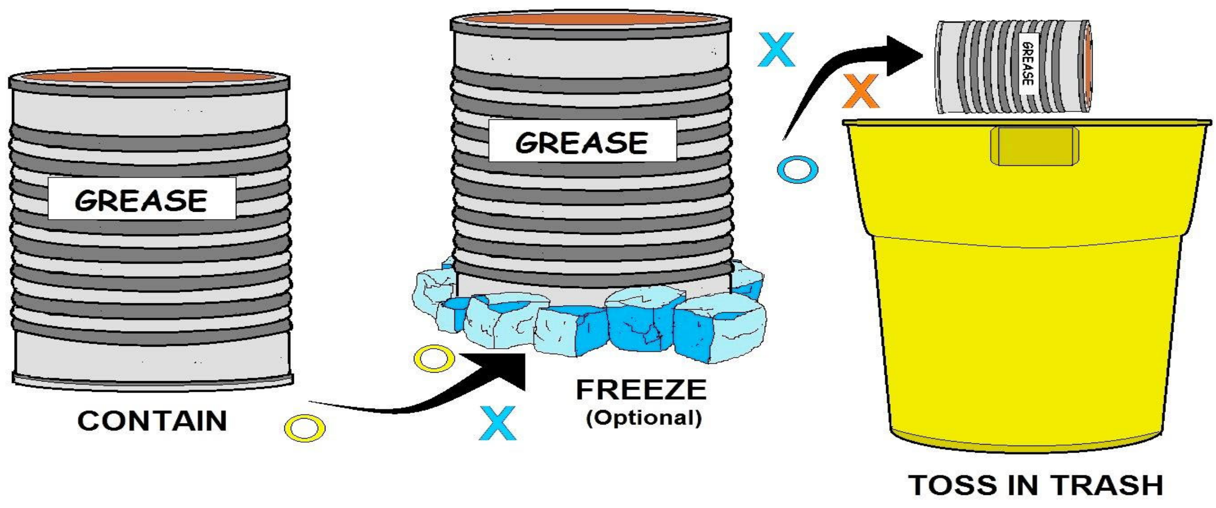
POTWs control methods for FOG discharges from FSEs

Proper design, installation, and maintenance procedures are critical for these devices to control and capture the FOG.

For example,

- ✓ Interceptor/collector devices must be designed and sized appropriately to allow FOG to cool and separate in a non-turbulent environment.
- ✓ FSE must be diligent in having their interceptor/ collector devices serviced at regular intervals.

Methods of Recycling FOG



THE SINK SHOULD NEVER BE USED TO DISPOSE OF:
OILS , FATS OR GREASE

FOG Customers and Violators Should be Encouraged or Written Up to…

Rendering FOG
Liquid fats and solid meat products can be used as raw materials in the rendering industry, which converts them into animal food, cosmetics, soap, and other products. Many companies will provide storage barrels and free pick-up service.

Converting FOG to Biodiesel
FOG are collected and converted by a local manufacturer into environmentally friendly biodiesel fuel. Biodiesel is an alternative fuel produced from renewable resources such as virgin oils (soybean, canola, palm), waste cooking oil, or other bio-waste feedstock.

Biodiesel significantly reduces greenhouse gases, sulfur dioxide in air emissions, and asthma-causing soot. Along with creating less pollution, biodiesel is simple to use, biodegradable and nontoxic.

Inspection Checklists
Pretreatment programs are developing and using inspection checklists for both food service establishments and municipal pretreatment inspectors to control FOG discharges.

Additionally, EPA identified typical numeric local limits controlling oil and grease in the range of 50 mg/L to 450 mg/L with 100 mg/L as the most common reported numeric pretreatment limit.

EPA expects that blockages from FOG discharges will decrease as POTWs incorporate FOG reduction activities into their Capacity, Management, Operations, and Maintenance (CMOM) program and daily practices.

CMOM programs are comprehensive, dynamic, utility specific programs for better managing, operating and maintaining sanitary sewer collection systems, investigating capacity constrained areas of the collection system, and responding to SSOs.

Collection system owners or operators who adopt FOG reduction activities as part of their CMOM program activities are likely to reduce the occurrence of sewer overflows and improve their operations and customer service.

Industrial Uses (Fats, Oils, and Grease)

Fats, Oils, and Grease Resources
Liquid fats and solid meat products are materials that should not be sent to landfills or disposed of in the sanitary sewer system. Fats, oils, and grease (FOG) can clog pipes and pumps both in the public sewer lines as well as in wastewater treatment facilities. This prevents combined sewer overflows, which protects water quality and lowers bills. FOG should be sent to the rendering industry to be made into another product, converted to biofuels, or sent to an anaerobic digester.

Proper Disposal Methods
Ways in which you as a customer can reduce the amounts of FOG that enters the sewer system is by doing the following:

- ✓ Have grease interceptors or traps inspected, maintained and cleaned regularly. (Usually every 6 months they should be pumped out).
- ✓ Scrape grease and food residue from dishes and pans into a garbage bag before placing them into your dishwasher or sink.
- ✓ Allow grease to cool to a safe temperature after cooking before disposal.
- ✓ Only dispose of fat and grease in an approved container or by an approved method.
- ✓ Recycle used cooking or motor oil at a recycling center.
- ✓ First freeze the grease or oil and then throw the hardened oil away on trash day.
- ✓ Mix oils with unscented kitty litter, sawdust or sand to solidify the oil (Avoid scented or disinfectant types of kitty litter as they can react with the oil and cause a fire).
- ✓ Use a paper towel to wipe small amounts of cooking oil, such as meat drippings, and throw the paper towel in the trash.
- ✓ Install “No Grease” signs around sinks to remind employees to avoid dumping fry grease and other fat products down the drain.
- ✓ Frying oils can generally be stored for up to six months and also can be reused for up to six hours of frying time. Store oil in the original container after cooling and strain for foreign materials as it is being poured back into the container.

Methods that should be avoided:

- ✓ Pouring household grease into sinks, garbage disposals or other drains. This is one of the major contributors to sewer stoppages.
- ✓ Flushing grease, diapers, sanitary napkins, newspapers, soiled rags, and/or paper towels down toilets.
- ✓ Pouring oil or grease into a storm drain; it is the same as pouring it directly into a lake.
- ✓ Ignoring your grease trap maintenance schedule.

National Pretreatment Program's Tools

The National Pretreatment Program provides regulatory tools and authority to state and local POTW pretreatment programs for eliminating pollutant discharges that cause interference at POTWs, including interference caused by the discharge of Fats, Oils, and Grease (FOG) from food service establishments (FSE).

More specifically, the Pretreatment Program regulations at 40 CFR 403.5(b)(3) prohibit "solid or viscous pollutants in amounts which will cause obstruction" in the POTW and its collection system.

EPA's Report to Congress on combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs) identified that "grease from restaurants, homes, and industrial sources are the most common cause (47%) of reported blockages.

Grease is problematic because it solidifies, reduces conveyance capacity, and blocks flow."

Controlling FOG discharges will help POTWs prevent blockages that impact CSOs and SSOs, which cause public health and water quality problems.

Controlling FOG discharges from FSEs is an essential element in controlling CSOs and SSOs and ensuring the proper operations for many POTWs. The interference incidents identified in CSO/SSO report to Congress may indicate the need for additional oversight and enforcement of existing regulations and controls.

Best Management Practices (BMPs)

The required maintenance frequency for interceptor/collector devices depends greatly on the amount of FOG a facility generates as well as any best management practices (BMPs) that the establishment implements to reduce the FOG discharged into its sanitary sewer system. In many cases, an establishment that implements BMPs will realize financial benefit through a reduction in their required grease interceptor and trap maintenance frequency.

A growing number of control authorities are using their existing authority (e.g., general pretreatment standards in Part 403 or local authority) to establish and enforce more FOG regulatory controls (e.g., numeric pretreatment limits, best management practices including the use of interceptor/collector devices) for food service establishments to reduce interferences with POTW operations (e.g., blockages from fats, oils, and greases discharges, POTW treatment interference from Nocardia filamentous foaming, damage to collection system from hydrogen sulfide generation).

Non-Compliance Rate Example

For example, since identifying a 73% non-compliance rate with its grease trap ordinance among restaurants, New York POTW has instituted a $1,000-per-day fine for FOG violations. Likewise, more and more municipal wastewater authorities are addressing FOG discharges by imposing mandatory measures of assorted kinds, including inspections, periodic grease pumping, stiff penalties, and even criminal citations for violators, along with 'strong waste' monthly surcharges added to restaurant sewer bills. Surcharges are reportedly ranging from $100 to as high as $700 and more, the fees being deemed necessary to cover the cost of inspections and upgraded infrastructure.

FOG Customers Using Best Management Practices Can:

- Lessen the likelihood of customer's losing revenue to emergency shutdowns caused by sewage backups and expensive bills for plumbing and property repairs.

- Lessen the likelihood of customer's lawsuits by nearby businesses over sewer problems caused by negligence.

- Lessen the likelihood of customer's lawsuits from workers or the public exposed to raw sewage during a backup.

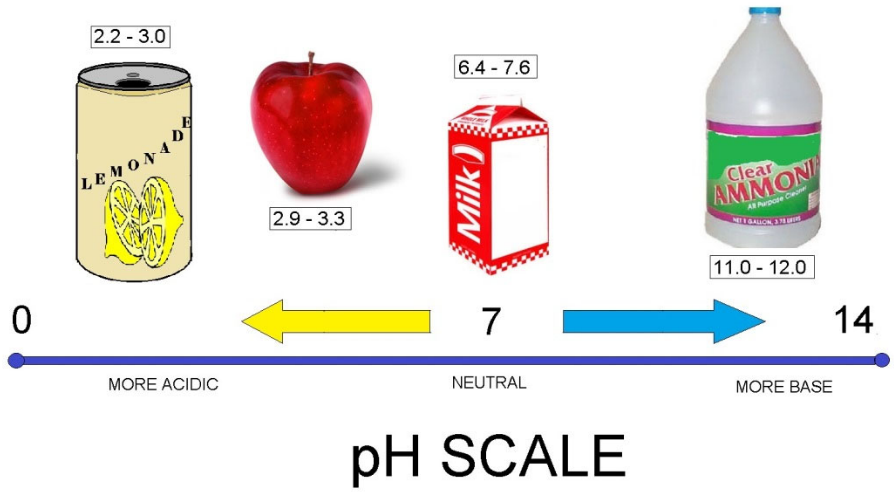
- Reduce the number of times customers have to pump and clean your grease interceptors or traps.

- Lessen the likelihood of surcharges from the local sewer authority, or chargebacks for repairs to sewer pipes attributable customer's FOG.

- Reduce testing customer's requirements imposed due to a history of violations.

- Lessen the likelihood of customer's enforcement action by POTW authorities due to violations of ordinances.

pH Testing Sub-Section



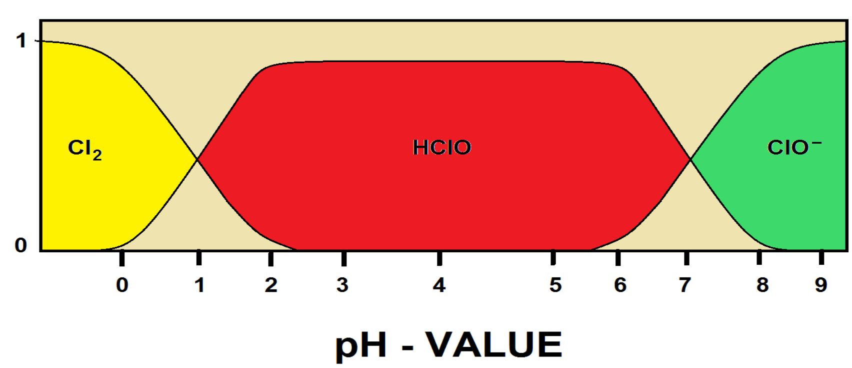
Because of FOG, it will lower the pH of the wastewater to very acidic conditions. You may be asked to test the pH of the wastewater to ensure the acid is not strong enough to cause corrosion to the sewer system.

In water and wastewater processes, **pH** is a measure of the acidity or basicity of an aqueous solution. Solutions with a pH greater than 7 are basic or alkaline and solution or samples with a pH less than 7 are said to be acidic. Pure water has a pH very close to 7.

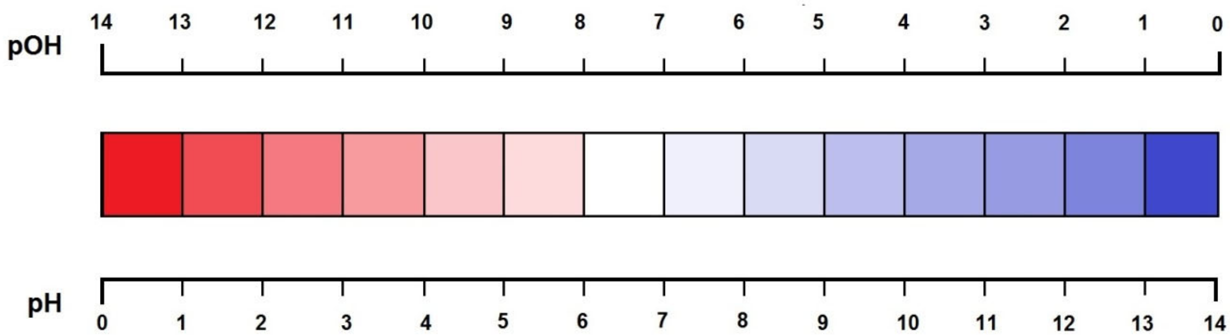
Primary pH standard values are determined using a concentration cell with transference, by measuring the potential difference between a hydrogen electrode and a standard electrode such as the silver chloride electrode. The pH scale is traceable to a set of standard solutions whose pH is established by international agreement.

Measurement of pH for aqueous solutions can be done with a glass electrode and a pH meter, or using indicators like strip test paper.

pH measurements are important in water and wastewater processes (sampling) but also in medicine, biology, chemistry, agriculture, forestry, food science, environmental science, oceanography, civil engineering, chemical engineering, nutrition, water treatment & water purification, and many other applications.



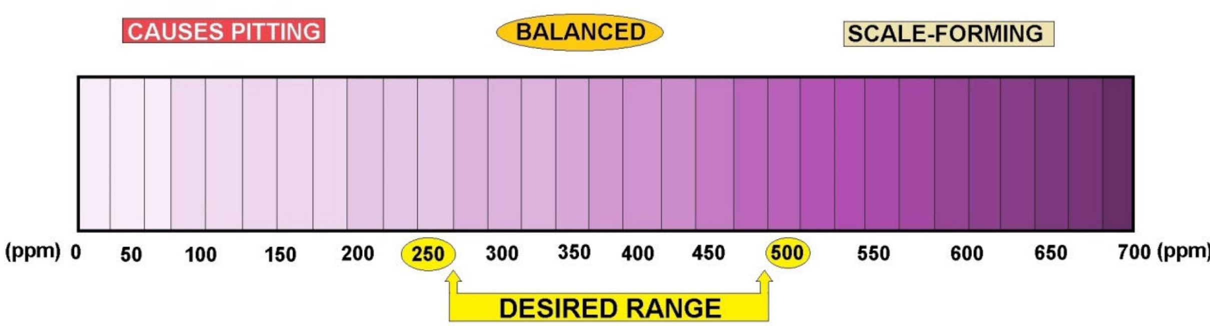
Mathematically, pH is the measurement of hydroxyl ion activity and expressed as the negative logarithm of the activity of the (solvated) hydronium ion, more often expressed as the measure of the hydronium ion concentration.



IN RELATION BETWEEN p(OH) AND p(H) (red= ACIDIC / blue= BASIC)

Contents
History
The scientific discovery of the p[H] concept of was first introduced by Danish chemist Søren Peder Lauritz Sørensen at the Carlsberg Laboratory back in 1909 and revised to the modern pH in 1924 to accommodate definitions and measurements in terms of electrochemical cells. In the first papers, the notation had the "H" as a subscript to the lowercase "p", as so: pH.

Alkalinity
Alkalinity is the quantitative capacity of an aqueous solution to neutralize an acid. Measuring alkalinity is important in determining a stream's ability to neutralize acidic pollution from rainfall or wastewater. It is one of the best measures of the sensitivity of the stream to acid inputs. There can be long-term changes in the alkalinity of rivers and streams in response to human disturbances.



CALCIUM HARDNESS MEASUREMENT

Reference. Bates, Roger G. Determination of pH: theory and practice. Wiley, 1973.

pH Definition and Measurements

CONCENTRATION OF HYDROGEN IONS COMPARED TO DISTILLED H2O	pH	EXAMPLES OF SOLUTIONS AND THEIR RESPECTIVE pH
1/10,000,000	14	LIQUID DRAIN CLEANER CAUSTIC SODA
1/1,000,000	13	BLEACHES OVEN CLEANERS
1/100,000	12	SOAPY WATER
1/10,000	11	HOUSEHOLD AMMONIA (11.9)
1/1,000	10	MILK OF MAGNESIUM (10.5)
1/100	9	TOOTHPASTE (9.9)
1/10	8	BAKING SODA (8.4) / SEA WATER EGGS
0	7	"PURE" WATER (7)
10	6	URINE (6) / MILK (6.6)
100	5	ACID RAIN (5.6) BLACK COFFEE (5)
1000	4	TOMATO JUICE (4.1)
10,000	3	GRAPEFRUIT & ORANGE JUICE SOFT DRINK
100,000	2	LEMON JUICE (2.3) VINEGAR (2.9)
1,000,000	1	HYDROCHLORIC ACID SECRETED FROM STOMACH LINING (1)
10,000,000	0	BATTERY ACID

pH Scale

Technical Definition of pH
In technical terms, pH is defined as the decimal logarithm of the reciprocal of the hydrogen ion activity, *a*H+, in a solution.

$$pH = -\log_{10}(a_H+) = \log_{10}\left(\frac{1}{aH+}\right)$$

Ion-selective electrodes are often used to measure pH, respond to activity.

In this calculation of electrode potential, *E*, follows the Nernst equation, which, for the hydrogen ion can be written as

$$E = E^0 + \frac{RT}{F} In\,(a_H +) = E^0 - \frac{2.303RT}{F} pH$$

where *E* is a measured potential, E^0 is the standard electrode potential, *R* is the gas constant, *T* is the temperature in kelvin, *F* is the Faraday constant.

For H^+ number of electrons transferred is one. It follows that electrode potential is proportional to pH when pH is defined in terms of activity.

International Standard ISO 31-8 is the standard for the precise measurement of pH as follows: A galvanic cell is set up to measure the electromotive force (EMF) between a reference electrode and an electrode sensitive to the hydrogen ion activity when they are both immersed in the same aqueous solution.

The reference electrode may be a silver chloride electrode or a calomel electrode. The hydrogen-ion selective electrode is a standard hydrogen electrode.

Reference electrode | concentrated solution of KCl || test solution | H_2 | Pt

Firstly, the cell is filled with a solution of known hydrogen ion activity and the emf, E_S, is measured. Then the emf, E_X, of the same cell containing the solution of unknown pH is measured.

$$pH(X) = pH(S) + \frac{E_s - E_x}{z}$$

The difference between the two measured emf values is proportional to pH. This method of calibration avoids the need to know the standard electrode potential. The proportionality constant, *1/z* is ideally equal to $\frac{1}{2.303RT/F}$ the "Nernstian slope".

If you were to apply this practice the above calculation, a glass electrode is used rather than the cumbersome hydrogen electrode. A combined glass electrode has an in-built reference electrode. It is calibrated against buffer solutions of known hydrogen ion activity. IUPAC has proposed the use of a set of buffer solutions of known H^+ activity.

Two or more buffer solutions should be used in order to accommodate the fact that the "slope" may differ slightly from ideal.

The electrode is first immersed in a standard solution and the reading on a pH meter is adjusted to be equal to the standard buffer's value, to implement the proper calibration. The reading from a second standard buffer solution is then adjusted, using the "slope" control, to be equal to the pH for that solution. Further details, are given in the IUPAC recommendations.

When more than two buffer solutions are used the electrode is calibrated by fitting observed pH values to a straight line with respect to standard buffer values. Commercial standard buffer solutions usually come with information on the value at 25 °C and a correction factor to be applied for other temperatures.

The pH scale is logarithmic and pH is a dimensionless quantity.

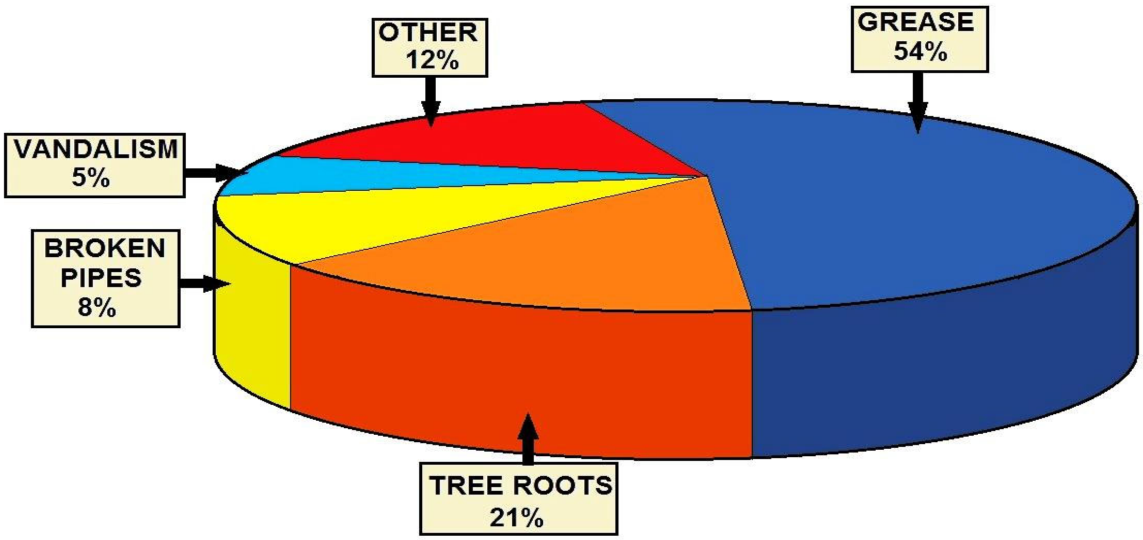
FOG Summary

Reducing Fats, Oils, and Grease in Your Commercial Kitchen
Any business or institution with a commercial kitchen has to deal with fats, oils, and grease (FOG). Commercial kitchens are found in restaurants, hospitals, churches, hotels, nursing homes, mobile food preparation facilities, etc.

Environmental problem with FOG sewers
FOG that enters the sewer system eventually solidifies and forms grease balls. These grease balls can range in size from marbles to the size of cantaloupes and must be removed periodically. Since the sewer system is unable to handle or treat these substances effectively, this incurs greater expenditures on the maintenance of the collection systems and/or treatment plants which in turn can lead to higher customer rates.

Sewer backups can also cost customers thousands of dollars for the repair or replacement of their damaged property.

Controlling FOG Discharges



CAUSES OF SANITARY SEWER OVERFLOWS

FOG wastes are generated at FSEs as by-products from food preparation activities. FOG captured on-site is generally classified into two broad categories: yellow grease and grease trap waste. Yellow grease is derived from used cooking oil and waste greases that are separated and collected at the point of use by the food service establishment.

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The National Pretreatment Program already provides the necessary regulatory tools and authority to local pretreatment programs for controlling interference problems. Under the provisions of Part 403.5(c)(1) & (2), in defined circumstances, a POTW must establish specific local limits for industrial users to guard against interference with the operation of the municipal treatment works.

Consequently, pretreatment oversight programs should include activities designed to identify and control sources of potential interference and, in the event of actual interference, enforcement against the violator.

Food service establishments can adopt a variety of best management practices or install interceptor/collector devices to control and capture the FOG material before discharge to the collection system. For example, instead of discharging yellow grease to POTWs, food service establishments usually accumulate this material for pick up by consolidation service companies for re-sale or re-use in the manufacture of tallow, animal feed supplements, bio-fuels, or other products.

Additionally, food service establishments can install interceptor/collector devices (e.g., grease traps) in order to accumulate grease on-site and prevent it from entering the POTW collection system.

Residential and Commercial Guidelines
The fats, oil and grease (FOG) found in food ingredients such as meat, cooking oil, shortening, butter, margarine, baked goods, sauces and dairy products is a major concern for POTW's sewers. When not disposed of properly, FOG builds up in the sewer system constricting flow, which can cause sewer back-ups into homes and overflow discharges onto streets. It can also interfere with sewage treatment processes at the POTW's Wastewater Treatment Plants.

To remediate this problem, many control authorities have developed an outreach program aimed at eliminating FOG from the sewer system. FOG buildup in sewer lines has many harmful and costly effects.

Sewer backups into homes create a health hazard as well as an unpleasant mess that can cost hundreds and sometimes thousands of dollars to clean up. In certain parts of the POTW, FOG can enter storm drains and flow directly into water bodies and onto beaches creating serious environmental and health conditions.

In addition to problems caused by cooking oils, petroleum-based oils can also cause sewer-related problems. POTW residents or customers may not be aware of or understand their role in these sewer-related problems or pollution, but they can do a lot to help eliminate FOG and other contaminants from the sewer system.

For example:

- Car washing can result in soap and oil residue entering the storm sewers.
- Run-off from your sprinkler, watering hose, or from the rain can carry yard waste and fertilizer into storm sewers.
- Littering can cause trash and debris to clog catch basins and storm drains.
- A gallon of oil poured down a storm drain could contaminate up to one million gallons of water.

FOG Section Post Quiz

Food Service Establishments (FSEs)

1. Because of the amount of grease used in cooking, ___________________are a significant source of fats, oil and grease (FOG).

2. To assist improper handling and disposal of their FOG ________________ are generally developed to assist restaurants and other FSEs with instruction and compliance.

3. The ___________________ can handle properly disposed wastes, but to work effectively, sewer systems need to be properly maintained, from the drain to the treatment plant.

4. Proper sewer disposal by commercial establishments is required by ___________________.

Environmental problem with FOG sewers

5. The various sizes of grease balls can range in size from cantaloupes to the size of marble and must be removed periodically.
A. True B. False

6. The repair or replacement of their damaged property caused by FOG creating _____________ can also cost customers thousands of dollars for the repair or replacement of their damaged property.

Controlling FOG discharges

7. FOG wastes are generated at FSEs as byproducts from food preparation activities. FOG captured on-site is generally classified into two broad categories: yellow grease and grease trap waste.
A. True B. False

8. The POTW collection system(s) will require that certain food service establishments install interceptor/collector devices (e.g., grease traps) in order to accumulate grease on-site and prevent it from entering the?

Keeping Fats, Oils, and Grease out of the Sewer System

9. Manholes can overflow into parks, yards, streets, and storm drains, allowing FOG to contaminate local waters, including drinking water. Exposure to untreated wastewater is a public-health hazard and is an EPA violation. FOG discharged into septic systems and drain fields can cause malfunctions, resulting in more frequent tank pump-outs and other expenses.
A. True B. False

10. __________________ will back up into homes and businesses, resulting in high costs for cleanup and restoration?

POTWs control methods for FOG discharges from FSEs

11. FOG must be able to cool and separate in a non-turbulent environment, therefore. _________________ must be designed and sized appropriately.

12. Grease interceptor/ collector devices shall be serviced at regular intervals and ___________ must be diligent in providing proper maintenance and records.

Best Management Practices (BMPs)

13. The amount of FOG a facility generates as well as any best management practices (BMPs) that the establishment implements to reduce the *FOG* discharged into its sanitary sewer system.
A. True B. False

Answers

1. Food Service Establishments (FSEs), 2. POTW Commercial FOG Program, 3. POTW's sewer system, 4. Law, 5. True, 6. Sewer backup(s), 7.True, 8. POTW collection system(s), 9. True, 10. Untreated wastewater, 11. Interceptor/collector device(s), 12. FSE, 13. True

Chapter 4- COLLECTION RULES AND REGULATIONS

Section Focus: You will learn the Clean Water Act and the basics of the wastewater collection system. At the end of this section, you the student will be able to describe the basics of the Capacity, Management, Operation and Maintenance program. There is a post quiz at the end of this section to review your comprehension and a final examination in the Assignment for your contact hours.

Scope/Background: Sanitary sewage overflows that reach waters of the U.S. are point source discharges. Like other point source discharges from municipal sanitary sewer systems, sanitary sewage overflows are prohibited unless authorized by a NPDES permit. Moreover, SSOs, including those that do not reach waters of the U.S., may be indicative of improper operation and maintenance of the sewer systems, and may violate NPDES permit conditions.

What are Sanitary Sewer Overflows?
Sanitary Sewer Overflows (SSOs) are discharges of raw sewage from municipal sanitary sewer systems. SSOs can release untreated sewage into basements or out of manholes and onto city streets, playgrounds, and into streams before it can reach a treatment facility. SSOs are often caused by blockages and breaks in the sewer lines.

Why do Sewers Overflow?
SSOs occasionally occur in almost every sewer system, even though systems are intended to collect and contain all the sewage that flows into them. When SSOs happen frequently, it means something is wrong with the system.

Top photograph, new manhole. Bottom, a repaired sewer main after being damaged by the water distribution department using a backhoe without locates.

Clean Water Act Preface *(Credit USEPA)*

33 U.S.C. s/s 1251 et seq. (1977)

The Clean Water Act is a 1977 amendment to the Federal Water Pollution Control Act of 1972, which set the basic structure for regulating discharges of pollutants to waters of the United States.

The law gave the EPA the authority to set effluent standards on an industry basis (technology-based) and continued the requirements to set water quality standards for all contaminants in surface waters. The CWA makes it unlawful for any person to discharge any pollutant from a point source into navigable waters unless a permit (NPDES) is obtained under the act.

The 1977 amendments focused on toxic pollutants. In 1987, the PCA was reauthorized and again focused on toxic substances, authorized citizen suit provisions, and funded sewage treatment plants (POTW's) under the Construction Grants Program.

The CWA made provides for the delegation by the EPA of many permitting, administrative, and enforcement aspects of the law to state governments. In states with the authority to implement CWA programs, the EPA still retains oversight responsibilities.

In 1972, Congress enacted the first comprehensive national clean water legislation in response to growing public concern for serious and widespread water pollution. The Clean Water Act is the primary federal law that protects our nation's waters, including lakes, rivers, aquifers and coastal areas.

Lake Erie was dying. The Potomac River was clogged with blue-green algae blooms that were a nuisance and a threat to public health. Many of the nation's rivers were little more than open sewers and sewage frequently washed up on shore. Fish kills were a common sight. Wetlands were disappearing at a rapid rate.

Today, the quality of our waters has improved dramatically as a result of a cooperative effort by federal, state, tribal and local governments to implement the pollution control programs established in 1972 by the Clean Water Act.

The Clean Water Act's primary objective is to restore and maintain the integrity of the nation's waters. This objective translates into two fundamental national goals:

- eliminate the discharge of pollutants into the nation's waters, and
- achieve water quality levels that are fishable and swimmable.

The Clean Water Act focuses on improving the quality of the nation's waters. It provides a comprehensive framework of standards, technical tools and financial assistance to address the many causes of pollution and poor water quality. It includes municipal and industrial wastewater discharges, polluted runoff from urban and rural areas, and habitat destruction.

For example, the Clean Water Act requires major industries to meet performance standards to ensure pollution control; charges states and tribes with setting specific water quality criteria appropriate for their waters and developing pollution control programs to meet them; provides funding to states and communities to help them meet their clean water infrastructure needs;

protects valuable wetlands and other aquatic habitats through a permitting process that ensures development and other activities are conducted in an environmentally sound manner. After 25 years, the Act continues to provide a clear path for clean water and a solid foundation for an effective national water program.

In 1972
Only a third of the nation's waters were safe for fishing and swimming. Wetlands losses were estimated at about 460,000 acres annually.

Agricultural runoff resulted in the erosion of 2.25 billion tons of soil and the deposit of large amounts of phosphorus and nitrogen into many waters. Sewage treatment plants served only 85 million people.

Today
Two-thirds of the nation's waters are safe for fishing and swimming.

The rate of annual wetlands losses is estimated at about 70,000-90,000 acres according to recent studies. The amount of soil lost due to agricultural runoff has been cut by one billion tons annually, and phosphorus and nitrogen levels in water sources are down. Modern wastewater treatment facilities serve 173 million people.

The Future
All Americans will enjoy clean water safe for fishing and swimming. We will achieve a net gain of wetlands by preventing additional losses and restoring hundreds of thousands of acres of wetlands. Soil erosion and runoff of phosphorus and nitrogen into watersheds will be minimized, helping to sustain the nation's farming economy and aquatic systems. The nation's waters will be free of effects of sewage discharges.

As a collection system worker or pretreatment inspector, you will need sewer knowledge, mastery of the Clean Water Act and of your wastewater ordinances.

Problems that Can Cause Chronic SSOs Include:

Infiltration and Inflow (I&I): Too much rainfall or snowmelt infiltrating through the ground into leaky sanitary sewers not designed to hold rainfall or to drain property, and excess water inflowing through roof drains connected to sewers, broken pipes, and badly connected sewer service lines.

Undersized Systems: Sewers and pumps are too small to carry sewage from newly-developed subdivisions or commercial areas.

Pipe Failures: blocked, broken or cracked pipes, tree roots grow into the sewer, sections of pipe settle or shift so that pipe joints no longer match, and sediment and other material builds up causing pipes to break or collapse.

Equipment Failures: Pump failures, power failures.

Sewer Service Connections: Discharges occur at sewer service connections to houses and other buildings; some cities estimate that as much as 60% of overflows comes from the service lines.

Deteriorating Sewer System: Improper installation, improper maintenance; widespread problems that can be expensive to fix develop over time, some municipalities have found severe problems necessitating billion-dollar correction programs, often communities have to curtail new development until problems are corrected or system capacity is increased.

Why are SSOs a Problem?
The EPA has found that SSOs caused by poor sewer collection system management pose a substantial health and environmental challenge. The response to this challenge varies considerably from state to state.

Many municipalities have asked for national consistency in the way permits are considered for wastewater discharges, including SSOs, and in enforcement of the law prohibiting unpermitted discharges. In response, the EPA has convened representatives of states, municipalities, health agencies, and environmental advocacy groups to advise the Agency on how to best meet this challenge.

How Big is the SSO Problem?
The total number of SSOs that occur nationwide each year is not known. In some areas, they might not be reported or are underreported to the EPA and state environmental agencies. Two surveys, however, help to define the size of the problem:

- In a 1994 survey of 79 members of the Association of Metropolitan Sewerage Agencies, 65 percent of the respondents reported wet weather SSOs. They reported that between 15 and 35 percent of their sewers were filled above capacity and/or overflowed during wet weather. However, municipal respondents with SSOs had only limited information about them. Only 60 percent had estimated the annual number. Half of those had estimated the amount of sewerage discharged, and 17 percent had determined what pollutants were in their overflows.

- A 1981 survey conducted by the National Urban Institute indicated an average of 827 backups and 143 breaks per 1,000 miles of sewer pipe (about 1,000 miles of sewer pipe are needed to serve 250,000 people.) per year. Breaks occurred most often in the young, growing cities of the South and West.

Downstream of a nonfunctional Combined Sewer Overflow (CSO) Control Facility.

Combined Sewer Overflows

Combined sewer systems are sewers that are designed to collect rainwater runoff, domestic sewage, and industrial wastewater in the same pipe. Most of the time, combined sewer systems transport all of their wastewater to a sewage treatment plant, where it is treated and then discharged to a water body. During periods of heavy rainfall or snowmelt, however, the wastewater volume in a combined sewer system can exceed the capacity of the sewer system or treatment plant. For this reason, combined sewer systems are designed to overflow occasionally and discharge excess wastewater directly to nearby streams, rivers, or other water bodies.

These overflows, called combined sewer overflows (CSOs), contain not only storm water but also untreated human and industrial waste, toxic materials, and debris. They are a major water pollution concern for the approximately 772 cities in the U.S. that have combined sewer systems. CSOs may be thought of as a type of "urban wet weather" discharge. This means that, like sanitary sewer overflows (SSOs) and storm water discharges, they are discharges from a municipality's wastewater conveyance infrastructure that are caused by precipitation events such as rainfall or heavy snowmelt. The EPA's CSO Control Policy, published April 19, 1994, is the national framework for control of CSOs.

The Policy provides guidance on how communities with combined sewer systems can meet Clean Water Act goals in as flexible and cost-effective a manner as possible. EPA's Report to Congress on implementation of the CSO Control Policy assesses the progress made by EPA, states, and municipalities in implementing and enforcing the CSO Control Policy.

Proper function of sanitary sewer systems is vital to protect public health, property, and waterways in the surrounding area. Most utilities have a management, operation, and maintenance (MOM) plan to ensure their system is in working order. However, more than 40,000 sanitary sewage overflows SSOs occur every year, causing huge monetary losses, damage to fish/shellfish beds, polluting groundwater, and decreased tourism. Sanitary sewage overflows (SSOs) release raw sewage from the collection system before it can reach a treatment facility. Sewage may flow out of manholes, into businesses and homes, and eventually ends up in local waterways.

Many factors are involved in SSOs. Many municipalities started constructing sewer systems over 100 years ago. Some of these have not been adequately maintained, improved, or repaired over the last century.

Cities have used a wide variety of building materials, designs, and installation techniques, which aren’t durable enough to withstand heavy, continuous use. Problems can be especially bad where an older system is attached to a new system or an older system has fallen into disrepair.

EPA believes that every sanitary sewer system has the capacity to have a sanitary sewer overflows (SSO). This may be due to a number of factors including, but not limited to:

- Blockages
- Structural, mechanical, or electrical failures
- Collapsed or broken sewer pipes • Insufficient conveyance capacity
- Vandalism

Additionally, high levels of inflow and infiltration (I/I) during wet weather can cause SSOs. Many collection SSOs include untreated discharges from sanitary sewer systems that reach waters of the United States systems that were designed according to industry standards experience wet weather SSOs because levels of I/I may exceed levels originally expected; prevention of I/I has proven more difficult and costly than anticipated; or the capacity of the system has become inadequate due to an increase in service population without corresponding system upgrades (EPA 2004).

The Management, Operation and Maintenance (MOM) Programs Project is a pilot enforcement approach developed by EPA Region 4 to bring municipal sewer systems into full compliance with the Clean Water Act by eliminating sanitary sewer overflows (SSOs) from municipal sewer systems. A SSO is a release of untreated wastewater before the flow reaches a treatment plant. SSOs pose a significant threat to public health and water quality.

Treatment Balance and the Effects of Undesirable Solids
For any wastewater treatment plant to operate properly, the operator has to maintain a skillfully balanced mixture of microorganisms which contact and digest the organics in the wastewater, and bacteria then grows on this media to treat the wastewater. When a plant is properly maintained these bacteria or bugs eat the dissolved organics in the water, thus removing BOD, Ammonia, Nitrates, and Phosphorus.

All of these constituents must be treated and removed from the water. When this is accomplished you achieve a low turbidity and clean decantible water which is then filtered and chlorinated to kill all the remaining bacteria. This incredible process leaves extremely clean and reusable water that can be injected back into the ground, sent to ponds or used for irrigation.

Certain compounds and undesirable solids, like grease and grass clippings, can disturb this delicate balance and necessary process at the wastewater treatment facility. There are compounds and mixtures that should never be introduced into a sanitary sewer system. These destructive compounds include but are not limited to: cleaning solvents, grease (both household and commercial), oils (both household and commercial), pesticides, herbicides, antifreeze and other automotive products.

The solids include but are not limited to: plastics, rubber goods, grass clippings, metal products such as aluminum foil, beer or soda cans, wood products, glass, paper products such as disposable diapers and sanitary napkins. Items such as these disturb or even kill the delicate balance of microorganisms and bacteria that are needed to treat the wastewater. These will also clog the sanitary sewer causing back-ups and sewer overflows. First, we will examine the damage to equipment and we will finish with resolution methods.

Costly Maintenance
These harmful compounds and solids can also cause equipment damage and create costly and unnecessary repairs, as well as frequent and costly maintenance. Repairs include but are not limited to: SBR Motive Pumps--these should last at least 5 years but are failing after only 2 or 3 years because of material that was placed in the sewer system. In a recent 2007 study, the cost of repairing these pumps was around $30,000.00. The replacement of the influent grinder or, “Muffin Monster” after only 3 years of service was nearly $7,000.00. The cost of frequent maintenance consists of, but is not limited to: the extensive amounts of damaging solids that clog lift stations and damage lift station pumps. These costs have almost doubled in today’s costs.

To properly clean a lift station may cost around $3,0000 -10,000 for each time that common problems occur like grass clippings from a golf course, overflowing grease from improperly maintained grease traps from a casino, hotel or golf course and improperly maintained grease and oil interceptors.

These costs do not touch the cost of cleaning the sewer mains and manholes. In most cases, no serious damage will occur to the sewer main or manhole, but the chance of overflowing sewage or untreated wastewater getting to the street is greatly increased and does happen in most communities. Most of us know about it and accept it as part of our jobs. But time and rules have changed. We must work harder and be smarter to stop these problems before the damage and overflow occurs.

Municipality Self-Assessment
Under the MOM Programs Project, municipalities are encourages to undertake a detailed self-assessment of their MOM programs. The municipalities submit this self-assessment along with recommendations for improvements to the MOM programs and/or remedial measures to correct sewer infrastructure problems.

In consideration for undertaking the self-assessment, the municipality is able to establish its own reasonable goals and schedules, which could result to significantly reduced penalties related to SSOs. Where an enforcement action is necessary, the regulator works with the municipality to identify necessary remedial measures and to establish schedules. The Regulator will likely defer any penalty decision until after the completion of the necessary improvements.

Project Initiation
In 1998, Region 4 began the MOM Programs Project by identifying priority watersheds and geographical areas in each of the eight States in the Region. These included areas where SSOs could cause significant public health concerns, such as beaches, shellfish harvesting areas and drinking water supplies. In addition, watersheds already listed as impaired by collection system overflows or bacterial contamination were identified.

Region 4, working with the States, selected a watershed (or geographical area) in each State. All municipal sewer systems in each watershed were identified and invited to participate in the Project and to attend a kickoff meeting held at a location in the watershed.

Those municipalities wanting to participate in the MOM Project undertake the self-assessment using the guidance materials provided and submit the self-assessment to the Region within seven months of the kickoff. Municipalities that don't participate are inspected by the Region and/or State and are subject to traditional enforcement actions, including penalties where appropriate. Improper management and maintenance cause a majority of avoidable SSOs.

Leading Causes of SSOs

Problem/Cause	% of SSOs	Description
Blockages	43%	Blockages may be caused by tree roots or a build-up of sediment and other materials (i.e., grease, grit, debris). Structural defects and a flat slope can also cause excessive deposits of material. Build-ups can cause pipes to break or collapse.
Infiltration and Inflow (I/I)	27%	Infiltration and inflow occurs when rain or snowmelt enters the ground and seeps into leaky sanitation sewers, which were not designed to carry rainfall or drain property. Inflow can also occur when excess waters from roof drains, broken pipes and bad connections at sewer service lines infiltrates the sanitary sewer.
Structural Failures	12%	Line/main breaks are a major result of structural failure. Undersized systems do not have large enough pumps or lines to carry all the sewage generated by the buildings attached to them. This is especially true for new subdivisions or commercial areas. SSOs can occur at sewer service connections to houses or buildings. Some cities estimate that up to 60% of SSOs come from service lines.
Power Failure	11%	Stops pump operation, interrupting sewage flow
Other	7%	Scheduling, vandalism

Above, a cracked sewer main, a SSO waiting to happen.

Purpose of CMOM Programs

CMOM programs incorporate many of the standard operation and maintenance activities that are routinely implemented by the owner or operator with a new set of information management requirements in order to:

- Better manage, operate, and maintain collection systems
- Investigate capacity constrained areas of the collection system
- Proactively prevent SSOs
- Respond to SSO events

The CMOM approach helps the owner or operator provide a high level of service to customers and reduce regulatory noncompliance. CMOM can help utilities optimize use of human and material resources by shifting maintenance activities from “reactive” to “proactive”–often leading to savings through avoided costs due to overtime, reduced emergency construction costs, lower insurance premiums, changes in financial performance goals, and fewer lawsuits.

CMOM programs can also help improve communication relations with the public, other municipal works and regional planning organizations, and regulators. It is important to note that the collection system board members or equivalent entity should ensure that the CMOM program is established as a matter of policy. The program should not be micro-managed, but an understanding of the resources required of the operating staff to implement and maintain the program is necessary. In CMOM planning, the owner or operator selects performance goal targets, and designs CMOM activities to meet the goals.

The CMOM planning framework covers operation and maintenance (O&M) planning, capacity assessment and assurance, capital improvement planning, and financial management planning. Information collection and management practices are used to track how the elements of the CMOM program are meeting performance goals, and whether overall system efficiency is improving. On a periodic basis, utility activities should be reviewed and adjusted to better meet the performance goals. Once the long-term goal of the CMOM program is established, interim goals may be set. For instance, an initial goal may be to develop a geographic information system (GIS) of the system.

Once the GIS is complete, a new goal might be to use the GIS to track emergency calls and use the information to improve maintenance planning. An important component of a successful CMOM program is periodically collecting information on current systems and activities to develop a “snapshot-in-time” analysis. From this analysis, the owner or operator evaluates its performance and plans its CMOM program activities. Maintaining the value of the investment is also important. Collection systems represent major capital investments for communities and are one of the communities’ major capital assets.

Equipment and facilities will deteriorate through normal use and age. Maintaining value of the capital asset is a major goal of the CMOM program. The infrastructure is what produces sales and service. Proper reinvestment in capital facilities maintains the ability to provide service and generate sales at the least cost possible and helps ensure compliance with environmental requirements.

The performance of wastewater collection systems is directly linked to the effectiveness of its CMOM program. Performance characteristics of a system with an inadequate CMOM program include frequent blockages resulting in overflows and backups.

Other major performance indicators include pump station reliability, equipment availability, and avoidance of catastrophic system failures such as a collapsed pipe.

A CMOM program is what an owner or operator should use to manage its assets; in this case, the collection system itself. The CMOM program consists of a set of best management practices that have been developed by the industry and are applied over the entire life cycle of the collection system and treatment plant.

These practices include:

- Designing and constructing for O&M
- Knowing what comprises the system (inventory and physical attributes)
- Knowing where the system is (maps and location)
- Knowing the condition of the system (assessment)
- Planning and scheduling work based on condition and performance
- Repairing, replacing, and rehabilitating system components based on condition and performance
- Managing timely, relevant information to establish and prioritize appropriate CMOM activities

EPA and state NPDES inspectors evaluate collection systems and treatment plants to determine compliance with permit conditions including proper O&M. Among others, these permit conditions are based on regulation in 40 CFR 122.41(e): “The permittee shall at all times properly operate and maintain all facilities and systems of treatment and control (and related appurtenances) which are installed or used by the permittee to achieve compliance with the conditions of this permit.”

When violations occur, the collection system or wastewater treatment plant owner or operator can face fines and requirements to implement programs to compensate residents and restore the environment.

The Elements of a Proper CMOM Program

Utility Specific
The complexity and expense associated with a utility's CMOM or MOM programs is specific to the size and complexity of the Publicly Owned Treatment Works (POTW) and related infrastructure. Factors such as population growth rate and soil/groundwater conditions also dictate the level of investment which should be made.

Purposeful
When MOM programs are present and properly maintained, they support customer service and protect system assets, public health, and water quality.

Goal-Oriented
Proper MOM programs have goals directed toward their individual purposes. Progress toward these goals is measurable, and the goals are attainable.

Uses Performance Measures
Performance measures should be established for each MOM program in conjunction with the program goal. These measures are quantifiable, and used in determining progress to, or beyond, the program goal.

Periodically Evaluated
An evaluation of the progress toward reaching the goals, or a reassessment of the goals, should be made periodically and based upon the quantified performance measures.

Available In Writing
The effectiveness of a MOM program quickly breaks down unless it is available in writing. Personnel turnover and lapses in communication between staff and management can change otherwise proper MOM programs to improper ones. Written MOM programs are useful only if they are made readily available to all personnel and clearly documented.

Implemented by Trained Personnel
Appropriate safety, equipment, technical, and program training is essential for implementing MOM programs properly.

What MOM programs should be audited?
MOM activity at a utility involves its entire wastewater infrastructure. Common utility management activities and operations and maintenance activities associated with sewer systems and pretreatment are listed in the Self-Audit Review Document.

If a utility owns treatment works or a pond system, then activities associated with the management, operation, and maintenance of these facilities should also be included in the audit. A helpful guide for this part is the NPDES Compliance Inspection Manual. Instruction for obtaining this manual is provided in a list of references.

What are the elements of a proper Self-Audit?
Initial Assessment
Begin by performing a general assessment of the utility, and prioritizing the order of programs to be audited. The NPDES Compliance Inspection Manual and Guidance may be useful references in making this assessment.

Develop the Audit Plan
Identify the MOM programs present and/or needed at the utility, establish performance measures, and develop a schedule for auditing the programs.

Conduct the Audit
Evaluate each MOM program against the defined elements of a proper program. This can be accomplished by reviewing the program's records and resources, conducting a field evaluation, and comparing the program understanding of both personnel and management.

Identify Deficiencies
Define any programs needed, or improvements to programs needed, and any infrastructure deficiencies found. Identify any unpermitted discharges that have occurred in the past five years.

Develop Improvement Plan
Define the utility's plan/schedule to remediate the necessary improvements. This plan should include any short-term or long-term program improvements, and any short-term or long-term capital improvements that need addressing.

Prepare the Self-Audit Report
Generate a report of the audit results, including any deficiencies found and the corresponding improvement plan, which is useful for the utility. This report should be capable of serving the utility as a reference when conducting any needed remedial measures, and as a reference to compare current performance with future self-audit results.

Are there federal grants or other compliance assistance resources available to conduct a Self-Audit?
Currently, there are no funds available for the specific purpose of conducting a MOM Programs Self-Audit. However, the Office of Wastewater Management offers a number of financial resources to assist qualified utilities in making improvements to their programs.

Small publicly-owned wastewater treatment plants which discharge less than 5 million gallons per day are also eligible for the Wastewater Treatment Plant Operator On-Site Assistance Training Program. The program provides on-site operator training, financial management, troubleshooting, and other operation and maintenance assistance. A network of operator training personnel, EPA Regional Office Coordinators and States and State Training Centers work in the field with small under-served communities to help solve their operation and maintenance problems. There is no cost incurred by the facility in need of assistance. The only requirement of the program is the willingness to work with a trainer to correct the facility's problems.

What Health Risks do SSOs present?
Because SSOs contain raw sewage they can carry bacteria, viruses, protozoa (parasitic organisms), helminths (intestinal worms), and borroughs (inhaled molds and fungi). The diseases they may cause range in severity from mild gastroenteritis (causing stomach cramps and diarrhea) to life-threatening ailments such as cholera, dysentery, infectious hepatitis, and severe gastroenteritis.

People can be Exposed Through:
- Sewage in drinking water sources.
- Direct contact in areas of high public access such as basements, lawns or streets, or waters used for recreation. At least one study has estimated a direct relationship between gastrointestinal illness contracted while swimming and bacteria levels in the water.

- Shellfish harvested from areas contaminated by raw sewage. One study indicates that an average of nearly 700 cases of illness per year were reported in the 1980s from eating shellfish contaminated by sewage and other sources. The number of unreported cases is estimated to be 20 times that.
- Some cases of disease contracted through inhalation and skin absorption have also been documented.

What other Damage can SSOs do?
SSOs also damage property and the environment. When basements flood, the damaged area must be thoroughly cleaned and disinfected to reduce the risk of disease. Cleanup can be expensive for homeowners and municipalities. Rugs, curtains, flooring, wallboard panels, and upholstered furniture usually must be replaced. A key concern with SSOs that enter oceans, bays, estuaries, rivers, lakes, streams, or brackish waters is their effect on water quality. When bodies of water cannot be used for drinking water, fishing, or recreation, society experiences an economic loss. Tourism and waterfront home values may fall. Fishing and shellfish harvesting may be restricted or halted. SSOs can also close beaches. One 1994 study claims that SSOs closed beaches across the nation that year for a total of more than 300 days.

How can SSOs be Reduced or Eliminated?
Many avoidable SSOs are caused by inadequate or negligent operation or maintenance, inadequate system capacity, and improper system design and construction. These SSOs can be reduced or eliminated by:

- Sewer system cleaning and maintenance
- Reducing infiltration and inflow through system rehabilitation and repairing broken or leaking service lines.
- Enlarging or upgrading sewer, pump station, or sewage treatment plant capacity and/or reliability.
- Construction of wet weather storage and treatment facilities to treat excess flows.

Communities also should address SSOs during sewer system master planning and facilities planning, or while extending the sewer system into previously unsewered areas. A few SSOs may be unavoidable. Unavoidable SSOs include those occurring from unpreventable vandalism, some types of blockages, extreme rainstorms, and acts of nature such as earthquakes or floods.

What Costs are Involved with Reducing or Eliminating SSOs?
Sanitary sewer collection systems are a valuable part of the nation's infrastructure. The EPA estimates that our nation's sewers are worth a total of more than $1 trillion. The collection system of a single large municipality is an asset worth billions of dollars and that of a smaller city could cost many millions to replace.

Sewer rehabilitation to reduce or eliminate SSOs can be expensive, but the cost must be weighed against the value of the collection system asset and the added costs if this asset is allowed to further deteriorate. Ongoing maintenance and rehabilitation adds value to the original investment by maintaining the system's capacity and extending its life. The costs of rehabilitation and other measures to correct SSOs can vary widely by community size and sewer system type. Those being equal, however, costs will be highest and ratepayers will pay more in communities that have not put together regular preventive maintenance or asset protection programs.
Assistance is available through the Clean Water Act State Revolving Fund for capital projects to control SSOs. State Revolving Funds in each state and Puerto Rico can help arrange low-interest loans. For the name of your State Revolving Fund contact, please call the EPA Office of Water Resource Center, (202) 566-1729.

To reduce sanitary sewer overflows (SSOs), the EPA is proposing to clarify and expand permit regulations that are already in force under the Clean Water Act. This will affect over 19,000 municipal sanitary sewer systems, including 4800 satellite collection systems that will be regulated for the first time. It will allow streamlined CMOM requirements for small communities, and permit them to skip self-audits and annual reports if an SSO hasn't occurred.

More Specifically, CMOM will Require Facilities to:

- Establish general performance standards.
- Have a management program.
- Create an overflow response plan.
- Ensure system evaluations.
- Verify capacity assurance.
- Submit to periodic audits of the CMOM program.
- Notify the public and regulatory agencies of SSOs.

General Performance Standards

A CMOM program will ensure:

- There is enough capacity to handle base and peek flows.
- The use of all reasonable measure to stop SSOs.
- Proper collection, management, operation and maintenance of the system.
- Prompt notification of all parties that may be exposed to an SSO.

Management Programs

Management program documents must include:

- The goals of the CMOM program (may differ depending on the facility.)
- Legal authorities that will help implement CMOM.
- The "chain of command" for implementing CMOM and reporting SSOs.
- Design and performance requirements.
- Measures that will be taken to help implement CMOM.
- Monitoring/performance measures to how effective the CMOM program is.
- Communication plan.

Overflow Response Plan

The overflow response plan should be designed provide a quick response to SSOs. Rapid response to an SSO can mitigate structural damage, pollution of waterways, and the public health risk. The plan must include the following:

- SSO response procedures.
- Immediate notification of health officials.
- Public notification.
- Plan made available to the public.
- Distribution to all appropriate personnel.
- Revision and maintenance of the plan by appropriate personnel.

Collection System Management

Collection system management activities form the backbone for operation and effective maintenance activities. The goals of a management program should include:

- Protection of public health and prevention of unnecessary property damage
- Minimization of infiltration, inflow and exfiltration, and maximum conveyance of wastewater to the wastewater treatment plant
- Provision of prompt response to
- Staffing plans–Number of people and service interruptions
- Efficient use of allocated funds
- Sewer use ordinance
- Identification of and remedy solutions to design, construction, and operational deficiencies
- Performance of all activities in a safe manner to avoid injuries

Without the proper procedures, management and training systems, O&M activities may lack organization and precision, resulting in a potential risk to human health and environmental contamination of surrounding water bodies, lands, dwellings, or groundwater. The following sections discuss the common elements of a robust collection system management program.

Organizational Structure
Well-established organizational structure, which delineates responsibilities and authority for each position, is an important component of a CMOM program for a collection system. This information may take the form of an organizational chart or narrative description of roles and responsibilities, or both. The organizational chart should show the overall personnel structure, including operation and maintenance staff. Additionally, up-to-date job descriptions should be available.

Job descriptions should include the nature of the work performed, the minimum requirements for the position, the necessary special qualifications or certifications, examples of the types work, lists of licenses required for the position, performance measures or promotion potential. Other items to note in regard to the organizational structure are the percent of staff positions currently vacant, on average, the length of time positions remain vacant, and the percent of collection system work that is contracted out.

Reviewer - Point to Note
The reviewer may want to note the turnover rate and current levels of staffing (i.e., how many vacant positions exist and for how long they have been vacant). This may provide some indication of potential understaffing, which can create response problems. Reviewers should evaluate specific qualifications of personnel and determine if the tasks designated to individuals, crews, or teams match the job descriptions and training requirements spelled out in the organizational structure.

From an evaluation standpoint, the reviewer might try to determine what type of work is performed by outside contractors and what specific work is reserved for collection system personnel. If much of the work is contracted, it is appropriate to review the contract and to look at the contractor's capabilities. If the contractor handles emergency response, the reviewer should examine the contract with the owner or operator to determine if the emergency response procedures and requirements are outlined.
The inclusion of job descriptions in the organizational structure ensures that all employees know their specific job responsibilities and have the proper credentials.

Additionally, it is useful in the course of interviews to discuss staff management. The reviewer should note whether staff receive a satisfactory explanation of their job descriptions and responsibilities. In addition, when evaluating the CMOM program, job descriptions will help a reviewer determine who should be interviewed.

Reviewer - Point to Note
A reviewer should look for indications that responsibilities are understood by employees. Such indications may include training programs, meetings between management and staff, or policies and procedures.

When evaluating the organizational structure, the reviewer should look for the following:

- Except in very small systems, operation and maintenance personnel ideally should report to the same supervisor or director. The supervisor or director should have overall responsibility for the collection system. Guide for Evaluating CMOM Programs at Sanitary Sewer Collection Systems

- In some systems, maintenance may be carried out by a citywide maintenance organization, which may also be responsible for such diverse activities as road repair and maintenance of the water distribution system. This can be an effective approach, but only if adequate lines of responsibility and communication are established.

- In general, one supervisor should manage a team of individuals small enough that is safe and effective. However, the individuals on the team may have additional employees reporting to them. This prevents the top supervisors from having to track too many individuals. The employee-supervisor ratio at individual collection systems will vary depending on their need for supervisors. In a utility with well-established organizational structure, staff and management should be able to articulate their job and position responsibilities.

Personnel should be trained to deal with constantly changing situations and requirements, both regulatory and operational. The system's personnel requirements vary in relation to the overall size and complexity of the collection system. In very small systems, these responsibilities may include operation of the treatment plant as well as the collection system.

In many systems, collection system personnel are responsible for the stormwater as well as wastewater collection system. References providing staff guidelines or recommendations are available to help the reviewer determine if staffing is adequate for the collection system being reviewed.

Potential Performance Indicators

Input measures	Per capita costs Number of employee hours
Output measures	Length of pipe maintained Number of service calls completed Percentage of length maintained repaired this year Percentage of length maintained needing repair Length of new sewer constructed Number of new services connected
Outcomes	Number of stoppages per 100 miles of pipe Average service response time Number of complaints
Ecological/Human health/ Resource use	Shellfish bed closures Benthic Organism index Biological diversity index Beach closures Recreational activities Commercial activities

CMOM Audits
CMOM will require regular, comprehensive audits, done by each facility. These audits will help identify non-conformance to CMOM regulations so problems can be addressed quickly. All findings, proposed corrective actions and upcoming improvements should be documented in the audit report.

Communication/Notification
If an SSO occurs, sanitary sewer facilities will be required to immediately notify the NPDES permit authority, appropriate health agencies, state authorities, drinking water suppliers, and, if necessary, the general public in the risk area. This rule will also require an annual report of all overflows, including minor SSOs such as building backups. Facilities must post locations of recurrent SSOs and let the public know that the annual report is available to them. The record keeping provisions mandate that facilities must maintain records for three years about all overflows, complaints, work orders on the system, and implementation measures.

According to the EPA, an effective CMOM program would help NPDES permitees to:

- Develop/revise routine preventive maintenance activities that prevent service interruption and protect capital investments.
- Create an inspection schedule and respond to the inspection results.
- Investigate the causes of SSOs and take corrective measures.
- Respond quickly to SSOs to minimize impacts to human health and the environment.
- Identify and evaluate SSO trends.
- Develop budgets and identify staffing needs.
- Plan for future growth to ensure adequate capacity is available when it's needed.
- Identify hydraulic (capacity) and physical deficiencies and prioritize responses, including capital investments.

- Identify and develop appropriate responses to program deficiencies (e.g., lack of legal authority, inadequate funding, and inadequate preventive maintenance).
- Keep parts and tools inventories updated and equipment in working order.
- Report and investigate safety incidents and take steps to prevent their recurrence.

Implementation
The EPA estimates that implementing this rule will impose an additional $93.5 to $126.5 million every year on municipalities (includes planning and permitting costs). A system serving 7,500 people may need to spend an average of $6,000 every year to comply with the rule.

CMOM regulations will be added to the permit when facilities need to have a permit re-issued. Although a compliance deadline has not been set, the EPA recommends that facilities begin to implement “SSO Standard Conditions” right after the proposed rule is published. Considering the time and costs associated with compliance, this may be good advice.

Continuous Training
Procedures for emergency response plans should be understood and practiced by all personnel in order to ensure safety of the public and the collection system personnel responding. Procedures should be specific to the type of emergency that could occur.

It is important to keep detailed records of all past emergencies in order to constantly improve response training, as well as the method and timing of future responses.

The ability to deal with emergencies depends on the knowledge and skill of the responding crews, in addition to availability of equipment. The crew should be able to rapidly diagnose problems in the field under stress and select the right equipment needed to correct the problem.

If resources are limited, consideration should be given to contracting other departments or private industries to respond to some emergencies, for example, those rare emergencies that would exceed the capacity of staff.

System Evaluation and Capacity Assurance Plan
These two activities work hand-in-hand to detect and address deficiencies and scheduling. These will provide:

- An evaluation of parts of the collection system that have substandard performance.
- Capacity assurance measures to address substandard performance.
- Explanation of prioritization and scheduling.

Performance measures and indicators are important in evaluating collection system performance and implementing capacity management, operation and maintenance programs.

Hydrogen Sulfide Monitoring and Control Sub-Section

The collection system owner or operator should have a program under which they monitor areas of the collection system that may be vulnerable to the adverse effects of hydrogen sulfide. It may be possible to perform visual inspections of these areas. The records should note such items as the condition of metal components, the presence of exposed rebar (metal reinforcement in concrete), copper sulfate coating on copper pipes and electrical components, and loss of concrete from the pipe crown or walls.

Areas Subject to Generation of Hydrogen Sulfide:

- Sewers with low velocity conditions and/or long detention times
- Sewers subject to solids deposition
- Pump stations
- Turbulent areas, such as drop manholes or force main discharge points
- Inverted siphon discharges

The collection system owner or operator should be carrying out routine manhole inspections. The hydrogen sulfide readings generated as a result of these inspections should be added to the records of potential areas of corrosion. A quick check of the pH of the pipe crown or structure enables early indication of potential hydrogen sulfide corrosion. A pH of less than four indicates further investigation is warranted. “Coupons” may be installed in structures or pipelines believed to be potentially subject to corrosion. Coupons are small pieces of steel inserted into the area and measured periodically to determine whether corrosion is occurring.

Reviewer - Point to Note
The reviewer should be aware that a system in which infiltration and inflow (I/I) has successfully been reduced may actually face an increased risk of corrosion. The reviewer should pay particular attention to the hydrogen sulfide monitoring program in these systems. The reduction of flow through the pipes allows room for hydrogen sulfide gases to rise into the airway portion of the sewer pipe and react with the bacteria and moisture on the pipe walls to form sulfuric acid. Sulfuric acid corrodes ferrous metals and concrete. There are several methods to prevent or control hydrogen sulfide corrosion. The first is proper design. Design considerations are beyond the scope of this manual but may be found in the Design Manual: Odor and Corrosion Control in Sanitary Sewerage Systems and Treatment Plants (EPA 1985).

The level of dissolved sulfide in the wastewater may also be reduced by chemical or physical means such as aeration, or the addition of chlorine, hydrogen peroxide, potassium permanganate, iron salts, or sodium hydroxide. Whenever chemical control agents are used, the owner or operator should have procedures for their application and maintain records of the dosages of the various chemicals.

Alternatively, sewer cleaning to remove deposited solids reduces hydrogen sulfide generation. Also, air relief valves may be installed at the high points of the force main system. The valve allows air to exit thus avoiding air space at the crown of the pipe where acid can form. The reviewer should examine the records to see that these valves are receiving periodic maintenance.

Collection systems vary widely in their vulnerability to hydrogen sulfide corrosion. Vitrified clay and plastic pipes are very resistant to hydrogen sulfide corrosion while concrete, steel, and iron pipes are more susceptible. The physical aspects of the collection system are also important.

Sewage in pipes on a decline that moves the wastewater at a higher velocity will have less hydrogen sulfide than sewage in pipes where the wastewater may experience longer detention times. Therefore, some systems may need a more comprehensive corrosion control program while some might limit observations to vulnerable points.

Safety

The reasons for development of a safety program should be obvious for any collection system owner or operator. The purpose of the program is to define the principles under which the work is to be accomplished, to make the employees aware of safe working procedures, and to establish and enforce specific regulations and procedures. The program should be in writing (e.g., procedures, policies, and training courses) and training should be well documented. The purpose of safety training is to stress the importance of safety to employees. Safety training can be accomplished through the use of manuals, meetings, posters, and a safety suggestion program.

One of the most common reasons for injury and fatalities in wastewater collection systems is the failure of victims to recognize hazards. Safety training cuts across all job descriptions and should emphasize the need to recognize and address hazardous situations.

Safety programs should be in place for the following areas:

- Confined spaces
- Chemical handling
- Trenching and excavations
- Safety Data Sheets (SDS)
- Biological hazards in wastewater
- Traffic control and work site safety
- Lockout/Tagout
- Electrical and mechanical safety
- Pneumatic or hydraulic systems safety

The collection system owner or operator should have written procedures that address all of the above issues and are made available to employees. In addition to training, safety programs should incorporate procedures to enforce the program.

For example, this could include periodic tests or "pop" quizzes to monitor performance and/or compliance and follow-up on safety related incidents. The owner or operator should maintain all of the safety equipment necessary for system staff to perform their daily activities and undertake any emergency repairs.

This equipment should include, at minimum:

- Atmospheric gas testing equipment
- Respirators and/or self-contained breathing apparatus
- Full body harness
- Tripods or non-entry rescue equipment
- Hard hats
- Safety glasses
- Rubber boots
- Rubber and/or disposable gloves
- Antibacterial soap
- First aid kit
- Protective clothing
- Confined space ventilation equipment
- Traffic and/or public access control equipment

• Hazardous gas meter

Reviewer - Point to Note
The reviewer should, in the course of interviewing personnel, determine their familiarity with health and safety procedures according to their job description. Each field crew vehicle should have adequate health and safety supplies. If the reviewer has access to the municipal vehicle storage area, he or she might choose to check actual vehicle stocks, not just supplies in storage.

Confined Space Safety
Collection system operators typically assist with manhole cover removal and other physical activities. The inspector should refrain from entering confined spaces. A confined space is defined by the Occupational Safety and Health Administration (OSHA) as a space that:
(1) is large enough and so configured that an employee can bodily enter and perform assigned work; and
(2) has limited or restricted means for entry or exit; and
(3) is not designed for continuous employee occupancy

[29 CFR 1910.146(b)].
A "permit-required confined space (permit space)" is a confined space that has one or more of the following characteristics:
(1) contains or has a potential to contain a hazardous atmosphere;
(2) contains a material that has the potential for engulfing an entrant;
(3) has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly converging walls or by a floor which slopes downward and tapers to a smaller cross-section; or
(4) contains any other recognized serious safety or health hazard [29 CFR 1910.146(b)].

Though OSHA has promulgated standards for confined spaces, those standards do not apply directly to municipalities, except in those states that have approved plans and have asserted jurisdiction under Section 18 of the OSHA Act.

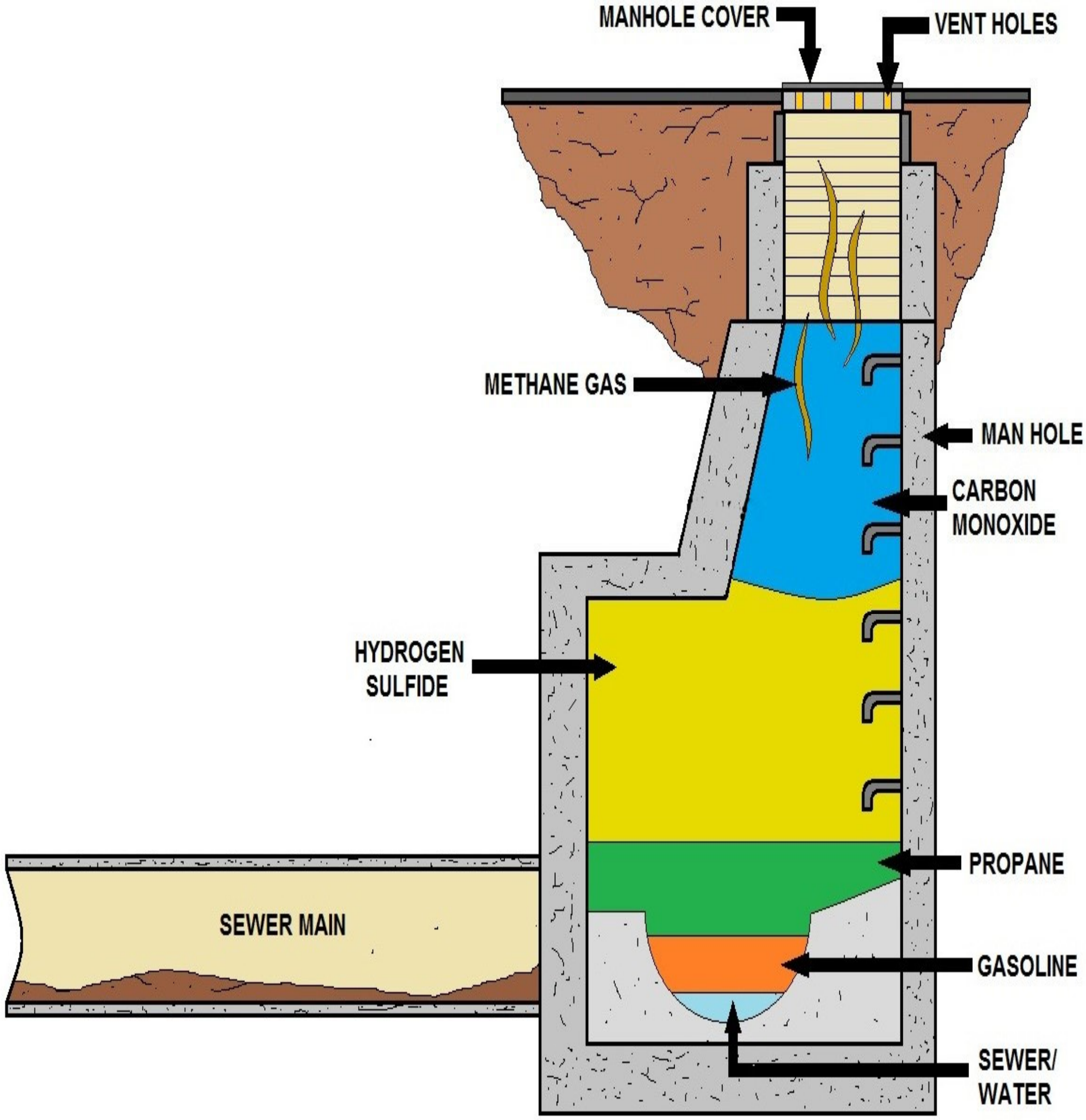
Contract operators and private facilities do have to comply with the OSHA requirements and the inspector may find that some municipalities elect to do so voluntarily. In sewer collection systems, the two most common confined spaces are the underground pumping station and manholes.

The underground pumping station is typically entered through a relatively narrow metal or concrete shaft via a fixed ladder. Inspectors conducting the field evaluation component of the CMOM audit should be able to identify and avoid permit-required confined spaces.

Although most confined spaces are unmarked, confined spaces that may have signage posted near their entry containing the following language:

DANGER–PERMIT REQUIRED–CONFINED SPACE AUTHORIZED PERSONNEL ONLY

If confined space entry is absolutely necessary, inspectors should consult with the collection system owner or operator first, have appropriate training on confined space entry, and use the proper hazard detection and personal safety equipment.



POSSIBLE HAZARDOUS ATMOSPHERES PRESENT IN A CONFINED SPACE
(EXAMPLE IS OF A SEWER MAIN)

CMOM Summary

Sewers deteriorate over time and develop cracks, breaks and blockages if not properly maintained. Aging, out-of-sight, out-of-mind sewer systems can be neglected and thus not be inspected or maintained on a regular basis. A CMOM Program is an effective, holistic management tool that owners of collection systems (primarily municipalities) create to operate and manage a collection system to significantly reduce, if not eliminate, sanitary sewer overflows and basement backups. It assures sewage collection system owners proactively operate and maintain this significant and valuable community infrastructure through planned ongoing maintenance and prioritizing rehabilitation and replacement projects.

For EPA and state inspectors or other reviewers, conducting an evaluation of collection system CMOM programs shares many similarities with other types of compliance reviews. Overall, the reviewer would examine records, interview staff and conduct field investigations, generally in that order although tailored, if necessary, to meet site-specific needs.

Prior to performing the onsite interviews and evaluations, preliminary information may be requested that will provide an overall understanding of the organization to allow for a more focused approach for the review. This information also provides a basis for more detailed data gathering during on site activities. The information typically requested prior to the review should include a schematic map of the collection system (could be as-built drawings) and any written operations or maintenance procedures. Depending on the volume of information, the collection system owner or operator may need ample lead time to gather and copy these documents.

Alternatively, the reviewer may offer to examine the documents and bring them back when doing the on-site review so that extra copies are not necessary. No matter which method is used, the importance of up-front preparation cannot be overemphasized. With the exception of pump stations and manholes, much of the collection system is not visible. Therefore, the more complete the reviewer's understanding of the system is prior to the review, the more successful the assessment will be. The reviewer would then proceed with the on-site activities.

Guidance for conducting compliance reviews is provided in the NPDES Compliance Inspection Manual (EPA 2004). The manual provides the general procedures for performing compliance reviews and is a valuable source of information on such topics as entry, legal authority, and responsibilities of the reviewer. Although CMOM evaluations are not specifically addressed in the manual, the general review procedures can be applied to CMOM reviews. Another good reference for general review information is the Multi-Media Investigations Manual, NEIC (EPA 1992). Some issues with entry are specific to CMOM reviews.

Some facilities may be on private property and the reviewer may need property owner consent for entry.

Documents to Review On-site Include:

- Organization chart(s)
- Staffing plans
- Job descriptions

- Sewer use ordinance
- Overall map of system showing facilities such as pump stations, treatment plants, major gravity sewers, and force mains
- O&M budget with cost centers for wastewater collection
- Performance measures for inspections, cleaning, repair, and rehabilitation
- Recent annual report, if available
- Routine reports regarding system O&M activities
- Collection system master plan
- Capital improvement projects (CIP) plan
- Flow records or monitoring
- Safety manual
- Emergency response plan
- Management policies and procedures
- Detailed maps/schematics of the collection system and pump stations
- Work order management system
- O&M manuals
- Materials management program
- Vehicle management and maintenance records
- Procurement process
- Training plan for employees
- Employee work schedules
- Public complaint log
- Rate ordinance or resolution
- Financial report ("notes" section)
- As built plans
- Discharge monitoring reports (DMRs)

Field reviews are typically conducted after interviews. The following is a list of typical field sites the team should visit:

- Mechanical and electrical maintenance shop(s)
- Fleet maintenance facilities (vehicles and other rolling stock)
- Materials management facilities (warehouse, outside storage yards)
- Field maintenance equipment storage locations (i.e., crew trucks, mechanical and hydraulic cleaning equipment, construction and repair equipment, and television inspection equipment)
- Safety equipment storage locations
- Pump stations
- Dispatch and supervisory control and data acquisition (SCADA) systems
- Crew and training facilities
- Chemical application equipment and chemical storage areas (use of chemicals for root and grease control, hydrogen sulfide control [odors, corrosion])
- Site of SSOs, if applicable
- A small, but representative, selection of manholes

Pretreatment Preface *(Credit USEPA)*

The industrial boom in the United States during the 1950s and 60s brought with it a level of pollution never before seen in this country. Scenes of dying fish, burning rivers, and thick black smog engulfing major metropolitan areas were images and stories repeated regularly on the evening news. In December of 1970, the President of the United States created the U.S. Environmental Protection Agency (EPA) through an executive order in response to these critical environmental problems.

In 1972, Congress passed the Clean Water Act (CWA) to restore and maintain the integrity of the nation's waters. Although prior legislation had been enacted to address water pollution, those previous efforts were developed with other goals in mind. For example, the 1899 Rivers and Harbors Act protected navigational interests while the 1948 Water Pollution Control Act and the 1956 Federal Water Pollution Control Act merely provided limited funding for State and local governments to address water pollution concerns on their own.

The CWA required the elimination of the discharge of pollutants into the nation's waters and the achievement of fishable and swimmable water quality levels. The EPA's National Pollutant Discharge Elimination System (NPDES) Permitting Program represents one of the key components established to accomplish this feat.

The NPDES program requires that all point source discharges to waters of the U.S. (i.e., *"direct discharges*") must be permitted. To address *"indirect discharges*" from industries to Publicly Owned Treatment Works (POTWs), the EPA, through CWA authorities, established the National Pretreatment Program as a component of the NPDES Permitting Program. The National Pretreatment Program requires industrial and commercial dischargers to treat or control pollutants in their wastewater prior to discharge to POTWs.

In 1986, more than one-third of all toxic pollutants entered the nation's waters from publicly owned treatment works (POTWs) through industrial discharges to public sewers. Certain industrial discharges, such as slug loads, can interfere with the operation of POTWs, leading to the discharge of untreated or inadequately treated wastewater into rivers, lakes, etc. Some pollutants are not compatible with biological wastewater treatment at POTWs and may pass through the treatment plant untreated.

This "pass through" of pollutants impacts the surrounding environment, occasionally causing fish kills or other detrimental alterations of the receiving waters. Even when POTWs have the capability to remove toxic pollutants from wastewater, these toxins can end up in the POTW's sewage sludge, which in many places is land applied to food crops, parks, or golf courses as fertilizer or soil conditioner.

The National Pretreatment Program is unique in that the General Pretreatment Regulations require all large POTWs (i.e., those designed to treat flows of more than 5 million gallons per day) and smaller POTWs with significant industrial discharges to establish local pretreatment programs.

These local programs must enforce all national pretreatment standards and requirements in addition to any more stringent local requirements necessary to protect site-specific conditions at the POTW.

More than 1,500 POTWs have developed and are implementing local pretreatment programs designed to control discharges from approximately 30,000 significant industrial users. Since 1983, the Pretreatment Program has made great strides in reducing the discharge of toxic pollutants to sewer systems and to waters of the U.S. In the eyes of many, the Pretreatment Program, implemented as a partnership between the EPA, States, and POTWs, is a notable success story in reducing impacts to human health and the environment. These strides can be attributed to the efforts of many Federal, State, local, and industrial representatives who have been involved with developing and implementing the various aspects of the Pretreatment Program.

The EPA has supported the Pretreatment Program through development of numerous guidance manuals. The EPA has released more than 30 manuals that provide guidance to the EPA, States, POTWs, and industry on various pretreatment program requirements and policy determinations. Through the EPA's guidance, the Pretreatment Program has maintained national consistency in interpretation of the regulations. Nevertheless, turnover in pretreatment program staff has diluted historical knowledge, leaving new staff and other interested parties unaware of existing materials.

(1) provide a reference for anyone interested in understanding the basics of pretreatment program requirements, *and*
(2) provide a roadmap to additional and more detailed guidance materials for those trying to implement specific elements of the Pretreatment Program.

While the Pretreatment Program has demonstrated significant reductions in pollutants discharged to POTWs, Congress' goals of zero discharge of toxic pollutants and fishable/swimmable water quality have not been realized. The EPA is currently working to establish more cost-effective and common sense approaches to environmental protection (e.g., using watershed, streamlining, and reinvention concepts), creating new responsibilities for all those involved in the National Pretreatment Program. Many current challenges remain, while many new ones likely lie ahead.

This course is intended to provide an understanding of the basic concepts that drive the Program, the current status of the Program and program guidance, and an insight into what the future holds for all those involved with implementing the Pretreatment Program.

Two lab techs examine various samples, including QA/QC and Trip Blanks to ensure both sample integrity and lab equipment/sample equipment quality.

Post Quiz

Purpose of CMOM Programs

1. The CMOM approach helps the owner or operator provide a high level of service to customers and reduce _________________________.

2. Once the GIS is complete, a new goal might be to use the GIS to track emergency calls and use the information to improve ______________.

3. In CMOM planning, the owner or operator selects ___________ targets, and designs CMOM activities to meet the goals.

4. Information collection and management practices are used to track how the elements of the CMOM program are meeting _________________, and whether overall system efficiency is improving.

5. An important component of a ______________________is periodically collecting information on current systems and activities to develop a “snapshot-in-time” analysis. From this analysis, the owner or operator evaluates its performance and plans its CMOM program activities.

6. Performance characteristics of a system with an inadequate CMOM program include frequent blockages resulting in ________________________.

7. Other major performance indicators include pump station reliability, equipment availability, and avoidance of _________________ such as a collapsed pipe.

The Elements of a Proper CMOM Program
Purposeful

8. ____________________ when present and properly maintained, they support customer service and protect system assets, public health, and water quality.

Goal-Oriented

9. _____________________ have goals directed toward their individual purposes. Progress toward these goals is measurable, and the goals are attainable.

Uses Performance Measures

10. Performance measures should be established for each of this _________________________ in conjunction with the program goal.

Periodically Evaluated

11. An evaluation of the progress toward reaching the goals, or ________________________, should be made periodically and based upon the quantified performance measures.

Available In Writing

12. The effectiveness of a MOM program quickly breaks down unless it is available in writing. Personnel turnover and lapses in communication between staff and management can change otherwise proper MOM programs to improper ones.
A. True B. False

Implemented by Trained Personnel

13. Appropriate safety, equipment, technical, and program training is essential for implementing?

What MOM programs should be audited?

14_____________________ at a utility involves its entire wastewater infrastructure. Common utility management activities and operations and maintenance activities associated with sewer systems and pretreatment are listed in the Self-Audit Review Document?

15. If a utility owns treatment works or a pond system, then activities associated with the management, operation, and maintenance of these facilities should be included in the audit.
A. True B. False

Identify Deficiencies

16. Identify any permitted discharges that have occurred in the past seven years.
A. True B. False

Develop Improvement Plan

17. Define the utility's plan/schedule to remediate the?

Prepare the Self-Audit Report

18. ___________________ including any deficiencies found and the corresponding improvement plan, which is useful for the utility?

Answers

1. Regulatory noncompliance, 2. Maintenance planning, 3. Performance goal, 4. Performance goals, 5. Successful CMOM program, 6. Overflows and backups, 7. Catastrophic system failures, 8. MOM programs, 9. Proper MOM programs, 10. MOM program, 11. A reassessment of the goals, 12. True, 13. MOM program(s), 14. MOM activity, 15. True, 16. False, 17. Necessary improvements, 18. Audit results

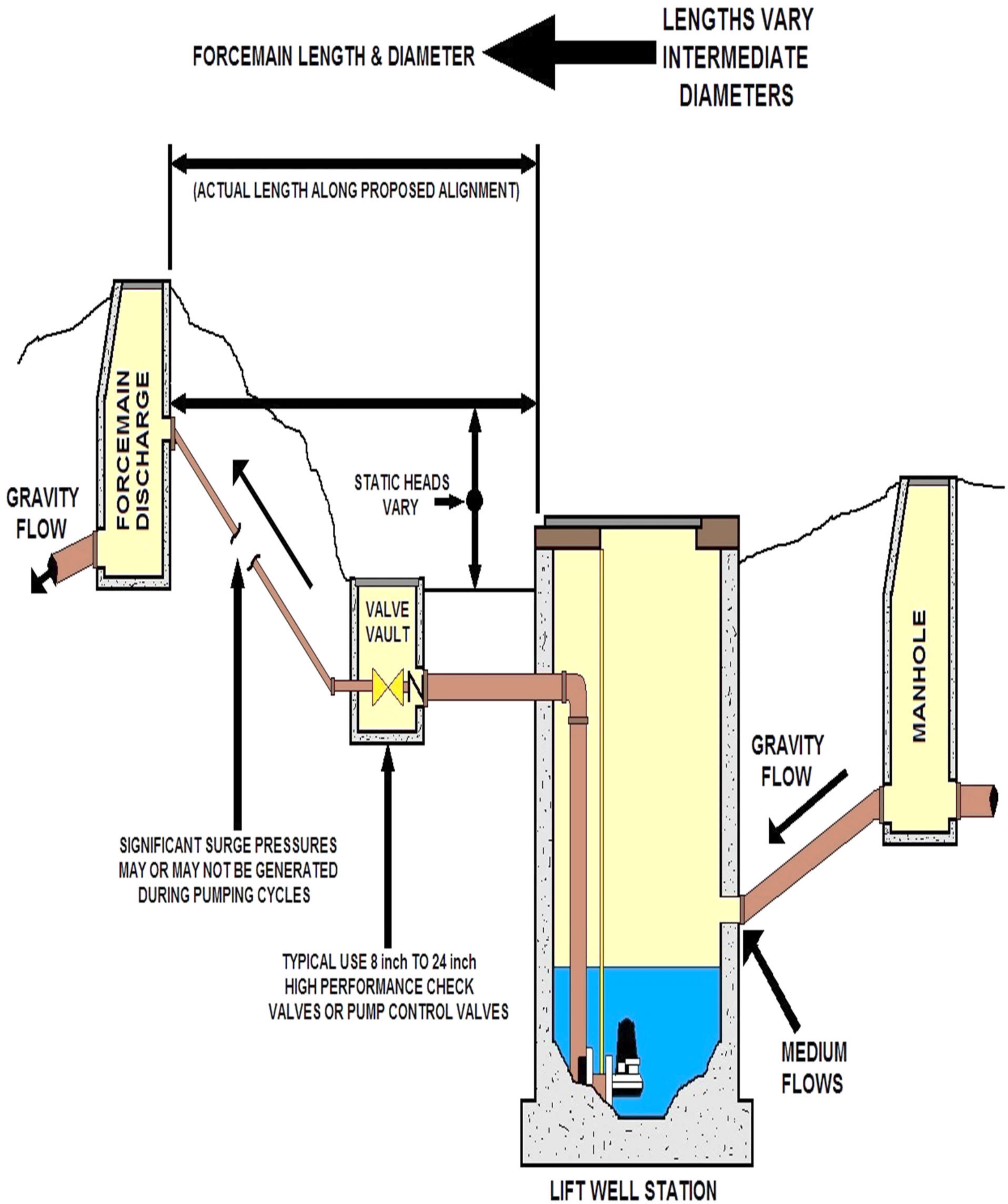
Chapter 5 – PUMPS AND LIFT STATIONS SECTION

Section Focus: You will learn the Clean Water Act and the basics of the wastewater collection pumping or lift stations. At the end of this section, you the student will be able to describe the basics of the pumping station system. There is a post quiz at the end of this section to review your comprehension and a final examination in the Assignment for your contact hours.

Scope/Background: In many systems, a lift or pumping station is a major component of lifting wastewater to the onsite facility. Sewer pipes are generally gravity driven. Wastewater flows slowly downhill until it reaches a certain low point. Then, pump or "lift" stations push the wastewater back uphill to a high point where gravity can once again take over the process.

Lift Station: A facility in a sewer system consisting of a receiving chamber, pumping equipment, and associated drive and control devices which collect and lift wastewater to a higher elevation when the continuance of the sewer at reasonable slopes would involve excessive trench depths; or that collects and raises wastewater through the use of force mains from areas too low to drain into available sewers. There should not be an odor coming from a Lift Station.

Pumping Station: A relatively large sewage pumping installation designed not only to lift sewage to a higher elevation, but also to convey it through force mains to gravity flow points located relatively long distances from the pumping station.



MEDIUM SEWAGE LIFT STATION TYPICAL CHARACTERISTICS

Wastewater Lift Stations
Reference EPA - EPA 832-F-00-073

Wastewater lift stations are facilities designed to move wastewater from lower to higher elevation through pipes. Key elements of lift stations include a wastewater receiving well (wet-well), often equipped with a screen or grinding to remove coarse materials; pumps and piping with associated valves; motors; a power supply system; an equipment control and alarm system; and an odor control system and ventilation system.

Lift station equipment and systems are often installed in an enclosed structure. They can be constructed on-site (custom-designed) or prefabricated.

Lift station capacities range from 76 liters per minute (20 gallons per minute) to more than 378,500 liters per minute (100,000 gallons per minute).

Pre-fabricated lift stations generally have capacities of up to 38,000 liters per minute (10,000 gallons per minute).

Centrifugal pumps are commonly used in lift stations.

Top photo, Centrifugal pump is the most common wastewater lift station pump. Bottom photo, A trapped air column, or bubbler system, that senses pressure and level is commonly used for pump station control.

Other control alternatives include electrodes placed at cut-off levels, floats, mechanical clutches, and floating mercury switches.

A more sophisticated control operation involves the use of variable speed drives.

Lift stations are typically provided with equipment for easy pump removal. Floor access hatches or openings above the pump room and an overhead monorail beam, bridge crane, or portable hoist are commonly used.

The two most common types of lift stations are the dry-pit or dry-well and submersible lift stations. In dry-well lift stations, pumps and valves are housed in a pump room (dry pit or dry-well), that is easily accessible. The wet-well is a separate chamber attached or located adjacent to the dry-well (pump room) structure.

Submersible Lift Stations

Submersible lift stations do not have a separate pump room; the lift station header piping, associated valves, and flow meters are located in a separate dry vault at grade for easy access. Submersible lift stations include sealed pumps that operate submerged in the wet-well. These are removed to the surface periodically and reinstalled using guide rails and a hoist.

Prefabricated submersible lift station

A key advantage of dry-well lift stations is that they allow easy access for routine visual inspection and maintenance. In general, they are easier to repair than submersible pumps. An advantage of submersible lift stations is that they typically cost less than dry-well stations and operate without frequent pump maintenance.

Submersible lift stations do not usually include large aboveground structures and tend to blend in with their surrounding environment in residential areas. They require less space and are easier and less expensive to construct for wastewater flow capacities of 38,000 liters per minute (10,000 gallons per minute) or less.

Applicability

Lift stations are used to move wastewater from lower to higher elevation, particularly where the elevation of the source is not sufficient for gravity flow and/or when the use of gravity conveyance will result in excessive excavation depths and high sewer construction costs.

Current Status

Lift stations are widely used in wastewater conveyance systems.

Dry-well lift stations have been used in the industry for many years. However, the current industry-wide trend is to replace drywell lift stations of small and medium size (typically less than 24,000 liters per minute or 6,350 gallons per minute) with submersible lift stations mainly because of lower costs, a smaller footprint, and simplified operation and maintenance.

Variable Speed Pumping

Variable speed pumping is often used to optimize pump performance and minimize power use. Several types of variable-speed pumping equipment are available, including variable voltage and frequency drives, eddy current couplings, and mechanical variable-speed drives.

Variable-speed pumping can reduce the size and cost of the wetwell and allows the pumps to operate at maximum efficiency under a variety of flow conditions. Because variable-speed pumping allows lift station discharge to match inflow, only nominal wet-well storage volume is required and the well water level is maintained at a near constant elevation.

Variable-speed pumping may allow a given flow range to be achieved with fewer pumps than a constant-speed alternative. Variable-speed stations also minimize the number of pump starts and stops, reducing mechanical wear. Although there is significant energy saving potential for stations with large friction losses, it may not justify the additional capital costs unless the cost of power is relatively high.

Variable speed equipment also requires more room within the lift station and may produce more noise and heat than constant speed pumps.

Lift stations are complex facilities with many auxiliary systems. Therefore, they are less reliable than gravity wastewater conveyance. However, lift station reliability can be significantly improved by providing stand-by equipment (pumps and controls) and emergency power supply systems. In addition, lift station reliability is improved by using non-clog pumps suitable for the particular wastewater quality and by applying emergency alarm and automatic control systems.

Advantages and Disadvantages

Advantages
Lift stations are used to reduce the capital cost of sewer system construction. When gravity sewers are installed in trenches deeper than three meters (10 feet), the cost of sewer line installation increases significantly because of the more complex and costly excavation equipment and trench shoring techniques required. The size of the gravity sewer lines is dependent on the minimum pipe slope and flow. Pumping wastewater can convey the same flow using smaller pipeline size at shallower depth, and thereby, reducing pipeline costs.

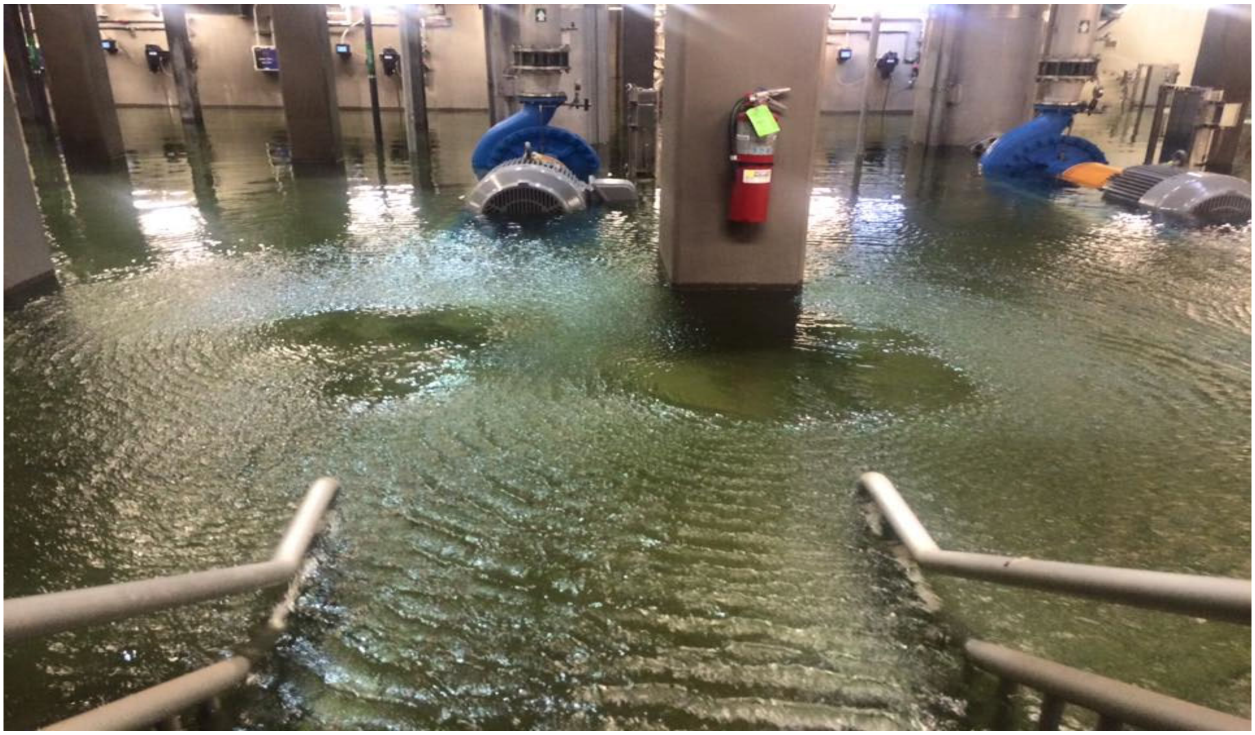
Disadvantages
Compared to sewer lines where gravity drives wastewater flow, lift stations require a source of electric power. If the power supply is interrupted, flow conveyance is discontinued and can result in flooding upstream of the lift station. It can also interrupt the normal operation of the downstream wastewater conveyance and treatment facilities. This limitation is typically addressed by providing an emergency power supply.

Key disadvantages of lift stations include the high cost to construct and maintain and the potential for odors and noise.

Lift stations also require a significant amount of power, are sometimes expensive to upgrade, and may create public concerns and negative public reaction. The low cost of gravity wastewater conveyance and the higher costs of building, operating, and maintaining lift stations means that wastewater pumping should be avoided, if possible and technically feasible.

Wastewater pumping can be eliminated or reduced by selecting alternative sewer routes or extending a gravity sewer using direction drilling or other state-of-the-art deep excavation methods. If such alternatives are viable, a cost benefit analysis can determine if a lift station is the most viable choice.

Design Criteria
Cost effective lift stations are designed to:
(1) match pump capacity, type, and configuration with wastewater quantity and quality;
(2) provide reliable and uninterruptible operation;
(3) allow for easy operation and maintenance of the installed equipment;
(4) accommodate future capacity expansion;
(5) avoid septic conditions and excessive release of odors in the collection system and at the lift station;
(6) minimize environmental and landscape impacts on the surrounding residential and commercial developments; and
(7) avoid flooding of the lift station and the surrounding areas.



Flooded pump station

The minimum recommended wet-well bottom slope is to 2:1 to allow self-cleaning and minimum deposit of debris. Effective volume of the wet-well may include sewer pipelines, especially when variable speed drives are used. Wet-wells should always hold some level of sewage to minimize odor release. Bar screens or grinders are often installed in or upstream of the wet-well to minimize pump clogging problems.

Wet Well/Dry Well Introduction

Wet-well

Wet-well design depends on the type of lift station configuration (submersible or dry-well) and the type of pump controls (constant or variable speed). Wet-wells are typically designed large enough to prevent rapid pump cycling but small enough to prevent a long detention time and associated odor release.

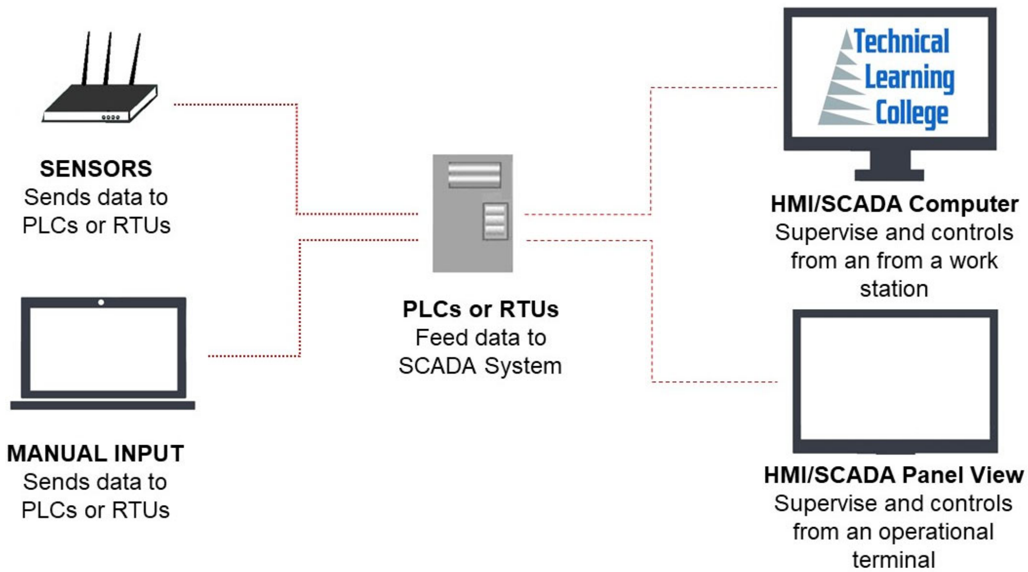
Wet-well maximum detention time in constant speed pumps is typically 20 to 30 minutes. Use of variable frequency drives for pump speed control allows wet-well detention time reduction to 5 to 15 minutes.

A Lift Station typically contains 4 main Components:

- A wet well - usually 15+ ft. in depth and 8 ft. in diameter - that houses two submersible pumps (there are some stations with up to 5 submersibles) of varying horsepower, discharging piping and floats that operate the pumps and keep a set level in the well.
- A dry well that houses the piping and valves that prevent backflow in the station, and camlock connection used to bypass the submersibles in an emergency.
- An electrical panel houses control for the submersible pumps. It also houses the telemetry used to monitor and control the station remotely.
- A “Log Book” or “Station Book” which contains the records and maps of the Lift Station’s area.

Sewer pipes are generally gravity driven. Wastewater flows slowly downhill until it reaches a certain low point. Then, pump or "lift" stations push the wastewater back uphill to a high point where gravity can once again take over the process.

Lift stations are used in sanitary sewer systems where water is accumulated in wet wells and then pumped to a higher elevation. They are generally designed to operate continuously to keep sewerage from backing up through the system. That means that most lift stations have a backup electrical supply in the event that normal power is disrupted.



BASIC SCADA DIAGRAM

Most Wastewater Collection systems will have installed radio/WIFI telemetry, or SCADA systems. The telemetry system is used to monitor and control pump stations via computer at the WW Collections facility.

This type of system gives up to the minute pump station status such as wet well level, pump performance, electrical power conditions, etc. This allows wastewater technicians to prevent wastewater spills and protect public health. Using telemetry, Operators have the ability to identify potential problems instantaneously and take the proper steps to rectify the situation before it becomes a public health risk.

Odor Control

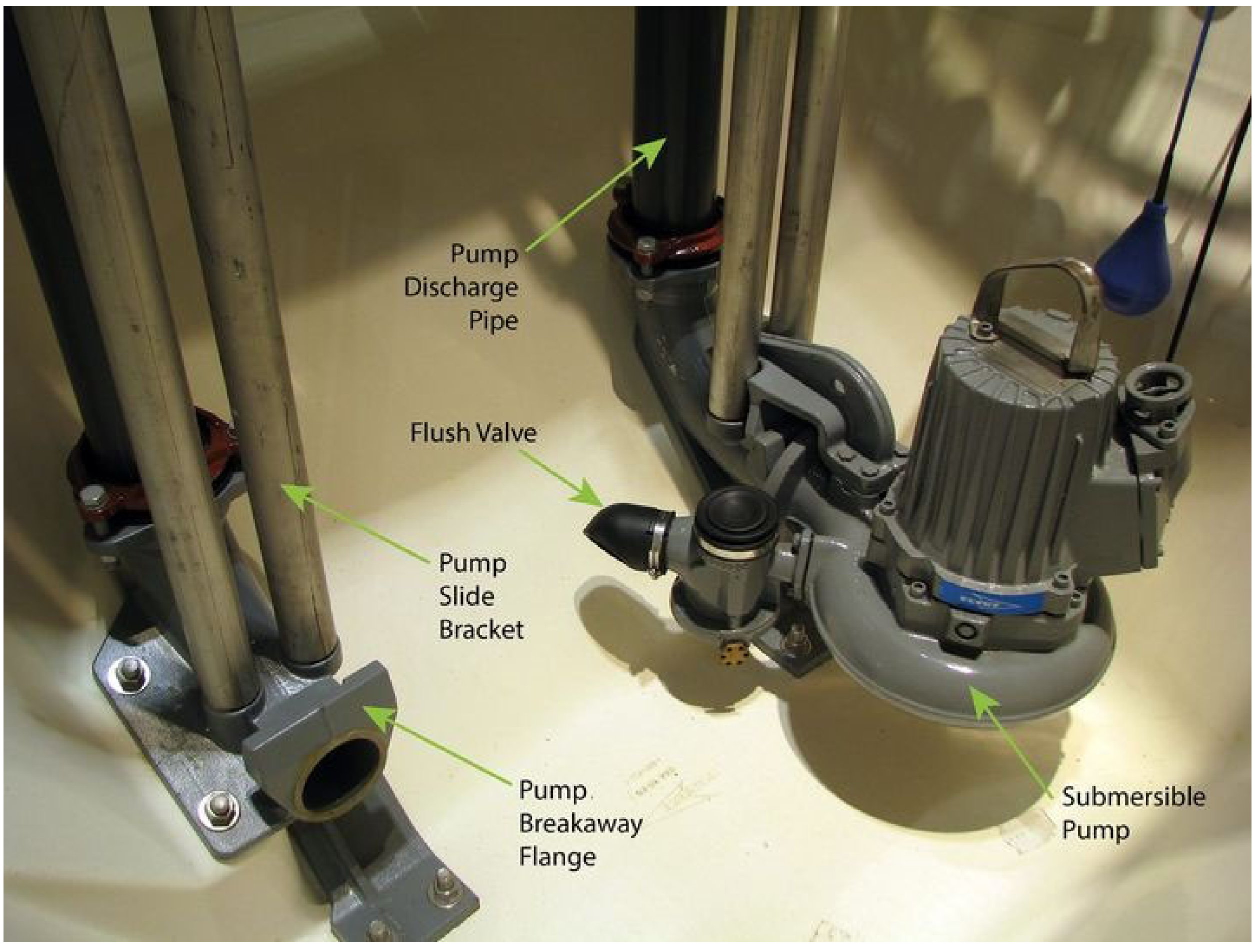
Odor control is frequently required for lift stations. A relatively simple and widely used odor control alternative is minimizing wet-well turbulence. More effective options include collection of odors generated at the lift station and treating them in scrubbers or biofilters or the addition of odor control chemicals to the sewer upstream of the lift station.

Chemicals typically used for odor control include chlorine, hydrogen peroxide, metal salts (ferric chloride and ferrous sulfate) oxygen, air, and potassium permanganate. Chemicals should be closely monitored to avoid affecting downstream treatment processes, such as extended aeration.

Wastewater Pumps- Introduction

The number of wastewater pumps and associated capacity should be selected to provide head capacity characteristics that correspond as nearly as possible to wastewater quantity fluctuations. This can be accomplished by preparing pump/pipeline system head-capacity curves showing all conditions of head (elevation of a free surface of water) and capacity under which the pumps will be required to operate.

The number of pumps to be installed in a lift station depends on the station capacity, the range of flow and the regulations. In small stations, with maximum inflows of less than 2,640 liters per minute (700 gallons per minute), two pumps are customarily installed, with each unit able to meet the maximum influent rate. For larger lift stations, the size and number of pumps should be selected so that the range of influent flow rates can be met without starting and stopping pumps too frequently and without excessive wet-well storage.



Depending on the system, the pumps are designed to run at a reduced rate. The pumps may also alternate to equalize wear and tear. Additional pumps may provide intermediate capacities better matched to typical daily flows. An alternative option is to provide flow flexibility with variable speed pumps.

For pump stations with high head-losses, the single pump flow approach is usually the most suitable.

Parallel pumping is not as effective for such stations because two pumps operating together yield only slightly higher flows than one pump. If the peak flow is to be achieved with multiple pumps in parallel, the lift station must be equipped with at least three pumps: two duty pumps that together provide peak flow and one standby pump for emergency backup.

Parallel peak pumping is typically used in large lift stations with relatively flat system head curves. Such curves allow multiple pumps to deliver substantially more flow than a single pump. The use of multiple pumps in parallel provides more flexibility.

Several types of centrifugal pumps are used in wastewater lift stations. In the straight-flow centrifugal pumps, wastewater does not change direction as it passes through the pumps and into the discharge pipe. These pumps are well suited for low-flow/high head conditions. In angle-flow pumps, wastewater enters the impeller axially and passes through the volute casing at 90 degrees to its original direction. This type of pump is appropriate for pumping against low or moderate heads.

Mixed flow pumps are most viable for pumping large quantities of wastewater at low head. In these pumps, the outside diameter of the impeller is less than an ordinary centrifugal pump, increasing flow volume.

Ventilation

Ventilation and heating are required if the lift station includes an area routinely entered by personnel. Ventilation is particularly important to prevent the collection of toxic and/or explosive gases. According to the Nation Fire Protection Association (NFPA) Section 820, all continuous ventilation systems should be fitted with flow detection devices connected to alarm systems to indicate ventilation system failure.

Dry-well ventilation codes typically require six continuous air changes per hour or 30 intermittent air changes per hour. Wet-wells typically require 12 continuous air changes per hour or 60 intermittent air changes per hour.

Motor control center (MCC) rooms should have a ventilation system adequate to provide six air changes per hour and should be air conditioned to between 13 and 32 degrees Celsius (55 to 90 degrees F).

If the control room is combined with an MCC room, the temperature should not exceed 30 degrees C or 85 degrees F.

All other spaces should be designed for 12 air changes per hour. The minimum temperature should be 13 degrees C (55 degrees F) whenever chemicals are stored or used.

Power Supply

The reliability of power for the pump motor drives is a basic design consideration. Commonly used methods of emergency power supply include electric power feed from two independent power distribution lines; an on-site standby generator; an adequate portable generator with quick connection; a stand-by engine driven pump; ready access to a suitable portable pumping unit and appropriate connections; and availability of an adequate holding facility for wastewater storage upstream of the lift station.

Performance Terms

The overall performance of a lift station depends on the performance of the pumps. All pumps have four common performance characteristics: capacity, head, power, and overall efficiency.

Capacity (flow rate) is the quantity of liquid pumped per unit of time, typically measured as gallons per minute (gpm) or million gallons per day (mgd).

Head is the energy supplied to the wastewater per unit weight, typically expressed as feet of water.

Power is the energy consumed by a pump per unit time, typically measured as kilowatt-hours.

Overall efficiency is the ratio of useful hydraulic work performed to actual work input. Efficiency reflects the pump relative power losses and is usually measured as a percentage of applied power.

Pump Performance Curves

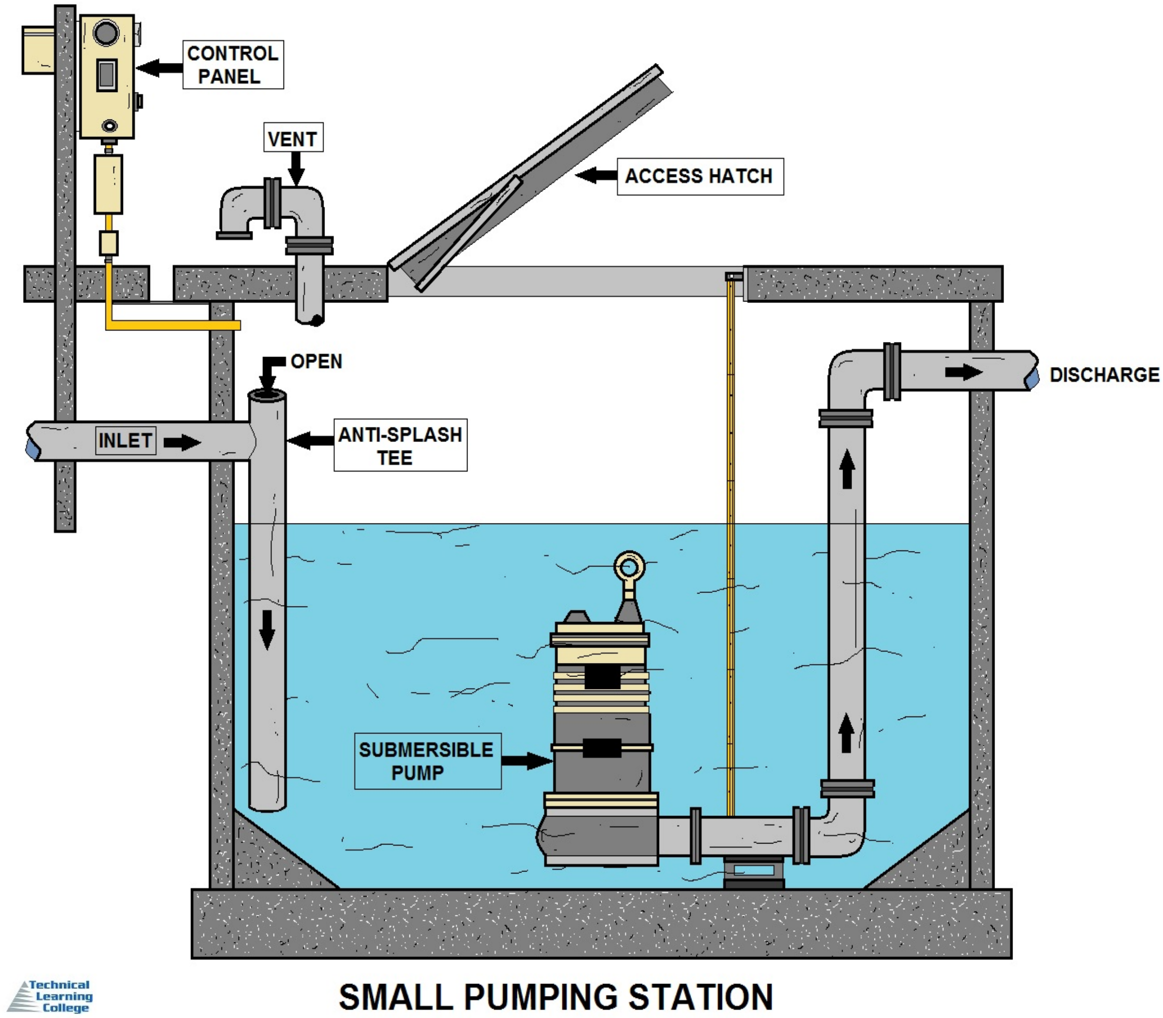
Pump performance curves are used to define and compare the operating characteristics of a pump and to identify the best combination of performance characteristics under which a lift station pumping system will operate under typical conditions (flows and heads).

Pump systems operate at 75 to 85 percent efficiency most of the time, while overall pump efficiency depends on the type of installed pumps, their control system, and the fluctuation of influent wastewater flow.

Performance optimization strategies focus on different ways to match pump operational characteristics with system flow and head requirements. They may include the following options:

a. adjusting system flow paths installing variable speed drives;
b. using parallel pumps installing pumps of different sizes trimming a pump impeller;
c. or putting a two-speed motor on one or more pumps in a lift station.

Optimizing system performance may yield significant electrical energy savings.



SMALL PUMPING STATION

Operation and Maintenance

Lift station operation is usually automated and does not require continuous on-site operator presence. However, frequent inspections are recommended to ensure normal functioning and to identify potential problems. Lift station inspection typically includes observation of pumps, motors and drives for unusual noise, vibration, heating and leakage, check of pump suction and discharge lines for valving arrangement and leakage, check of control panel switches for proper position, monitoring of discharge pump rates and pump speed, and monitoring of the pump suction and discharge pressure.

Weekly inspections are typically conducted, although the frequency really depends on the size of the lift station.

If a lift station is equipped with grinder bar screens to remove coarse materials from the wastewater, these materials are collected in containers and disposed of to a sanitary landfill site as needed.

If the lift station has a scrubber system for odor control, chemicals are supplied and replenished typically every three months.

If chemicals are added for odor control ahead of the lift station, the chemical feed stations should be inspected weekly and chemicals replenished as needed.

Routine Preventive Maintenance

The most labor-intensive task for lift stations is routine preventive maintenance. A well-planned maintenance program for lift station pumps prevents unnecessary equipment wear and downtime. Lift station operators must maintain an inventory of critical spare parts. The number of spare parts in the inventory depends on the critical needs of the unit, the rate at which the part normally fails, and the availability of the part.

The operator should tabulate each pumping element in the system and its recommended spare parts. This information is typically available from the operation and maintenance manuals provided with the lift station.

Costs

Lift station costs depend on many factors, including
(1) wastewater quality, quantity, and projections;
(2) zoning and land use planning of the area where the lift station will be located;
(3) alternatives for standby power sources;
(4) operation and maintenance needs and support;
(5) soil properties and underground conditions;
(6) required lift to the receiving (discharge) sewer line;
(7) the severity of impact of accidental sewage spill upon the local area; and
(8) the need for an odor control system.

These site and system specific factors must be examined and incorporated in preparing a lift station cost estimate.

Operation and Maintenance Costs
Lift station operation and maintenance costs include power, labor, maintenance, and chemicals (if used for odor control). Usually, the costs for solids disposal are minimal, but are included if the lift station is equipped with bar screens to remove coarse materials from the wastewater.

Typically, power costs account for 85 to 95 percent of the total operation and maintenance costs and are directly proportional to the unit cost of power and the actual power used by the lift station pumps. Labor costs average 1 to 2 percent of total costs. Annual maintenance costs vary, depending on the complexity of the equipment and instrumentation.

References
Other Related Fact Sheets

Small Diameter Gravity Sewer
EPA 832-F-00-038
September 2000

In-Plant Pump Stations
EPA 832-F-00-069
September 2000

Other EPA Fact Sheets can be found at the following web address:
http://www.epa.gov/owmitnet/mtbfact.htm

Common Hydraulic Terms

Head
The height of a column or body of fluid above a given point expressed in linear units. Head is often used to indicate gauge pressure. Pressure is equal to the height times the density of the liquid.

Head, Friction
The head required to overcome the friction at the interior surface of a conductor and between fluid particles in motion. It varies with flow, size, type, and conditions of conductors and fittings, and the fluid characteristics.

Head, Static
The height of a column or body of fluid above a given point.

Hydraulics
Engineering science pertaining to liquid pressure and flow.

Hydrokinetics
Engineering science pertaining to the energy of liquid flow and pressure.

Pascal's Law
A pressure applied to a confined fluid at rest is transmitted with equal intensity throughout the fluid.

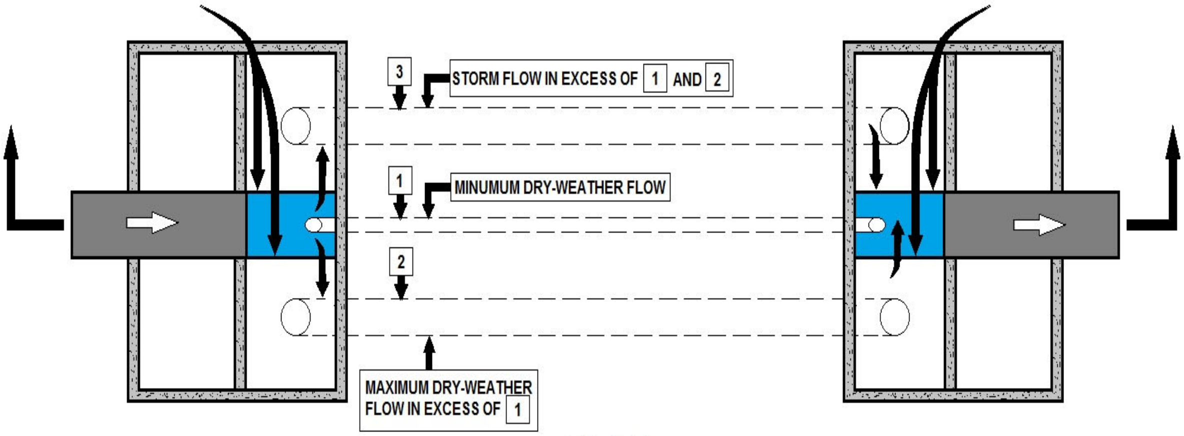
Pressure
The application of continuous force by one body upon another that it is touching; compression.
Force per unit area, usually expressed in pounds per square inch (Pascal or bar).

Pressure, Absolute
The pressure above zone absolute, i.e. the sum of atmospheric and gauge pressure. In vacuum related work it is usually expressed in millimeters of mercury. (mmHg).

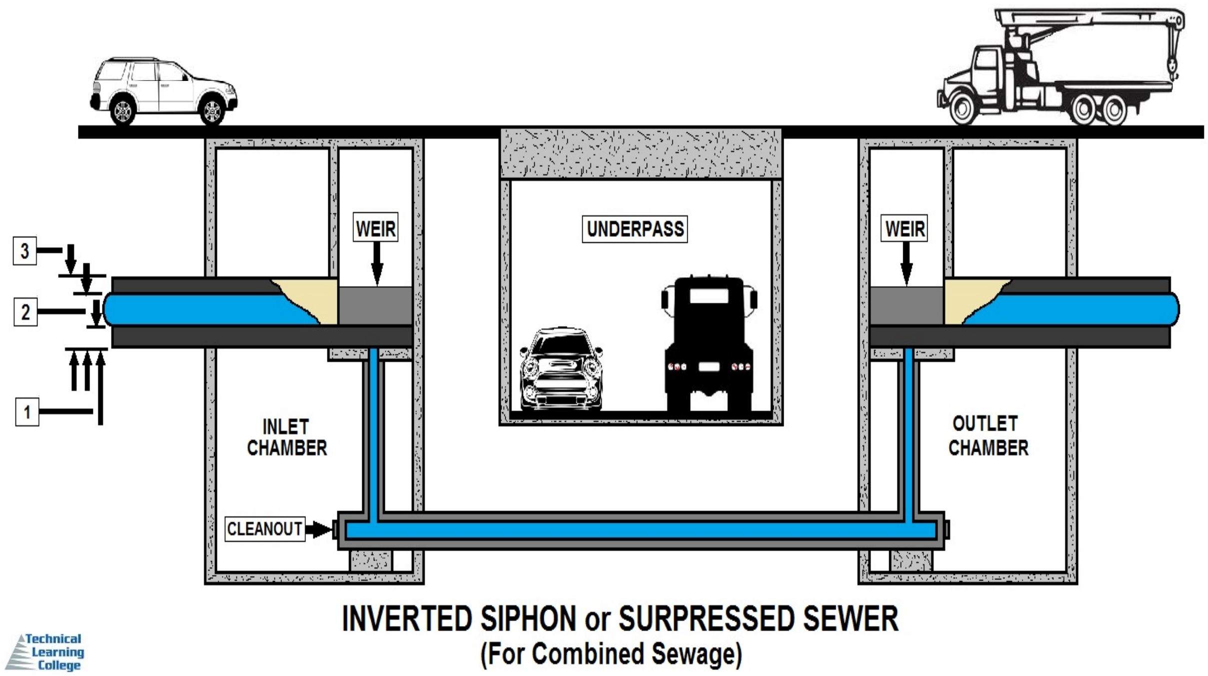
Pressure, Atmospheric
Pressure exerted by the atmosphere at any specific location. (Sea level pressure is approximately 14.7 pounds per square inch absolute, 1 bar = 14.5psi.)

Pressure, Gauge
Pressure differential above or below ambient atmospheric pressure.

Pressure, Static
The pressure in a fluid at rest.

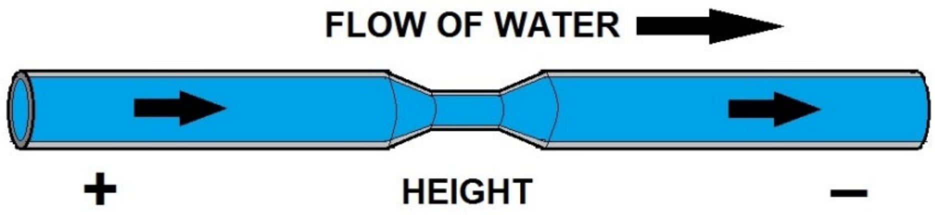


PLAN

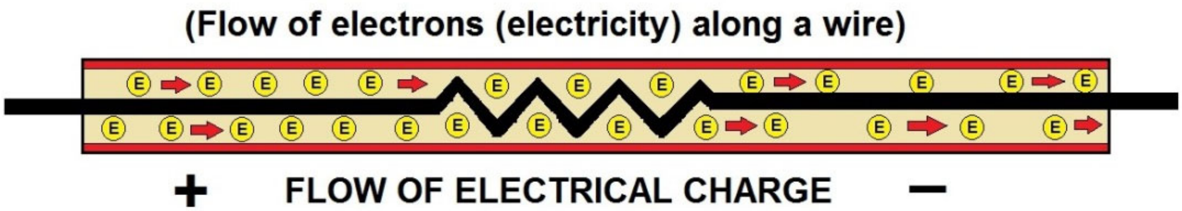


INVERTED SIPHON or SURPRESSED SEWER
(For Combined Sewage)

Hydraulic/Electrical Analogy Principles



Electricity flow can be compared to flow of water:
- When pressure is applied at one end of a pipe (or wire) then, water (or electricity) will come out the other end.

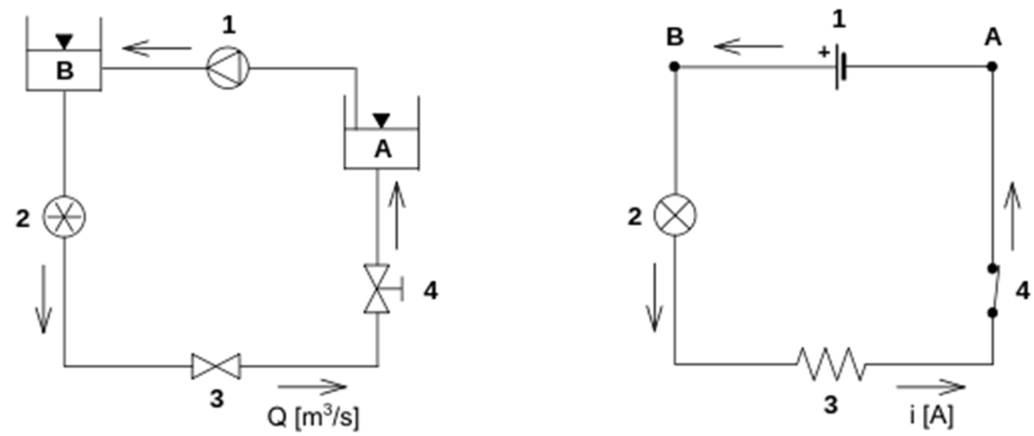


BASIC ELECTRICAL CONCEPT DIAGRAM

Water (Hydraulic) and Electrical Principles Are Very Similar

The electronic–**hydraulic analogy** (derisively referred to as the **drain-pipe theory** by Oliver Heaviside) is the most widely used analogy for "electron fluid" in a metal conductor. Since electric current is invisible and the processes at play in electronics are often difficult to demonstrate, the various electronic components are represented by hydraulic equivalents.

Electricity (as well as heat) was originally understood to be a kind of fluid, and the names of certain electric quantities (such as current) are derived from hydraulic equivalents. As all analogies, it demands an intuitive and competent understanding of the baseline paradigms (electronics and hydraulics).



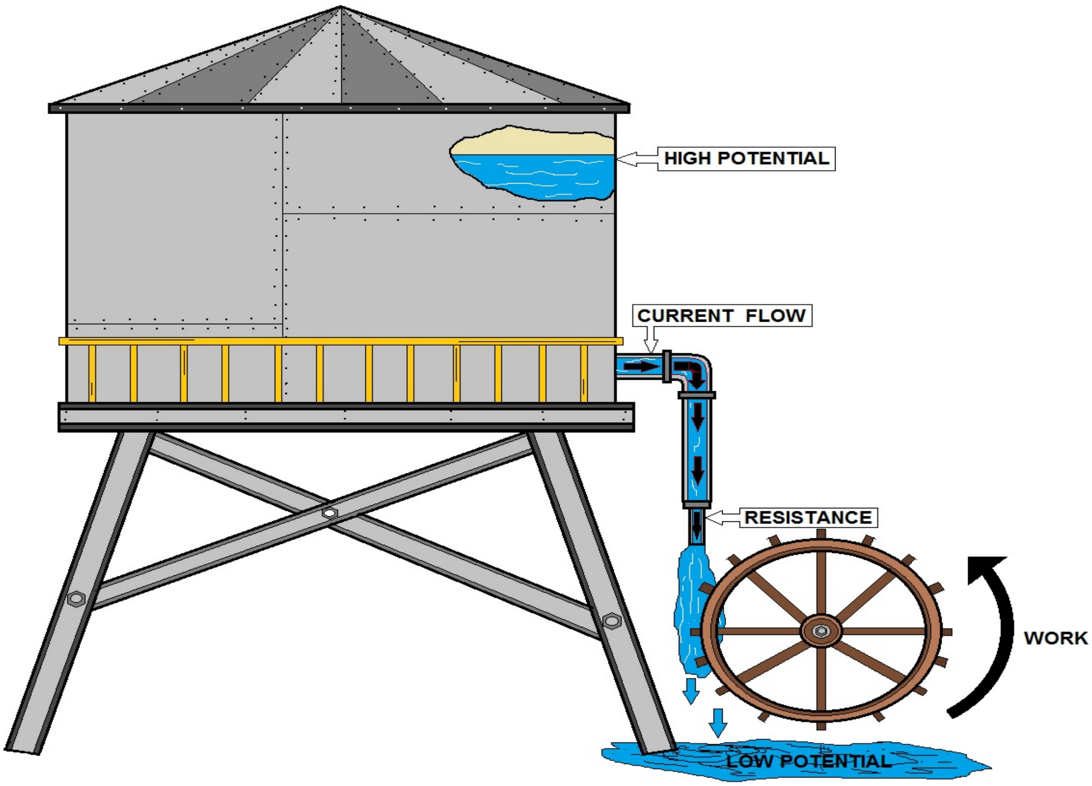
Analogy between a hydraulic circuit (left) and an electronic circuit (right).

Basic Hydraulic Ideas
There are two basic paradigms:

- Version with pressure induced by gravity. Large tanks of water are held up high, or are filled to differing water levels, and the potential energy of the water head is the pressure source. This is reminiscent of electrical diagrams with an up arrow pointing to +V, grounded pins that otherwise are not shown connecting to anything, and so on.

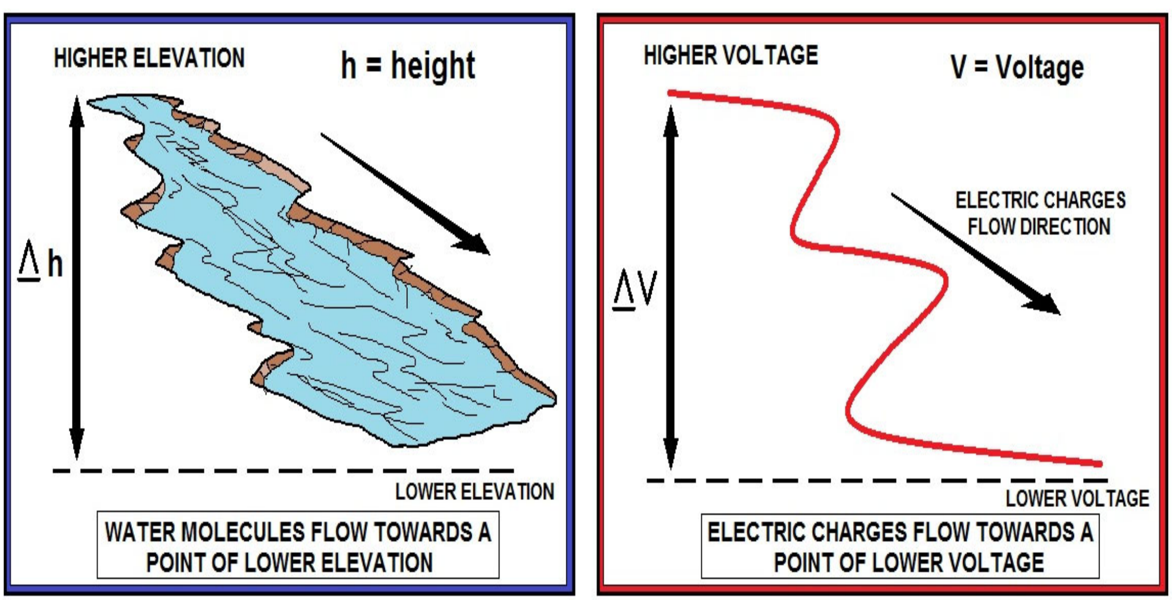
- Completely enclosed version with pumps providing pressure only; no gravity. This is reminiscent of a circuit diagram with a voltage source shown and the wires actually completing a circuit.

Applications: Flow and pressure variables can be calculated in fluid flow network with the use of the hydraulic ohm analogy. The method can be applied to both steady and transient flow situations.



Technical Learning College

WATER FLOWS LIKE ELECTRICITY



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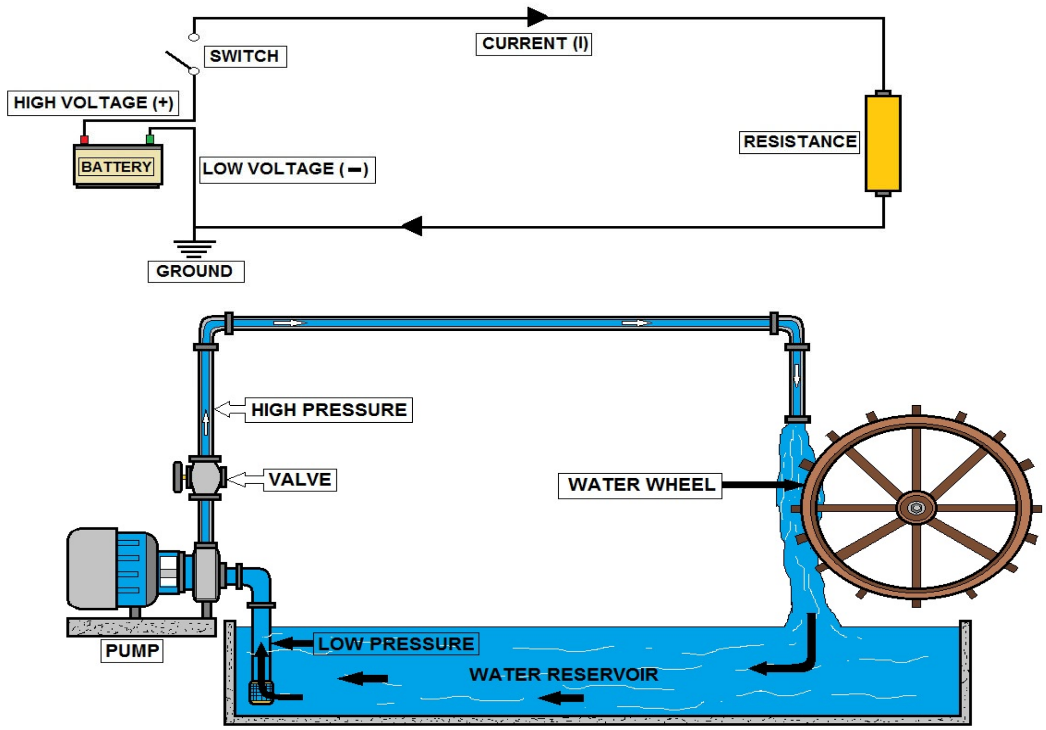
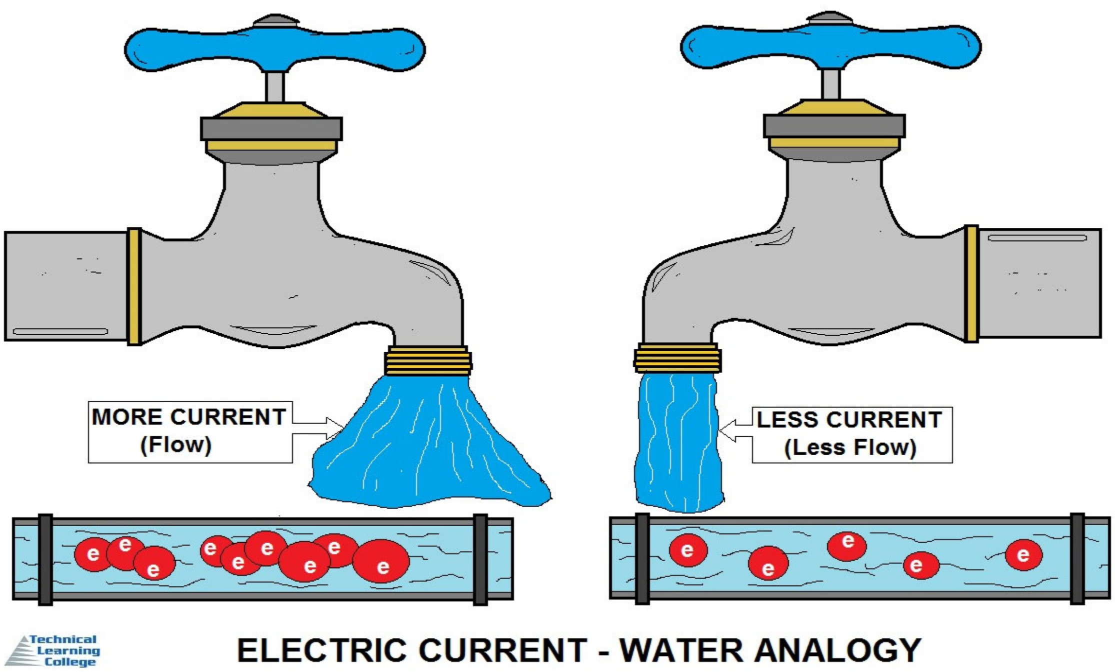
WATER FLOWS LIKE ELECTRICITY EXAMPLE



EXAMPLE OF HOW WATER FLOWS SIMILAR TO ELECTRICITY



ELECTRIC CURRENT - WATER ANALOGY

Hydraulic Component Equivalents

Wires
A relatively wide pipe completely filled with water is equivalent to a piece of wire. When comparing to a piece of wire, the pipe should be thought of as having semi-permanent caps on the ends. Connecting one end of a wire to a circuit is equivalent to forcibly un-capping one end of the pipe and attaching it to another pipe. With few exceptions (such as a high-voltage power source), a wire with only one end attached to a circuit will do nothing; the pipe remains capped on the free end, and thus adds nothing to the circuit.

Electric potential
In general, it is equivalent to hydraulic head. In this article, it is assumed that the water is flowing horizontally, so that the force of gravity can be ignored, and then electric potential is equivalent to pressure.

Voltage
Also called voltage drop or *potential difference*. A difference in pressure between two points. Usually measured in volts.

Electric charge
Equivalent to a quantity of water.

Current
Equivalent to a hydraulic volume flow rate; that is, the volumetric quantity of flowing water over time. Usually measured in amperes.

Ideal voltage source, or ideal battery
A dynamic pump with feedback control. A pressure meter on both sides shows that regardless of the current being produced, this kind of pump produces constant pressure difference. If one terminal is kept fixed at ground, another analogy is a large body of water at a high elevation, sufficiently large that the drawn water does not affect the water level.

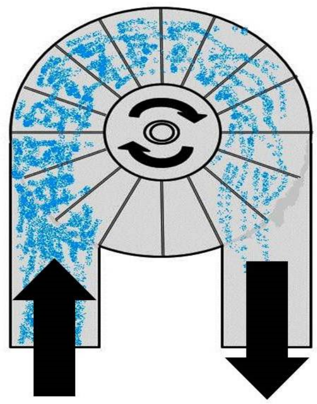
Ideal current source
A positive displacement pump. A current meter (little paddle wheel) shows that when this kind of pump is driven at a constant speed, it maintains a constant speed of the little paddle wheel.

Resistor
A constriction in the bore of the pipe which requires more pressure to pass the same amount of water. All pipes have some resistance to flow, just as all wires have some resistance to current.

Capacitor
A tank with one connection at each end and a rubber sheet dividing the tank in two lengthwise (a hydraulic accumulator). When water is forced into one pipe, equal water is simultaneously forced out the other pipe, yet no water can penetrate the rubber diaphragm. Energy is stored by the stretching of the rubber. As more current flows "through" the capacitor, the back-pressure (voltage) becomes greater, thus current "leads" voltage in a capacitor. As the back-pressure from the stretched rubber approaches the applied pressure, the current becomes less and less. Thus capacitors "filter out" constant pressure differences and slowly varying, low-frequency pressure differences, while allowing rapid changes in pressure to pass through.

Note that the device described will pass all changes in pressure "through" equally well, regardless of rate of change, just as an electrical capacitor will. Any device in series must obey (electrical) Kirchhoff's Current Law, or its hydraulic equivalent. Considering the "filter" action, a better and more exact analogy is the hydraulic accumulator "pressure tank", as described, but with a closed, pressurized air bladder and only one water connection. Such accumulators are commonly used in hydraulic power systems exactly for the purpose of damping out pressure surges and "hammers" due to valves opening and closing.

Inductor
A heavy paddle wheel placed in the current. The mass of the wheel and the size of the blades restrict the water's ability to rapidly change its rate of flow (current) through the wheel due to the effects of inertia, but, given time, a constant flowing stream will pass mostly unimpeded through the wheel, as it turns at the same speed as the water flow. The mass and surface area of the wheel and its blades are analogous to inductance, and friction between its axle and the axle bearings corresponds to the resistance that accompanies any non-superconducting inductor.



TURBINE INDUCTOR PADDLE

Inductors are analogous to a heavy paddle wheel/turbine placed in the current.

> An alternative inductor model is simply a long pipe, perhaps coiled into a spiral for convenience. This fluid-inertia device is used in real life as an essential component of a hydraulic ram. The inertia of the water flowing through the pipe produces the inductance effect; inductors "filter out" rapid changes in flow, while allowing slow variations in current to be passed through. The drag imposed by the walls of the pipe is somewhat analogous to parasitic resistance.
>
> In either model, the pressure difference (voltage) across the device must be present before the current will start moving, thus in inductors voltage "leads" current. As the current increases, approaching the limits imposed by its own internal friction and of the current that the rest of the circuit can provide, the pressure drop across the device becomes lower and lower.

Diode
Equivalent to a one-way check valve with a slightly leaky valve seat. As with a diode, a small pressure difference is needed before the valve opens. And like a diode, too much reverse bias can damage or destroy the valve assembly.

Transistor
A valve in which a diaphragm, controlled by a low-current signal (either constant current for a BJT or constant pressure for a FET), moves a plunger which affects the current through another section of pipe.

CMOS
A combination of two MOSFET transistors. As the input pressure changes, the pistons allow the output to connect to either zero or positive pressure.

Memristor
A needle valve operated by a flow meter. As water flows through in the forward direction, the needle valve restricts flow more; as water flows the other direction, the needle valve opens further providing less resistance.

Hydraulic - Electrical Principle Equivalents

EM Wave Speed (velocity of propagation)
Speed of sound in water. When a light switch is flipped, the electric wave travels very quickly through the wires.

Charge Flow Speed (drift velocity)
Particle speed of water. The moving charges themselves move rather slowly.

DC
Constant flow of water in a circuit of pipe.

Low Frequency AC
Water oscillating back and forth in a pipe.

Higher-Frequency AC and Transmission Lines
Sound being transmitted through the water pipes: Be aware that this does not properly mirror the cyclical reversal of alternating electric current. As described, the fluid flow conveys pressure fluctuations, but fluids “do not” reverse at high rates in hydraulic systems, which the above "low frequency" entry does accurately describe. A better concept (if sound waves are to be the phenomenon) is that of direct current with high-frequency "ripple" superimposed.

Inductive Spark
Used in induction coils, similar to water hammer, caused by the inertia of water.

Hydraulic Equation Examples

Some examples of equivalent electrical and hydraulic equations:

type	hydraulic	electric	thermal	mechanical
quantity	volume V [m³]	charge q [C]	heat Q [J]	momentum P [Ns]
potential	pressure p [Pa=J/m³]	potential ϕ [V=J/C]	temperature T [K=J/k_B]	velocity v [m/s]
flux	Volumetric flow rate Φ_V [m³/s]	current I [A=C/s]	heat transfer rate $\dot{Q}$ [J/s]	force F [N]
flux density	velocity v [m/s]	current density j [C/(m²·s) = A/m²]	heat flux $\dot{Q}''$ [W/m²]	stress σ [N/m² = Pa]
linear model	Poiseuille's law $\Phi_V = \frac{\pi r^4}{8\eta} \frac{\Delta p^\star}{\ell}$	Ohm's law $j = -\sigma \nabla \phi$	Fourier's law $\dot{Q}'' = \kappa \nabla T$	Dashpot $\sigma = c \Delta v$

If the differential equations have the same form, the response will be similar.

Limits to the Hydraulic Analogy

If taken too far, the water analogy can create misconceptions. For it to be useful, we must remain aware of the regions where electricity and water behave very differently.

Fields (Maxwell equations, Inductance)
Electrons can push or pull other distant electrons via their fields, while water molecules experience forces only from direct contact with other molecules. For this reason, waves in water travel at the speed of sound, but waves in a sea of charge will travel much faster as the forces from one electron are applied to many distant electrons and not to only the neighbors in direct contact. In a hydraulic transmission line, the energy flows as mechanical waves through the water, but in an electric transmission line the energy flows as fields in the space surrounding the wires, and does not flow inside the metal. Also, an accelerating electron will drag its neighbors along while attracting them, both because of magnetic forces.

Charge
Unlike water, movable charge carriers can be positive or negative, and conductors can exhibit an overall positive or negative net charge. The mobile carriers in electric currents are usually electrons, but sometimes they are charged positively, such as H^+ ions in proton conductors or holes in p-type semiconductors and some (very rare) conductors.

Leaking Pipes
The electric charge of an electrical circuit and its elements is usually almost equal to zero, hence it is (almost) constant. This is formalized in Kirchhoff's current law, which does not have an analogy to hydraulic systems, where amount of the liquid is not usually constant. Even with incompressible liquid the system may contain such elements as pistons and open pools, so the volume of liquid contained in a part of the system can change. For this reason, continuing electric currents require closed loops rather than hydraulics' open source/sink resembling spigots and buckets.

> **James Thurber spoke of his maternal grandmother thus:**
>> *She came naturally by her confused and groundless fears, for her own mother lived the latter years of her life in the horrible suspicion that electricity was dripping invisibly all over the house. - My Life and Hard Times (1933).*

Fluid Velocity and Resistance of Metals
As with water hoses, the carrier drift velocity in conductors is directly proportional to current. However, water only experiences drag via the pipes' inner surface, while charges are slowed at all points within a metal. Also, typical velocity of charge carriers within a conductor is less than centimeters per minute, and the "electrical friction" is extremely high. If charges ever flowed as fast as water can flow in pipes, the electric current would be immense, and the conductors would become incandescently hot and perhaps vaporize.

To model the resistance and the charge-velocity of metals, perhaps a pipe packed with sponge, or a narrow straw filled with syrup, would be a better analogy than a large-diameter water pipe. Resistance in most electrical conductors is a linear function: as current increases, voltage drop increases proportionally (Ohm's Law). Liquid resistance in pipes is not linear with volume, varying as the square of volumetric flow (see Darcy–Weisbach equation).

Quantum Mechanics
Conductors and insulators contain charges at more than one discrete level of atomic orbit energy, while the water in one region of a pipe can only have a single value of pressure. For this reason there is no hydraulic explanation for such things as a battery's charge pumping ability, a diode's voltage drop, solar cell functions, Peltier effect, etc., however equivalent devices can be designed which exhibit similar responses, although some of the mechanisms would only serve to regulate the flow curves rather than to contribute to the component's primary function.

Usefulness requires that the reader or student has a substantial understanding of the model (hydraulic) system's principles. It also requires that the principles can be transferred to the target (electrical) system. Hydraulic systems are deceptively simple: the phenomenon of pump cavitation is a known, complex problem that few people outside of the fluid power or irrigation industries would understand. For those who do, the hydraulic analogy is amusing, as no "cavitation" equivalent exists in electrical engineering. The hydraulic analogy can give a mistaken sense of understanding that will be exposed once a detailed description of electrical circuit theory is required.

One must also consider the difficulties in trying to make the analogy work. The above "electrical friction" example, where the hydraulic analog is a pipe filled with sponge material, illustrates the problem: the model must be increased in complexity beyond any realistic scenario.

Electrical Measurements and Equipment

Molecule of liquid → electron of electricity

Flow rate (gpm) → current (ampere) I, A

Pressure (psi) → potential (V)

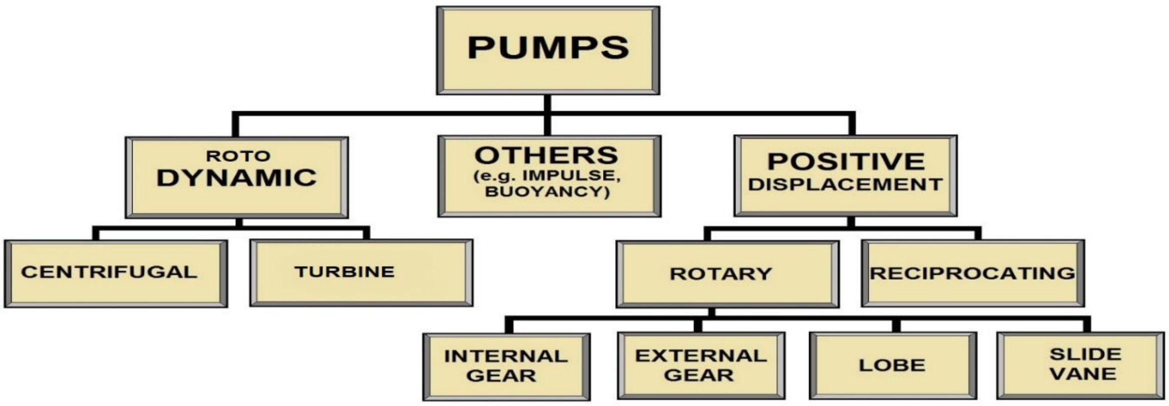
Pressure drop → voltage drop

Pump → generator

Pumps and Pumping Water

Moving fluids plays a major role in the process of a plant. Liquid can only move on its own power from top to bottom or from a high pressure to a lower pressure system. This means that energy to the liquid must be added to move the liquid from a low to a higher level.

To add the required energy to liquids, pumps are used. There are many different definitions of a pump but it can be described as: A machine used for the purpose of transferring quantities of liquids, gases and even solids from one location to another.



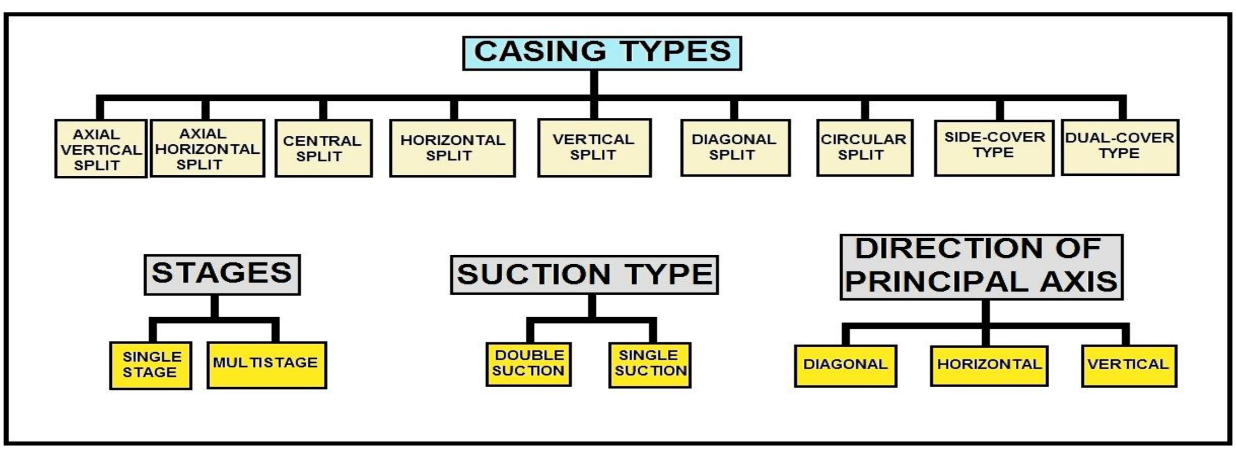
PUMP CATEGORIES

Types of Pumps

Pump types generally fall into two main categories - Rotodynamic and Positive Displacement, of which there are many forms.

The Rotodynamic pump transfers rotating mechanical energy into kinetic energy in the form of fluid velocity and pressure. The Centrifugal and Liquid Ring pumps are types of rotodynamic pump, which utilize centrifugal force to transfer the fluid being pumped.

The Rotary Lobe pump is a type of positive displacement pump, which directly displaces the pumped fluid from pump inlet to outlet in discrete volumes.



PUMP CONFIGUARATIONS

General Pumping Fundamentals

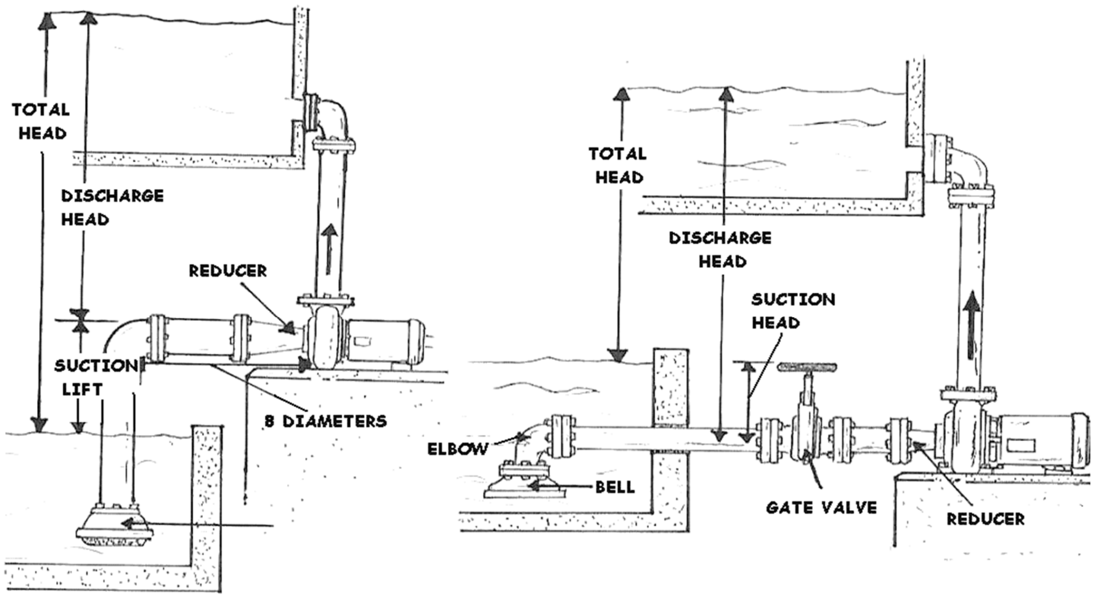


ILLUSTRATION 1 ILLUSTRATION 2

Here are the important points to consider about suction piping when the liquid being pumped is below the level of the pump:

- First, suction lift is when the level of water to be pumped is below the centerline of the pump. Sometimes suction lift is also referred to as '**negative suction head'**.

- The ability of the pump to lift water is the result of a partial vacuum created at the center of the pump.

- This works similar to sucking soda from a straw. As you gently suck on a straw, you are creating a vacuum or a pressure differential. Less pressure is exerted on the liquid inside the straw, so that the greater pressure is exerted by the atmosphere on the liquid around the outside of the straw, causing the liquid in the straw to move up. By sucking on the straw, this allows atmospheric pressure to move the liquid.

- Look at the diagram illustrated as "**1**". The foot valve is located at the end of the suction pipe of a pump. It opens to allow water to enter the suction side, but closes to prevent water from passing back out of the bottom end.

- The suction side of pipe should be one diameter larger than the pump inlet. The required eccentric reducer should be turned so that the top is flat and the bottom tapered.

Notice in illustration "**2**" that the liquid is above the level of the pump. Sometimes this is referred to as ***'flooded suction'*** or ***'suction head'*** situations.

Common Types of Water/Wastewater Pumps

The most common type of water pumps used for municipal and domestic water supplies are *variable displacement* pumps another term for dynamic pumps. A variable displacement pump will produce at different rates relative to the amount of pressure or lift the pump is working against. *Centrifugal* pumps are variable displacement pumps that are by far used the most. The water production well industry almost exclusively uses *Turbine* pumps, which are a type of centrifugal pump.

The turbine pump utilizes *impellers* enclosed in single or multiple *bowls or stages* to lift water by *centrifugal force*. The impellers may be of either a *semi-open or closed type*. Impellers are rotated by the *pump motor*, which provides the horsepower needed to overcome the pumping head. A more thorough discussion of how these and other pumps work is presented later in this section. The size and number of stages, horsepower of the motor and pumping head are the key components relating to the pump's lifting capacity.

Vertical turbine pumps are commonly used in groundwater wells but also in many other applications. These pumps are driven by a shaft rotated by a motor that is usually found on the surface. The shaft turns the impellers within the pump housing while the water moves up the column.

This type of pumping system is also called a *line-shaft turbine*. The rotating shaft in a line shaft turbine is actually housed within the column pipe that delivers the water to the surface. The size of the column, impeller, and bowls are selected based on the desired pumping rate and lift requirements.

Column pipe sections can be threaded or coupled together while the drive shaft is coupled and suspended within the column by *spider bearings*. The spider bearings provide both a seal at the column pipe joints and keep the shaft aligned within the column. The water passing through the column pipe serves as the lubricant for the bearings. Some vertical turbines are lubricated by oil rather than water. These pumps are essentially the same as water lubricated units; only the drive shaft is enclosed within an *oil tube*.

Food grade oil is supplied to the tube through a gravity feed system during operation. The oil tube is suspended within the column by *spider flanges,* while the line shaft is supported within the oil tube by *brass or redwood bearings*. A continuous supply of oil lubricates the drive shaft as it proceeds downward through the oil tube.

A small hole located at the top of the pump bow unit allows excess oil to enter the well. This results in the formation of an oil film on the water surface within oil-lubricated wells. Careful operation of oil lubricated turbines is needed to ensure that the pumping levels do not drop enough to allow oil to enter the pump. Both water and oil lubricated turbine pump units can be driven by electric or fuel powered motors. Most installations use an electric motor that is connected to the drive shaft by a keyway and nut.

However, where electricity is not readily available, fuel powered engines may be connected to the drive shaft by a right angle drive gear. Also, both oil and water lubricated systems will have a strainer attached to the intake to prevent sediment from entering the pump.

When the line shaft turbine is turned off, water will flow back down the column, turning the impellers in a reverse direction. A pump and shaft can easily be broken if the motor were to turn on during this process.

This is why a *time delay* or *ratchet* assembly is often installed on these motors to either prevent the motor from turning on before reverse rotation stops or simply not allow it to reverse at all.

Three Main Types of Diaphragm Pumps
In the first type, the diaphragm is sealed with one side in the fluid to be pumped, and the other in air or hydraulic fluid. The diaphragm is flexed, causing the volume of the pump chamber to increase and decrease. A pair of non-return check valves prevents reverse flow of the fluid.

The second type of diaphragm pump works with volumetric positive displacement, but differs in that the prime mover of the diaphragm is neither oil nor air; but is electro-mechanical, working through a crank or geared motor drive. This method flexes the diaphragm through simple mechanical action, and one side of the diaphragm is open to air.

The third type of diaphragm pump has one or more unsealed diaphragms with the fluid to be pumped on both sides. The diaphragm(s) again are flexed, causing the volume to change.

When the volume of a chamber of either type of pump is increased (the diaphragm moving up), the pressure decreases, and fluid is drawn into the chamber. When the chamber pressure later increases from decreased volume (the diaphragm moving down), the fluid previously drawn in is forced out. Finally, the diaphragm moving up once again draws fluid into the chamber, completing the cycle. This action is similar to that of the cylinder in an internal combustion engine.

Cavitation
Cavitation is defined as the phenomenon of formation of vapor bubbles of a flowing liquid in a region where the pressure of the liquid falls below its vapor pressure.

Cavitation is usually divided into two classes of behavior: inertial (or transient) cavitation and non-inertial cavitation. Inertial cavitation is the process where a void or bubble in a liquid rapidly collapses, producing a shock wave. Such cavitation often occurs in pumps, propellers, impellers, and in the vascular tissues of plants. Non-inertial cavitation is the process in which a bubble in a fluid is forced to oscillate in size or shape due to some form of energy input, such as an acoustic field. Such cavitation is often employed in ultrasonic cleaning baths and can also be observed in pumps, propellers etc.

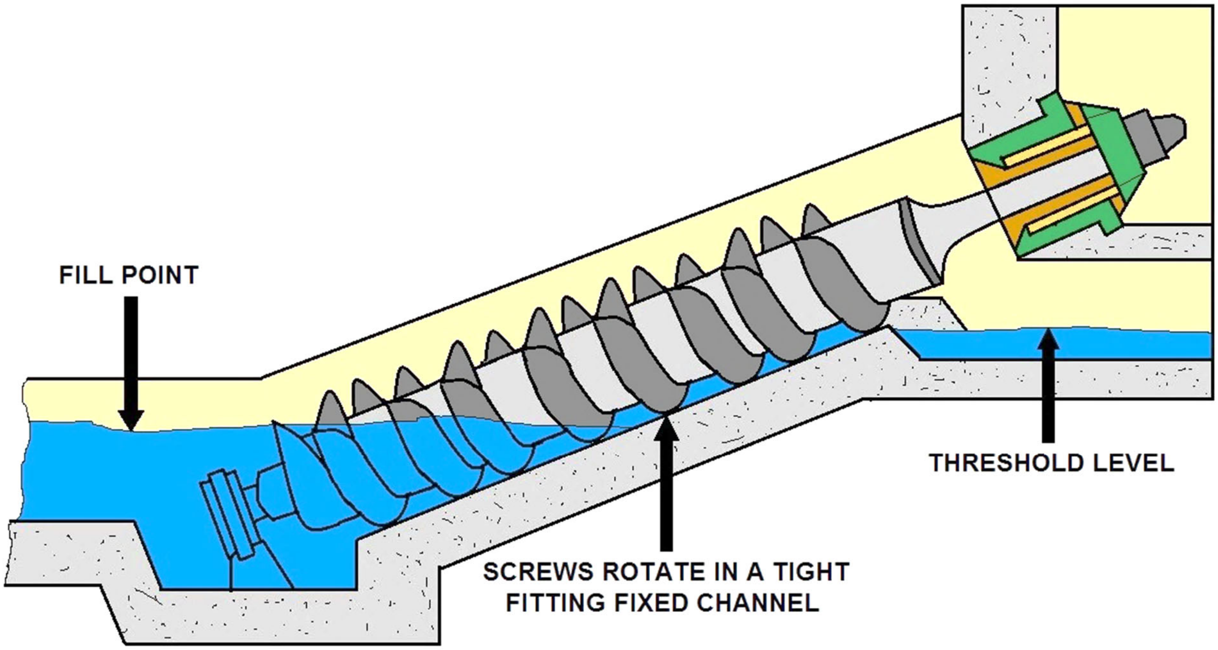
Cavitation is, in many cases, an undesirable occurrence. In devices such as propellers and pumps, cavitation causes a great deal of noise, damage to components, vibrations, and a loss of efficiency. When the cavitation bubbles collapse, they force liquid energy into very small volumes, thereby creating spots of high temperature and emitting shock waves, the latter of which are the source of rattling noise. The noise created by cavitation is a particular problem for military submarines, as it increases the chances of being detected by passive sonar.

Although the collapse of a cavity is a relatively low-energy event, highly localized collapses can erode metals, such as steel, over time. The pitting caused by the collapse of cavities produces great wear on components and can dramatically shorten a propeller's or pump's lifetime.

Simple Pumps Sub-Section

Screw or Auger Pump

The Archimedes' screw, Archimedean screw, or screwpump is a machine historically used for transferring water from a low-lying body of water into irrigation ditches. It was one of several inventions and discoveries traditionally attributed to Archimedes in the 3rd century BC.



AUGER PUMP DIAGRAM

The machine consists of a screw inside a hollow pipe. Some attribute its invention to Archimedes in the 3rd century BC, while others attribute it to Nebuchadnezzar II in the 7th century BC. A screw can be thought of as an inclined plane (another simple machine) wrapped around a cylinder.

The screw is turned (usually by a windmill or by manual labor). As the bottom end of the tube turns, it scoops up a volume of water. This amount of water will slide up in the spiral tube as the shaft is turned, until it finally pours out from the top of the tube and feeds the irrigation system.

The contact surface between the screw and the pipe does not need to be perfectly water-tight because of the relatively large amount of water being scooped at each turn with respect to the angular speed of the screw.

Also, water leaking from the top section of the screw leaks into the previous one and so on. So a sort of equilibrium is achieved while using the machine, thus preventing a decrease in efficiency.

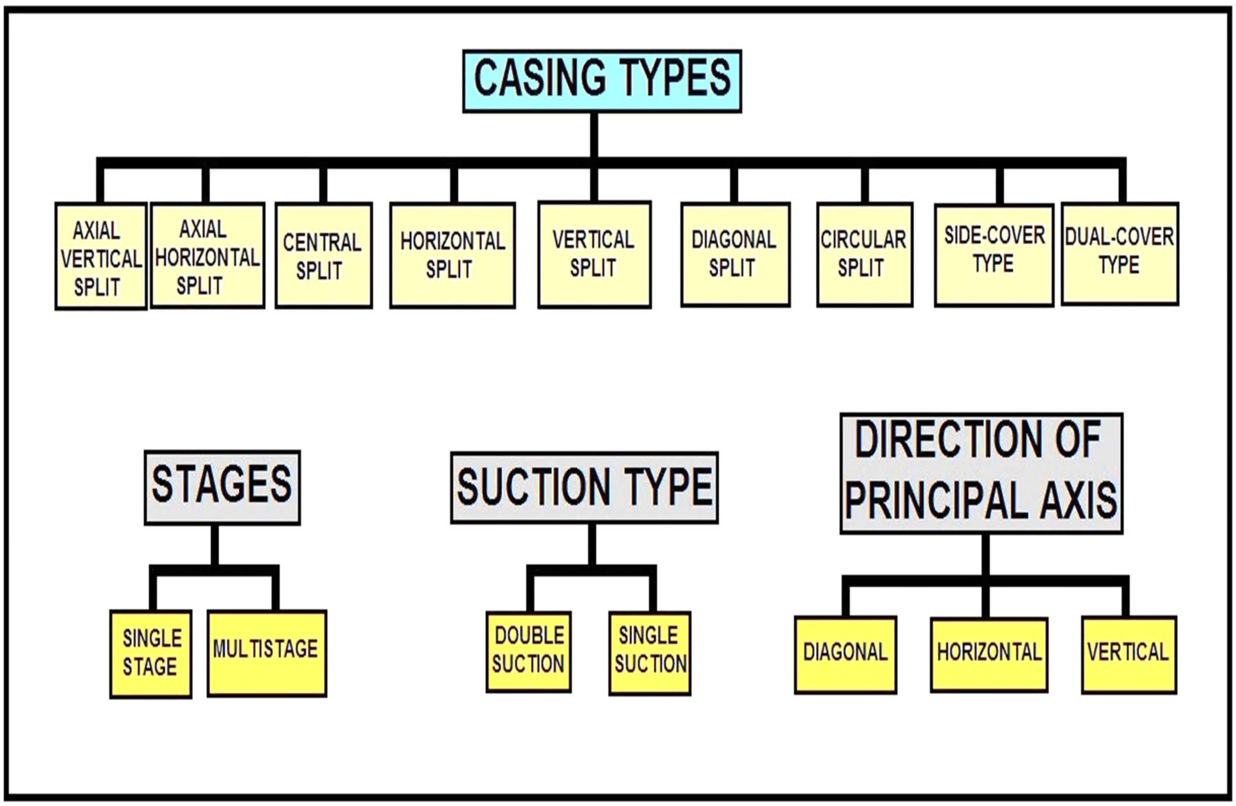
The "screw" does not necessarily need to turn inside the casing, but can be allowed to turn with it in one piece. A screw could be sealed with pitch or some other adhesive to its casing, or, cast as a single piece in bronze, as some researchers have postulated as being the devices used to irrigate Nebuchadnezzar II's Hanging Gardens of Babylon.

Depictions of Greek and Roman water screws show the screws being powered by a human treading on the outer casing to turn the entire apparatus as one piece, which would require that the casing be rigidly attached to the screw.

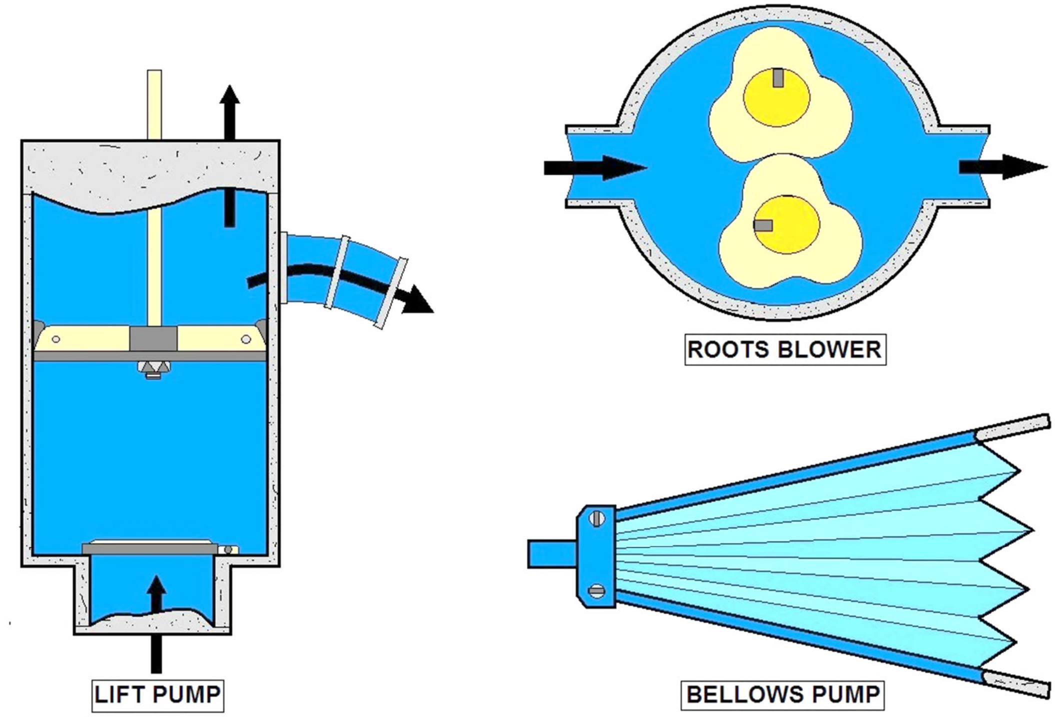
In this type of pump, a large screw provides the mechanical action to move the liquid from the suction side to the discharge side of the pump. Here are some typical characteristics of screw pumps:

- Most screw pumps rotate in the 30 to 60 rpm range, although some screw pumps are faster.
- The slope of the screw is normally either 30° or 38°.

The maximum lift for the larger diameter pumps is about 30 feet. The smaller diameter pumps have lower lift capabilities.



PUMP CONFIGURATION DIAGRAM



TYPES OF POSITIVE DISPLACEMENT PUMPS

The pump is a machine or mechanical equipment which is required to lift liquid from low level to high level or to flow liquid from low pressure area to high pressure area or as a booster in a piping network system.

Principally, pump converts mechanical energy of motor into fluid flow energy.

Pumps are used in process operations that requires a high hydraulic pressure. This can be seen in heavy duty equipment's. Often heavy duty equipment's requires a high discharge pressure and a low suction pressure. Due to low pressure at suction side of pump, fluid will lift from certain depth, whereas due to high pressure at discharge side of pump, it will push fluid to lift until reach desired height.

Classification of Pumps

Pump types generally fall into two main categories –

1. Dynamic (Centrifugal) Pumps
2. Positive Displacement Pumps

The family of pumps comprises a large number of types based on application and capabilities. The two major groups of pumps are dynamic and positive displacement.

Differences between the Dynamic and Positive Displacement Pumps

Factor	Dynamic (Centrifugal) Pump	Positive Displacement Pump
Mechanics	Impellers pass on velocity from the motor to the liquid which helps move the fluid to the discharge port (produces flow by creating pressure).	Traps confined amounts of liquid and forces it from the suction to the discharge port (produces pressure by creating flow).
Performance	Flow rate varies with a change in pressure.	Flow rate remains constant with a change in pressure.
Viscosity	Flow rate rapidly decreases with increasing viscosity, even any moderate thickness, due to frictional losses inside the pump.	Due to the internal clearances high viscosities are handled easily and flow rate increases with increasing viscosity.
Efficiency	Efficiency peaks at a specific pressure; any variations decrease efficiency dramatically. Does not operate well when run off the middle of the curve; can cause damage and cavitation.	Efficiency is less affected by pressure, but if anything tends to increase as pressure increases. Can be run at any point on their curve without damage or efficiency loss.
Suction Lift	Standard models cannot create suction lift, although self-priming designs are available and manometric suction lift is possible through a non-return valve on the suction line.	Create a vacuum on the inlet side, making them capable of creating suction lift.
Shearing	High speed motor leads to shearing of liquids. Not good for shear sensitive mediums.	Low internal velocity means little shear is applied to the pumped medium. Ideal for shear sensitive fluids.

Hyperlink to the Glossary and Appendix
http://www.abctlc.com/downloads/PDF/PumpGlossary.pdf

Types of Pumps

The family of pumps comprises a large number of types based on application and capabilities. The two major groups of pumps are dynamic and positive displacement.

Dynamic Pumps (Centrifugal Pump)

Centrifugal pumps are classified into three general categories:
Radial flow—a centrifugal pump in which the pressure is developed wholly by centrifugal force.
Mixed flow—a centrifugal pump in which the pressure is developed partly by centrifugal force and partly by the lift of the vanes of the impeller on the liquid.
Axial flow—a centrifugal pump in which the pressure is developed by the propelling or lifting action of the vanes of the impeller on the liquid.

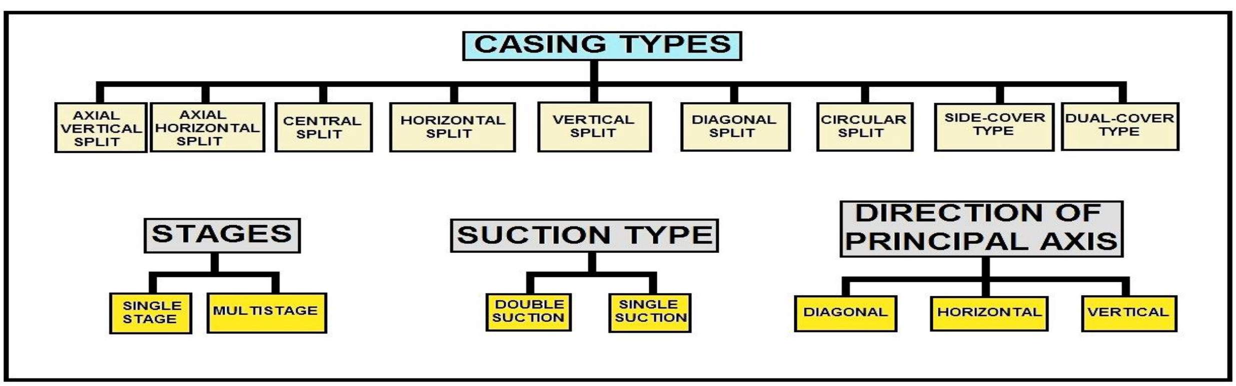
Plunger Pump
The plunger pump is a positive displacement pump that uses a plunger or piston to force liquid from the suction side to the discharge side of the pump. It is used for heavy sludge. The movement of the plunger or piston inside the pump creates pressure inside the pump, so you have to be careful that this kind of pump is never operated against any closed discharge valve.

All discharge valves must be open before the pump is started, to prevent any fast build-up of pressure that could damage the pump.

Diaphragm Pumps
In this type of pump, a diaphragm provides the mechanical action used to force liquid from the suction to the discharge side of the pump. The advantage the diaphragm has over the plunger is that the diaphragm pump does not come in contact with moving metal. This can be important when pumping abrasive or corrosive materials.

There are three main types of diaphragm pumps available:

1. Diaphragm sludge pump
2. Chemical metering or proportional pump
3. Air-powered double-diaphragm pump



PUMP CONFIGURATIONS

Pump Categories

Let's cover the essentials first. The key to the whole operation is, of course, the *pump.* And regardless of what type it is (reciprocating piston, centrifugal, turbine or jet-ejector, for either shallow or deep well applications), its purpose is to move water and generate the delivery force we call pressure.

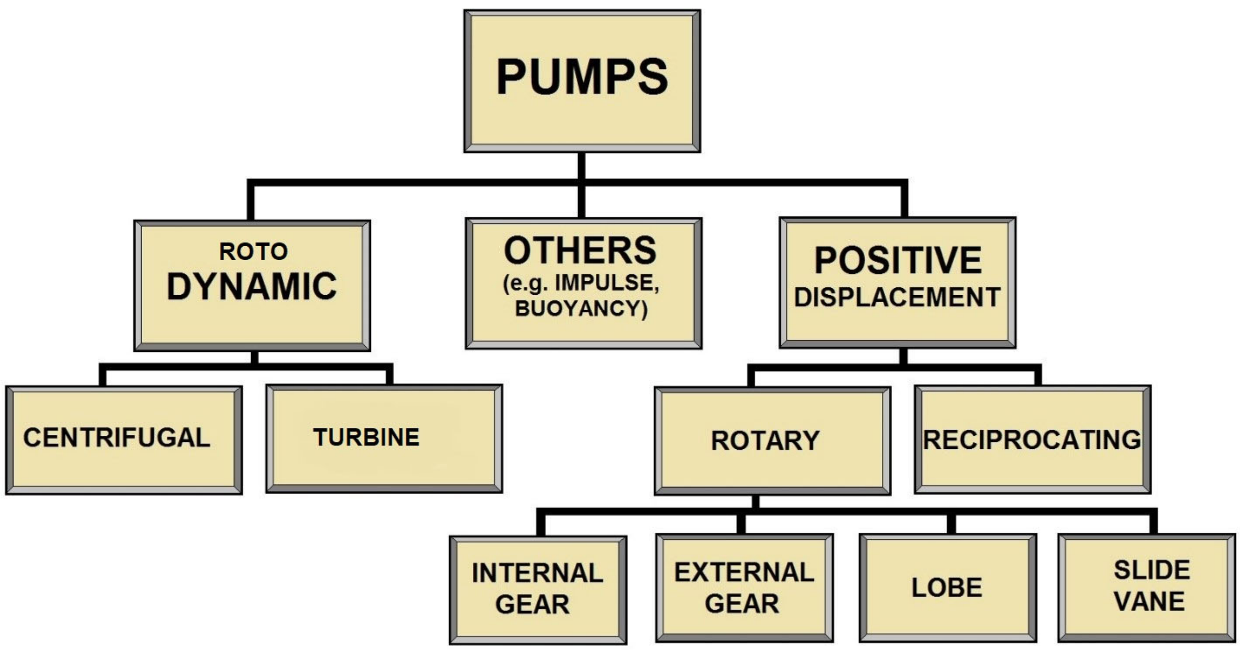
From time to time— with centrifugal pumps in particular — pressure is not referred to in pounds per square inch but rather as the equivalent in elevation, called “head”.

Head in feet divided by 2.31 equals pressure, so it's simple enough to establish a common figure.

Pumps may be classified on the basis of the application they serve.

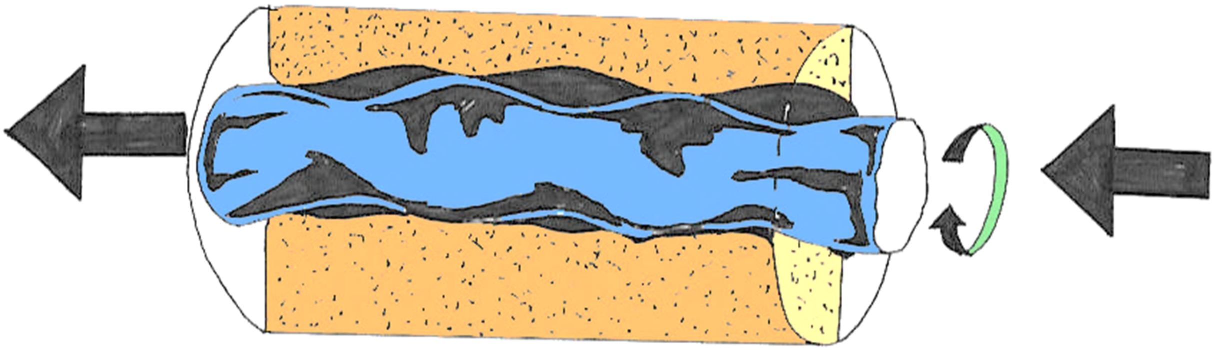
All pumps may be divided into two major categories:
(1) dynamic, in which energy is continuously added to increase the fluid velocities within the machine, and

(2) displacement, in which the energy is periodically added by application of force.



PUMP CATEGORIES

Progressing Cavity Pump Sub-Section



PROGRESSING CAVITY ACTION

In this type of pump, components referred to as a rotor and an elastic stator provide the mechanical action used to force liquid from the suction side to the discharge side of the pump. As the rotor turns within the stator, cavities are formed which progress from the suction to the discharge end of the pump, conveying the pumped material.

The continuous seal between the rotor and the stator helices keeps the fluid moving steadily at a fixed flow rate proportional to the pump's rotational speed. Progressing cavity pumps are used to pump material very high in solids content. The progressive cavity pump must never be run dry, because the friction between the rotor and stator will quickly damage the pump.

More on the Progressive Cavity Pump

A progressive cavity pump is also known as a progressing cavity pump, eccentric screw pump, or even just cavity pump, and as is common in engineering generally, these pumps can often be referred to by using a generalized trademark. Hence, names can vary from industry to industry and even regionally; examples include: Mono pump, Moyno pump, Mohno pump, and Nemo pump.

This type of pump transfers fluid by means of the progress, through the pump, of a sequence of small, fixed shape, discrete cavities, as its rotor is turned. This leads to the volumetric flow rate being proportional to the rotation rate (bi-directionally) and to low levels of shearing being applied to the pumped fluid.

Therefore, these pumps have application in fluid metering and pumping of viscous or shear sensitive materials. It should be noted that the cavities taper down toward their ends and overlap with their neighbors, so that, in general, no flow pulsing is caused by the arrival of cavities at the outlet, other than that caused by compression of the fluid or pump components.

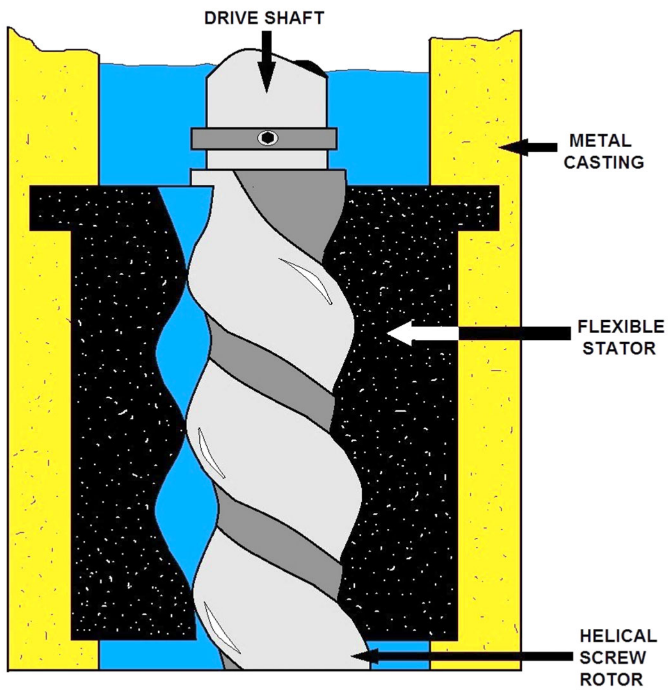
The principle of this pumping technique is frequently misunderstood; often it is believed to occur due to a dynamic effect caused by drag, or friction against the moving teeth of the screw rotor.

Nevertheless, in reality it is due to sealed cavities, like a piston pump, and so has similar operational characteristics, such as being able to pump at extremely low rates, even to high pressure, revealing the effect to be purely positive displacement.

The mechanical layout that causes the cavities to, uniquely, be of fixed dimensions as they move through the pump, is hard to visualize (it’s essentially 3D nature renders diagrams quite ineffective for explanation), but it is accomplished by the preservation in shape of the gap formed between a helical shaft and a two start, twice the wavelength and double the diameter, helical hole, as the shaft is "rolled" around the inside surface of the hole. The motion of the rotor being the same as the smaller gears of a planetary gears system. This form of motion gives rise to the curves called Hypocycloids.

In order to produce a seal between cavities, the rotor requires a circular cross-section and the stator an oval one. The rotor so takes a form similar to a corkscrew, and this, combined with the off-center rotary motion, leads to the name; *Eccentric screw pump*.

Different rotor shapes and rotor/stator pitch ratios exist, but are specialized in that they don't generally allow complete sealing, so reducing low speed pressure and flow rate linearity, but improving actual flow rates, for a given pump size, and/or the pump’s solids handling ability.



PROGRESSIVE CAVITY PUMP

At a high enough pressure the sliding seals between cavities will leak some fluid rather than pumping it, so when pumping against high pressures a longer pump with more cavities is more effective, since each seal has only to deal with the pressure difference between adjacent cavities. Pumps with between two and a dozen or so cavities exist.

In operation, progressive cavity pumps are fundamentally fixed flow rate pumps, like piston pumps and peristaltic pumps. This type of pump needs a fundamentally different understanding to the types of pumps to which people are more commonly first introduced, namely ones that can be thought of as generating a pressure.

This can lead to the mistaken assumption that all pumps can have their flow rates adjusted by using a valve attached to their outlet, but with this type of pump this assumption is a problem, since such a valve will have practically no effect on the flow rate and completely closing it will involve very high, probably damaging, pressures being generated.

In order to prevent this, pumps are often fitted with cut-off pressure switches, burst disks (deliberately weak and easily replaced points), or a bypass pipe that allows a variable amount of a fluid to return to the inlet. With a bypass fitted, a fixed flow rate pump is effectively converted to a fixed pressure one.

At the points where the rotor touches the stator, the surfaces are generally traveling transversely, so small areas of sliding contact occur, these areas need to be lubricated by the fluid being pumped (Hydrodynamic lubrication), this can mean that more torque is required for starting, and if allowed to operate without fluid, called 'run dry', rapid deterioration of the stator can result.

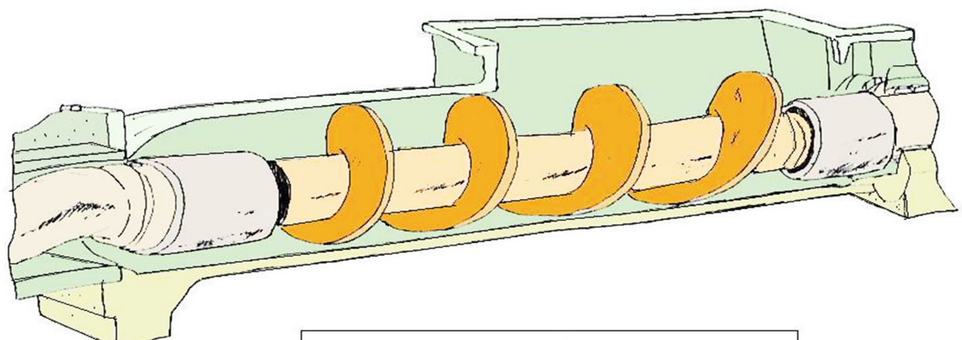
While progressive cavity pumps offer long life and reliable service transporting thick or lumpy fluids, abrasive fluids will significantly shorten the life of the stator. However, slurries (particulates in a medium) can be pumped reliably, as long as the medium is viscous enough to maintain a lubrication layer around the particles and so provide protection to the stator.

Specific designs involve the rotor of the pump being made of a steel, coated in a smooth hard surface, normally chromium, with the body (the stator) made of a molded elastomer inside a metal tube body. The Elastomer core of the stator forms the required complex cavities.

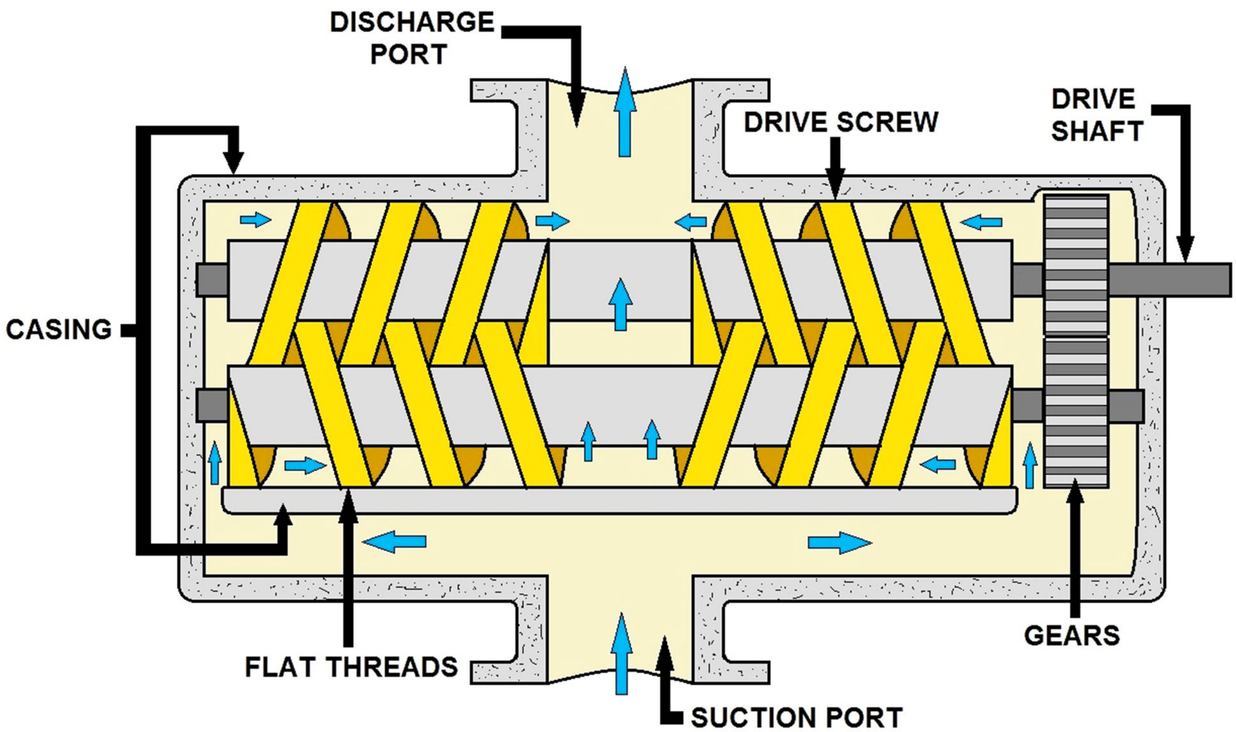
The rotor is held against the inside surface of the stator by angled link arms, bearings (which have to be within the fluid) allowing it to roll around the inner surface (un-driven).

Elastomer is used for the stator to simplify the creation of the complex internal shape, created by means of casting, and also improves the quality and longevity of the seals by progressively swelling due to absorption of water and/or other common constituents of pumped fluids. Elastomer/pumped fluid compatibility will thus need to be taken into account.

Two common designs of stator are the "Equal-walled" and the "Unequal walled". The latter, having greater elastomer wall thickness at the peaks, allows larger-sized solids to pass through because of its increased ability to distort under pressure.



PROGRESSIVE CAVITY PUMP



**POSITIVE DISPLACEMENT PUMP
SCREW TYPE**

Peristaltic Pump Sub-Section

A peristaltic pump is a type of positive displacement pump used for pumping a variety of fluids. The fluid is contained within a flexible tube fitted inside a circular pump casing (though linear peristaltic pumps have been made). A rotor with a number of "rollers", "shoes" or "wipers" attached to the external circumference compresses the flexible tube.

As the rotor turns, the part of the tube under compression closes (or "occludes") thus forcing the fluid to be pumped to move through the tube. Additionally, as the tube opens to its natural state after the passing of the cam ("restitution") fluid flow is induced to the pump. This process is called peristalsis and is used in many biological systems such as the gastrointestinal tract.

Priming a Pump
Liquid and slurry pumps can lose prime and this will require the pump to be primed by adding liquid to the pump and inlet pipes to get the pump started. Loss of "prime" is usually due to ingestion of air into the pump. The clearances and displacement ratios in pumps used for liquids and other more viscous fluids cannot displace the air due to its lower density.

Plunger Pumps
Plunger pumps are reciprocating positive displacement pumps. They consist of a cylinder with a reciprocating plunger in them. The suction and discharge valves are mounted in the head of the cylinder. In the suction stroke the plunger retracts and the suction valves open causing suction of fluid into the cylinder. In the forward stroke the plunger pushes the liquid out of the discharge valve.

Efficiency and Common Problems
With only one cylinder in plunger pumps, the fluid flow varies between maximum flow when the plunger moves through the middle positions and zero flow when the plunger is at the end positions. A lot of energy is wasted when the fluid is accelerated in the piping system. Vibration and "water hammer" may be a serious problem. In general, the problems are compensated for by using two or more cylinders not working in phase with each other.

Priming a Pump
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Compressed-Air-Powered Double-Diaphragm Pumps
One modern application of positive displacement diaphragm pumps is compressed-air-powered double-diaphragm pumps.

Run on compressed air these pumps are intrinsically safe by design, although all manufacturers offer ATEX certified models to comply with industry regulation.

Commonly seen in all areas of industry from shipping to processing, Wilden Pumps, Graco, SandPiper or ARO are generally the larger of the brands.

They are relatively inexpensive and can be used for almost any duty from pumping water out of bunds, to pumping hydrochloric acid from secure storage (dependent on how the pump is manufactured – elastomers / body construction).

Lift is normally limited to roughly 18 feet (6m) although heads can reach almost 200 Psi.

Understanding Progressing Cavity Pump Theory

Progressing cavity pumps (PCPs) are a special type of rotary positive displacement pump where the produced fluid is displaced axially at a constant rate. This characteristic enables progressing cavity pumps to produce viscous, abrasive, multiphase and gaseous fluids and slurries over a wide range of flow rates and differential pressures. Progressing cavity pumps are comprised of two helicoidal gears (rotor and stator), where the rotor is positioned inside the stator. The combination of rotational movement and geometry of the rotor inside the stator results in the formation of cavities that move axially from pump suction to pump discharge.

Rotors are typically machined from high-strength steel and then coated with a wear resistant material to resist abrasion and reduce stator/rotor friction. Stators consist of steel tubular with an elastomer core bonded to the steel. The elastomer is molded into the shape of an internal helix to match the rotor.

Progressive cavity pumps are fundamentally fixed flow rate pumps, like piston pumps and peristaltic pumps, and this type of pump needs a fundamentally different understanding to the types of pumps to which people are more commonly first introduced, namely ones that can be thought of as generating pressure.

This can lead to the mistaken assumption that all pumps can have their flow rates adjusted by using a valve attached to their outlet, but with this type of pump this assumption is a problem, since such a valve will have practically no effect on the flow rate and completely closing it will involve very high pressures being generated.

To prevent this, pumps are often fitted with cut-off pressure switches, burst disks (deliberately weak and easily replaced), or a bypass pipe that allows a variable amount a fluid to return to the inlet. With a bypass fitted, a fixed flow rate pump is effectively converted to a fixed pressure one.

At the points where the rotor touches the stator, the surfaces are generally traveling transversely, so small areas of sliding contact occur. These areas need to be lubricated by the fluid being pumped (Hydrodynamic lubrication). This can mean that more torque is required for starting, and if allowed to operate without fluid, called 'run dry', rapid deterioration of the stator can result. Progressive cavity pumps offer long life and reliable service transporting thick or lumpy substances.

Helical Rotor and a Twin Helix
The progressive cavity pump consists of a helical rotor and a twin helix, twice the wavelength and double the diameter helical hole in a rubber stator. The rotor seals tightly against the rubber stator as it rotates, forming a set of fixed-size cavities in between. The cavities move when the rotor is rotated but their shape or volume does not change. The pumped material is moved inside the cavities.

The principle of this pumping technique is frequently misunderstood. Often it is believed to occur due to a dynamic effect caused by drag, or friction against the moving teeth of the screw rotor. In reality, it is due to the sealed cavities, like a piston pump, and so has similar operational characteristics, such as being able to pump at extremely low rates, even to high pressure, revealing the effect to be purely positive displacement.

At a high enough pressure, the sliding seals between cavities will leak some fluid rather than pumping it, so when pumping against high pressures a longer pump with more cavities is more effective, since each seal has only to deal with the pressure difference between adjacent cavities. Pumps with between two and a dozen (or so) cavities exist.

When the rotor is rotated, it rolls around the inside surface of the hole. The motion of the rotor is the same as the smaller gears of a planetary gears system. As the rotor simultaneously rotates and moves around, the combined motion of the eccentrically mounted drive shaft is in the form of a hypocycloid. In the typical case of single-helix rotor and double-helix stator, the hypocycloid is just a straight line. The rotor must be driven through a set of universal joints or other mechanisms to allow for the movement.

The rotor takes a form similar to a corkscrew, and this, combined with the off-center rotary motion, leads to the alternative name: eccentric screw pump. Different rotor shapes and rotor/stator pitch ratios exist, but are specialized in that they don't generally allow complete sealing, so reducing low speed pressure and flow rate linearity, but improving actual flow rates, for a given pump size, and/or the pump's solids handling ability

Specific designs involve the rotor of the pump being made of a steel, coated with a smooth hard surface, normally chromium, with the body (the stator) made of a molded elastomer inside a metal tube body. The elastomer core of the stator forms the required complex cavities. The rotor is held against the inside surface of the stator by angled link arms, bearings (immersed in the fluid) allowing it to roll around the inner surface (un-driven).

Elastomer

Elastomer is used for the stator to simplify the creation of the complex internal shape, created by means of casting, which also improves the quality and longevity of the seals by progressively swelling due to absorption of water and/or other common constituents of pumped fluids. Elastomer/pumped fluid compatibility will thus need to be taken into account. Two common designs of stator are the "equal-walled" and the "unequal-walled". The latter, having greater elastomer wall thickness at the peaks allows larger-sized solids to pass through because of its increased ability to distort under pressure.

The former have a constant elastomer wall thickness and therefore exceed in most other aspects such as pressure per stage, precision, heat transfer, wear and weight. They are more expensive due to the complex shape of the outer tube.

Cavities are created by the geometry of the rotor and stator where the stator has one more lobe than the rotor. The cavities are moved axially along the pump by the rotating motion of the rotor.

The motion of the rotor is a combination of a clockwise rotation of the rotor along its own axis and a counterclockwise rotation of the rotor eccentrically about the axis of the stator. Because the volume of each cavity remains constant throughout the process, the pump delivers a uniform non-pulsating flow. The total pressure capability of the pump is determined by the maximum pressure that can be generated within each cavity times the total number of cavities.

PC pumps are manufactured with a variety of stator/rotor tooth combinations. Typically, artificial lift applications use a two-tooth stator and a single tooth rotor pump referred to as single-lobe pump. Higher stator/rotor tooth combinations, such as 3/2, are used to achieve higher volumetric and lift capacity although with higher torque requirements.

Understanding Pump NPSH
NPSH is an initialism for Net Positive Suction Head. In any cross-section of a generic hydraulic circuit, the NPSH parameter shows the difference between the actual pressure of a liquid in a pipeline and the liquid's vapor pressure at a given temperature. NPSH is an important parameter to take into account when designing a circuit: whenever the liquid pressure drops below the vapor pressure, liquid boiling occurs, and the final effect will be cavitation: vapor bubbles may reduce or stop the liquid flow, as well as damage the system.

Centrifugal pumps are particularly vulnerable especially when pumping heated solution near the vapor pressure, whereas positive displacement pumps are less affected by cavitation, as they are better able to pump two-phase flow (the mixture of gas and liquid), however, the resultant flow rate of the pump will be diminished because of the gas volumetrically displacing a disproportion of liquid. Careful design is required to pump high temperature liquids with a centrifugal pump when the liquid is near its boiling point.

The violent collapse of the cavitation bubble creates a shock wave that can literally carve material from internal pump components (usually the leading edge of the impeller) and creates noise often described as "pumping gravel". Additionally, the inevitable increase in vibration can cause other mechanical faults in the pump and associated equipment.

A somewhat simpler informal way to understand NPSH…
Fluid can be pushed down a pipe with a great deal of force. The only limit is the ability of the pipe to withstand the pressure. However, a liquid cannot be pulled up a pipe with much force because bubbles are created as the liquid evaporates into a gas. The greater the vacuum created, the larger the bubble, so no more liquid will flow into the pump.

Rather than thinking in terms of the pump's ability to pull the fluid, the flow is limited by the ability of gravity and air pressure to push the fluid into the pump. The atmosphere pushes down on the fluid, and if the pump is below the tank, the weight of the fluid from gravity above the pump inlet also helps. Until the fluid reaches the pump, those are the only two forces providing the push. Friction loss and vapor pressure must also be considered.

Friction loss limits the ability of gravity and air pressure to push the water toward the pump at high speed. Vapor pressure refers to the point at which bubbles form in the liquid. NPSH is a measure of how much spare pull you have before the bubbles form.

Some helpful information regarding atmospheric pressure; Atmospheric pressure is always naturally occurring and is always around us. At sea level, it equates to 101.325 kPa or approximately 14 Psi OR 10 meters of liquid pressure head. As we move higher up mountains, the air gets thinner and the atmospheric pressure reduces.

This should be taken into account when designing pumping systems. The reason there is atmospheric pressure is simply due to earth’s gravity and its position in our solar system. It is a natural phenomenon and we are very lucky to have it as water wells and bores with shallow aquifers allow us to use this atmospheric pressure to our advantage.

We all know that pressure gauges exist on pumping systems and other machines to give us an indication of what performances are being achieved. We also use known pressures versus known performance in order to create a reference for system designs. An example would be an experienced pump technician or plumber knowing that a pressure of between 300 kPa and 500 kPa will provide adequate and comfortable pressure for household use.

A typical pressure gauge reads what is known as 'Gauge Pressure,' or pressure relative to atmospheric pressure. An 'Absolute Pressure' gauge displays atmospheric pressure (typically 100 kPa or 14 psi or 10 meters of liquid pressure head) before any system had been connected. Manufacturers set typical gage pressure gauges to read ZERO at sea level as a standard, assuming designers will make allowances for the atmospheric pressure calculations themselves. Knowing this simple fact can make NPSH easier to understand. If we now know that there is 100 kPa or 10 meters of head pressure, plus or minus whatever the gage pressure gauge shows, then we can safely see that this gives us an instant advantage of 10 meters of head pressure at sea level.

This means we can borrow against this and drop a maximum of 10 meters into or under the ground (or below sea level) reducing the gauge to zero and still get natural 'push' into our pump. Great for wells and bores with shallow aquifers within this depth! It is important to note that to get to exactly 10 meters may be difficult, but with the correct pipework and system design, it is possible to get very close.

Once NPSH is fully understood, sizing and controlling pumps and pumping machines is a much simpler task.

NPSH is the liquid suction force at the intake of a pump. In other words, the force of a liquid naturally “pushing” into a pump from gravity pressure plus liquid head pressure only - into a single pump intake.

This means;
NPSH = the net (left over) positive pressure of suction force into a pump intake after friction loss has occurred. Liquid head height or liquid head pressure + gravity pressure, minus friction loss, leaves a net head pressure of force into the pump. If we want to pump some amount of liquid, we have to ensure that this liquid can reach the center line of the suction point of the pump. NPSH represents the head (pressure and gravity head) of liquid in the suction line of the pump that will overcome the friction along the suction line.

NPSHR is the amount of liquid pressure required at the intake port of a pre-designed and manufactured pump. This is known as NPSHR (Net Positive Suction Head Required). The pump manufacturer will usually clearly have a NPSH curve to assist you in the correct installation.

NPSHA is the amount (A = available) to the pump intake after pipe friction losses and head pressures have been taken into account.

The Reason for This Requirement?
When the pump is receiving liquid at intake port and the impeller is pushing the liquid out the discharge port, they are effectively trying to tear each other apart because the pump is changing the liquid movement by a pressure increase at the impeller vanes, (general pump installations).

Insufficient NPSHR will cause a low or near-vacuum pressure (negative NPSHA) to exist at the pump intake. This will cause the liquid to boil and cause cavitation, and the pump will not receive the liquid fast enough because it will be attempting to pump vapor.

Cavitation will lower pump performance and damage pump internals. At low temperatures the liquid can "hold together" (remain fluid) relatively easily, hence a lower NPSH requirement.

However, at higher temperatures, the higher vapor pressure starts the boiling process much quicker, hence a high NPSH requirement.

- ✓ Water will boil at lower temperatures under lower pressures. Conversely its boiling point is higher at higher pressures.
- ✓ Water boils at 100 degrees Celsius at sea level and an atmospheric pressure of 1 bar.
- ✓ Vapor Pressure is the pressure of a gas in equilibrium with its liquid phase at a given temperature. If the vapor pressure at a given temperature is greater than the pressure of the atmosphere above the liquid, then the liquid will boil. (This is why water boils at a lower temperature high in the mountains).
- ✓ At normal atmospheric pressure minus 5 psi (or -0.35 bar) water will boil at 89 degrees Celsius.
- ✓ At normal atmospheric pressure minus 10 psi (or -0.7 bar) water will boil at 69 degrees Celsius.
- ✓ At a positive pressure of +12 psi or +0.82 bar above atmospheric, water will boil at 118 degrees Celsius.

Pump Operating Problems

If a centrifugal pump **DOES NOT DELIVER ANY LIQUID**, the trouble may be caused by (1) insufficient priming; (2) insufficient speed of the pump; (3) excessive discharge pressure, such as might be caused by a partially closed valve or some other obstruction in the discharge line; (4) excessive suction lift; (5) clogged impeller passages; (6) the wrong direction of rotation (this may occur after motor overhaul); (7) clogged suction screen (if used); (8) ruptured suction line; or (9) loss of suction pressure.

If a centrifugal pump delivers some liquid but operates at **INSUFFICIENT CAPACITY**, the trouble may be caused by (1) air leakage into the suction line; (2) air leakage into the stuffing boxes in pumps operating at less than atmospheric pressure; (3) insufficient pump speed; (4) excessive suction lift; (5) insufficient liquid on the suction side; (6) clogged impeller passages; (7) excessive discharge pressure; or (8) mechanical defects, such as worn wearing rings, impellers, stuffing box packing, or sleeves.

If a pump **DOES NOT DEVELOP DESIGN DISCHARGE PRESSURE**, the trouble may be caused by (1) insufficient pump speed; (2) air or gas in the liquid being pumped; (3) mechanical defects, such as worn wearing rings, impellers, stuffing box packing, or sleeves; or (4) reversed rotation of the impeller (3-phase electric motor-driven pumps).

If a pump **WORKS FOR A WHILE AND THEN FAILS TO DELIVER LIQUID,** the trouble may be caused by (1) air leakage into the suction line; (2) air leakage in the stuffing boxes; (3) clogged water seal passages; (4) insufficient liquid on the suction side; or (5) excessive heat in the liquid being pumped.

If a motor-driven centrifugal pump **DRAWS TOO MUCH POWER**, the trouble will probably be indicated by overheating of the motor. The basic causes may be (1) operation of the pump to excess capacity and insufficient discharge pressure; (2) too high viscosity or specific gravity of the liquid being pumped; or (3) misalignment, a bent shaft, excessively tight stuffing box packing, worn wearing rings, or other mechanical defects.

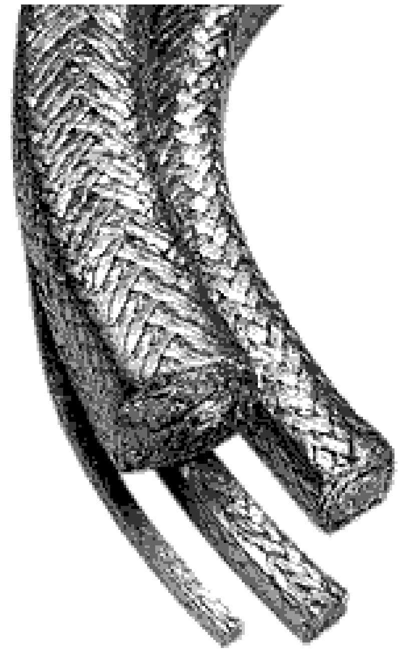
VIBRATION of a centrifugal pump is often caused by (1) misalignment; (2) a bent shaft; (3) a clogged, eroded, or otherwise unbalanced impeller; or (4) lack of rigidity in the foundation. Insufficient suction pressure may also cause vibration and cavitation, as well as noisy operation and fluctuating discharge pressure, particularly in pumps that handle hot or volatile liquids. If the pump fails to build up pressure when the discharge valve is opened and the pump comes up to normal operating speed, proceed as follows:

1. Shut the pump discharge valve.
2. Secure the pump.
3. Open all valves in the pump suction line.
4. Prime the pump (***fill casing with the liquid being pumped***) and be sure that all air is expelled through the air cocks on the pump casing.
5. Restart the pump. If the pump is electrically driven, be sure the pump is rotating in the correct direction.
6. Open the discharge valve to "**load**" the pump. If the discharge pressure is not normal when the pump is up to its proper speed, the suction line may be clogged, or an impeller may be broken. It is also possible that air is being drawn into the suction line or into the casing. If any of these conditions exist, stop the pump and continue troubleshooting according to the technical manual for that unit.

Some of the operating problems you may encounter with centrifugal pumps as an Operator, together with the probable causes, are discussed in the following pages

Maintenance of Centrifugal Pumps

When properly installed, maintained and operated, centrifugal pumps are usually trouble-free. Some of the most common preventative and corrective maintenance actions that you may be required to perform are discussed in the following sections.



Repacking

Lubrication of the pump packing is extremely important. The quickest way to wear out the packing is to forget to open the water piping to the seals or stuffing boxes. If the packing is allowed to dry out, it will score the shaft. When operating a centrifugal pump, be sure there is always a slight trickle of water coming out of the stuffing box or seal. How often the packing in a centrifugal pump should be renewed depends on several factors, such as the type of pump, condition of the shaft sleeve, and hours in use.

To ensure the longest possible service from pump packing, make certain the shaft or sleeve is smooth when the packing is removed from a gland. Rapid wear of the packing will be caused by roughness of the shaft sleeve (or shaft where no sleeve is installed). If the shaft is rough, it should be sent to the machine shop for a finishing cut to smooth the surface. If it is very rough, or has deep ridges in it, it will have to be renewed. It is absolutely necessary to use the correct packing. When replacing packing, be sure the packing fits uniformly around the stuffing box. If you have to flatten the packing with a hammer to make it fit, **YOU ARE NOT USING THE RIGHT SIZE.** Pack the box loosely, and set up the packing gland lightly. Allow a liberal leak-off for stuffing boxes that operate above atmospheric pressure.

Next, start the pump. Let it operate for about 30 minutes before you adjust the packing gland for the desired amount of leak-off. This gives the packing time to run-in and swell. You may then begin to adjust the packing gland. Tighten the adjusting nuts one flat at a time. Wait about 30 minutes between adjustments. Be sure to tighten the same amount on both adjusting nuts. If you pull up the packing gland unevenly (or cocked), it will cause the packing to overheat and score the shaft sleeves. Once you have the desired leak-off, check it regularly to make certain that sufficient flow is maintained.

Mechanical Seals

Mechanical seals are rapidly replacing conventional packing as the means of controlling leakage on rotary and positive-displacement pumps. Mechanical seals eliminate the problem of excessive stuffing box leakage, which can cause failures of pump and motor bearings and motor windings. Mechanical seals are ideal for pumps that operate in closed systems (such as fuel service and air-conditioning, chilled-water, and various cooling systems). They not only conserve the fluid being pumped, but also improve system operation.

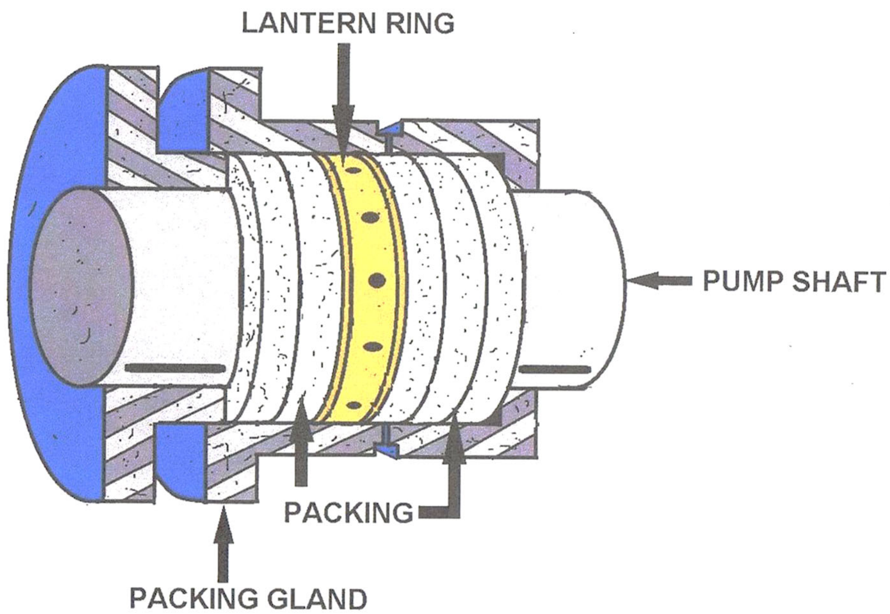
The type of material used for the seal faces will depend upon the service of the pump. Most water service pumps use a carbon material for one of the seal faces and ceramic (tungsten carbide) for the other. When the seals wear out, they are simply replaced.

You should replace a mechanical seal whenever the seal is removed from the shaft for any reason, or whenever leakage causes undesirable effects on equipment or surrounding spaces.

Do not touch a new seal on the sealing face because body acid and grease or dirt will cause the seal to pit prematurely and leak.

Mechanical shaft seals are positioned on the shaft by stub or step sleeves. Mechanical shaft seals must not be positioned by setscrews. Shaft sleeves are chamfered (beveled) on outboard ends for easy mechanical seal mounting.

Mechanical shaft seals serve to ensure that liquid pressure is supplied to the seal faces under all conditions of operation. They also ensure adequate circulation of the liquid at the seal faces to minimize the deposit of foreign matter on the seal parts.



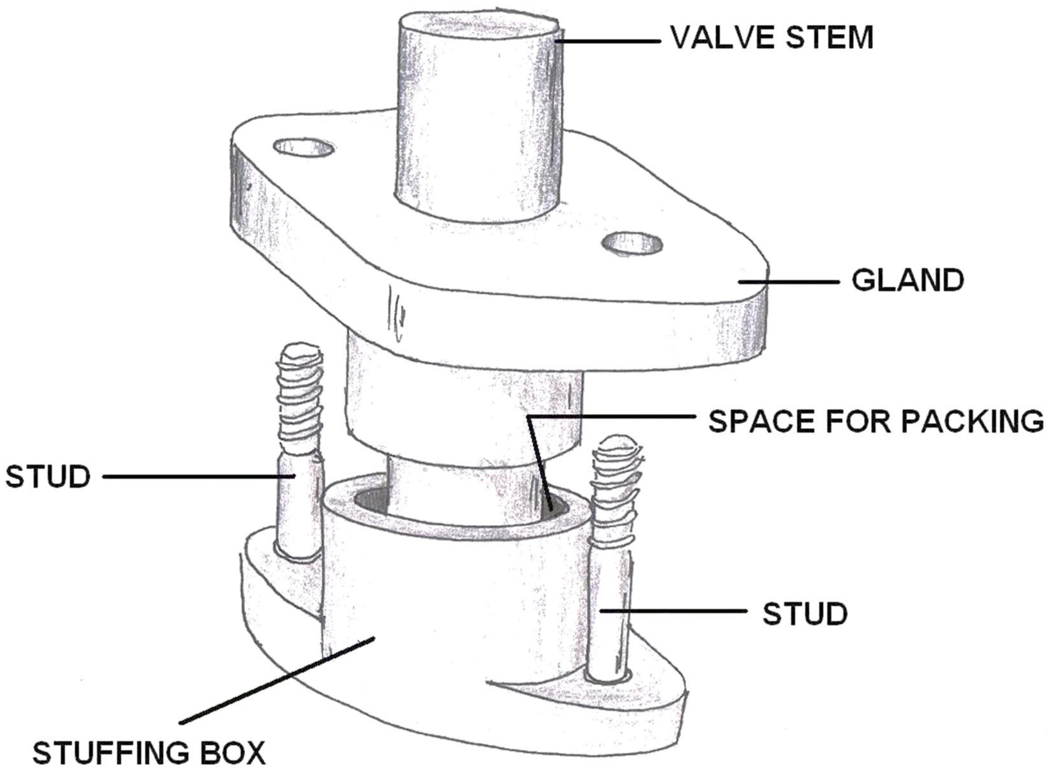
Choosing Coupling Gaskets

Using a gasket in a coupling that it was not made for is a common cause of leaky gaskets. Get the right gasket and the right kind of gasket for the fitting.

Flat Gaskets
Most are made of neoprene and are used on flanged, bolt-together fittings. They are usually not expensive. They normally fail by "creeping" out of their fitting. Look for new neoprene gaskets that contain a cotton backing sandwiched in the gasket to reduce the creeping action.

Shaped Gaskets
The three most common materials are styrene-butadiene (SBR), ethylene-propylene (EPDM), and polyethylene (poly). SBR and EPDM have much better resistance to cracking, abrasion, ozone, and weathering resistance than poly gaskets. They are more expensive than poly but will last longer. When buying shaped gaskets look for gaskets that are dull; this indicates that little or no plasticizer has been added to the gasket. Plasticizers significantly reduce gasket life.

Installation of Standard Stuffing Boxes



1. Stuffing Box

A. Slide the stuffing box over the shaft and fit into place (be sure to include the O-ring or gasket below the stuffing box flange). Bolt securely in place using the studs and nuts provided.

2. Packing

A. Insert four packing rings, fitting ends together so they contact face to face on the cut end. Turn each cut piece 90O from the previous piece. Be sure each piece is set against the piece below it.

CAUTION

Do not tamp packing tight in the stuffing box. Excessive tamping will stop the flow of fluid through the packing. This will result in the destruction of the shaft area.

3. Packing Gland

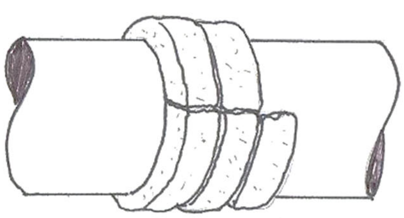
A. Thread the two studs in the threaded holes on top of the stuffing box. Insert the packing gland on top of the packing and pull snug (not tight). The packing gland nuts should be tightened together to keep equal pressure on the packing.

4. Slinger

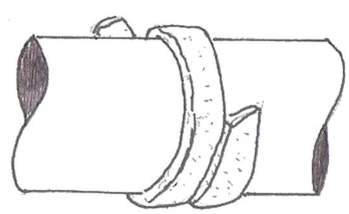
A. Attach slinger above packing gland.

CAUTION
The stuffing box must be allowed to leak for proper operation. The proper amount of leakage can be determined by checking the temperature of the leakage. This should be cool or just lukewarm, not hot. Shutting off leakage flow from the packing will result in burned packing and a scored shaft.

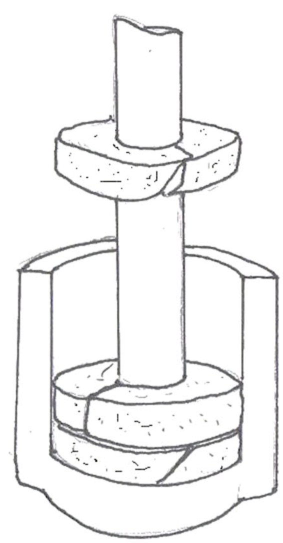
Installation of Optional Stuffing Boxes
A. Stuffing Box
A. Slide the stuffing box over the shaft and fit into place (be sure to include the O-ring or gasket on the bottom
side of the stuffing box in the groove provided. Bolt securely in place using the studs and nuts.
B. Packing
a. Insert the lower lantern ring (threaded holes up) in bottom of box.
b. Insert three packing rings, fitting ends together so they contact face to face on an angle. Turn each cut piece 90^{O} from the previous piece. Be sure each piece is set against the piece below it.
c. Insert the second lantern ring (threaded holes up) on top of the packing. The lantern ring should be aligned with the grease port.
d. Insert three more packing rings on top of the lantern ring, as before.
e. Thread two studs into the holes on top of the stuffing box.
f. Insert the packing gland on top of packing, press down snug. The packing gland nuts should be tightened together to keep equal pressure on the packing.
The packing must be allowed to leak for proper operation. The proper amount of leakage can be determined by checking the temperature of the leakage. This should be cool or just lukewarm, not hot.
g. Insert the grease zerk and grease with a high quality grease.
C. If high pressure bypass is necessary, remove bypass plug. Install bypass line back to suction side of pump or drain.
D. Attach a slinger above packing gland.



INCORRECT
(butt joint)



CORRECT
(skive joint)
(stagger @ 45 degree angle)



Pumping and Lift Station Chapter Highlights

Pump Stations
Proper operation, maintenance, and repair of pump stations typically requires special electrical, hydraulic, and mechanical knowledge. Pump station failure may damage equipment, the environment, or endanger public health. Variation in equipment types, pump station configuration, and geographical factors determine pump station design and O&M requirements.

The reviewer should verify that the O&M manual contains procedures in writing for the following:

- Are pumps rotated manually or automatically? If manually, how frequently?

- Are wet well operating levels set to limit pump starts and stops?

- Is there a procedure for manipulating pump operations (manually or automatically) during wet weather to increase in-line storage of wet weather flows?

- Is flow monitoring provided? How is the collected data used?

- Does the pump station have capacity-related overflows? Maintenance related overflows? Is overflow monitoring provided?

- Is there a history of power outages? Is there a source of emergency power? If the emergency power source is a generator, is it regularly exercised under load?

Operation and Maintenance (O&M) Activities
Proactive O&M initiatives are critical to effective prevention of SSOs. Nationwide, improved O&M activities such as implementation of hot spot cleaning programs, routine pipeline cleaning, and video inspections to find structural deficiencies have dramatically reduced the frequency and severity of SSOs in many cities.

Your system should conduct various types of proactive O&M activities throughout their service area.

Suggested goals of your system's wastewater collection system maintenance programs should be as follows:

- Maintain wastewater collection system flow capacity.
- Reduce the frequency and duration of overflow events.
- Optimize the use of resources.
- Optimize the life cycle of system components.
- Maintain accurate maintenance records.

Your section of the CMOM Plan shall include descriptions of maintenance facilities, mapping and data management, routine O&M activities, system repairs, and training.

Maintenance Program
Every collection system owner or operator should have a well-planned, systematic, and comprehensive maintenance program. The goals of a maintenance program should include:
- Prevention of overflows.
- Maximization of service and system reliability at minimum cost.
- Assurance of infrastructure sustainability (i.e., ensure all components reach their service life).

There should then be procedures which describe the maintenance approach for various systems. In addition, there should be detailed instructions for the maintenance and repair of individual facilities. These instructions should provide a level of detail such that any qualified collection system personnel or repair technician could perform the repair or maintenance activity.

Maintenance may be planned or unplanned. There are essentially two types of planned maintenance; predictive and preventive. Predictive maintenance is a method that tries to look for early warning signs of equipment failure such that emergency maintenance is avoided.

Preventive maintenance consists of scheduled maintenance activities performed on a regular basis. There are two types of unplanned maintenance, corrective and emergency. Corrective maintenance consists of scheduled repairs to problems identified under planned or predictive maintenance. Emergency maintenance is activities (typically repairs) performed in response to a serious equipment or line failure where action must be taken immediately. The goal of every owner or operator should be to reduce corrective and emergency maintenance through the use of planned and predictive maintenance. The reviewer should evaluate the progress of the owner or operator in achieving that goal.

The goals of the reviewer in assessment of the maintenance program are:
- Identify SSOs caused by inadequate maintenance.
- Determine maintenance trends (i.e., frequent emergency maintenance performed as opposed to predictive maintenance.)
- Identify sustainability issues (i.e., inadequate maintenance to allow system components to reach service life and/or many components nearing or at service life.)

Pump Station Inspection
Pump stations should be subject to inspection and preventive maintenance on a regular schedule. The frequency of inspection may vary from once a week, for a reliable pump station equipped with a telemetry system, to continuous staffing at a large pump station.

The basic inspection should include verification that alarm systems are operating properly, wet well levels are properly set, all indicator lights and voltage readings are within acceptable limits, suction and discharge pressures are within normal limits, that the pumps are running without excessive heat or vibration and have the required amount of lubrication, and that the emergency generator is ready if needed. Less frequent inspections may include such items as vibration analysis and internal inspection of pump components.

Pump Station Checklist

Observations and tasks performed should be recorded in a log book or on a checklist at the pump station. It is important to note how this data returns to the central maintenance data management system. At the time of the inspection, collection system personnel may perform minor repairs if necessary. If non-emergency repairs are required that are beyond the staff's training, it will probably be necessary to prepare a work order which routes a request though the proper channels to initiate the repair action. During the review the reviewer should check a random number of work orders to see how they move through the system. The reviewer should note whether repairs are being carried out promptly. In pump stations, for critical equipment (pumps, drives, power equipment, and control equipment), there should not be much backlog, unless the staff is waiting for parts.

During the review, the reviewer should also make on-site observations of representative pump stations. The reviewer should plan at least half an hour to look at the simplest two-pump prefabricated station, and one to two hours to look at a larger station. In large systems, drive time between stations may be significant. The reviewer should strive to see a range of pump station sizes and types (i.e., the largest, smallest, most remote, and any that review of work orders has indicated might be problematic).

Overall, the pump station should be clean, in good structural condition, and exhibit minimal odor. The reviewer should note the settings of the pumps (i.e., which are operating, which are on stand-by, and which are not operating and why). The operating pumps should be observed for noise, heat, and excessive vibration. The settings in the wet well should be noted (as indicated on the controls, as direct observation of the wet well by the reviewer is not recommended) and the presence of any flashing alarm lights.

Atmospheric Hazards

The reviewer is reminded of the atmospheric hazards in a pump station (make sure ventilation has been running prior to arrival) and to avoid confined space entry. If the pump station has an overflow its outlet should be observed, if possible, for signs of any recent overflows such as floatable materials or toilet paper. The reviewer should check the log book and/or checklist kept at the pump station to ensure that records are current and all maintenance activities have been performed. Below is a listing of items that indicate inadequate maintenance:

- Overall poor housekeeping and cleanliness.
- Excessive grease accumulation in wet well.
- Excessive corrosion on railings, ladders, and other metal components.
  - Sagging, worn, improperly sized, or inadequate belts.
- Excessive equipment out of service for repair or any equipment for which repair has not been ordered (i.e., a work order issued.)
  - Pumps running with excessive heat, vibration, or noise.
- Peeling paint and/or dirty equipment (the care given to equipment's outer surfaces often, but not always, mirrors internal condition.)
- Check valves not closing when pumps shut off.
- Inoperative instrumentation, alarms, and recording equipment.
  - "Jury-rigged" repairs (i.e., "temporary" repairs using inappropriate materials.)
- Leakage from pumps, piping, or valves (some types of pump seals are designed to "leak" seal water.)
- Inadequate lighting or ineffective/inoperative ventilation equipment.

Routine Preventative O&M Activities – Wastewater Lift Stations and Force Mains

Perform Regular Preventative Maintenance

The wastewater collections service technicians should perform regular preventative maintenance on the various components at the lift stations. An outside contractor may also be used to clean each lift station twice a year.

Most wastewater lift station and force main operations are typically remotely monitored and controlled through a telemetry or WIFI system that sends signals to the system's operation center. In the event of a malfunction, all of the lift stations should have redundant pump and pump monitoring systems, and all should have emergency backup power generation.

System Repairs

Deficiencies in the sewer system requiring repair are noted during cleaning and video inspections or are discovered through investigation of customer complaints. A Supervisor should arrange for all repairs; small repairs are often completed by the system's crews and larger repairs may be completed by a qualified outside contractor.

Deficiencies in lift stations and force mains requiring repair should be noted by the wastewater collections technicians during their routine visits, by alarms or through customer complaints. The Supervisor should make arrangements for all lift station and force main repairs.

Maintenance Budgeting

The cost of a maintenance program is a significant part of the annual operating budget. The collection system owner or operator should track all maintenance costs incurred throughout the year, both by internal staff and contractors, to ensure that the budget is based on representative costs from past years. Budgets should be developed from past cost records which usually are categorized according to preventive maintenance, corrective maintenance, and projected and actual major repair requirements. Annual costs should be compared to the budget periodically to control maintenance expenditures.

The reviewer should evaluate the maintenance budget, keeping in mind the system's characteristics, such as age. Costs for emergency repairs should be a relatively small percentage of the budget--five to ten percent would not be considered excessive. The establishment of an "emergency reserve" may also be included as part of the maintenance budget. This is especially useful where full replacement is not funded. The budget should also be considered in light of maintenance work order backlog.

Planned and Unplanned Maintenance

A planned maintenance program is a systematic approach to performing maintenance activities so that equipment failure is avoided. Planned maintenance is composed of predictive and preventive maintenance. In the end, a good planned maintenance program should reduce material, capital repair, and replacement costs, improve personnel utilization and morale, reduce SSOs, and sustain public confidence.

Examples of predictive maintenance includes monitoring equipment for early warning signs of impending failure, such as excess vibration, heat, dirty oil, and leakage. Assessment and inspection activities can be classified as predictive maintenance. Vibration and lubrication analyses, thermography, and ultrasonics are among the more common predictive maintenance tools.

Predictive maintenance also takes into account historical information about the system as all systems will deteriorate over time. A predictive maintenance program strives to identify potential problem areas and uncover trends that could affect equipment performance.
Predictive maintenance offers an early warning. It allows collection system personnel to detect early signs of increasing rates of wear and therefore failure, and thus shift a "corrective" task into a "planned" task. To be truly effectively predictive, however, maintenance should not spur personnel into doing the work too soon and wasting useful life and value of the equipment in question.

The reviewer should inquire as to whether tools such as vibration and lubrication analysis, thermography, or ultrasonics are used, and obtain information on the extent of the programs.

The basis of a good predictive maintenance program is recordkeeping. Only with accurate recordkeeping can baseline conditions be established, problem areas identified, and a proactive approach taken to repairs and replacement.

Effective preventive maintenance minimizes system costs and environmental impacts by reducing breakdowns and thus the need for corrective or emergency maintenance; improves reliability by minimizing the time equipment is out of service; increases the useful life of equipment, thus avoiding costly premature replacement; and avoids potential noncompliance situations.

An Effective Preventive Maintenance Program Includes:

- Trained personnel.
- Scheduling based on system specific knowledge.
- Detailed instructions related to the maintenance of various pieces of equipment.
- A system for recordkeeping.

System knowledge in the form of maps, historical knowledge and records. An effective preventive maintenance program builds on the inspection activities and predictive maintenance described above, and includes a well thought-out schedule for these activities.

The basis of the schedule for mechanical equipment maintenance (i.e., pump station components) should be the manufacturers' recommended activities and frequencies. This schedule may then be augmented by the knowledge and experience of collection system personnel to reflect the site-specific requirements.

The schedule for sewer line cleaning, inspection, root removal, and repair activities should be based on periodic inspection data. In most systems, uniform frequencies for sewer line cleaning, inspection, and root removal are not necessary and inefficient. In many systems, a relatively small percentage of the pipe generates most of the problems.

Efficient use of inspection data allows the owner or operator to implement a schedule in the most constructive manner. In rare cases it may be appropriate to reduce maintenance frequency for a particular piece of equipment.

Lubrication

Lubrication is probably one of the most important maintenance activities for mechanical systems, such as pumps and motors. Frequencies of lubrication, choice of lubricant and lubrication procedure are all important factors in this activity. These items should closely follow manufacturer instructions, but may be modified to fit site-specific conditions and particular equipment applications. An example of a scheduling code and maintenance schedule for a pump is shown below:

Rotary Pump Maintenance Schedule	
Frequency	Maintenance Required
D	Check packing gland assembly
D	Check discharge pressure
S	Inspect and lubricate bearings
A	Flush bearings and replace lubricant

D = Daily A = Annually S = Semiannually

Typically, there is a maintenance card or record for each piece of equipment within the collection system. These records should contain maintenance recommendations, schedule, and instructions on conducting the specific maintenance activity. The records should include documentation regarding any maintenance activities conducted to date and other observations related to that piece of equipment or system.

Maintenance records are generally kept where maintenance personnel have easy access to them. The reviewer should examine the full series of periodic work orders (i.e. weekly, monthly, semiannually, and annually) for a selection of system components (e.g., a few pump stations, several line segments).

The reviewer should then compare the recommended maintenance frequency to that which is actually performed. He or she should also look at the backlog of work; not focusing solely on the number of backlogged work orders, but on what that number represents in time. A very large system can have a hundred orders backlogged and only be one week behind. In a computerized system, a listing of all open work orders is usually very simple for collection system personnel to generate. The owner or operator should be able to explain their system for prioritizing work orders.

The reviewer needs to clearly understand the following:
• How the maintenance data management system works
• How work orders are generated and distributed
• How field crews use the work orders
• How data from the field is collected and returned
• How and on whose authority work orders are closed out

The reviewer should check to see if data entry is timely and up to date.

Unplanned Maintenance
Unplanned maintenance is that which takes place in response to equipment breakdowns or emergencies. Unplanned maintenance may be corrective or emergency maintenance. Corrective maintenance could occur as a result of preventive or predictive maintenance activities which identified a problem situation.

A work order should be issued so that the request for corrective maintenance is directed to the proper personnel. An example of non-emergency corrective maintenance could be a broken belt on a belt driven pump.

The worn belt was not detected and replaced through preventive maintenance and therefore the pump is out of service until corrective maintenance can be performed. Although the pump station may function with one pump out of service, should another pump fail, the situation may become critical during peak flow periods.

If the information can be easily generated the reviewer should select a sampling of work orders and compare them to the corrective maintenance database to determine if repairs are being made in a timely manner. Reviewers should note the current backlog of corrective maintenance work orders. A corrective maintenance backlog of two weeks or less would indicate an owner or operator in control of corrective maintenance. The owner or operator should be able to explain corrective maintenance work orders that have not been completed within six months.

Corrective Maintenance
Corrective maintenance takes resources away from predictive and preventive maintenance. When corrective maintenance becomes a predominant activity, personnel may not be able to perform planned maintenance, thus leading to more corrective maintenance and emergency situations. Emergency maintenance occurs when a piece of equipment or system fails, creating a threat to public health, the environment, or associated equipment. This type of maintenance involves repairs on short notice, of malfunctioning equipment or sewers. A broken force main, totally non-functional pump station and street cave-ins are all examples of emergency situations.

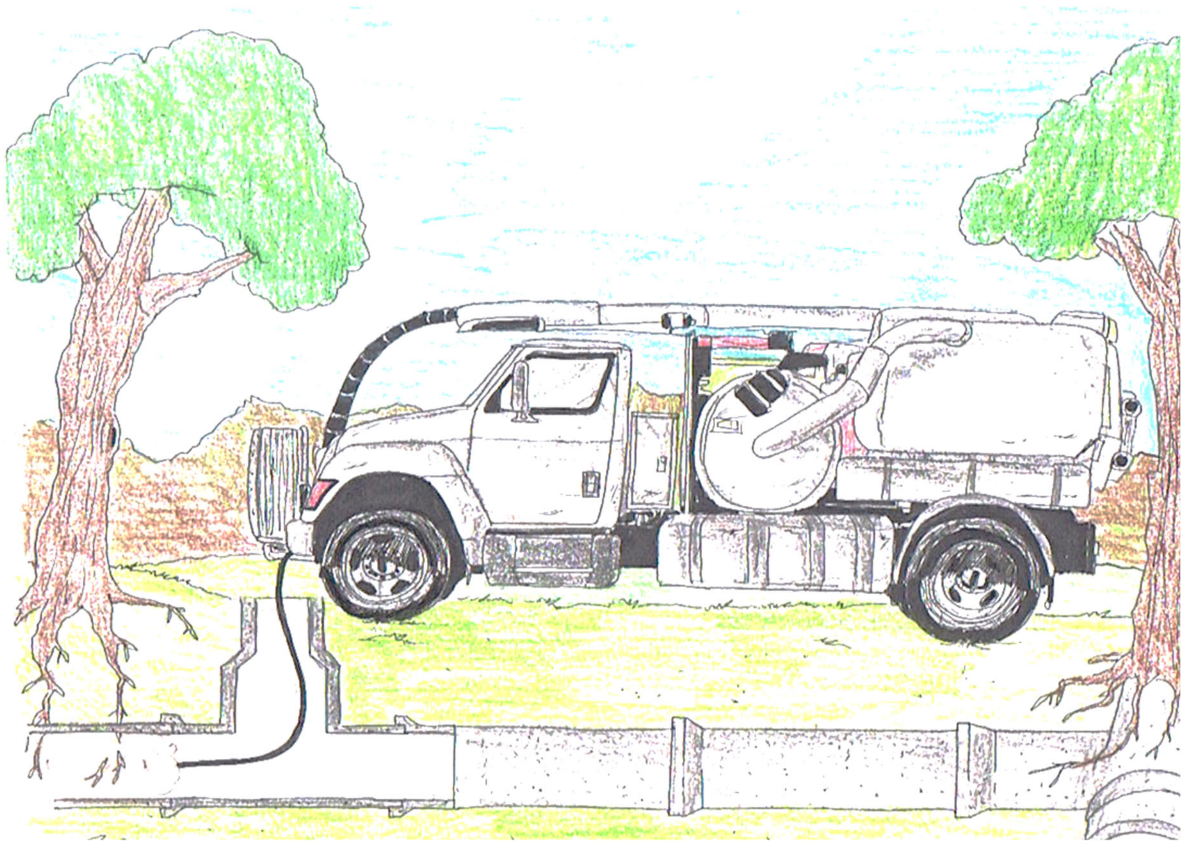
Types of Portable Emergency Equipment
- Bypass pumps
- Portable generator
- Air compressor, trailer-mounted
- Manhole lifters and gas testing equipment
- Sewer rodder and/or flushing machine
- Portable lights and hand tools
- Chemical spray units (for insects and rodent control)
- Truck (1-ton) and trailers
- Vacuum truck
- Repair equipment for excavation (backhoe, shoring equipment, concrete mixers, gasoline operated saws, traffic control equipment, etc.)
- Confined space entry gear

Emergency Crews
Emergency crews should be geared to a 24-hour-a-day, year-round operation. Most large systems have staffed 24-hour crews; many small systems have an "on-call" system. The owner or operator should be able to produce written procedures which spell out the type of action to take in a particular type of emergency and the equipment and personnel requirements necessary to carry out the action.

The crews should have copies of these procedures and be familiar with them. Equipment must be located in an easily accessible area and be ready to move in a short period of time.

Vehicles and equipment must be ready to perform, under extreme climatic conditions if necessary. The emergency crew may need materials such as piping, pipe fittings, bedding materials, and concrete. The owner or operator should have supplies on hand to allow for two point (i.e. segment, fitting, or appurtenance) repairs of any part of its system.

The reviewer should note the presence of supplies during the review of the yard where equipment and spare parts are maintained and personnel are dispatched.



The best method of controlling hydrogen sulfide is to eliminate its habitat or growth area by keeping sewers cleaner, this will harbor fewer slime bacteria.

Post Quiz

1. _______________are rapidly replacing conventional packing as the means of controlling leakage on rotary and positive-displacement pumps.

2. Mechanical seals eliminate the problem of excessive ___________leakage, which causes failure of pump and motor bearings and motor windings.

3. Mechanical seals are ideal for pumps that operate in________________. They not only conserve the fluid being pumped, but also improve system operation.

4. Most water service pumps use a carbon material for one of the ____________and ceramic (tungsten carbide) for the other. When the seals wear out, they are simply replaced.

5. You should replace a ________________whenever the seal is removed from the shaft for any reason, or whenever leakage causes undesirable effects on equipment or surrounding spaces.

6. ______________ a new seal on the sealing face because body acid and grease or dirt will cause the seal to pit prematurely and leak.

7. Mechanical shaft seals are positioned on the shaft by stub or step sleeves. Mechanical shaft seals must not be positioned by______________.

8. _______________are chamfered (beveled) on outboard ends for easy mechanical seal mounting.

9. Mechanical shaft seals serve to ensure that ____________is supplied to the seal faces under all conditions of operation. They also ensure adequate circulation of the liquid at the seal faces to minimize the deposit of foreign matter on the seal parts.

10. If the packing is allowed to dry out, it will score______________.

11. When operating a centrifugal pump, be sure there is always a slight trickle of water coming out of the_________________.

12. How often the __________in a centrifugal pump should be renewed depends on several factors, such as the type of pump, condition of the shaft sleeve, and hours in use.

13. To ensure the longest possible service from pump packing, make certain the shaft or sleeve is smooth when the packing is removed from_____________.

14. Rapid wear of the packing will be caused by _____________(or shaft where no sleeve is installed).

15. When replacing packing, be sure the packing fits uniformly around___________.

Answers: 1. Mechanical seals, 2. Stuffing box, 3. Closed systems, 4. Seal faces, 5. Mechanical seal, 6. Do not touch, 7. Setscrews, 8. Shaft sleeves, 9. Liquid pressure, 10. The shaft, 11. Stuffing box or seal, 12. Packing, 13. A gland, 14. Roughness of the shaft sleeve, 15. The stuffing box

Chapter 5 – HYDROGEN SULFIDE SECTION

Section Focus: You will learn the basics of hydrogen sulfide gas. At the end of this section, you the student will be able to understand and describe the dangers of hydrogen sulfide gas. There is a post quiz at the end of this section to review your comprehension and a final examination in the Assignment for your contact hours.

Scope/Background: Hydrogen sulfide (H_2S) is a colorless gas with a strong odor of rotten eggs. Exposure to hydrogen sulfide may cause irritation to the eyes and respiratory system. It can also cause apnea, coma, convulsions; dizziness, headache, weakness, irritability, insomnia; stomach upset, and if liquid: frostbite. Workers may be harmed from exposure to hydrogen sulfide. The level of exposure depends upon the dose, duration, and work being done.

The corrosive effects of Sulfuric acid are created by Hydrogen Sulfide gas.

COMMON HAZARDOUS GASES THAT MAY BE PRESENT IN CONFINED SPACE					
SUBSTANCE *	8-HOUR TIME-WEIGHTED AVERAGE (TWA)	15-MINUTE SHORT-TERM EXPOSURE LIMIT (STEL)	CEILING LIMIT (Never To Be Exceeded)	IMMEDIATELY DANGEROUS TO LIFE AND HEALTH (IDLH)	RECOMMENDED ALARM SETTINGS (Low / High)
AMMONIA	25 ppm	35 ppm	—	300 ppm	13 ppm / 25 ppm
CARBON MONOXIDE	25 ppm	100 ppm	—	1200 ppm	13 ppm / 25 ppm
CHLORINE	0.5 ppm	1 ppm	—	10 ppm	0.25 ppm / 0.5 ppm
HYDROGEN SULFIDE	—	—	10 ppm	100 ppm	5 ppm / 10 ppm
METHANE	1000 ppm	—	—	—	500 ppm / 1000 ppm
NITROGEN DIOXIDE	—	—	1 ppm	20 ppm	0.5 ppm / 1 ppm
SULFUR DIOXIDE	2 ppm	5 ppm	—	100 ppm	1 ppm / 2 ppm
OXYGEN	—	—	—	—	20.5 % of Atmosphere
LOWER EXPLOSIVE LIMIT (LEL)	—	—	—	—	5 % LEL

EXAMPLE OF A CHART OF CONFINED SPACE GASES

Hydrogen Sulfide Gas

This section provides answers to basic questions about hydrogen sulfide gas. It will explain what hydrogen sulfide gas is, where it is found, how it can affect your health, and what you can do to prevent or reduce exposure to it. Hydrogen sulfide gas is also known as "sewer gas" because it is often produced by the decay of waste material. Hydrogen sulfide gas has a strong odor at low levels. At higher levels, your nose can become overwhelmed by the gas and you cannot smell it. At these higher levels, hydrogen sulfide gas can make you sick and even kill you.

Hydrogen Sulfide Gas
If you wait for a warning, it may be too late
Hydrogen sulfide is a powerful and deadly gas which smells like rotten eggs at low concentrations and has a sweet smell at high concentrations. But workers should not rely on the smell as a warning. At high concentrations H_2S may overcome one's sense of smell. The result could be instant death. Long exposure to low concentrations will also deaden the sense of smell.

What it is
H_2S is explosive - it will ignite and explode when subjected to a spark or an ordinary flame - in any concentration from 4% to 44% of the air. It is also soluble in water and oil, so it may flow for a considerable distance from its origin before escaping above ground or in an entirely unexpected place. Because the vapor (gas) is heavier than air, it may travel for a long way until ignited and then flash back towards the source. Hydrogen sulfide is found in large amounts in the wastewater collection system.

H_2S Sources
H_2S is easily found widely in our industry and a good manager will warn operators of its dangers or of their exposure. It is formed by the decomposition of organic materials, so it is found in sewers and cesspools.

Health Effects of H_2S Acute Exposure
Most importantly, H_2S will kill you. The extent of acute poisoning danger depends on the concentration of H_2S in the atmosphere. When you breathe in H_2S, it goes directly through your lungs and into your bloodstream. To protect itself, your body "oxidizes" (breaks down) the H_2S as rapidly as possible into a harmless compound. If you breathe in so much H_2S that your body can't oxidize all of it, the H_2S builds up in the blood and you become poisoned. The nervous centers in your brain which control breathing are paralyzed.

Your lungs stop working and you asphyxiate--just as though someone had come up and put their hands around your neck and strangled you. A worker can be overcome by H_2S and lose consciousness in a few seconds. If he is luckily rescued in time and is given artificial respiration within a few minutes, the worker may recover.

This is acute poisoning. It can occur with no warning at all, since even the sense of smell may be overcome, and it can be fatal within a few seconds. Although acute poisoning is deadly if it is not caught in time, when caught and treated it is reversible; this is why rescue attempts with proper safety equipment are so important. Recent evidence has shown irreversible brain damage from acute high doses.

Chronic Effects

H_2S can also cause a wide range of sub-acute and chronic effects. At very low concentrations of 10-100 ppm, headache, dizziness, nausea and vomiting may develop, together with irritation of the eyes and respiratory tract (the lungs and trachea and bronchi, or air pipes from the nose and mouth to the lungs). The eyes become red, sore, inflamed, and sensitive to light. Respiratory system effects include cough, pain in the nose and throat, and painful breathing.

If exposure at low levels continues, the worker may develop a state of chronic poisoning. In addition to eye and respiratory tract irritation, there will be a slowed pulse rate, fatigue, insomnia, digestive disturbances, and cold sweats. More dangerous, if exposure at the level of 100 ppm (which results in eye and respiratory tract irritation and drowsiness after 15 minutes) lasts for several hours, it may result in death within the next 48 hours. Symptoms of chronic exposures at low levels are conjunctivitis (eye infections), headache, and attack of dizziness, diarrhea, and loss of weight. Chronic hydrogen sulfide intoxication is marked by headaches, eye disorders, chronic bronchitis, and a grey-green line on the gums. Reports of nervous system disorders including paralysis, meningitis, and neurological problems have been reported, but not confirmed. A study of workers and community residents of a California Wastewater Treatment facility forum complained of headaches, nausea, vomiting, depression, personality changes, nosebleeds and breathing difficulties. When compared to a non-exposed group of people, the exposed people showed abnormalities of color discrimination, hand-eye coordination, balance, and mood disturbances. In rats, exposure to hydrogen sulfide has caused teratogenic effects.

How Much is Safe?

The OSHA Permissible Exposure Limit (PEL) for a ceiling concentration is 20 ppm hydrogen sulfide, a level which may not ever be exceeded. The acceptable maximum peak, for 10 minutes only, once during an 8 hour day if there is no other measurable exposure, is 50 ppm.

There is no time-weighted average because H_2S is so fast-acting that no fluctuations above 20 ppm are safe; only one peak per day is allowed. This level is too high and recent recommendations are that it be lowered to 10 ppm. You should remember, however, that H_2S is an invisible gas, floating freely and unpredictably, and a reading even below a 10 ppm Permissible Exposure Limit (PEL) may not guarantee your safety. There are no particular medical exams for exposure to H_2S.

Work Practices and Emergency Procedures

Whenever you enter a confined space such as a tank, make sure that you follow strict work practices, including a permit system. Make sure that the Confined Space Entry Standard 1910.146 is followed, that the air is continually monitored for the presence of H_2S, and that an attendant be stationed outside a confined space. Both of you should wear supplied air and lifelines and rescue equipment must be immediately available.

- **If you work with H_2S make sure that...**
  Your employer has trained you in the hazards of H_2S.
  Your employer has appropriate rescue equipment onsite.

Hazard Information Bulletin

Following are excerpts from a Hazard Bulletin issued by OSHA after a fatality due to H_2S exposure.

Fundamentally, employers and employees must be alert to the fact that working with a "closed system" does not always ensure safety. Operations involving the opening of valves or pumps on otherwise closed systems, or working on such equipment that is not isolated or locked out, are particular sources of danger. When a normally closed system is opened, the potential exists for releasing hazardous chemicals into the workers' breathing zones in unknown concentrations.

Respiratory Protection -- Respirators must be provided by the employer when effective engineering controls are not feasible, or while they are being instituted, when such equipment is necessary to protect the health of the worker. The employer must provide respirators that are applicable for the purpose intended. Written procedures must be developed for the safe use of respirators during the performance of operations presenting a potential exposure to hazardous chemicals. Under circumstances where individuals may be exposed to an unknown concentration of hydrogen sulfide or some other hazardous chemical, back-up personnel with appropriate respirators and emergency equipment must be present.

You must be careful around sewer mains and always be careful of Hydrogen Sulfide and Carbon Monoxide gases. Never try to enter a confined space to rescue a downed employee unless you have been trained in rescue procedures and have called 911 first.

Hydrogen Sulfide Highlights

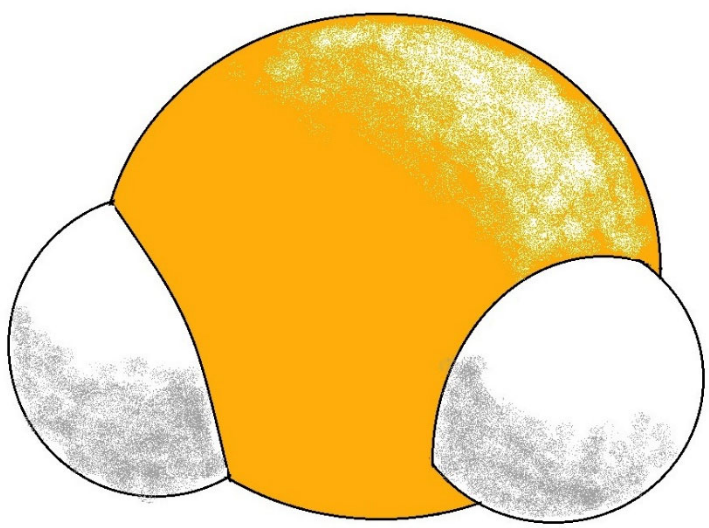
Hydrogen sulfide or H_2S problems are very common in the collection and wastewater system. There are many chemicals used to help or treat this problem. Salts of zinc, lime, hydrogen peroxide, chlorine and magnesium hydroxide are used in the treatment of hydrogen sulfide problems.

Hydrogen sulfide production in collection systems can cause a number of problems, including the following: Corrosion of the pipes and manholes, creation of hazardous atmospheres and foul odors.

The best method of controlling hydrogen sulfide is to eliminate its habitat or growth area by keeping sewers cleaner, this will harbor fewer slime bacteria.

Statements regarding the reduction of hydrogen sulfide: Salts of zinc and iron may precipitate sulfides, lime treatments can also kill bacteria that produces hydrogen sulfide, but this creates a sludge disposal problem. Chlorination is effective at reducing the bacteria which produce hydrogen sulfide.

Hydrogen sulfide conditions occur in the sewer system because of the lack of oxygen.



H_2S

Hydrogen Sulfide Post-Quiz

1. At very low H_2S concentrations of _______________ ppm, headache, dizziness, nausea and vomiting may develop, together with irritation of the eyes and respiratory tract.

2. At very _______________ H_2S concentrations, respiratory system effects include cough, pain in the nose and throat, and painful breathing.

3. More dangerous, if exposure at the level of 100 ppm (which results in eye and respiratory tract irritation and drowsiness after 15 minutes) lasts for several hours, it may result in death within the next _________________hours.

How Much is Safe?

4. The OSHA Permissible Exposure Limit (PEL) for a ceiling concentration is _____________ ppm hydrogen sulfide, a level which may not ever be exceeded.

5. The acceptable maximum peak, for 10 minutes only, once during an ______________ hour day if there is no other measurable exposure, is 50 ppm.

6. There is no time-weighted average because H_2S is so fast-acting that no fluctuations above _______________ ppm are safe; only one peak per day is allowed. This level is too high and recent recommendations are that it be lowered to 10 ppm.

7. You should remember, however, that H_2S is an invisible gas, floating freely and unpredictably, and a reading even below a ______________ppm Permissible Exposure Limit (PEL) may not guarantee your safety. There are no particular medical exams for exposure to H_2S.

Work Practices and Emergency Procedures

8. Whenever you enter a confined space such as a tank, make sure that you follow work recommendations, including some type of permit system. True or False

9. Make sure that the Confined Space Entry Standard 1910.146 is followed, that the air is continually monitored for the presence of H_2S, and that an attendant be stationed outside a confined space. Both of you should wear supplied air and lifelines and rescue equipment must be immediately available. True or False

10. Respirators must be provided by the employer when effective engineering controls are not feasible, or while they are being instituted, when such equipment is necessary to protect the health of the worker. True or False

Answers

1. 10-100, 2. Low, 3. 48, 4. 20, 5. 8, 6. 20, 7. 10,8. False, 9. True, 10. True

Math Conversion Factors

1 PSI = 2.31 Feet of Water
1 Foot of Water = .433 PSI
1.13 Feet of Water = 1 Inch of Mercury
454 Grams = 1 Pound
2.54 CM =Inch
1 Gallon of Water = 8.34 Pounds
1 mg/L = 1 PPM
17.1 mg/L = 1 Grain/Gallon
1% = 10,000 mg/L
694 Gallons per Minute = MGD
1.55 Cubic Feet per Second = 1 MGD
60 Seconds = 1 Minute
1440 Minutes = 1 Day
.746 kW = 1 Horsepower

LENGTH
12 Inches = 1 Foot
3 Feet = 1 Yard
5280 Feet = 1 Mile

AREA
144 Square Inches = 1 Square Foot
43,560 Square Feet =1 Acre

VOLUME
1000 Milliliters = 1 Liter
3.785 Liters = 1 Gallon
231 Cubic Inches = 1 Gallon
7.48 Gallons = 1 Cubic Foot of water
62.38 Pounds = 1 Cubic Foot of water

Dimensions

SQUARE: Area (sq.ft.) = Length X Width
Volume (cu.ft.) = Length (ft) X Width (ft) X Height (ft)

CIRCLE: Area (sq.ft.) = 3.14 X Radius (ft) X Radius (ft)

CYLINDER: Volume (Cu. ft) = 3.14 X Radius (ft) X Radius (ft) X Depth (ft)

PIPE VOLUME: .785 X Diameter ^{2} X Length = ? To obtain gallons multiply by 7.48

SPHERE: $\frac{(3.14)\ (\text{Diameter})^3}{(6)}$

Circumference = 3.14 X Diameter

General Conversions

Flowrate

Multiply	**—>**	**to get**
to get	**<—**	**Divide**
cc/min	1	mL/min
cfm (ft^3/min)	28.31	L/min
cfm (ft^3/min)	1.699	m^3/hr
cfh (ft^3/hr)	472	mL/min
cfh (ft^3/hr)	0.125	GPM
GPH	63.1	mL/min
GPH	0.134	cfh
GPM	0.227	m^3/hr
GPM	3.785	L/min
oz/min	29.57	mL/min

POUNDS PER DAY= Concentration (mg/L) X Flow (MG) X 8.34
***A.K.A.* Solids Applied Formula** = Flow X Dose X 8.34

PERCENT EFFICIENCY = $\frac{\text{In} - \text{Out}}{\text{In}} \times 100$

TEMPERATURE: $^0F = (^0C \times 9/5) + 32$ $9/5 = 1.8$
$^0C = (^0F - 32) \times 5/9$ $5/9 = .555$

CONCENTRATION: Conc. (A) X Volume (A) = Conc. (B) X Volume (B)

FLOW RATE (Q): Q = A X V (**Q**uantity = **A**rea X **V**elocity)

FLOW RATE (gpm): Flow Rate (gpm) = $\frac{2.83 \text{ (Diameter, in)}^2 \text{ (Distance, in)}}{\text{Height, in}}$

% SLOPE = $\frac{\text{Rise (feet)}}{\text{Run (feet)}} \times 100$

ACTUAL LEAKAGE = $\frac{\text{Leak Rate (GPD)}}{\text{Length (mi.) X Diameter (in)}}$

VELOCITY = $\frac{\text{Distance (ft)}}{\text{Time (Sec)}}$

N = Manning's Coefficient of Roughness
R = Hydraulic Radius (ft.)
S = Slope of Sewer (ft/ft.)

HYDRAULIC RADIUS (ft) = $\frac{\text{Cross Sectional Area of Flow (ft)}}{\text{Wetted pipe Perimeter (ft)}}$

WATER HORSEPOWER = $\frac{\text{Flow (gpm) X Head (ft)}}{3960}$

BRAKE HORSEPOWER = $\frac{\text{Flow (gpm) X Head (ft)}}{\text{3960 X Pump Efficiency}}$

MOTOR HORSEPOWER = $\frac{\text{Flow (gpm) X Head (ft)}}{\text{3960 X Pump Eff. X Motor Eff.}}$

MEAN OR AVERAGE = $\frac{\text{Sum of the Values}}{\text{Number of Values}}$

TOTAL HEAD (ft) = Suction Lift (ft) X Discharge Head (ft)

SURFACE LOADING RATE (gal/min/sq.ft) = $\frac{\text{Flow Rate (gpm)}}{\text{Surface Area (sq. ft)}}$

MIXTURE STRENGTH (%) = $\frac{\text{(Volume 1, gal) (Strength 1, \%) + (Volume 2, gal) (Strength 2,\%)}}{\text{(Volume 1, gal) + (Volume 2, gal)}}$

INJURY FREQUENCY RATE = $\frac{\text{(Number of Injuries) 1,000,000}}{\text{Number of hours worked per year}}$

DETENTION TIME (hrs) = $\frac{\text{Volume of Basin (gals) X 24 hrs}}{\text{Flow (GPD)}}$

SLOPE = $\frac{\text{Rise (ft)}}{\text{Run (ft)}}$ **SLOPE (%)** = $\frac{\text{Rise (ft) X 100}}{\text{Run (ft)}}$

POPULATION EQUIVALENT (PE):

1 PE = .17 Pounds of BOD per Day
1 PE = .20 Pounds of Solids per Day
1 PE = 100 Gallons per Day

LEAKAGE (GPD/inch) = $\frac{\text{Leakage of Water per Day (GPD)}}{\text{Sewer Diameter (inch)}}$

CHLORINE DEMAND (mg/L) = Chlorine Dose (mg/L) – Chlorine Residual (mg/L)

MANNING FORMULA

τQ = Allowable time for decrease in pressure from 3.5 PSI to 2.5 PSI
τq = As below

$\tau Q = (0.022)\,(d_1^2 L_1)/Q$ $\quad \tau q = \frac{[\,0.085]}{q}\,[(d_1^2 L1)/(d_1 L_1)]$

Q = 2.0 cfm air loss
θ = .0030 cfm air loss per square foot of internal pipe surface
δ = Pipe diameter (inches)
L = Pipe Length (feet)

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

V = Velocity (ft./sec.)
ν = Pipe Roughness
R = Hydraulic Radius (ft)
S= Slope (ft/ft)

HYDRAULIC RADIUS (ft) = $\frac{\text{Flow Area (ft.}^2)}{\text{Wetted Perimeter (ft.)}}$

WIDTH OF TRENCH (ft) = Base (ft) + (2 Sides) X $\frac{\text{Depth (ft}^2)}{\text{Slope}}$

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Conversion Factors

1 acre = 43,560 square feet
1 cubic foot = 7.48 gallons
1 foot = 0.305 meters
1 gallon = 3.785 liters
1 gallon = 8.34 pounds
1 grain per gallon = 17.1 mg/L
1 horsepower = 0.746 kilowatts
1 million gallons per day = 694.45 gallons per minute
1 pound = 0.454 kilograms
1 pound per square inch = 2.31 feet of water
1% = 10,000 mg/L
Degrees Celsius = (Degrees Fahrenheit - 32) (5/9)
Degrees Fahrenheit = (Degrees Celsius * 9/5) + 32
64.7 grains = 1 cubic foot
1,000 meters = 1 kilometer
1,000 grams = 1 kilogram

Formula/Conversion Table

Acid Feed Rate = $\frac{\text{(Waste Flow) (Waste Normality)}}{\text{Acid Normality}}$

Alkalinity = $\frac{\text{(mL of Titrant) (Acid Normality) (50,000)}}{\text{mL of Sample}}$

Amperage = Voltage ÷ Ohms

Area of Circle = (0.785)(Diameter^2) OR (π)(Radius^2)

Area of Rectangle = (Length)(Width)

Area of Triangle = $\frac{\text{(Base) (Height)}}{2}$

C Factor Slope = Energy loss, ft. ÷ Distance, ft.

C Factor Calculation = Flow, GPM ÷ [193.75 (Diameter, ft.)2.63(Slope)0.54]

Chemical Feed Pump Setting, % Stroke = $\frac{\text{(Desired Flow) (100\%)}}{\text{Maximum Flow}}$

Chemical Feed Pump Setting, mL/min =
$\frac{\text{(Flow, MGD) Dose, mg/L) (3.785L/gal) (1,000,000 gal/MG)}}{\text{(Liquid, mg/mL) (24 hr. / day) (60 min/hr.)}}$

Chlorine Demand (mg/L) = Chlorine dose (mg/L) – Chlorine residual (mg/L)

Circumference of Circle = (3.141) (Diameter)

Composite Sample Single Portion = $\frac{\text{(Instantaneous Flow) (Total Sample Volume)}}{\text{(Number of Portions) (Average Flow)}}$

Detention Time = $\frac{\text{Volume}}{\text{Flow}}$

Digested Sludge Remaining, % = $\frac{\text{(Raw Dry Solids) (Ash Solids) (100\%)}}{\text{(Digested Dry Solids) (Digested Ash Solids)}}$

Discharge = $\frac{\text{Volume}}{\text{Time}}$

Dosage, lbs/day = (mg/L)(8.34)(MGD)

Dry Polymer (lbs.) = (gal. of solution) (8.34 lbs/gal)(% polymer solution)

$$\text{Efficiency, \%} = \frac{(\text{In} - \text{Out})\ (100\%)}{\text{In}}$$

$$\text{Feed rate, lbs/day} = \frac{(\text{Dosage, mg/L})\ (\text{Capacity, MGD})\ (8.34\ \text{lbs/gals})}{(\text{Available fluoride ion})\ (\text{Purity})}$$

$$\text{Feed rate, gal/min (Saturator)} = \frac{(\text{Plant capacity, gal/min.})\ (\text{Dosage, mg /L})}{18{,}000\ \text{mg/L}}$$

$$\text{Filter Backwash Rate} = \frac{\text{Flow}}{\text{Filter Area}}$$

$$\text{Filter Yield, lbs/hr./sq. ft} = \frac{(\text{Solids Loading, lbs/day})\ (\text{Recovery, \% / 100\%})}{(\text{Filter operation, hr./day})\ (\text{Area, ft2})}$$

Flow, cu. ft./sec. = (Area, Sq. Ft.)(Velocity, ft./sec.)

$$\text{Gallons/Capita/Day} = \frac{\text{Gallons / day}}{\text{Population}}$$

$$\text{Hardness} = \frac{(\text{mL of Titrant})\ (1{,}000)}{\text{mL of Sample}}$$

$$\text{Horsepower (brake)} = \frac{(\text{Flow, gpm})\ (\text{Head, ft})}{(3{,}960)\ (\text{Efficiency})}$$

$$\text{Horsepower (motor)} = \frac{(\text{Flow, gpm})\ (\text{Head, ft})}{(3960)\ (\text{Pump, Eff})\ (\text{Motor, Eff})}$$

$$\text{Horsepower (water)} = \frac{(\text{Flow, gpm})\ (\text{Head, ft})}{(3960)}$$

$$\text{Hydraulic Loading Rate} = \frac{\text{Flow}}{\text{Area}}$$

Leakage (actual) = Leak rate (GPD) ÷ [Length (mi.) x Diameter (in.)]

Mean = Sum of values ÷ total number of values

$$\text{Mean Cell Residence Time (MCRT)} = \frac{\text{Suspended Solids in Aeration System, lbs}}{\text{SS Wasted, lbs / day} + \text{SS lost, lbs / day}}$$

$$\text{Organic Loading Rate} = \frac{\text{Organic Load, lbs BOD / day}}{\text{Volume}}$$

$$\text{Oxygen Uptake} = \frac{\text{Oxygen Usage}}{\text{Time}}$$

Pounds per day = (Flow, MGD) (Dose, mg/L) (8.34)

$$\text{Population Equivalent} = \frac{\text{(Flow MGD) (BOD, mg/L) (8.34 lbs / gal)}}{\text{Lbs BOD / day / person}}$$

$$\text{RAS Suspended Solids, mg/l} = \frac{1{,}000{,}000}{\text{SVI}}$$

$$\text{RAS Flow, MGD} = \frac{\text{(Infl. Flow, MGD) (MLSS, mg/l)}}{\text{RAS Susp. Sol., mg/l – MLSS, mg/l}}$$

$$\text{RAS Flow \%} = \frac{\text{(RAS Flow, MGD) (100 \%)}}{\text{Infl. Flow, MGD}}$$

$$\text{Reduction in Flow, \%} = \frac{\text{(Original Flow – Reduced Flow) (100\%)}}{\text{Original Flow}}$$

$$\text{Slope} = \frac{\text{Drop or Rise}}{\text{Run or Distance}}$$

$$\text{Sludge Age} = \frac{\text{Mixed Liquor Solids, lbs}}{\text{Primary Effluent Solids, lbs / day}}$$

$$\text{Sludge Index} = \frac{\text{\% Settleable Solids}}{\text{\% Suspended Solids}}$$

$$\text{Sludge Volume Index} = \frac{\text{(Settleable Solids, \%) (10,000)}}{\text{MLSS, mg/L}}$$

$$\text{Solids, mg/L} = \frac{\text{(Dry Solids, grams) (1,000,000)}}{\text{mL of Sample}}$$

Solids Applied, lbs/day = (Flow, MGD)(Concentration, mg/L)(8.34 lbs/gal)

$$\text{Solids Concentration} = \frac{\text{Weight}}{\text{Volume}}$$

Solids Loading, lbs/day/sq. ft = $\frac{\text{Solids Applied, lbs / day}}{\text{Surface Area, sq. ft}}$

Surface Loading Rate = $\frac{\text{Flow}}{\text{Rate}}$

Total suspended solids (TSS), mg/L =
(Dry weight, mg)(1,000 mL/L) ÷ (Sample vol., mL)

Velocity = $\frac{\text{Flow}}{\text{Area}}$ O R $\frac{\text{Distance}}{\text{Time}}$

Volatile Solids, % = $\frac{\text{(Dry Solids - Ash Solids) (100\%)}}{\text{Dry Solids}}$

Volume of Cone = (1/3)(0.785)(Diameter^2)(Height)

Volume of Cylinder = (0.785)(Diameter^2)(Height) OR (π)(r^2)(h)

Volume of Rectangle = (Length)(Width)(Height)

Volume of Sphere = [(π)(diameter^3)] ÷ 6

Waste Milliequivalent = (mL) (Normality)

Waste Normality = $\frac{\text{(Titrant Volume) (Titrant Normality)}}{\text{Sample Volume}}$

Weir Overflow Rate = $\frac{\text{Flow}}{\text{Weir Length}}$

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Other Guidance Documents that can help you

Guidance Manual For Implementing Total Toxic Organics (TTO) Pretreatment Standards

Guidance Manual for Preparation and Review of Removal Credit Applications

Guidance Manual for Preventing Interference at POTWs

Guidance Manual for the Identification of Hazardous Wastes Delivered to Publicly Owned Treatment Works by Truck, Rail, or Dedicated Pipe

Guidance Manual for the Use of Production-Based Pretreatment Standards and the Combined Wastestream Formula

Guidance Manual on the Development and Implementation of Local Discharge Limitations Under the Pretreatment Program

Guidance to Protect POTW Workers From Toxic And Reactive Gases And Vapors

Prelim User's Guide, Documentation for the EPA Computer Program/Model for Developing Local Limits for Industrial Pretreatment Programs at Publicly Owned Treatment Works

Supplemental Manual On the Development And Implementation of Local

Discharge Limitations Under The Pretreatment Program: Residential and Commercial

Toxic Pollutant Loadings And POTW Removal Efficiency Estimation

CERCLA Site Discharges to POTWs Guidance Manual

Control of Slug Loadings To POTWs: Guidance Manual

Guidance For Developing Control Authority Enforcement Response Plans

Guidance Manual for POTWs to Calculate the Economic Benefit of Noncompliance

Industrial User Inspection and Sampling Manual For POTWs

Industrial User Permitting Guidance Manual

Model Pretreatment Ordinance

Multijurisdictional Pretreatment Programs: Guidance Manual

NPDES Compliance Inspection Manual

POTW Sludge Sampling and Analysis Guidance Document

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