Collection System & Review

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Important Facts About Operator Certification

An operator, as defined by NM Water Quality Control Commission Regulations, is "any person employed by the owner as the person responsible for the operation of all or any portion of a water supply system or wastewater facility. Not included in this definition are such persons as directors of public works, city engineers, city managers, or other officials or persons whose duties do not include actual operation or direct supervision of water supply systems or wastewater facilities."

Under the Utility Operator Certification Act, "a certified operator is a person who is certified by the commission as being qualified to supervise or operate one of the classifications of water supply systems or wastewater facilities". Experience is "actual work experience, full or part-time, in the fields of public water supply or public wastewater treatment. Work experience in a related field may be accepted at the discretion of the commission". Any claim of related experience will be reviewed by the Water Quality control Commission (WQCC) or its advisory body, the Utility Operators Certification Advisory Board.

The Utility Operator Certification Advisory Board (UOCAB) is a seven-member board appointed to function with the WQCC to establish qualifications of operators, classify systems, adopt regulations, and advise the administration of the Utility Operators Certification Act. Its members are drawn from certified water systems operators and wastewater facility operators throughout the State of New Mexico.

Experience that includes operation, maintenance, or repair of water treatment and water distribution systems is accepted based on whether it is full or part-time. The NM Utility Operator Certification Advisory Board will review and approve experience in other related fields, such as commercial plumbing or utility construction. Credit for part-time experience will be based on the percentage of time devoted to actual operation or maintenance. Full time water or wastewater laboratory experience may be counted as operator experience at a rate of 25% of actual experience. The credit for this experience will be determined by review of the UOCAB.

Basic Certification Requirements

There are three basic requirements an operator must meet to qualify for New Mexico certification. All certified operators must have at least **one year** of actual experience in operation or maintenance of a public water system. All levels of certification require **high school graduation or GED** (see substitutions). All levels of certification require a certain number of **training credits** in water systems O&M or related fields.

	Experience	Training Credits	Education
Class 1	1 year*	10	HS Grad or GED*
Small Systems	1 year*	10	HS Grad or GED*
Class 2	2 years*	30	HS Grad or GED*
Class 3	4 years*	50	HS Grad or GED*
Class 4	1 year as Class 3	80	HS Grad or GED

*See Substitutions

Substitutions

One year of additional experience may be substituted for the high school graduation or GED requirement for all classes **except** Class 4. Education may be substituted for experience or training credits in some cases. The education must be in a water or wastewater related field. One year of vocational education can be substituted for up to one year of experience. Associate and Bachelor degrees in a related field may be substituted for up to three years of experience and 50 training credit hours, depending on the amount of actual experience. The criteria for substitution of education for experience are as follows:

- No more than one year (30 semester hours) of successfully completed college education in a **non-related field** may be substituted for an additional **six months** of the required experience.
- **One year** of approved vocational school in the water and/or wastewater field may be substituted for only **one additional year** of the required experience.

SAFETY

Based on past studies, the water and wastewater industries have the highest injury rates in the nation. Workers in these areas are involved in construction and excavations, confined spaces, hazardous chemicals, and mechanical equipment that pose a serious injury risk when proper training, equipment, and procedures are not utilized. The Occupational Safety and Health Administration (OSHA) is responsible for developing regulations regarding worker safety and protection.

Employers are responsible for providing employees with the proper safety equipment and training in its use. They are also responsible for development and implementation of safety policies for their workplace. The employees, after proper training, are responsible for recognizing the safety issues: following approved safety procedures, and properly utilizing the associated safety equipment.

LOCK OUT/TAG OUT (LOTO)

Lock out/tag out regulations deal with the need to isolate a machine from its energy source to prevent it from starting while work is being done in and around the equipment. Energy sources can include electrical, hydraulic, pneumatic, thermal, and chemical. This can be either active or stored energy. Stored energy can take many forms. Some examples of stored energy are electrical energy stored in capacitors, pneumatic energy stored in a compressor tank, and hydraulic water pressure in an isolated line. Stored energy must be dissipated prior to working on the equipment. Employers are responsible for establishing an Energy Control Plan for LOTO work and supply each worker with their individual LOTO locking devices. Only trained personnel should conduct lock out/tag out procedures.

LOTO requires each worker to attach their personal LOTO lock to the disconnect or isolation device to isolate and de-energize these sources and lock and tag them prior to working on the equipment or process. This assures that the equipment cannot be restarted until each individual is finished with their task and is clear of the equipment.

Any isolation that can be locked must be locked. Lockout devices may also include chains, valve clamps, wedges, jacks, or key blocks. Tags are essentially warnings affixed to energy isolating devices and do not provide the physical restraint provided by a lock. Lockout devices and tag out devices must indicate the identity of the employee.

Anyone who enters a LOTO work area must be informed that a LOTO situation exists. If they are to be involved in the work, they must also apply their own LOTO locks. The employee who applied the device shall remove each lockout or tagout device from each energy-isolating device. If that employee is not available, the supervisor may remove the lock or tag only if reasonable attempts were made to contact the employee. Also, the supervisor must inform the employee as soon as that person returns to work. If equipment must be temporarily restarted, the LOTO must be removed during the restart and reapplied before work can continue.

- An **Associate degree** in a two-year program at an approved school in the water and/or wastewater field, and **six months** of actual experience in that field (which may be accrued before, during, or after the school program) may be substituted for the requirements of any level up to and including **Class 2**.
- An **Associate degree** in a two-year program at an approved school in the water and/or wastewater field and **twelve months** of actual experience in that field (which may be accrued before, during, or after the school program) may be substituted for the requirements of any level up to and including **Class 3**.
- Completion of at least **three years** of actual experience in the water and/or wastewater field, plus **high school graduation** or equivalent, plus **15 semester hours** of successfully completed college education directly related to the water or wastewater field may be substituted for any level up to and including **Class 3**.
- A **Bachelor Degree** in a major directly related to the water or wastewater field, plus **two years** of actual experience in that field may be substituted for any level up to and including **Class 3**.

Fire Extinguisher Safety

Different types of fires require different types of fire extinguishers. Fire extinguishers are all rated based on the type of fire they can put out. **Class A** fires are combustible materials like wood or paper. **Class B** fires are flammable liquids like gasoline, oil, or organic solvents. **Class C** fires are electrical fires. Many fire extinguishers are rated for multiple uses. **A-B-C** fire extinguishers can be used on any of these three types of fires

Fire extinguisher use has been simplified to an acronym, **P. A. S. S.**

- Pull the pin
- Aim at the base of the fire
- Squeeze the trigger
- Sweep the area

Excavation Safety

Proper shoring or sloping of trenches and excavations is a major safety issue for many distribution system operators. New construction usually involves more controlled conditions than emergency repairs. Excavations for emergency repairs almost always involve digging and shoring in saturated soils and flooded trenches. A "competent person" must supervise all excavation operations. A competent person is someone who has extensive training in soil mechanics and shoring operations.

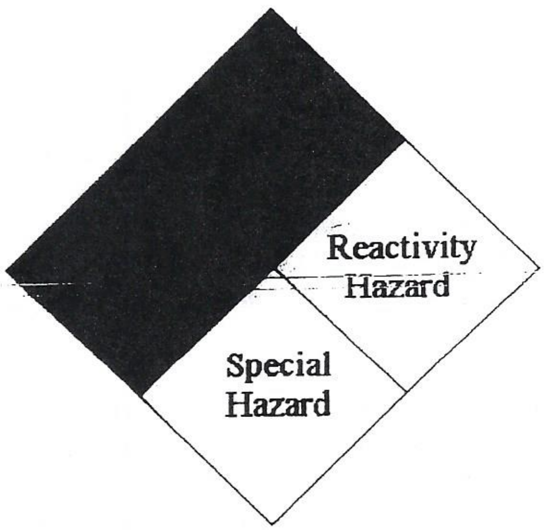
All trenches over 4 feet deep must have ladder from entry and exit. The ladders must extend at least 3 feet above the top of the trench and ladders must not be stationed more than 25 feet apart. Trenches over 5 feet deep must be properly shored or sloped to protect entrants from trench wall collapse and cave-ins. The competent person must determine the proper Maximum Allowable Slope, formerly referred to as Angle of Repose, for the given soils type. Soils are classified as Stable Rock or Type A, B, or C. Stable rock is natural solid mineral material that can be excavated with vertical sides and remain intact while exposed. Type C soils are the least stable and require the shallowest Maximum Allowable Slope. Repair excavations are almost always in wet soils. Soils that are saturated with water are considered to be Type C soils.

Soil Types and Maximum Allowable Slope

Stable Rock	**Vertical 90°**	
Type A	**¾:1**	**53°**
Type B	**1:1**	**45°**
Type C	**1½:1**	**34°**

NFPA COLOR-CODE WARNING SYSTEM

Hazardous materials stored in tanks or containers require hazard identification labels for plant workers and other personnel. One method of labeling is the NFPA diamond. The NFPA symbol has four color-coded diamond-shaped sections. The top (red) diamond is the Flammability Hazard rating. The left (Blue) diamond is the Health Hazard rating. The right (yellow) diamond is the Reactivity Hazard rating. The bottom (White) diamond contains special symbols to indicate properties not explained by the other categories. A number–based rating system is used for each section, ranging from 0 – least dangerous to 4 – extremely dangerous. Emergency responders, such as firefighters, can quickly assess the hazard when they arrive at a chemical spill at a facility.



NFPA Placard

SPECIAL HAZARD SYMBOLS

Acid	**Acids**
Base	**Alkalyes, cyanides**
Oxy	**Oxidizers**
Flam	**Flammables**
Rad	**Radioactive**
~~W~~	**Use no water**

Hazard Communication Standard

OSHA established the Hazard Communication Standard in 1986. The standard was created to provide an information system on hazardous chemicals for both employers and employees. The Haz-Com Standard requires employers to ensure their employees know what hazardous materials exist in the workplace, how to safely use these materials, and how to deal with any emergencies that arise during use. Employers are required to provide the proper safety equipment, train employees in the safe use of any hazardous materials on a jobsite, and maintain records of both.

Producers of hazardous materials are required to provide customers with a Material Safety Data Sheet (MSDS) for each individual chemical or material. MSDS's must be kept on file and available to employees. Employee training should also include how to read and understand the information on the MSDS. The hazards that are involved fall into two basic categories.

TYPES OF HAZARDS:
Health Hazards
Physical Hazards

Health hazards refer to immediate or long-term harm to the body caused by exposure to hazardous chemicals. Physical hazards like flammability or corrosivity can also cause injury to skin, eyes and the respiratory system. MSDS's are divided into eight sections.

Material Safety Data Sheet Sections

1. **Manufacturer's Contact Information**
2. **Hazardous Ingredients/Identity Information**
3. **Physical/Chemical Characteristics**
4. **Fire and Explosion Hazard Data**
5. **Reactivity Data**
6. **Health Hazard/First Aid Information**
7. **Precautions for Safe Handling and Use**
8. **Control/Cleanup Measures**

Confined Space Entry

The water and wastewater industry has one of the highest numbers of confined space injuries per capita in the country. The vast majority of confined space related injuries result in fatalities. Another disturbing fact is that 60% of the confined space related fatalities are people who tried to rescue someone else from a confined space.

A confined space is defined by the following parameters:

1) It must be large enough for a person to enter and do work.
2) It has openings that make entry or exit difficult.
3) It is not intended for continuous occupancy.
4) Any open surface tank deeper than four feet.

Confined spaces fall into two categories: permit required and non-permit required. A confined space becomes permit required when it has potential for a hazardous atmosphere, potential for engulfment, a hazardous internal configuration, or other recognized hazards such as dangerous equipment or hot work (welding, cutting torch, etc.) that is in progress.

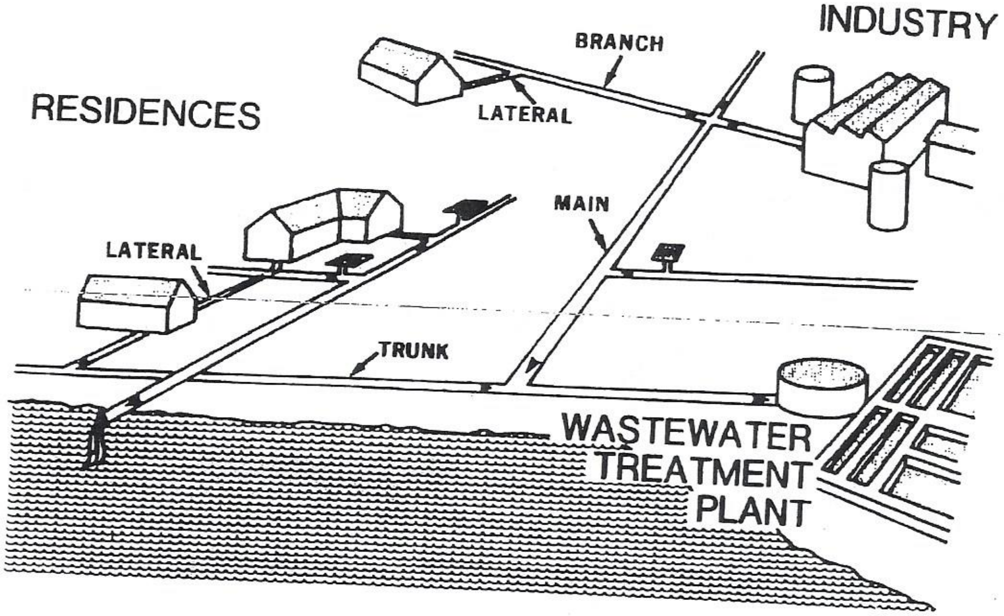
All employees involved in confined space entries must have the proper training in entry procedures and use of safety equipment. An entry supervisor is responsible for conducting the testing and completing the permit. Atmospheric testing should include oxygen concentration, Lower Explosive Limit (LEL) for explosives, and any toxic gases that may be present. The oxygen concentration must be between 19.5-23.5%. The alarm point for explosives is 10% of Lower Explosive Limit. The alarm point for hydrogen sulfide gas is 10 ppm. The alarm point for carbon monoxide is 35 ppm.

An attendant must be present and stationed outside the confined space to monitor the entrants while they are working. The attendant must maintain constant verbal and visual communications with the entrants. The attendant must also be prepared to instruct the entrants to exit the confined space should the equipment fail or the entrants exhibit impaired judgement.

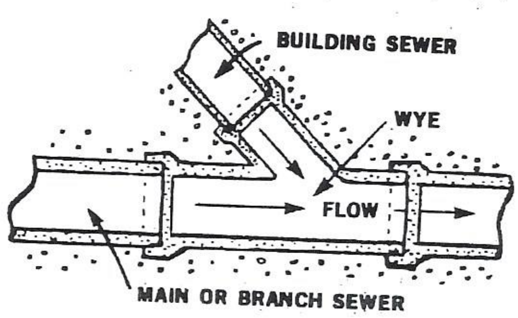
Any confined space must be tested for a hazardous atmosphere before the entry. Monitoring must continue while the entrants are in the confined space. Permit required confined spaces also require ventilation during the entry and self-contained or supplied air must be used if ventilation fails to produce a safe atmosphere. Permit required confined space entries also require rescue equipment such as a harness and tripod for emergency rescues. If the space is configured in a way that prevents the use of self-rescue equipment, an emergency rescue team must be on-site during the entry. When the entry is completed, the entry supervisor must complete the permit form and file a copy with the appropriate supervisor and a confined space entry master file. Non-permit confined spaces must be reassessed periodically. Any non-permit space can be reclassified, as permit required, based on the results of these assessments.

Wastewater Collection Systems

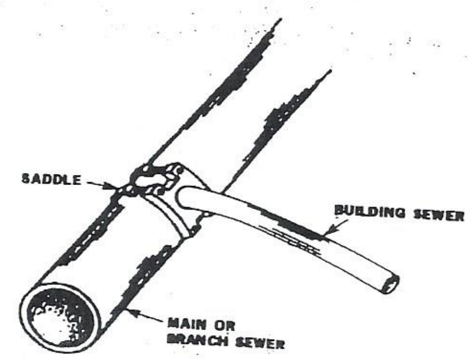
Wastewater collection systems are used to collect and transmit liquid wastes to a central treatment facility. Like a distribution system for water supply, the collection system resembles a tree that branches out from the treatment plant to collect the wastewater from across the system. Wastewater from individual homes enters the collection system through a service line. These services attach to a lateral line with a wye connection or a tap and saddle connection. Branch lines or laterals usually run down the residential streets collecting the flow from individual services. They, like tributaries in a watershed, flow into larger lines called mains. Mains intersect to form the largest lines in the system called trunk lines. A trunk line is a transmission line that doesn't have any mains branching off of it. It is the pipe that brings water into the treatment plant. This line is also referred to as the outfall.



Wastewater Collection System



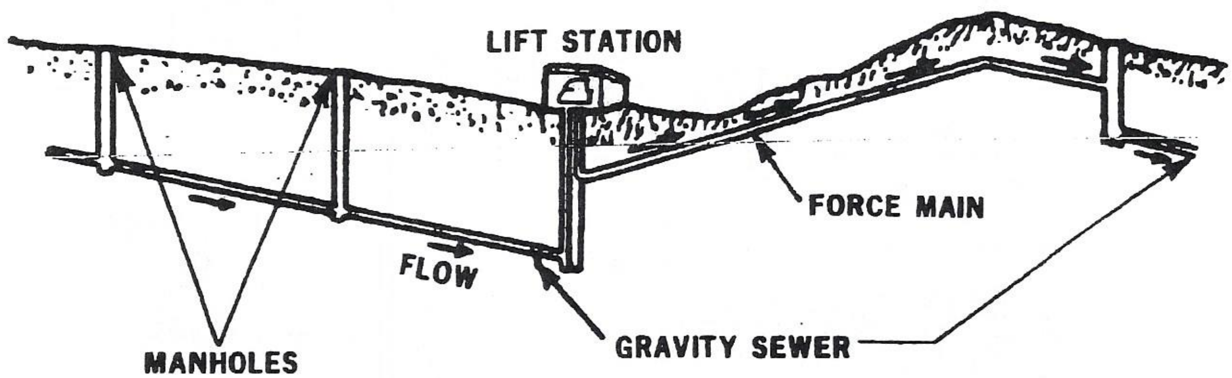
Wye Service Connection



Tap & Saddle Service Connection

Manholes are installed in sewer lines whenever two lines intersect or there is a change of direction, elevation, or slope of a line. They provide access to the system for cleaning, inspection, and clearing stoppages. Although they should be large enough to enter and work in, they can contain hazardous atmospheres that can endanger workers. With today's modern equipment, most sewer line maintenance tasks can be accomplished without entering the manhole and putting workers at risk.

Collection lines are installed with a downhill slope that allows the flow to move through most of the system by gravity. This minimizes the amount of pumping that must occur to get the water to the treatment plant. The slope must be adequate to maintain a velocity of at least 2 feet per second in the line. This is known as the scouring velocity. When the sewer lines reach a certain depth the flow must be lifted so that it can begin flowing by gravity again. Lift stations are built whenever wastewater must be pumped to a higher altitude, whether it's to lift water up so that it can gravity flow again or to pump it over a change in topography or a hill.



Lift Station and Force Main

Collection systems must be designed to handle peak flow conditions. The size of the pipe, the type of pipe, and the downhill grade of the line determine the amount of flow that a line can handle. The average per capita flow that is used to size the system is usually about 100 gallons/person/day. Infiltration and inflow are also concerns when designing a collection system. Infiltration occurs when groundwater enters the system through broken pipe or leaking joints in wet weather. Inflow enters the system directly. It may come from runoff that floods streets and enters through submerged manhole covers or illegal service connections that direct storm flows into the system. Exfiltration occurs when sewage leaks out the pipe into the surrounding soil. Systems can gain some control over inflow and infiltration through local sewer use ordinances.

Sanitary sewers carry wastewater to treatment facilities. Storm sewers carry storm water runoff to the receiving body. Although storm water is usually low in BOD, the initial flow can contain high concentrations of suspended solids in the form of grit and dirt.

If the service line is simply inserted into a hole in the main, it will intrude into the line and increase the possibility of creating a stoppage. It will also create a problem for cleaning equipment. This connection may also leak allowing root intrusion into the line and infiltration.

Collection System Construction

Sewer lines are usually laid deeper than water lines. They can run as deep as thirty feet before lift stations are needed. This means that trenching and shoring issues are much more complex than excavations for water lines. Trenching and shoring safety issues are addressed in Chapter 16. Trenches fourteen feet or deeper must have shoring systems that are designed by a professional engineer. Prior to digging, always get other utilities to spot their lines first. Most states have a blue stake or one-call system established for utility location. Traffic control must be established and area residents should be notified of construction and any interruption of service that could result before excavation begins.

Wastewater collection systems are designed to have water flow downhill by gravity. The only time pumps are used is when the flow needs to be lifted so it can flow by gravity again. A downhill grade or slope must be established in order to maintain a certain velocity in the piping. Sewer lines are more difficult to install because the pipe must be laid straight and the slope of the pipe must remain constant. The line must be straight so cleaning equipment can pass through it. Changes in slope or grade can lead to solids settling in the low spots.

Many operators are not directly involved in the installation of collection system piping. Knowing how to correctly and safely installing these lines is important because operators may be responsible for the inspection of a contractor's work or making repairs on existing lines.

Handling Pipe

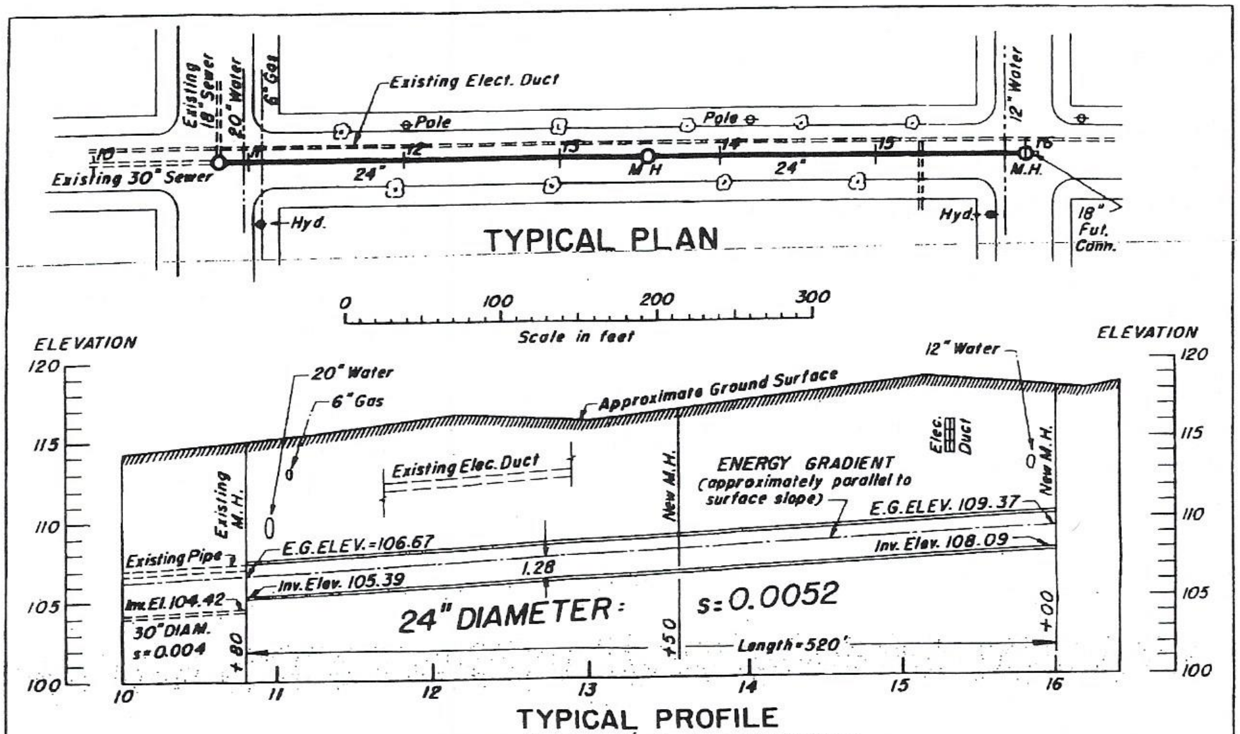
Water piping should always be handled with care. Although it is inspected before it leaves the factory, damage can occur during shipment. Always check all pipe materials, gaskets and fittings before accepting a shipment of pipe. Vitrified clay pipe is checked by tapping sections lightly with a hammer. A pipe that is not cracked will make a faint ringing sound. Cast iron pipe can be checked using the same technique. PVC pipe is checked for discoloration. Discolored pipe has been damaged by ultra-violet radiation.

Piping should be unloaded in the area where it is to be installed. It is usually placed along the side of the trench. It should never be moved using a backhoe bucket or blade. Proper rigging and slings should be used to safely move heavy iron or concrete cylinder pipe sections. Store all gaskets and fittings that can be removed indoors where they will not become damaged from exposure and sunlight.

EXCAVATIONS AND UTILITY LOCATION

It is important to remember that the collection system is not the only utility located in or near the street. The statewide "Blue Stake" number should be called to get the other utilities spotted before the trenching operations begin. Failure to request line spots for other utilities will make the system responsible for any loss of service or product and the cost of repair if they are damaged.

Excavations for sewer lines must be dug to grade. The depth of the line may vary with changes in surface contours. Plan and profile maps are used to determine the correct location and depth of the line. A plan view is a view from above. It is used to determine the location of the line and major components of the system. These are put together to create the section maps that maintenance crews use for line and manhole location.



Typical Plan and Profile Drawings for Sewer and Drain Design.

A profile view is a side view showing the soil contours and depth of the line. Distances are identified from a reference point as stations. The section of pipe shown begins at 10+80 or 1080 feet from the reference point and ends at 16+00 or 1600 feet from that point. If we subtract the run of pipe is 520 feet long.

Piping Grades

The downhill slope of the pipe must be adequate to maintain a 2 foot per second velocity. At 2 fps, the grit and heavy inorganic solids will not settle out in the lines and cause stoppages. Odor and corrosion problems are also more prevalent in lines where slopes are not adequate to maintain minimum velocities.

The slope of a line is calculated by dividing the rise (or drop) by the run or length of the line. For instance, if a run of pipe is 400 feet long and it drops 1 foot, the rise over the run is 1/400 or 0.0025. It would also be a 0.25% slope. It is important to make sure the grade is constant.

There should not be deviation above or below the grade line. The pipe is laid so that the invert, or inside bottom of the pipe, is at the proper slope. It is identified as the invert elevation. The inside top of the pipe is known as the crown. The bell ends of the pipe must be laid facing upstream.

Grade stakes and string lines or laser systems can be used to establish the proper grade during construction. String lines are established at the proper slope above the trench. Grade rods are used to check the invert elevation of each section of pipe. Laser systems shoot a beam down the inside of the pipe just above the invert of the pipe. This method is more precise than the string line method.

Laying Pipe to Grade

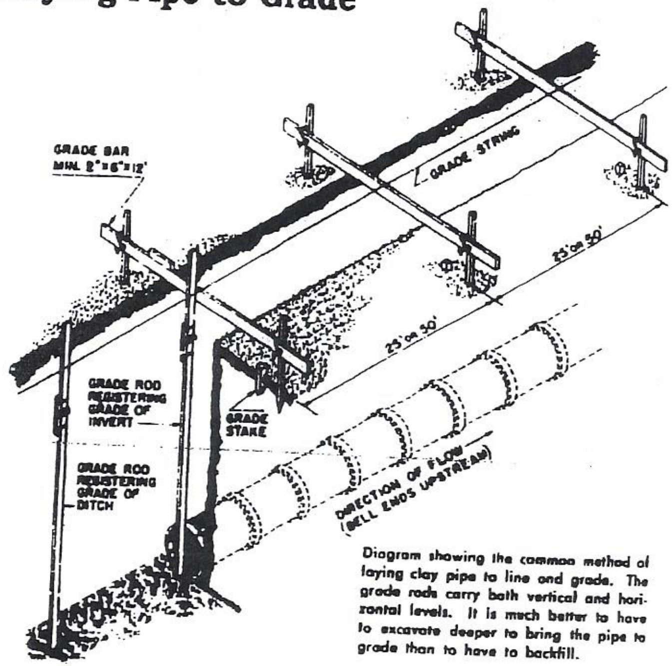
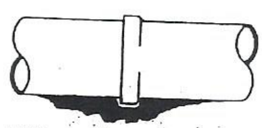


Diagram showing the common method of laying clay pipe to line and grade. The grade rods carry both vertical and horizontal levels. It is much better to have to excavate deeper to bring the pipe to grade than to have to backfill.

The lower 90 degree arc of the barrel of the pipe should be in firm contact with undisturbed earth.



Small excavations should be made for the bells. These should be no larger than necessary to clear the bell.

Once trench is excavated to the proper grade the trench floor must be leveled. Notches are dug in the floor of the trench where the bell end of each section of pipe is located. When water lines are encountered during construction the water line should always be relocated to avoid changing the grade of the sewer line. When a sewer line crosses over a water line, the sewer line should be cast iron pipe for 50 feet on either side of the intersection. Lines that must pass under roads or railroad tracks can be bored. But the line must be encased in cast iron or concrete. This maintains the proper grade and proper support for the piping.

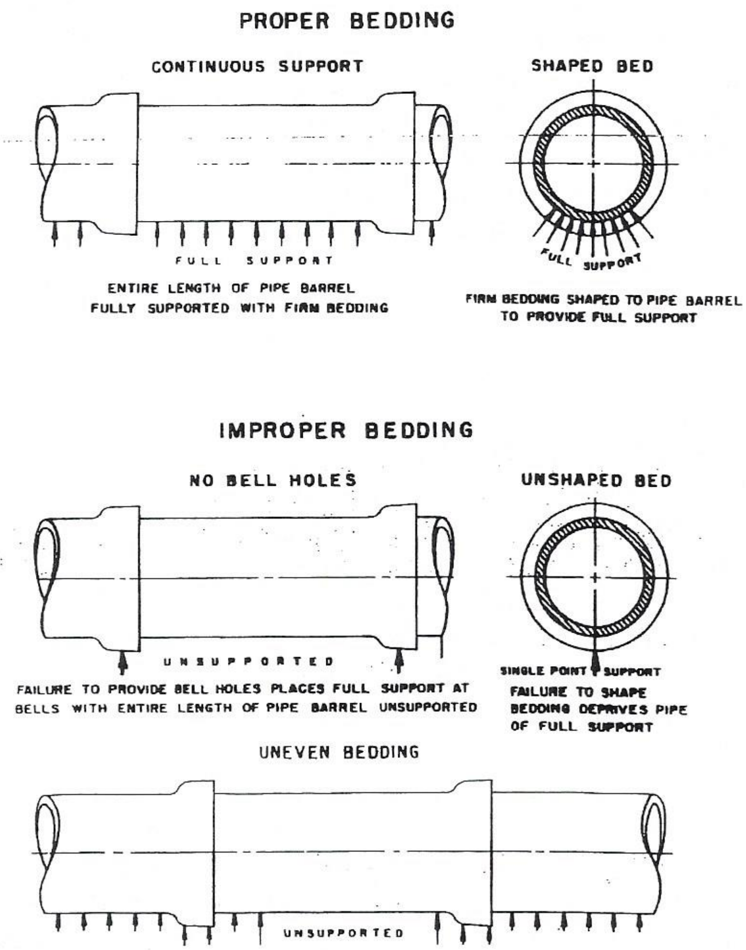
Most pipe sections have either a bell and spigot or a mortise and tenon joint. Rubber gaskets are used seal the connection. These pipe sections must be pushed together against the resistance of the gasket. When pushing pipe sections together, either by hand or with heavy equipment like a backhoe, a wooden block is placed between the bar or bucket and the pipe end. This blocking method is used to avoid damaging the pipe. Gaskets should be lubricated with grease to aid in making the connection.

BEDDING PIPING

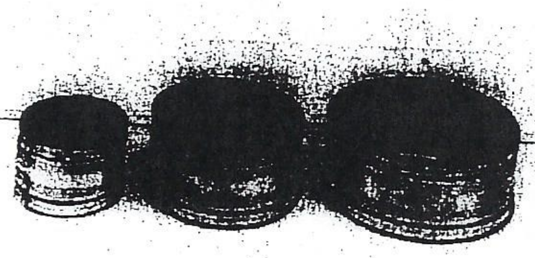
Bedding material is used to support and protect the pipe from trench loads and pressure points. Bedding material should be free of large or sharp racks. Sand is an excellent bedding material because it compacts around the pipe well and provides excellent support. If bedding materials are not used beneath the new piping, the trench floor must be prepped to support the piping properly. The floor of the trench must be level and free of any protruding rock. Indentations must be dug under the bell ends so that they do not act as the support for the section of pipe. Improper bedding will result in broken joints that leak or collapse.

Special bedding material may be required when heavy trench loads are encountered. Class "A" bedding is concrete that is used to encase the pipe. It may be also be used when inverted siphons go under steams or ditches.

Class "B" and "C" bedding are granular materials like gravel and sand. They would be used for bedding plastic pipes and VCP and concrete pipe in high load areas that don't require concrete bedding.



Great care must be taken to ensure that the repaired section of pipe is properly bedded and backfilled for support. If the bedding material is not properly tamped around the repair, the trench loading can cause another failure to occur. Service lines are reconnected to the pipe using a saddle tap and slip coupling.

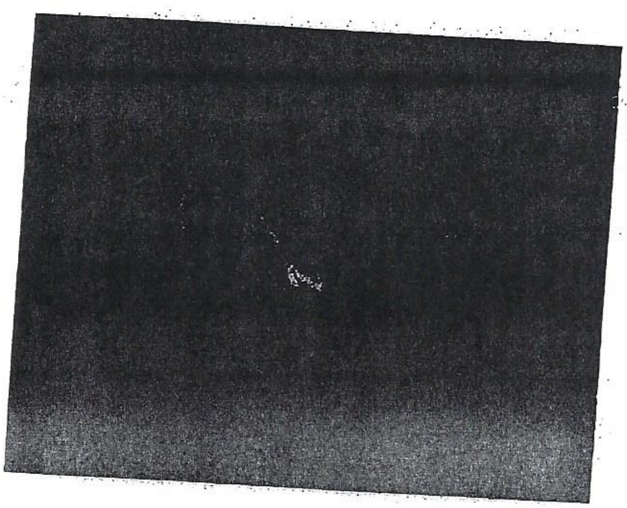


STEEL SLEEVE SLIP COUPLINGS

CHEMICAL GROUTING

Leaking pipe joints can draw bedding material and soil from outside the pipe into the line. This heavy material can easily create stoppages far downstream of the actual leak. The loss of the support material around pipe can result in misalignment of joints or a complete collapse of the line. Leaking pipe joints and joints with root intrusion may be repaired without replacement by sealing the joint with a chemical grout. The grouting process can only be used if the pipe wall integrity has not been compromised.

The chemical grout is not cement that hardens and gives support. It is a low viscosity polymer-based liquid that can be pumped into the joint and out into the surrounding soil. As the grouting cures it congeals into a gel that binds the material outside the joint to form a watertight seal. Root inhibiting chemicals can also be mixed with the grout to prevent additional root intrusion.



POSITIONING THE PACKER UNIT

A line that is going to be grouted must first be cleaned with a jet truck. Roots must also be cut prior to the packing operation. A power winch is set up at the remote manhole. A jet truck or rodding machine is used to run a cable back to the manhole where the grouting unit is located.

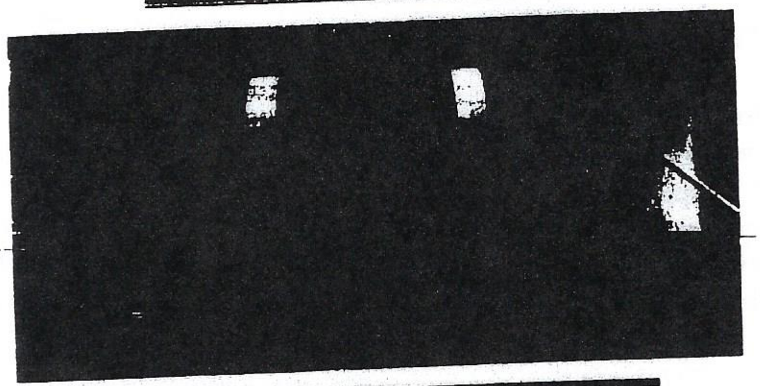
A CCTV camera is attached to the cable facing backwards. The grouting packer is attached to the camera. Five hoses are attached to the packer unit. Two carry grouting chemicals and the others are air lines used to inflate the three packer compartments and pressure test the seal.

The camera is used to center the packer unit under the joint. Once the packer is positioned the end chambers are inflated to seal the center of the unit where the grout will be injected.

After the center area is properly sealed, grouting chemicals are pumped into the void area in the center. The center of the packer unit is inflated to force the grouting chemicals into the joint and the surrounding soil.

It takes forty to sixty seconds for the grout to expand and solidify. After it has set up, the center of the packer is deflated and the seal is pressure tested. Some packing units are also capable of sealing sewer taps and lateral connections.

INFLATING THE ENDS OF THE PACKER UNIT



GROUT IS INJECTED AND THE CENTER IS PRESSURIZED

LINE REHABILITATION

Many collections systems are faced with the problems caused by deterioration in piping that can result in excessive infiltration, stoppages, and eventually catastrophic structural failure. Problems can also be created when flows begin to reach the carrying capacity of the line due to urban development in the area. Replacing a sewer line is a very expensive and disruptive operation. There are several options available to collection systems that can rehabilitate an undersized or failing sewer line. These processes are more cost effective and much less invasive than retrenching and replacing the pipe. All of these processes involve the insertion of new flexible piping or a liner into the existing pipe to seal it.

SLIP LINING

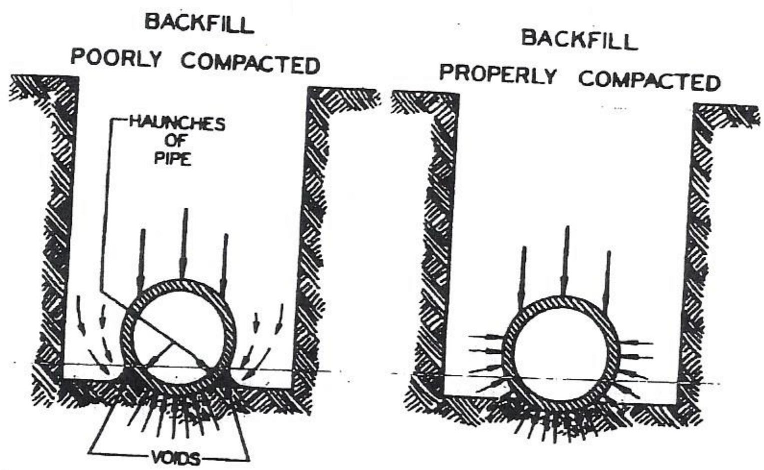
Slip lining has been used to rehabilitate aging sewer lines for over fifty years. The process involves pulling or pushing a flexible plastic pipe through an existing line. High Density Polyethylene (HDPE) pipe, PVC pipe, and Vylon pipe are most commonly used for slip lining operations.

Backfill Considerations

The type of backfill material used is also a very important factor in the protection of all pipes. This is especially important when PVC pipe, with its poor load bearing capability, is used. PVC piping should never be used under high load areas like highway or railroad crossings. If rocks or other abrasive material are present in the backfill, a sharp edge may create a single point of stress against the pipe wall. This can lead to misaligned or broken joints and structural collapse. To prevent this kind of damage from happening a select backfill material should be used.

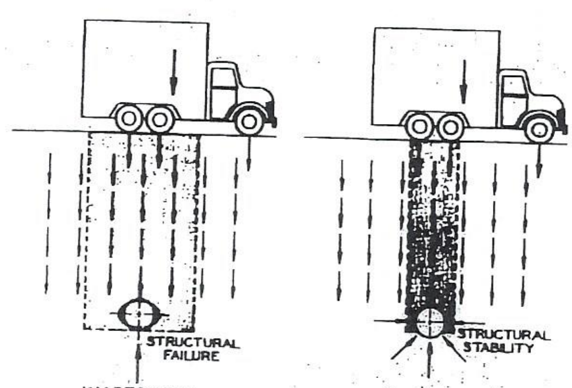
The backfill should be carefully added and properly tamped to help support trench loads. The backfill material should completely surround the pipe. It should be tamped when the pipe is still half exposed and again when the pipe is covered by about 6 inches of material. After the pipe is covered, backfill and compaction should be done in 12-18" lifts or layers that are tamped.

If the trench is filled completely before it is tamped, settling will occur. This will greatly increase the stress on the pipe as continuous loading from traffic occurs. This is also the reason why trenches should be cut narrow as possible. Wider trenches result in increased load stresses on the pipe.



VOIDS, OR POORLY COMPACTED BACKFILL AT HAUNCHES, CAUSES SUBSIDENCE OF THE BACKFILL AT SIDES OF PIPE AND SUBSEQUENT LOSS OF SIDE SUPPORT.

PROPERLY COMPACTED BACKFILL PROVIDES SIDE SUPPORT FOR PIPE.



INADEQUATE STRUCTURAL SUPPORT
EXCESSIVE TRENCH WIDTH
POOR COMPACTION OF BACKFILL
IMPROPER BEDDING OF PIPE

ADEQUATE STRUCTURAL SUPPORT
CONTROLLED TRENCH WIDTH
COMPACTED BACKFILL
PROPER BEDDING OF PIPE

Testing and Inspecting Sewer Lines

Testing and inspection of the collection system piping is necessary to insure that new lines are installed correctly and to check existing piping for damage or corrosion. Testing may also be a means to identify sources of inflow or infiltration from broken lines or illegal connections.

Testing Sewer Lines

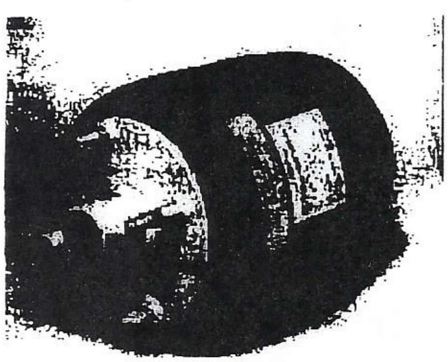
There are three tests that are performed on sewer lines. Dye testing, pressure testing and smoke testing are done to assess the general condition of the piping. While there are other means of inspecting piping, like closed-circuit TV, these tests are relatively easy to do and can give a quick indication of whether a closer look should be taken with a CCTV unit.

Dye Testing

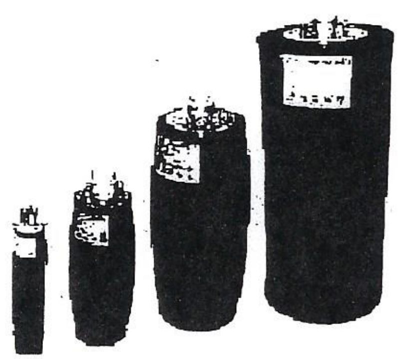
Dye testing is used to determine if drains are connected to the sewer system. It can be poured down a patio drain, which should not be connected to the sanitary sewer, to see if the dye appears at a downstream manhole. It can also be used to estimate the flow velocities in a pipe. When dyes are used to determine velocity in a pipe the results will normally be 10-15% faster than the actual average velocity. This is because the flow through the center of ~~the pipe moves faster than the flow at the edges where friction with the pipe wall~~ is encountered. The friction will cause dye marker to become elongated as it moves down the line. Add half of time the dye was visible to the time it took to first appear to get a more accurate velocity reading.

Pressure Testing

Pressure testing is usually done during new pipe installation. It should be part of the acceptance criteria for the installation. If a line is not able to hold pressure infiltration from groundwater may be excessive. The line is plugged at both ends and air is pumped in until the pressure reaches 3.5-5 psi. When the air pressure has stabilized, the airflow is turned off. The pressure will begin to drop. The length of time it takes to drop from 3.5 psi to 2.5 psi is used to determine whether the pipe meets the criteria. A calculation is used to determine the acceptable time for the pressure drop.

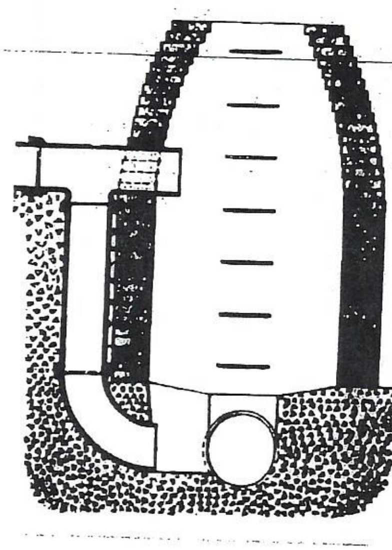


Inflatable Piping Plugs

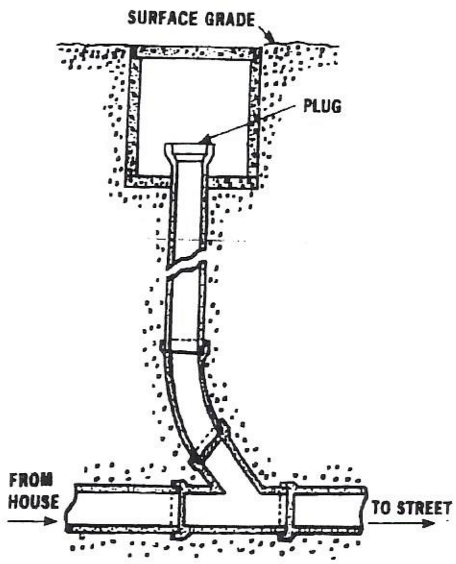


The base of the manhole is formed into a channel and bench. The bench on either side of the channel is flat but sloped toward the channel to insure drainage. Covers with multiple holes should not be used in low-lying areas or where streets are not properly crowned to drain runoff away from the covers.

Drop manholes are used when two sewer lines intersect at different elevations or when the velocity in the line gets too high. Velocities in sewer lines should not exceed a maximum of 10 feet per second or the scouring action of the grit in the flow can erode the piping.

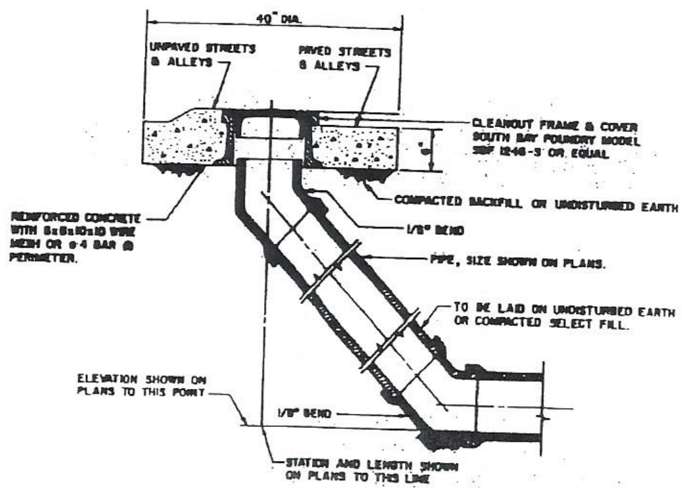


Drop Manhole



Sewer Service Cleanout

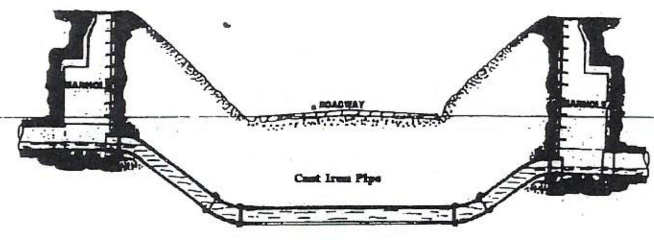
Cleanouts are installed on service lines and sometimes at ends of laterals instead of a manhole. They are installed for economic reasons. They cost 1/6 as much as a manhole. They allow access for some but not all types of cleaning equipment.



Sewer Main Cleanout

Inverted Siphon

Inverted siphons are used when the line must drop below grade to pass under an obstacle like a roadway or streambed. Inverted siphons are difficult to clean and rely on higher velocities created by smaller piping to remove grit and debris that may accumulate during low flow conditions. The siphon line will be a smaller watertight cast ball and socket iron pipe. The smaller pipe will need to create a velocity of over 2 fps at low flows.

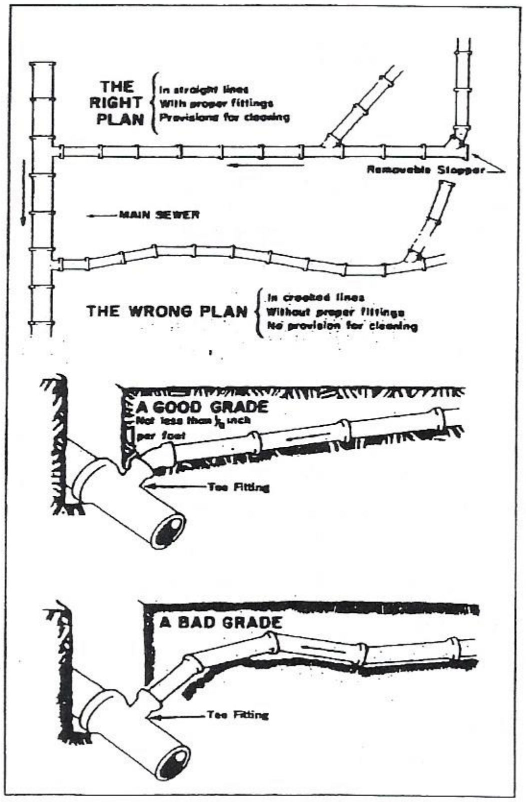


Inverted Siphon

Services

Service lines from residential customers must be properly installed. Improper installation can result in backups in the customer's plumbing or stoppages in the main. Service lines must slope at least 1% or 1/8" per foot so that the velocity is sufficient to carry solids to the main.

Crooked services or services with uneven grades are difficult to clean and can create conditions that allow debris to collect in the line. Bad joints that leak can be a source of infiltration and root intrusion into the service and the main.



Service connections are made using a pipe wye connection, installed when the main is laid, or a saddle and tap into an existing line. This method provides the best possible structural integrity in the line and prevents obstruction that can be caused by intrusion.

Saddle taps are attached to the main by drilling a hole in the main and attaching a saddle. The saddle has a connection for the service line that will prevent intrusion into the pipe. When a tap hole is drilled, it is important to remove the circular piece of the main, known as a coupon, so that it doesn't cause a stoppage downstream. Concrete should be poured around the tapping saddle for support.

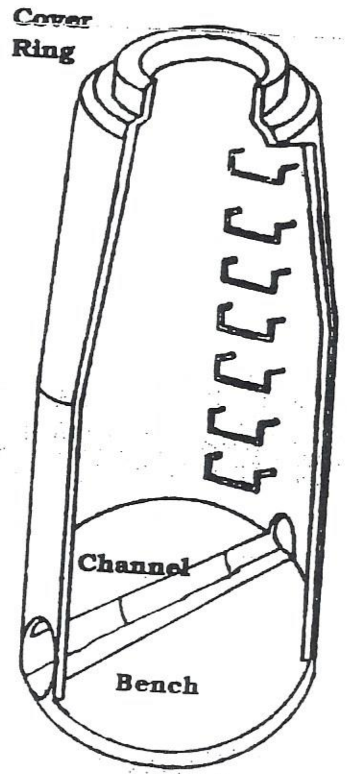
Acrylonitrile butadiene styrene (ABS) pipe is a plastic pipe. It is lightweight and flexible. It is impervious to corrosion from sewer gases, acids and bases, and inorganic salts found in wastewater. It is softened by petroleum products, which are not normally found in domestic wastewater. It can't withstand heavy trench loading. Polyvinyl chloride (PVC) piping is also lightweight and easy to install. Petroleum products do not affect it, but trench loading is still a problem. It has replaced VCP or ABS piping for residential laterals and small mains.

Manholes, Cleanouts, and Inverted Siphons

Manholes should be spaced no more than 400-500 feet apart in straight runs of pipe. The limiting factor is that most cleaning equipment will not have more than 500 feet of rod or hose on the unit. They should also be installed anywhere pipes intersect or there is a change of direction or grade. They are normally constructed of either brick or pre-formed concrete cylinders. In areas where groundwater infiltration is a problem, they can be made from fiberglass reinforced polyester rings.

A base is poured that is at least 1 foot larger in diameter than the manhole rings to support the loads that occur when vehicles drive over the manhole cover. If it cannot support the load and the manhole settles the piping at the manhole may be fractured. Most manhole rings are at least 4 feet in diameter to allow access and room to work inside them. They are stacked on the base and grouted to prevent infiltration.

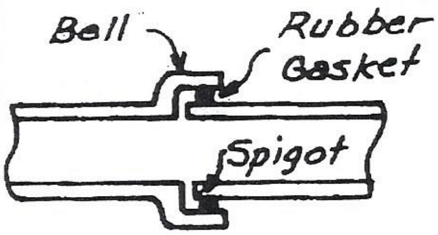
An eccentric cone is placed on top of the manhole that narrows the opening to the size of a manhole cover. An iron cover ring is then placed on top of the cone and the cover sets inside the ring. The ring and cover must be flush with the pavement so that it doesn't present a hazard to traffic. When streets are re-paved, adjustment rings are used to bring the cover back up to grade. For distances of more than 6 inches, the cone ring should be removed and additional manholes rings added.



Typical Manhole

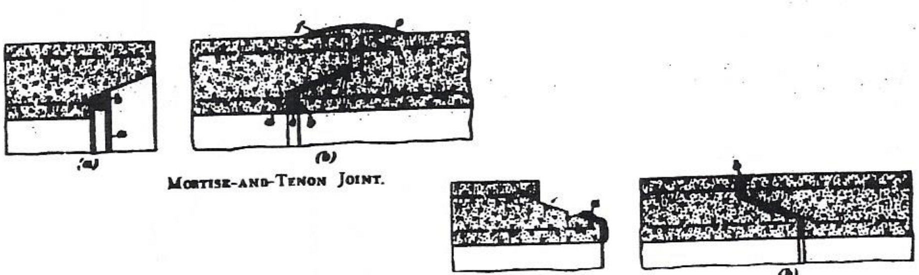
WASTEWATER PIPING

The most common type of wastewater piping is vitrified clay pipe (VCP). It is made of fired clay and is constructed with bell and spigot connections. The spigot end of the pipe will have a rubber gasket bonded to the outside of the pipe. It creates a watertight seal for the joint. VCP has sufficient strength to withstand most trench loads and is almost impervious to corrosion caused by acids that form when sewer gases are generated. VCP is available from 4" to 36" in diameter. It is very heavy in sizes above 18".



Bell & Spigot Joint

Reinforced concrete pipe (RCP) is used for larger lines from 18" to 60" in diameter. It is lighter than vitrified clay pipe. Concrete pipes can have bell and spigot connections. They can also have mortise and tenon or Burtnett joints that still have a big end a little end and are sealed with a rubber gasket or mastic compounds. The problem with concrete pipe is corrosion of the inside of the pipe at the top, or crown area, caused by sewer gases and organic acids.



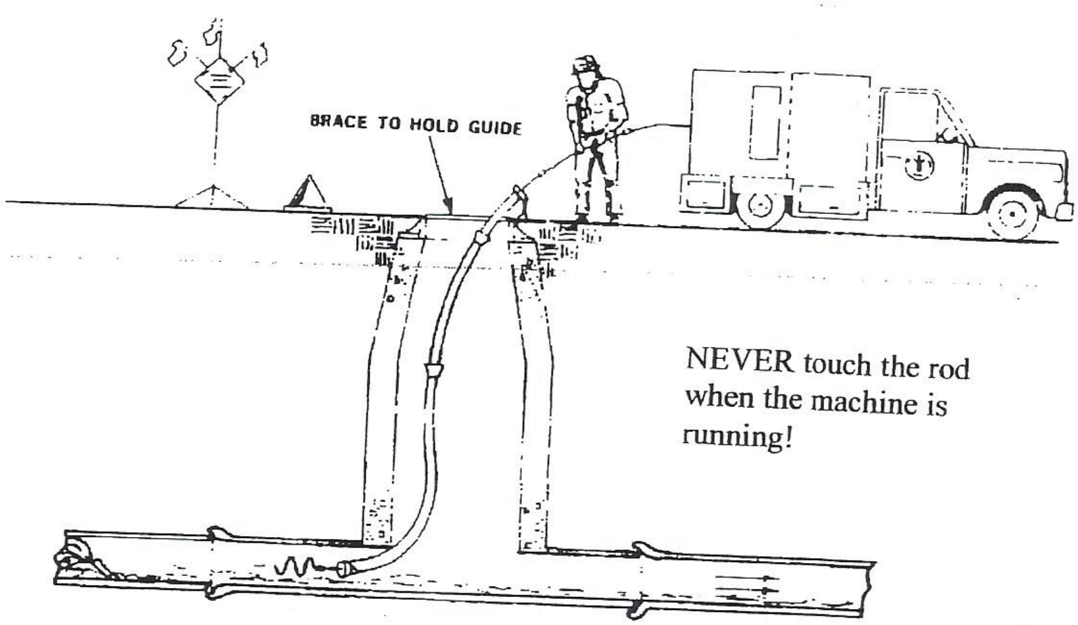
Concrete Pipe Joints

Cast iron pipe (CIP) or ductile iron pipe (DIP) are only used in collection systems for specific applications. They are used in areas where high trench loading exists like crossing under a railroad track or a dirt road that carries heavy equipment. Watertight cast iron pipe is also used for inverted syphons where collection lines run under roadbeds or streams. It may also be required if sewer lines pass too close to public drinking water facilities. Iron pipe is also subject to corrosion from sewer gases.

Rodding Machines

Rodding machines are used to cut roots and clear stoppages in lines. They use a long steel rod with a tool attached to the end to drill through the obstacle in the pipe. They use a variety of tools to accomplish different tasks. Few rodding machines are still in service. A jet truck can do all of the things a rodding machine can do and do it faster.

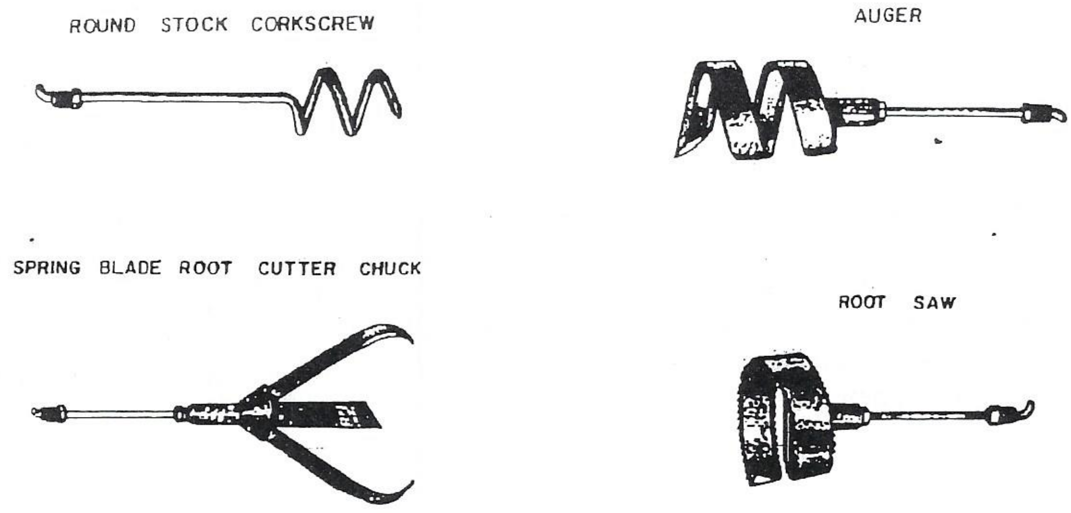
Like a jet cleaner, rodding machine operators should attack roots and stoppages from the downstream manhole. This way roots and debris are carried away from the stoppage as the ~~tool advances. It is important to know how far the tool is into line in case it gets stuck and~~ has requires excavation. Rodding machines generate tremendous torque as they spin the rodding tools. This energy can be dangerous to anyone in the vicinity if the tool gets hung up or the rod breaks. This energy can also result in damage to piping and joints that are offset when this happens.



Rodding Machine Operation

There are two types of root saws used on rodding machines. The spring blade root cutter can damage PVC piping and rods can break if they catch a misaligned joint or a protruding service tap. A circular root saw should be used on plastic pipe.

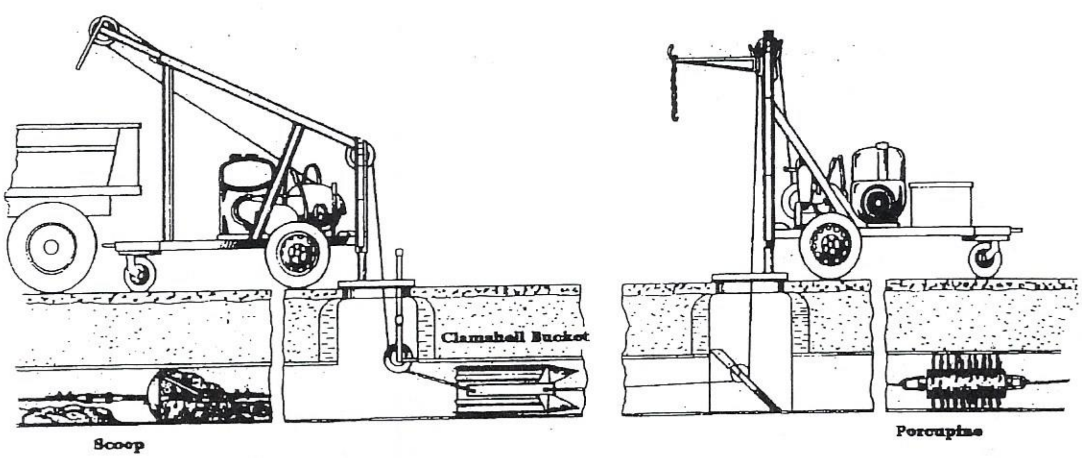
Corkscrews and augers are used to attack stoppages. The round stock corkscrew is the universal stoppage tool. It should be used if the cause of the stoppage is not known. A square bar auger is used for grit stoppages. A porcupine is used to remove grease.



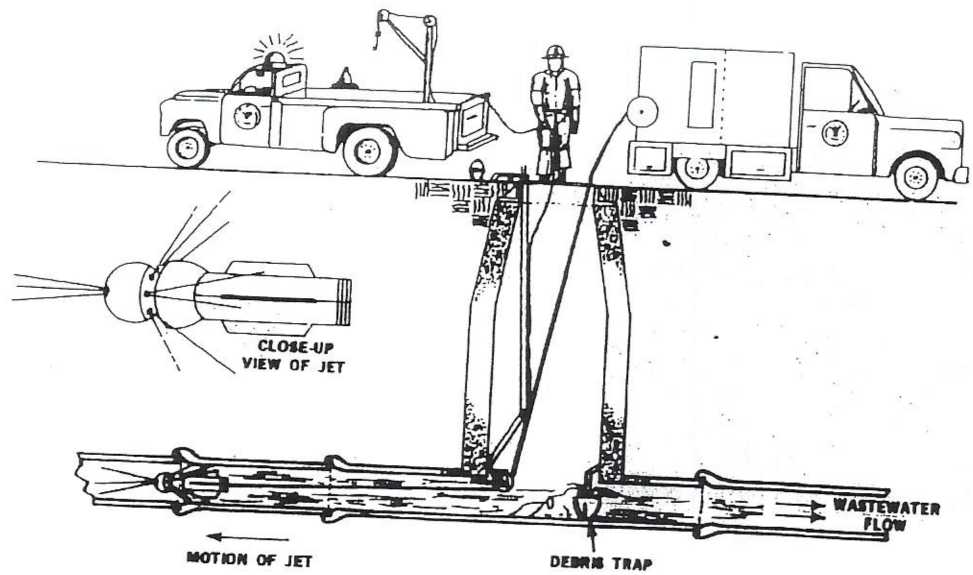
Rodding Machine Tools

Bucket Machines

Bucket machines use two winches to drag a clamshell bucket or porcupine through a line to clean it. They are slow and can damage piping if they get hung up in the line on things like protruding services. Because of the energy and torque involved in the winch operation, mechanical failures can cause serious injury to the operator. The bucket should be removed and an overnight barrel attached to the cables when a job is not completed by the end of the day. Bucket machines are rarely used today because a jet truck will do the same job ten times faster and safer.



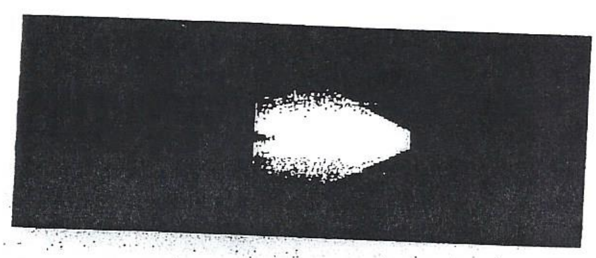
Bucket Machines



Jet Cleaner Operation

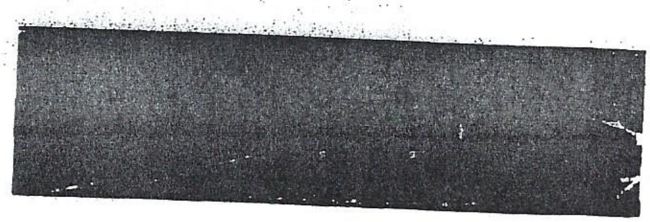
Most jet cleaners have a vacuum system to suck up the debris as it is washed back to the manhole. The debris and water are collected in a large tank. The water can be decanted back into the collection system and the grit is hauled to a landfill. Units that don't have ~~vacuuming capabilities are used primarily to string CCTV cables and clear emergency~~ stoppages.

There are different nozzles for different applications and pipe sizes. Nozzles with forward jets are used to clear stoppages. Stoppage clearing nozzles have a set of 15 to 20 degree jets in the back to maximize thrust. Early grease removal nozzles had wider jet angles of 45 to 50 degrees to put more energy on the pipe wall. Spinning nozzle heads are now used to remove grease.

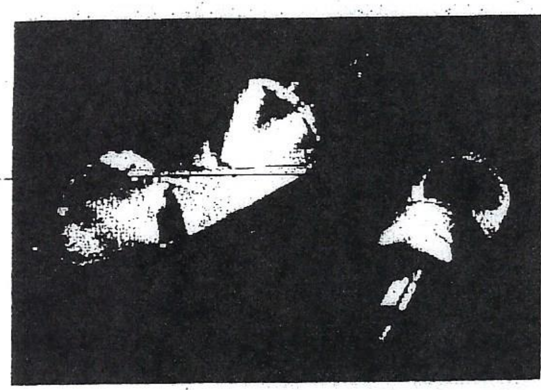


Forward Jets for Stoppages (Top)
Rotating Jets for Grease (Left)
Chain-Style Root Cutter (Below)

Rotating root saws with either chain whips or rigid blades are used to cut roots. The chain style cutters are easier of PVC piping.

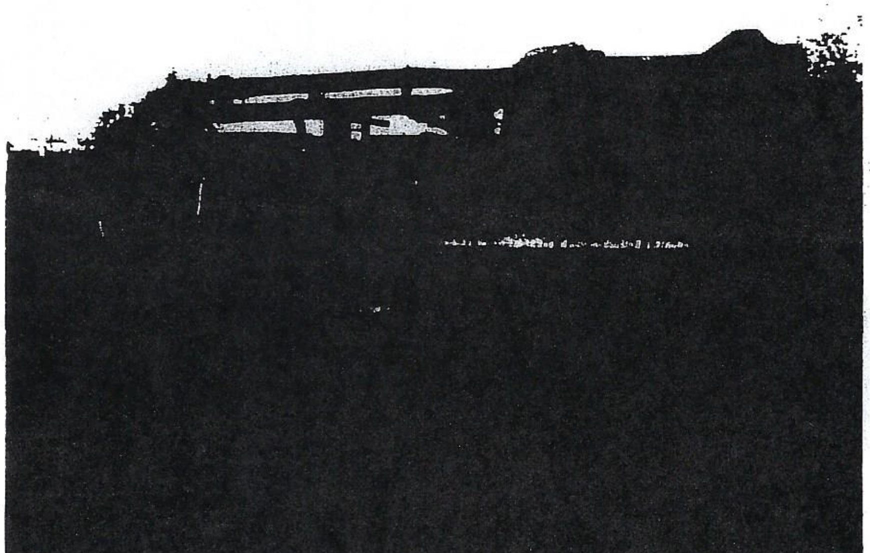


All of these nozzles tend to fly in the center of the pipe. In larger sewer lines grit is removed using a large heavy nozzle that sits on the bottom of the line. Grit nozzles will have forward jets to break up grit deposits and large rear jets that point down at the pipe invert to move the heavy grit deposits. They may weigh 70-80 pounds.



Grit Removal Nozzles

These combination jet and vacuum trucks usually carry between 500-1200 gallons of water with them in the saddle tanks. They must be refilled at fire hydrants after each cleaning run. The fill point must be equipped with an air gap to prevent the possibility of a cross connection. Fire hydrants must be opened slowly to prevent water hammer. Dry barrel hydrants must be fully open to prevent jetting water through the drain hole and undercutting the pavement. If the flow is throttled it must be done through a valve attached to the hydrant nozzle while the hydrant valve remains fully open.

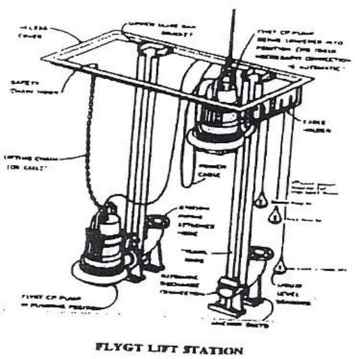


Combination Jet Cleaner and Vacuum Truck

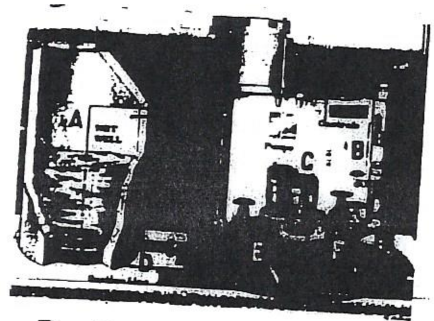
Lift Stations

There is a limit to how deep you can dig with a backhoe. That limit is between thirty and thirty three feet. When a gravity sewer reaches that depth a lift station is installed to lift the wastewater back up to a point where it begins gravity flow again. They are also used to lift the waste flow over a hill or other terrain obstacle. Lift stations are built as either wet well or dry well installations.

A wet well lift station consists of a wet well to contain the incoming flow and submersible pumps. It is cheaper to build than a dry well lift station, but maintenance can be problematic because of the grease and sewer gases that are present. The wet well is a confined space that requires special entry procedures. It can contain toxic gases even if the top is open.



Wet Well Lift Station



Dry Well Lift Station

A dry well lift station has a wet well to collect the flow and a dry well for the pumps and controls. They are more expensive to build but the machinery is easier to access. The dry well is still a confined space and should not be entered without following the proper confined space entry procedures. Continuous forced ventilation is required during entry.

The discharge line from the lift station is called a force main. It remains a force main until it discharges to a gravity sewer. A check valve on the discharge side of each pump prevents the flow from moving back through the pumps when they are not running. When one of the check valves becomes fouled, the other pumps will pump longer on each cycle because the flow leaks back through the clogged check valve and recirculates back to the wet well. If the pumps alternate and one pump has three to four times the running hours, the pump with the shorter run time probably has a clogged check valve that is allowing recirculation to occur. When seal water is required on a centrifugal wastewater pump an air gap must be used to provide a physical separation for cross connection prevention.

Odor problems can occur in lift stations with long wet well detention times. Air diffusers can be installed to add oxygen and create aerobic conditions. Chlorine, potassium permanganate, and hydrogen peroxide can also be used for odor control at lift stations. Pump start levels can also be lowered so that the pumps cycle more often. Cycling pumps too often can result in motor and starter problems. They shouldn't cycle more than three or four times an hour.

Another pump operational problem occurs when pumps are rotated in and out of service. One of the pumps in the lift station is usually taken off-line every week. When a pump that is full of sewage sits for a week, sewer gases are released that can air lock the pump. If these gases are not purged from the pump before it is returned to service, it may overheat and burn up. This is not an issue with submersible pumps. They have a volute designed to prevent air locking.

~~It is important to know the net positive suction head (NPSH) for the pumps. It is the~~ minimum suction pressure needed to avoid cavitation. The stop switch for the pump must be set high enough to maintain the pump's NPSH requirement. Lift station pumps may require clean seal water for packing or mechanical seals. If the source of water is the public water supply, cross connection prevention measures must be taken. A physical separation must be maintained using an air gap

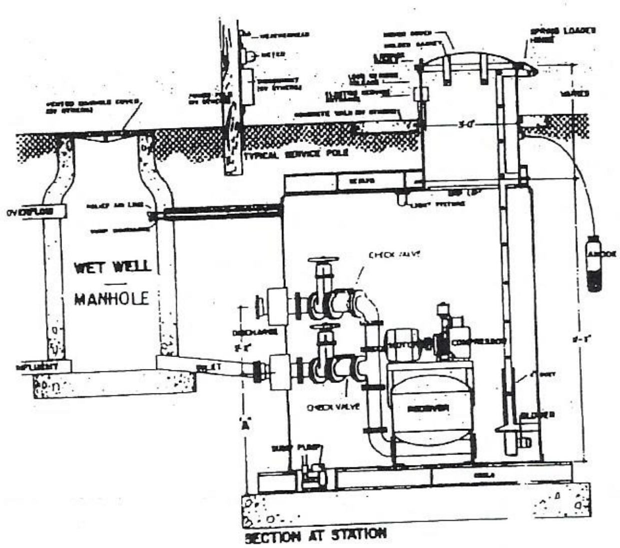
Level controls are needed to start and stop the lift station pumps. Some stations use floats as level controls. Unless they are tied off on a "Christmas tree", they can become entangled and cause wet wells to overflow or pumps to burn up. The best means of level control is the use of a pneumatic controller or air bubbler system. Air pressure in the bubbler is equal to the height of water above the end of the tube. The change in pressure as the level changes is used to control the pumps. Pneumatic systems are now being replaced with ultrasonic level sensors in many plants.

Lift Station Pumps

There are four types of pumps used in lift stations. Most lift station use end suction centrifugal pumps. Very small lift stations may use ejector-style positive displacement pumps or airlift pumps. Lift stations at treatment plants, lifting water from the primary clarifiers into the activated sludge basins, may use screw pumps.

An ejector pump operates like an air-powered diaphragm pump. Water enters the receiver tank on the suction stroke as air pressure is released. The discharge occurs when a blast of pressurized air is released into the receiver. This literally blows the water out of the tank and up the force main.

Airlift pumps move water by blowing air into the bottom of a standpipe. The rising air bubbles carry water up through the pipe to discharge. An airlift pump is very inefficient and can only lift water five to seven feet.



Ejector Pump Lift Station

Air relief valves are used to prevent air locking. They are located on the highest point on the pump volute and automatically vent air as it accumulates in the pump. It is also a good idea to repair leaking gaskets and joints on the suction piping. If the pressure in the line drops below atmospheric pressure when the pump is running, air will leak in instead of water leaking out.

Loss of Prime

Loss of prime happens when water drains out of the volute and impeller. The impeller can't create any suction at the impeller eye unless it is filled with fluid. This occurs only when negative suction head conditions exist. Pumps that operate with negative suction lift are usually installed with a foot valve or check valve at the bottom of the suction pipe. This valve holds the water in the suction pipe and pump when the pump is off.

When a pump loses its prime it must be shut down, reprimed, and all the air bled out of the suction line before starting the pump again. Worn packing and a defective foot valve normally cause loss of prime. The best way to prevent loss of prime is to design a pump installation so that there is positive suction head on the pump.

Electric Motors

Very few operators do electrical repairs or trouble shooting because this is a highly specialized field and unqualified operators can seriously injure themselves or damage costly equipment. For these reasons, the operator must be familiar with electricity, know the hazards, and recognize his own limitations when working with electrical equipment. Most water systems use a commercial electrician for major problems. However, the operator should be able to explain how the equipment is supposed to work and what it is doing or not doing when it fails. Electric motors are commonly used to convert electrical energy into mechanical energy. A motor generally consists of a stator, rotor, end bells, and windings. The rotor has an extending shaft, which allows a machine to be coupled to it. Most large motors will be three phase motors rated from 220 or 4160 volts.

Vertical turbine line shaft pumps will often have a hollow core or hollow shaft motor. The rotor is hollow and the motor shaft can slide up and down to allow adjustment of impeller clearance. This lateral adjustment is accomplished by raising and lowering the shaft with the adjusting nut on top of the upper bearing.

Phases

The term "phase" applies to alternating current (AC) systems and describes how many external winding connections are available from a generator, transformer, or motor for actual load connections. Motors are either single-phase or three-phase.

Single Phase Motors

Single-phase motors are normally operated on 110-220 volt A.C. single-phase systems. A straight single-phase winding has no starting torque so it must incorporate some other means of spinning the shaft. A single-phase motor requires a special start circuit within the motor to make sure it runs in the right direction. Several different types of starter windings are available in these motors. Single-phase power leads will have three wires, like a three-prong extension cord.

Three Phase Motors

Three-phase systems refer to the fact that there are three sets of windings in the motor and three legs of power coming in from the distribution system. This type of motor is used where loads become larger than single-phase circuits can handle. With three legs to carry power, more amps can be delivered to the motor. Three phase motors are the most common types used in water and wastewater systems. Three major types of three phase motors are the squirrel cage induction motor, synchronous motors, and wound rotor induction motors.

Squirrel cage induction motors are widely used because of its simple construction and relative low maintenance requirements. The windings are stationary and are built into the frame of the motor. The power supply is connected to the windings in the stator, which creates a rotating magnetic field. The rotor is made up of bars arranged in the shape of a cylinder and joined to form a "squirrel cage." Squirrel cage induction motors make up approximately 90% of all motors used in industry today.

Three-phase motors do not use a start circuit. The direction of rotation is determined by how the three leads are wired to the motor. If any two of the leads are switched, the motor rotation will be reversed.

Single Phasing

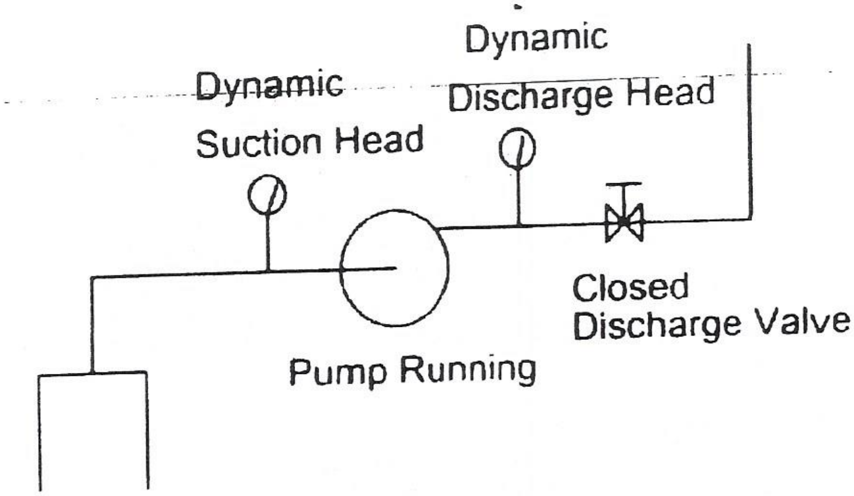
Anytime a lead becomes grounded, a dead short develops, or one of the contacts opens in a three-phase motor, single phasing will result. When this occurs, the speed of the motor will drop and it will begin to overheat. The single phase will draw too many amps and it will quickly burn up. When single phasing occurs while the motor is not running, it simply will not start up again. Special circuit protection is available that will shut the motor off if single phasing occurs.

Circuit Protection

Motors need to be protected from power surges and overloads. Fuses and circuit breakers are designed to open the circuit when the current load threatens to damage the motor. Fuses are generally sized at 120-150% of motor capacity. Circuit breakers can be reset when they trip, instead of being replaced like a fuse. Circuit breakers can react faster than fuses and are usually sized closer to the current rating of the motor.

NOTE: NEVER attempt to create shut off head conditions on a multi-staged turbine well. The shut off head may be several hundred feet higher than normal operating pressure, which can cause damage to piping.

2. With the pump running at shut off head, read the suction and discharge pressure gauges. Subtract the suction pressure from the discharge pressure to get the shut off head. Compare the field readings to the pump curve to see if the wear rings are in need of replacement.



Shut off Head = Dynamic Discharge Pressure - Dynamic Suction Pressure

Figure 9.16 - *How to Determine Shut-Off Head*

If the shut off head matches the curve, the same calculation can be used, when the pump is running normally, to estimate the Total Dynamic Head (TDH) and determine the flow when a meter is not available.

Common Operational Problems

The operator should check all pumps and motors every day to insure proper operation. After spending a certain amount of time with these pumps and motors, an operator should be able to tell just by listening to them whether they are working properly. The vast majority of pumping problems are either a result of improperly sizing a pump for the job or one of the three following operational problems.

Cavitation

One of the most serious problems an operator will encounter is cavitation. It can be identified by a noise that sounds like marbles or rocks are being pumped. The pump may also vibrate and shake. In severe cases, piping can be damaged. Cavitation occurs when the pump starts discharging water at a rate faster than it can be drawn into the pump. This situation is normally caused by the loss of discharge head pressure or an obstruction in the suction line. When this happens, a partial vacuum is created in the impeller causing the flow to become very erratic. These vacuum-created cavities are formed on the backside of the impeller vanes. As the water surges into the impeller, the partial vacuum is destroyed and the cavities collapse, allowing the water to slam into the impeller vanes. These cavities form and collapse several hundred times a second. As they collapse, they draw the water behind them into the impeller at about 760 mph! The impact created by the water slamming into the impeller is so great that pieces of the impeller may be chipped away.

When cavitation occurs, immediate action must be taken to prevent the impeller, pump and motor bearings, and piping from being damaged. Cavitation can be temporarily corrected by throttling the discharge valve. This action prevents damage to the pump until the cause can be found and corrected. Remember that the discharge valve is there to isolate the pump, not control its flow. If it is left in a throttled position the valve face may become worn to the point that it won't seal when the pump must be isolated for maintenance.

If you suspect that low suction pressure is the problem, check the pump curve to see what the Net Positive Suction Head (NPSH) is for the pump. If there is no NPSH curve, check with the pump supplier.

Air Locking

Table 9.2 - *Causes of Cavitation*

- Loss of discharge pressure due to open hydrants or line breaks
- Closed suction valve
- Obstruction in the suction line
- Low suction head due to drop in water level

Air locking is another common problem with pumps. It is caused by air or dissolved gases that become trapped in the volute of the pump. As the gas collects, it becomes compressed and creates an artificial head pressure in the pump volute. As more air collects in the pump, the pressure will continue to build until shut off head is reached. Air locking is most often caused by leaks in the suction line. The failure of low level cut off switches, allowing air in from the wet well, may also cause air locking.

An air locked pump will overheat in a matter of minutes. The shut off head conditions mean that no water is moving through the pump. Vertical pumps that use internal leakage to cool packing may also experience packing ring failure, since the trapped air can prevent water from reaching the packing.

Repacking the Pump

Before new rings are cut, it is important to determine the size and number of packing rings that are needed for the stuffing box. This information should be available in the vendor's engineering drawings. If these drawings are not available, measurements of the stuffing box and shaft can be used to make the determination. The correct packing size is determined using the following procedure:

1. Measure the inside diameter of the stuffing box and the outside diameter of the shaft.
2. Subtract the shaft diameter from the stuffing box diameter.
3. Divide the difference by two. (See Figure 10.1)

The correct number of rings can be determined using the following procedure:

1. Measure the depth of the stuffing box.
2. Divide the depth of the stuffing box by the size of the packing to get the total number of rings.
3. Subtract one from this total if a lantern ring is used in the stuffing box.

Once the size and number of rings has been determined, the new packing can be cut and installed. Great care should be taken to keep the packing material clean and free from dirt. Packing spools should be stored in plastic bags to prevent contamination. Dirt and grit in the packing rings will lead to serious shaft and sleeve damage. The two most important aspects of cutting packing rings involve cutting them the right length and cutting them so the ends will butt together squarely. Cutting rings the same length with ends that butt together squarely can be accomplished using the following procedure:

1. Cut the packing to the proper length and shape using a very sharp knife or carton cutter. Wrap the packing material around the shaft, an old sleeve, or even a piece of hardwood turned to the proper diameter. Cut all of the rings at once with the packing on the shaft to insure that the ends will butt together squarely.
2. Wrap each ring of packing around the shaft and seat it in the stuffing box completely before adding the next ring. Open the ring by twisting it instead of pulling the ends apart. A light coat of grease on the outside of the ring will make it much easier to push into the stuffing box. Stagger the joints of the rings so that they are 90 degrees apart. Make sure the lantern ring lines up with the seal water port when it is installed.
3. Install the packing gland. Make sure the gland tightened down evenly. It is usually made out of cast material and will break easily if it gets in a bind.

Adjusting the Packing Gland

The final adjustment of the packing gland is made while the pump is running. The pump can be restarted once the locks and tags have been removed, the dis-charge and suction valves are completely opened, and the pump has been primed. More packing jobs have been ruined by improper gland adjustment than any other single reason. Adjust the packing gland using the following procedure:

1. Tighten the gland one half turn a time on each side until it just begins to put pressure on the packing.
2. Start the pump and tighten the gland until the flow of water is reduced just enough to prevent flooding the drain line. Allow the pump to run for at least five minutes while the packing rings seat. Never allow the packing to get hot during this "breaking in" period. If the packing heats up and lubricant is seen oozing from the gland, the packing is already ruined and should be removed and replaced immediately.
3. After five minutes, adjust the packing slowly until the leakage is reduced to the desired level. The appropriate amount of leakage will vary with the size of the pump and type of packing, but a general rule of thumb is 20-60 drips per minute. Tighten the gland and checking the water temperature periodically. When the water turns lukewarm there is not enough flow to cool the packing properly. Loosen the packing gland just enough to cool the water back down to room temperature. The packing gland will probably need to be checked again, as the packing rings get properly seated. This may ~~have to be done several times over the next 24~~ hours of run time.

Bearing Maintenance

Proper bearing lubrication is a critical part of getting the designed life out of pump and motor bearings. As strange as it may sound, more bearings have failed from over-lubrication than from lack of lubrication. In fact, some bearings never require lubrication and may fail if they are greased. Shielded and sealed bearings come factory-lubricated and have sufficient lubricant to last the life of the bearing. Shielded bearings have a metal skirt that is attached to the outer race. It covers the rollers but doesn't touch the inner race. Sealed bearings have a rubber skirt that does touch the inner race. Bearings that do require periodic grease lubrication use a surprisingly small amount of grease when compared to the bearing housing size. A properly greased bearing will have a bearing housing that is never more than 25-30% full. The grease is responsible for lubricating and cooling the bearing.

Grease that is inside the bearing will get hot as the bearing heats up. When the grease gets hot it becomes more fluid and is thrown out of the bearing and onto the wall of the bearing housing, where it cools. Grease that is outside the bearing is drawn into the race, where it again heats up and is thrown out. This process keeps the bearing lubricated

Like any other business, a water system spends a great deal of money on infrastructure and capital improvements. These expenses include piping, storage and all of the mechanical equipment required to produce, treat, and deliver water. A maintenance program is essential to insuring that the mechanical components of the system stay in good working order and provide the longest possible service life. A preventive maintenance schedule should be utilized to make sure that each piece of equipment gets the proper attention. Most preventive maintenance consists of inspecting, cleaning, and lubricating the equipment. The equipment operators can usually complete these tasks. Specially trained personnel that possess the necessary mechanical skills should handle major maintenance, including component replacement and overhaul.

PUMP MAINTENANCE

The most common piece of equipment in a water system is the centrifugal pump. There are several maintenance procedures that must be performed periodically for any centrifugal pump. Pump packing wears out, bearings must be lubricated or replaced, mechanical seals need replacing, couplings must be maintained, and motor and pump shafts must be aligned.. These procedures are not difficult to learn. Some of the procedures may require the use of a few special tools. Once an operator understands the basic procedures and has a chance to put the theories into practice, it doesn't take long to become proficient at each task.

PUMP PACKING

Pump packing is one of the biggest problem areas for operators in charge of pump maintenance. Poor maintenance of pump packing is responsible for more pump damage than any other maintenance item. Improperly maintained packing can cause several problems including:

Table 10.1 - *Damage Caused by Packing Failure*

- **Loss of prime or suction due to an air leak**
- **Shaft and sleeve damage**
- **Water contamination of bearings**
- **Flooding of pump stations**

There are many different types of pump packing available for use in today's pumps. The most common type of packing comes in a square braided stock. There are a number of different kinds of braided packing. It can be manufactured from jute, asbestos, nylon, Teflon or other synthetics. It can be lubricated with graphite, grease, or other synthetic lubricants such as Teflon. Prices for packing range from several dollars a pound for graphite-impregnated jute to hundreds of dollars a pound for pure Teflon and other synthetics.

A rule of thumb is to buy the most expensive packing that you can afford, provided that you are taking care of the rest of the pump properly. If scored or damaged shaft sleeves and out of round or bent shafts are not going to be repaired, use the cheapest packing you can get. Expensive packing will not last any longer than the cheap stuff if the sleeve is scored or the shaft is bent. If the rest of the pump is properly cared for, the more expensive types of packing will last several times longer than the cheap packing and will usually pay for itself with a longer life.

REMOVING OLD PACKING

It's time to replace the packing when there is no more adjustment left in the packing gland and there is too much leakage from the stuffing box. When this occurs, all of the packing rings must be replaced. Adding an additional ring or just replacing one or two rings will only lead to premature packing failure and damage to the shaft and sleeve. Use the following procedure to remove the old packing:

1. Tag the pump in the "OFF" position and lock it out so that it can't be accidentally restarted.
2. Isolate the pump by closing the suction and discharge valves.
3. Drain the pump by opening the drain cock or removing the drain plug in the bottom of the volute.
4. Remove the packing gland. If it is not split for removal from the shaft, it should be tied off so that it is out of the way.
5. Remove the packing rings with a packing puller (corkscrew on the end of flexible T-handle) taking care not to score the shaft sleeve.
6. Measure the distance to the lantern ring and then remove it with the packing puller. It may take a puller on each side of the lantern ring to pull it out without getting it cocked sideways. If the lantern ring is split, it can be removed from the shaft. If you're not sure that the lantern ring was in the right placed to begin with, measure the distance from the face of the stuffing box to the seal water port or refer to the vendor's engineering drawing of the stuffing box for the correct position.
7. Remove the remaining packing rings and clean the stuffing box and shaft.
8. Disconnect, inspect, and clean the seal water line and seal water port.
9. Inspect the shaft or shaft sleeve. If it is scored or grooved, the pump should be dismantled and the shaft dressed or repaired by a machine shop.

Couplings

Couplings connect the motor shaft to the pump shaft. The exception to this would be a close-coupled pump. A close-coupled pump will have the impeller mounted directly to the motor shaft. Couplings can be rubber or steel. Steel couplings are most commonly gear-type or grid couplings.

Couplings are mounted and removed by pressing or heating the coupling. They should never be ~~mounted using a~~ hammer. The halves of the coupling should be separated by a gap large enough to accept the thermal expansion as the shaft and motor heat up. Couplings flex as the two shafts spin. This movement generates friction and heat in the coupling and requires grease lubrication. The main problem with lubrication in a coupling is centrifugation. As the coupling spins, it tries to throw the grease out of the housing.

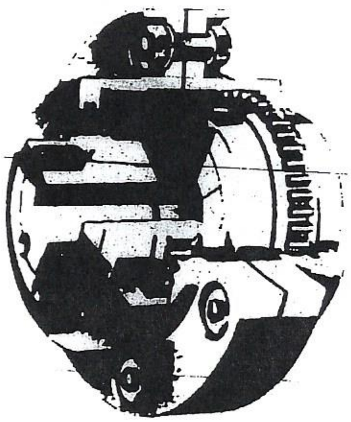


Figure 10.2 - ***Gear Coupling***

Couplings should be inspected periodically. The housing should be removed and the old grease removed using a solvent. Care must be taken not to get solvent in the bearings or seals. Broken or worn teeth and wear or pits on the grids are indicators that the coupling should be replaced. Gear-type housings are usually cast material. The housing bolts must be tightened carefully in a crossing pattern to avoid cracking the assembly. Vibration occurs in a coupling when it is misaligned.

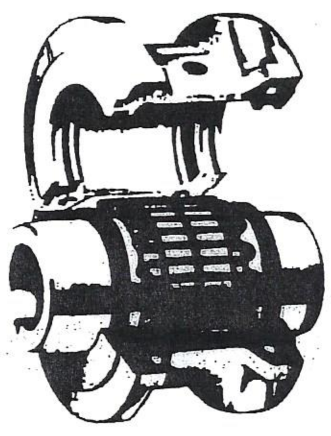


Figure 10.3 - ***Flexible Grid Coupling***

Alignment

If the pump and motor shafts are not aligned properly, the result will be vibration and subsequent damage to the pump coupling and mechanical seals, and the pump and motor bearings. Misalignment can be angular or offset (parallel.) Angular misalignment means that the motor is crooked when it lines up with the pump shaft. Offset misalignment means that the shafts are in a straight line but one of them is off center. Misalignment can also be in the horizontal plane, requiring a side-to-side movement of the motor. It can also be in the vertical plane, requiring raising the motor with shims. This means that measurements must be taken at the top, bottom, and both sides of the coupling.

A crude check of the misalignment can be done using a straight edge on the coupling halves. A dial indicator is used to more accurately gauge the amount of offset or angularity. A dial indicator is capable of precise measurements down to 0.001".

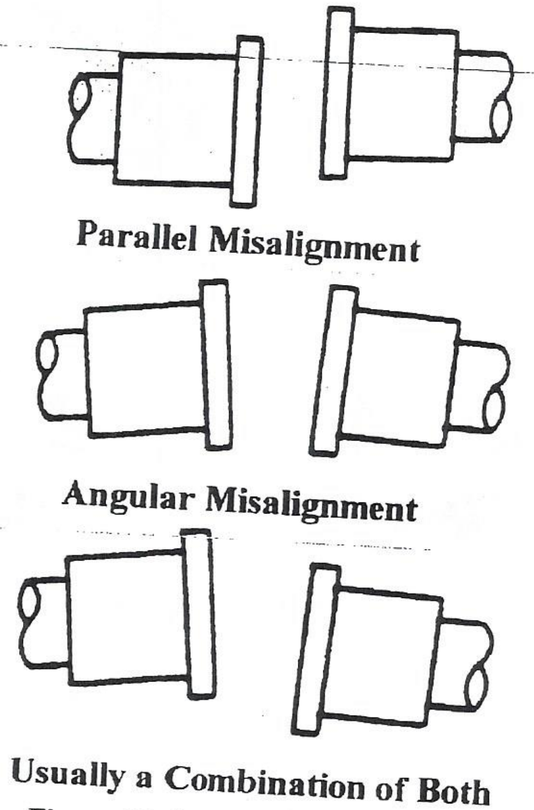
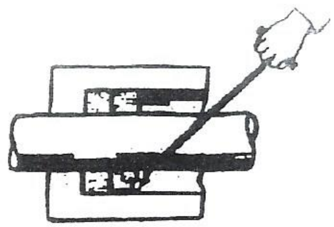


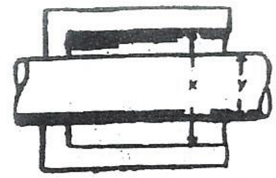
Figure 10.4 - ***Types of Misalignment***

Instrumentation

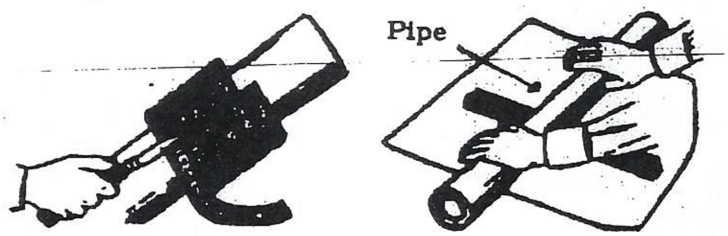
Instrumentation in water systems allows the operator to maintain and monitor water levels, flows, pressures, and chemical feed rates at a distance. This use of telemetry gives constant readings of changes in the system and allows



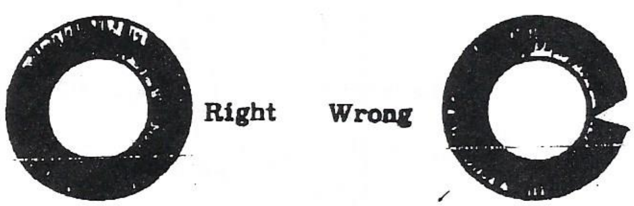
REMOVE OLD PACKING



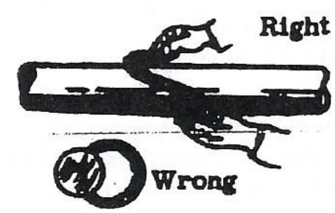
$\frac{X - Y}{2}$ = PACKING SIZE



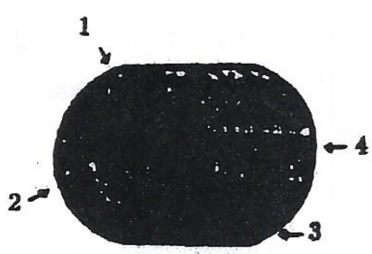
CUT AND FLATTEN PACKING



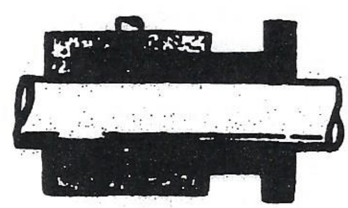
MAKE SURE ENDS ARE SQUARE



INSTALL NEW PACKING



STAGGER PACKING RINGS



POSITION LANTERN RING PROPERLY

Figure 10.1 - ***Repacking A Pump***

and removes heat from the bearing. If the bearing housing is full of grease there is no way for the hot grease to get out of the bearing. The lubricant inside the bearing overheats and breaks down. Bearings overheat and fail when this happens.

As bearings heat up and cool down, the races and rollers expand and contract. Bearings are temperature stabilized to about 250° F. This means they will assume their original dimensions as long as the temperature does not rise above 250°F. This is the reason small electric motors should not operate above 105°C. Lubrication schedules for low-speed (under 2500 rpm) anti-friction bearing applications are based on the operating temperature of the bearing. Always refer to the vendor recommendations for the proper lubricant and lubrication frequency.

Corrosion in sewer lines can be the result of chemicals from industrial discharges. It is more commonly caused by septic conditions that release hydrogen sulfide gas (H_2S). Sulfuric acid is created when the hydrogen sulfide gas reacts with the moisture on the inside of the pipe wall. This can cause serious corrosion problems in large concrete cylinder piping. It is less of an issue in vitrified clay pipe. Acids do not affect PVC pipe. Aeration in lift station wet wells and the addition of chlorine in the collection system are two ways of minimizing hydrogen sulfide production.

Crown Corrosion in a Concrete Pipe
Hydraulic Jet Cleaner in the background

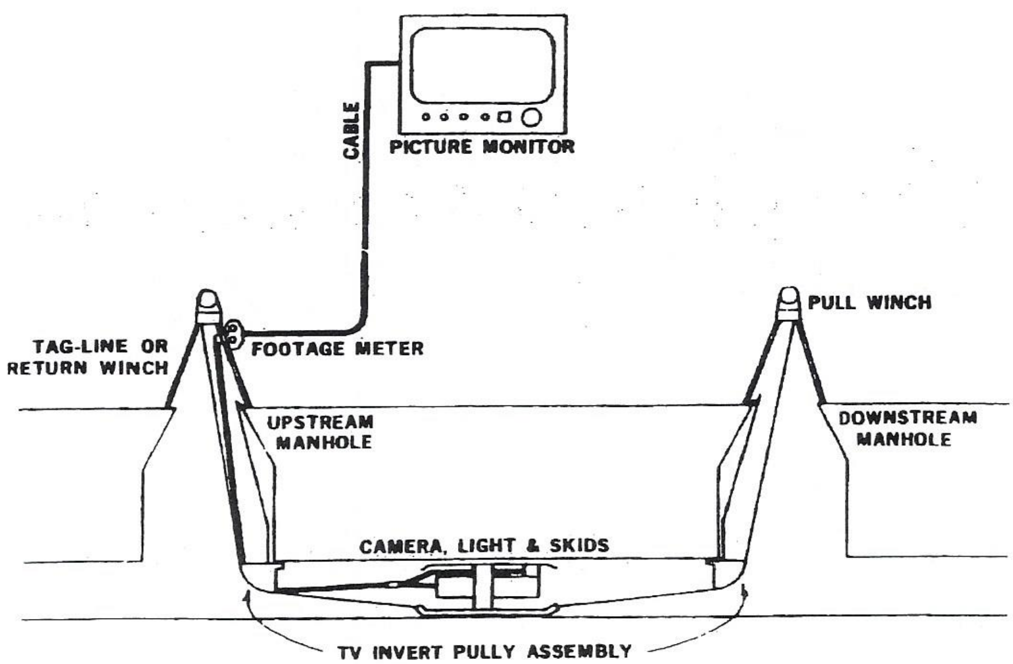
Crown corrosion will compromise the load carrying capacity of concrete piping. Once the structural integrity is compromised, plans should be made to rehabilitate the pipe by slip lining the pipe. Cast-in-place-pipelining will protect the pipe from further corrosion but will not provide any additional structural support.

Smoke should be found coming from residential roof vents and cleanouts. If it is found coming from gutters or patio drains, it indicates an illegal tap. Those drains should be reconnected to a storm sewer. If smoke surfaces in the street or residential yards it means there is a broken line. It may come up from a residential floor drain. This means the P-trap is dry. This situation can lead to harmful sewer gases collecting the customer's house. They should pour a quart of water down the drain every three months to maintain the water seal.

Before conducting a smoke test always make sure to notify the residents, the fire department, and the police department when and where the test will take place. Smoke coming up from the basement of a house can cause panic for the homeowner and result in 911 calls. It can be embarrassing to have fire trucks respond to false alarms due to inadequate communications.

CCTV INSPECTION

A closed circuit TV unit runs a camera down the line to televise and videotape the condition of the pipe, pipe joints, grade, and service connections. It can be used to identify cracks in piping, offset or broken joints, grease, and root intrusion while documenting the condition and location of the problem. These units consist of a van or trailer that has a generator, cable spool and winch, camera unit, and video tape recorder. Older units have a winch assembly that is mounted at the end of the line and is used to pull the camera through the line. The winch on the truck was used to retrieve the camera after the inspection was completed. Newer units have a self-propelled camera that is equipped with a set of tank-like treads or all-terrain tires that allow it to move by remote control without the need for a winch system. Most new cameras have a rotating lens that can be positioned to look up into service taps and inspect joints on the line.



CCTV Equipment

TYPES OF DISINFECTION

The process of killing pathogenic bacteria in the drinking water supply is known as disinfection. Disinfection is the final step in the treatment process and is necessary to provide a "bacteriologically safe" drinking water for the public. Disinfection is now required for all public water supplies. Chlorination is the most common means of killing disease-causing bacteria in water supplies.

While chlorine is used primarily for disinfection in water treatment, it also has other uses in the treatment process. Chlorine can be used to remove iron and manganese, some kinds of tastes and odors, and some dissolved gases, such as Ammonia (NH_3) and Hydrogen sulfide (H_2S). The use of chlorine in these instances usually occurs early in the treatment process. Pre-treatment of raw water by pre-chlorinating used to be a fairly common practice until the mid-1970's. Concerns over disinfection by-products, such as TriHaloMethanes (THM's) and halo acetic acids, have almost eliminated the practice of pre-chlorination in the United States. The removal of taste and odors from raw water is now accomplished using Powdered Activated Carbon (PAC) or oxidizing agents other than chlorine, that do not result in chlorinated by-products. The growing concern regarding the use of chlorine as a disinfectant may eventually mean a change to one of these other oxidizing agents as the primary means of disinfection at sometime in the future.

CHLORINATION

Chlorine is the most widely used disinfectant because it is readily available, easily applied, and cheaper than other oxidizing agents such as potassium permanganate ($KMnO_4$), chlorine dioxide (ClO_2),UV disinfection, or ozone (O_3). Chlorine is applied in one of three forms; chlorine gas, chlorine powder (HTH), or an aqueous solution like chlorine bleach.

CHLORINE GAS

Chlorine gas (Cl_2) is compressed into a liquid for storage. It can be purchased in cylinders containing 150 or 2000 pounds of the liquefied gas. Chlorine gas is cheaper per pound than either of the other forms.

CHLORINE POWDER

Chlorine in its dry form is calcium hypochlorite [$Ca(OCl)_2$]. It is also most commonly known by the trade name HTH (High Test Hypochlorite). Only about 65 - 70% of the HTH is available as chlorine. The rest is calcium, which is not a disinfectant. Dry chlorine is 2-3 times more expensive, per pound of chlorine, than chlorine gas.

CHLORINE BLEACH

Chlorine bleach is a liquid solution of sodium hypochlorite (NaOCl). Bleach is usually 3 - 12% available chlorine and 88 - 97% water. Bleach is the most expensive form of chlorine and is normally used for disinfecting small wells and water lines. It is sometimes used for supply disinfection in very small water systems.

CHLORINE TREATMENT TERMS

Several terms are used to identify the various stages and reactions that occur when chlorine is used as a disinfectant.

The basic unit of measurement for chlorination, or any other chemical treatment is milligrams per liter (mg/l) or parts per million (ppm). These are very small units reflecting concentrations that are essentially one part chemical for every million parts of water. To get some idea of how small a concentration this really is, it should be pointed out that 1% is equal to 10,000 mg/l or ppm.

CHLORINE DOSAGE

The chlorine dosage is the amount of chlorine that is added to the water. The dosage can be determined from the number of pounds of chlorine used and the number of millions of pounds of water treated.

CHLORINE DEMAND

Chlorine is a very reactive oxidizing agent. It will react with a certain substances that may be found in water. This list includes; iron, manganese, hydrogen sulfide, organic compounds and ammonia. When chlorine reacts with these substances, it loses it disinfecting properties. This is referred to as the chlorine demand. For chlorine to be effective as a disinfectant, the dosage must always exceed the demand that is present in the water. The chlorine demand may vary from day to day in a surface water supply. It is usually fairly constant in a ground water supply.

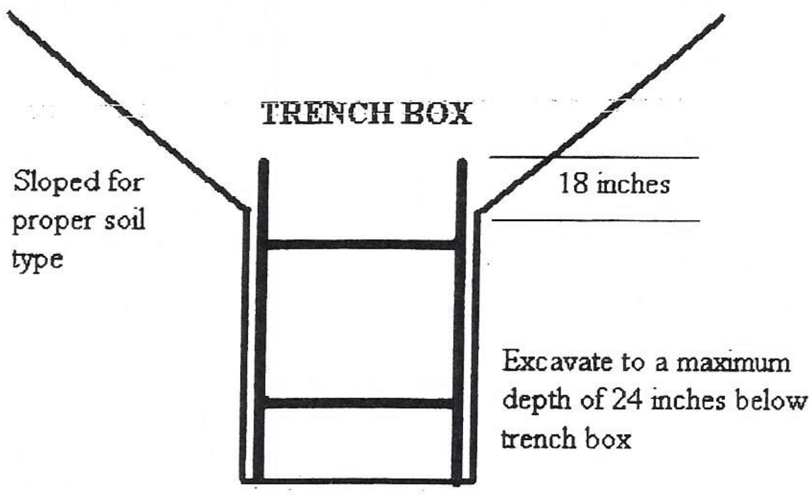
CHLORINE RESIDUAL

The chlorine that remains in the water, after it has finished reacting with those substances that represent the demand, is known as the chlorine residual. The concentration of the residual is determined by subtracting the demand from the dosage.

EXAMPLE: A 4.0 mg/l dosage is added to water that has a demand of 2.5 mg/l.
What is the residual?

Shoring must be installed without worker entry into the excavation. Screw jacks or cross braces must be installed from the top down and removed from the bottom up. This prevents entrants from working in an unprotected area. Jacks and cross braces must be anchored by nailing the foot to the vertical timbers. Hydraulic or pneumatic shoring can be installed without requiring worker entry into the trench. If water is used for hydraulic shoring, antifreeze should be added to prevent freezing in cold weather.

Trench boxes are useful for long trenches where it can be moved along the trench. This saves some of the setup and breakdown time required with shoring. When the excavation is deeper than the trench box, the portion above the box must be sloped based on the soil type. The trench box must extend at least 18 inches above the beginning of the sloped wall. Excavation below the trench box is allowed, but the maximum depth is 24 inches. Ladders must be positioned so that workers can enter and exit without stepping outside the shoring or trench box.



Trench Box Placement

Excavations may become confined spaces if they are located close to a source of potentially hazardous gases (underground gas tanks, landfills, etc.) Spoil from the excavation must be placed at least 2 feet from the edge of the excavation (farther with more unstable soils.)

- "B" - When the dosage reaches 3ppm (mg/l), the breakpoint occurs and first free chlorine residual is obtained. Once the breakpoint has been reached, the free residual will increase at the same rate as the dosage.
- "C" - There may still be some combined residual in the water even though the breakpoint has been reached, but it will remain at this minimum level as long as the dosage is greater that 3 ppm (mg/l).

A common complaint received by many operators is that the water has a "chlorine odor." These odors are almost always caused by chloramines in the water rather than a free chlorine residual. Understanding the break point curve may help solve this problem.

The initial reaction to this type of call may be to reduce the chlorine dosage to reduce the odors. This is actually the last thing that you would want to do. First, the problem may be remedied by simply flushing the line in the area of the complaint. The odors are usually a result of stale water sitting in the lines. The free chlorine that was originally present may have broken back down into chloramines. Flushing will remove the stale water and the odor problem, until the water gets stale again. If flushing doesn't correct the problem, look at the breakpoint curve before adjusting the chlorine feed rate.

If the current conditions place us on the left side of the breakpoint there is no free residual present. This can be confirmed with a residual test. That means the water is on the "B" portion of the curve. Decreasing the chlorine dosage will result in moving further to the left on the curve into the "A" portion. Here the chlormine concentration is even higher and the odors may become worse instead of better. If the dosage is increased to the point where free chlorine residuals are present again, the amount of chloramines (and their odors) will be kept to a minimum.

Testing For Chlorine Residuals

There are three methods that are used to test water for chlorine residual. Two of them are field tests. The Ortho-Tolidine-Arsenite (OTA) test was the industry standard until the mid - 1970's. The problem with the OTA test was that iron and nitrites in the water would interfere with the test. In addition, OTA was found to be a carcinogen. It is no longer used for chlorine residual testing today. Instead, the Diethyl-p-Phenylene-Diemine (DPD) test is used for field work. It is similar to OTA test but is not known as the amperometric titration method. It is normally run in a laboratory.

The DPD test is a colormetric analysis. The reagent is added to a vial of sample water. Another vial of sample water serves as a "blank." If chlorine is present the sample will turn pink or red. The vial is placed in front of the "color wheel" and the sample is compared to the color wheel and blank. There are two chemical packets for the DPD test. One is used for free chlorine and the other is used for total chlorine residual. Subtracting the free residual from the total residual will give you the combined residual.

General Chlorine Safety

Chlorine is a greenish-yellow gas. It is 2.5 times heavier than air. Chlorine gas is very corrosive. It turns into hydrochloric acid when it comes in contact with moisture (in the water, in the chlorine lines, or in your eyes or lungs). It does support combustion . It can be harmful if inhaled in small quantities and fatal in larger doses. The following table lists the effects of chlorine gas in various concentrations in the atmosphere. Because of the potential for injury to workers and the general public from chlorine gas accidents, safety must always be the first consideration when handling chlorine.

Table 5.1 - *Chlorine Symptoms*

SYMPTOM	CONCENTRATION
Noticeable odor	0.2 ppm
Irritation after several hours	1.0 ppm
Irritation of throat after a few minutes	15 ppm
Immediate coughing	30 ppm
Dangerous after 30 minute exposure	50 ppm
Lethal in minutes	1000 ppm

Chorinator Room

The chlorinator room should have a window in the door so that the operator in the room can be seen from the outside. The light and vent switches should also be located outside the room. The room should have ventilation located at floor level since chlorine gas is heavier than air and will settle in the lowest spot in the room.

The room should be kept between 60° F and 120° F. Below 60° F, chlorine gas forms chlorine hydrate, also known as "green ice," when it comes in contact with water. This green ice can clog the injector and gas piping, creating a serious maintenance problem.

When a chlorine cylinder is full and at room temperature, it is about 85% full of liquefied chlorine. As the temperature

Dosage - Demand = Residual

or

4.1 mg/l - 2.5 mg/l = 1.5 mg/l Residual

There are two types of residuals that result from the chlorination of water. They are free chlorine residual and combined chlorine residual.

Free Chlorine Residual

After the demand has been satisfied, any chlorine that is left will react with water to from hydrochloric acid and hyochlorous acid.

$$Cl_2 + H_2O > HCl + HOCl$$

The hypochlorous acid is the disinfecting agent and the presence of the hypochlorous ion (OCl^-) is measured to obtain the free chlorine residual.

Combined Chlorine Residual

Chlorine reacts with water to form hypochlorous acid. If ammonia is present, the hypochlorous acid will react with it to form compounds known as chloramines.

$$HOCl + NH_3 > NH_2Cl + H_2O$$

Chloramines are found in three forms. They may contain from one (NH_2Cl) up to three (NCl_3) atoms of chlorine. The chemistry of the water and concentration of chlorine will dictate which of the chloramines are formed. Chloramines are weak disinfectants. They require longer contact times and higher concentrations to achieve disinfection than free chlorine residual. However, they do not breakdown as quickly as free chlorine and remain in the system longer.

Disinfection Requirements

Two factors must be taken into consideration when disinfecting drinking water. First, enough chlorine must be added to reach a predetermined concentration in the water. Then the bacteria must come in contact with the solution for a certain period of time. This is referred to as achieving the proper residual and contact time. Killing pathogenic bacteria requires a minimum of 0.2-0.4 milligrams per liter (mg/l) of free chlorine residual and a contact time of 20 minutes. The contact time can be reduced if the residual is increased. Viruses, Giardia, and Cryptosporidium are harder to destroy than the other waterborne diseases. Free residuals of 1.5-2.0 mg/l and much longer contact times may be required to destroy these organisms.

Effects of Temperature and pH

Changes in temperature and pH of the water can reduce the effectiveness of chlorine. Colder temperatures slow down reaction times requiring higher concentrations and longer contact times to achieve proper disinfection. A high pH impedes the formation of the hypochlorous acid and requires a higher dosage to obtain the proper residual.

Breakpoint Chlorination

When chlorine is added to water that contains no ammonia, the residual that is obtained will be free available chlorine. If ammonia is present, and the demand has been satisfied, some of the free chlorine will react with the ammonia to form chloramines or combined chlorine residual. As more chlorine is added, it will breakdown the chloramines that have been formed and the combined residual will begin to drop. A point will be reached where the residual will begin to rise again after all of the chloramines, that can be, are destroyed. There may be some combined residual left in the water at this point. From this point, any additional chlorine dosage will result in the formation of only free chlorine residual. This is known as the "breakpoint". All water systems that chlorinate their water will, in fact, practice breakpoint chlorination. They will add enough chlorine to the water to achieve a free chlorine residual of at least 0.2-0.5 mg/l.

The Breakpoint Curve shown below illustrates the formation and destruction of chloramines before free residuals are achieved. Every system's breakpoint will vary depending on the chemical makeup and chlorine demand of the raw water.

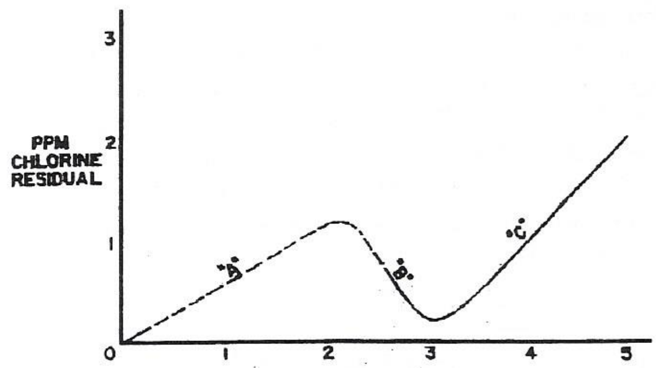


Figure 5.1 - *Breakpoint Curve*

As chlorine is added to the water, it reacts with the ammonia that is present and a combined residual reading is obtained.

Tracking the Breakpoint Curve illustrated in Figure 5.1:

- "A" - In this case, as the dosage increases to about 2ppm (mg/l) the combined residual drops because the chloramines are being destroyed.

Self-Contained Breathing Apparatus (SCBA)

The SCBA unit must be used when working in a chlorine gas atmosphere. It has an air tank that allows the wearer to breathe uncontaminated air while attempting to correct a chlorine leak situation. The SCBA tank will hold enough air for approximately 30 minutes, depending on working conditions. When the air pressure drops to a point where there is about five minutes of air remaining in the tank (500 psi), an alarm will ring to signal the operator that it is time to exit the area and change tanks.

Chlorination Equipment

There are two ways to feed chlorine into the water system. Gas chlorination uses liquefied chlorine gas. Hypochlorination uses a positive displacement pump to feed a solution of dissolved HTH or bleach into the system. Many smaller systems will use a hypochlorination system because the equipment cost is lower. The solution of dissolved HTH or bleach is much easier to handle and presents less of a risk compared to a gas system. Gas chlorinating is used where the system requires larger dosages of chlorine than can be delivered by hypochlorination. Though capital costs are higher for gas chlorination, the chemical costs are significantly lower than when HTH or bleach is used.

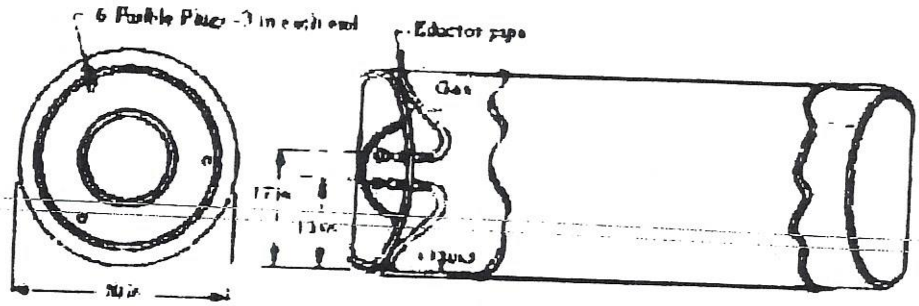
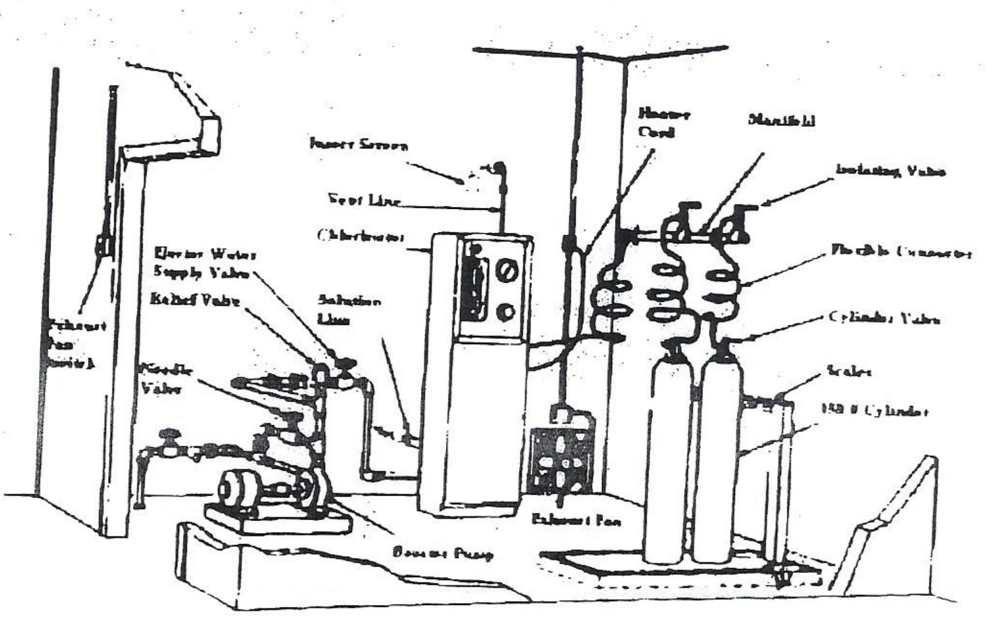


Figure 5.4 - ***Cross Section of a 1-ton Cylinder***

Gas Chlorination

A gas chlorine system consists of one or more gas cylinders connected to gas chlorinator. The gas chlorinator consists of a pressure regulating valve, a feed rate indicator, a flow regulating device (a V-notch plug or needle valve), and an injector or ejector. The chlorine pressure regulating valve (CPRV) opens when a vacuum is created by the injector and maintains a constant negative pressure inside the chlorinator. The feed rate indicator consists of a ball floating inside a glass tube. The feed rate is indicated on the glass tube and is read in "pounds per day." The feed rate should be read at the widest point of the ball or bead. The feed rate is controlled using the needle valve or V-notch plug. Water flowing past the injector creates a vacuum that draws the gas into the system.

The maximum feed rate for gas drawn from a 150 lb. Cylinder is 40 pounds/day. The maximum gas feed rate for a 1-ton cylinder is 400 pounds/day. If these feed rates are exceeded, the tanks will frost over because heat can't pass through the tanks as fast as it is used to evaporate the chlorine from a liquid to a gas. This can also occur in situations where several tanks are manifolded to the chlorinator. If one of the cylinder valves is partially closed the other tanks may try to feed too much gas and frost over. When this happens, check the tank that isn't frosted for a closed valve or plugged pigtail line. Ton cylinders are sometimes set up to feed liquefied gas. These systems use an evaporator to change the liquid to a gas before it goes to the chlorinator. There is no limit to how much liquid chlorine can be removed from a cylinder since the heat for evaporation is supplied by an outside source. NEVER manifold cylinders together when feeding liquefied chlorine to an evaporator. Expansion tanks equipped with rupture disks are used to protect all liquid feed piping. These provide protection from expansion of liquefied gas



rises, the liquid expands and takes up more space in the cylinder. At 157° F the liquid will expand to occupy 100% of the cylinder. If the liquid expands any further the cylinder will rupture, causing a massive chlorine leak.

NEVER enter a chlorine facility without ventilating for several minutes first. The National Fire Code now requires that new gas chlorine facilities be equipped with a scrubber system that will remove chlorine gas that may be present in the ventilation exhaust. These systems must have a backup power supply to keep the scrubber running in the event of a power failure. Check with local Fire authorities before new chlorine facilities are built to make sure they will be in compliance.

Chlorine Storage

The room where chlorine cylinders or HTH drums are stored must be kept dry and well ventilated. Chlorine should always be stored in a room separate from other chemicals. Chlorine cylinders that are empty should be separated from those that are full. When not in use, all cylinders should be chained to the wall.

Chlorine Cylinders

NEVER remove the valve hood from a chlorine cylinder unless it is chained to the scales and ready to be put on the system. All cylinders should be chained to the wall or the scales unless they are being moved. Emergency repair kits are available that can be used to seal leaks in the broken valves or leaking cylinders. Every system that operates a gas chlorine system should have an emergency kit or be able to get access to one on very short notice.

To prevent the cylinder from rupturing when it gets too hot, every gas cylinder will have a "fusible plug" that is designed to melt at 157° F. There is one in the valve assembly of every 150 lb. cylinder and six (three on each end) in the body of very 1-ton cylinder. As one of these fusible plugs melts, it will allow the release of chlorine gas from the cylinder. This still represents a serious problem, but the release will be more gradual than it would if the tank ruptured.

HTH Handling Safety

Powdered chlorine should be stored in a cool dry place separate from other chemicals. HTH must never be allowed to come in contact with petroleum products or organic solvents. If this happens, it will explode violently! This is also true for the other forms of chlorine, but is more likely to occur during the handling of HTH. Care must also be taken to avoid contact with the eyes or bare skin.

Respiratory Protection

Anyone involved in handling chlorine should have access to respiratory protection equipment. Chlorine gas forms hydrochloric acid when it gets in the eyes or lungs. This can result in serious injury or death depending on the concentration and exposure time. The damage caused by exposure to chlorine gas is cumulative. Several incidents involving minor exposure can contribute to serious health problems at sometime in the future.

There are two basic types of respiratory protection. One is the gas mask that uses a filtering device to remove chlorine. These are either a full-face mask or a mouth/nose type respirator. The other type of respirator is the self-contained breathing apparatus (SCBA). The SCBA unit is full-face mask with an air tank to provide the operator with fresh air to breathe when in hazardous atmospheres. Both of these devices may be rendered ineffective if the wearer has facial hair that interferes with the face-to-mask seal.

Gas Masks

The gas mask is designed to allow the operator time to escape the chlorine room when a leak occurs. THESE DEVICES ARE INTENDED FOR ESCAPE PURPOSES ONLY! A GAS CANISTER MASK MUST NEVER BE USED TO ENTER ANY AREA WHERE CHLORINE GAS IS PRESENT! If the release of chlorine drops the oxygen concentration below 12%, it is impossible to survive even if all the chlorine is filtered out. If an operator is wearing a canister mask he must still leave the area immediately upon detection of a chlorine leak. The gas canisters should be changed every six months or anytime it has been exposed to chlorine gas.

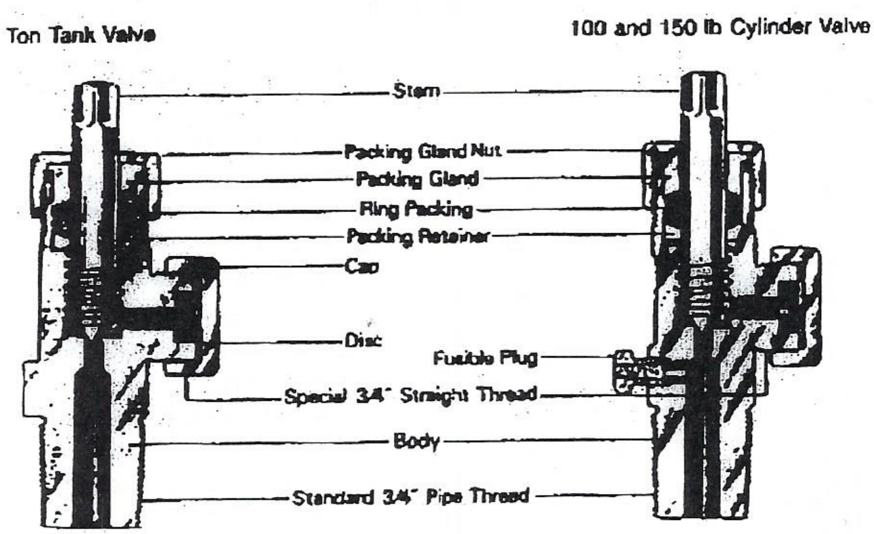


Figure 5.2 - *Chlorine Cylinder Valve*